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Virtual reality and gamification in autism rehabilitation: A systematic review

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Abstract
Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by impairments in social communication, restricted behaviors, and sensory sensitivities. Traditional therapies, though effective, often face limitations related to accessibility, scalability, and patient engagement. In recent years, Virtual Reality (VR) and gamification have emerged as promising tools that leverage immersive, interactive, and feedback-rich environments to support social, cognitive, and emotional rehabilitation in individuals with ASD.
Objective: This systematic review aimed to critically evaluate the effectiveness of VR and gamification in ASD rehabilitation, focusing on their impact on social communication, emotion recognition, engagement, and adaptive behavior. Additionally, it sought to assess the methodological quality of existing studies and identify challenges and future directions for integrating these tools into evidence-based practice.
Methods: A comprehensive search was conducted across PubMed, Scopus, Web of Science, PsycINFO, IEEE Xplore, and Google Scholar from January 2010 to July 2025. Studies were eligible if they assessed VR and/or gamification interventions in ASD populations and reported measurable cognitive, emotional, or social outcomes. Twenty-nine studies (18 randomized controlled trials, 7 quasi-experimental designs, and 4 pilot studies) met the inclusion criteria, encompassing a total of 1,432 participants. Data were extracted systematically, and study quality was assessed using the Cochrane RoB 2 and Joanna Briggs Institute appraisal tools. Effect sizes, heterogeneity statistics, and subgroup analyses were employed to synthesize findings.
Results: The pooled analysis revealed moderate-to-large improvements in social communication (Hedges' g=0.62, p<0.001) and significant gains in emotion recognition (SMD=0.48, p<0.001), particularly in immersive VR interventions. Engagement levels increased by 25-35% compared to controls, and adaptive behavior outcomes showed moderate improvements (SMD=0.39, P=0.002). However, methodological heterogeneity (I^2=41.7%), limited long-term follow-ups, and underrepresentation of adult participants were notable limitations.
Conclusion: VR and gamification significantly enhance core rehabilitation outcomes for individuals with ASD, particularly in social and emotional domains. Immersive VR appears more effective than gamified 2D platforms, though the latter offer scalable and cost-efficient alternatives. Practical integration requires clinician training, caregiver involvement, affordable technologies, and rigorous longitudinal research to confirm sustained benefits. These findings highlight VR and gamification as complementary and evidence-informed tools that, if strategically implemented, can broaden the reach and effectiveness of autism rehabilitation programs.

Keywords: Autism spectrum disorder, virtual reality, gamification, systematic review, social communication, emotion recognition, adaptive behavior, immersive technology, rehabilitation, serious games

Introduction
Autism spectrum disorder (ASD) is a pervasive neurodevelopmental condition characterized by difficulties in social communication, repetitive behaviors, and sensory sensitivities; global estimates suggest its prevalence is rising, now affecting approximately 1 in 100 children worldwide [1-3]. Traditional therapeutic approaches such as behavioral interventions, speech therapy, and social skills training are vital yet often resource-intensive, limited in accessibility, and sometimes insufficiently engaging for individuals with ASD [4-8]. In contrast, innovations in virtual reality (VR) and gamification present promising, scalable, and motivational platforms capable of delivering controlled, immersive experiences for practicing essential skills. Over the past decade, numerous studies have explored VR's capacity to simulate social situations and environments that are otherwise challenging to recreate in real life [9-12], while gamified strategies have been shown to enhance

engagement, sustain attention, and reinforce adaptive behaviors through reward-based mechanisms [13-17]. However, despite a burgeoning body of research, there remains a scarcity of comprehensive synthesis examining the effectiveness, methodological rigor, and practical applicability of VR and gamified interventions across diverse autism populations. This gap is particularly notable regarding standardized outcome measures, long-term retention, age-appropriateness, and cost-effectiveness [18-21]. Therefore, the primary objective of this systematic review is to critically evaluate and summarize the existing evidence on the use of VR and gamification in ASD rehabilitation, with particular attention to efficacy, intervention design, and implementation challenges across different age groups and settings. Specifically, we aim to (a) characterize the types of VR and gamified interventions employed, (b) assess their impact on social, cognitive, and emotional outcomes, (c) analyze methodological strengths and limitations of the studies, and (d) identify directions for future research and clinical translation. We hypothesize that VR and gamified interventions yield statistically significant improvements in social communication, emotional recognition, and engagement relative to baseline or control conditions, and that these improvements are sustained at short-to medium-term follow-ups, especially when interventions are immersive, personalized, and include explicit feedback loops.

Materials and Methods

Materials

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological rigor. A comprehensive literature search was performed across multiple electronic databases, including PubMed, Scopus, Web of Science, PsycINFO, IEEE Xplore, and Google Scholar, covering the period from January 2010 to July 2025. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to *"autism spectrum disorder", "virtual reality", "VR," "gamification", "serious games", "rehabilitation"*, and *"intervention."* Boolean operators (AND, OR) and truncation were applied to maximize sensitivity and specificity. Additional manual searches were conducted by screening the reference lists of relevant articles and systematic reviews to capture studies not indexed in databases. Inclusion criteria were: (i) peer-reviewed empirical studies evaluating the use of VR and/or gamification for rehabilitation in individuals diagnosed with ASD; (ii) participants of any age group and gender; (iii) studies reporting at least one outcome related to social, cognitive, or emotional skills; and (iv) studies published in English. Exclusion criteria included review papers, conference abstracts without full-text, case reports, editorials, and studies lacking quantitative or qualitative outcomes. The screening process was independently conducted by two reviewers, and disagreements were resolved by consensus or consultation with a third reviewer.

Methods

All identified records were imported into EndNote 21 for duplicate removal, after which titles and abstracts were screened. Full-text screening was carried out for potentially eligible articles. Data extraction was performed using a pre-designed form capturing details such as study design, sample characteristics (age, gender, ASD severity), type of VR or gamified intervention, duration and frequency of sessions, outcome measures, and main findings. To ensure reliability, two reviewers independently extracted data, and inter-rater agreement was calculated using Cohen's kappa statistic. The methodological quality of randomized controlled trials (RCTs) was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool, while non-randomized studies were evaluated using the Joanna Briggs Institute (JBI) critical appraisal checklists. A narrative synthesis was employed to summarize intervention characteristics and outcomes, while effect sizes and statistical significance (where available) were compared across studies. Where data permitted, results were pooled, and heterogeneity was assessed using the I^2 statistic. This systematic approach ensured transparent, replicable, and unbiased evaluation of the evidence on VR and gamification in ASD rehabilitation.

Results

Study Selection

The initial database search identified 1,238 records (PubMed: 346, Scopus: 289, Web of Science: 198, PsycINFO: 176, IEEE Xplore: 129, Google Scholar: 100). After removal of 312 duplicates, 926 unique records were screened by title and abstract. Of these, 745 were excluded as they did not meet inclusion criteria (e.g., unrelated interventions, non-ASD populations, or no reported outcomes). Full-text assessment was performed on 181 articles, with 152 excluded for reasons including lack of full data (N=46), reviews or editorials (N=38), non-empirical design (N=32), or absence of VR/gamification focus (N=36). Finally, 29 studies were included in this systematic review (18 randomized controlled trials, 7 quasi-experimental studies, and 4 pilot/feasibility studies).

Characteristics of Included Studies

Across the 29 included studies, a total of 1,432 participants with ASD were analyzed, with age ranges from 5 to 28 years. Most studies recruited children and adolescents (N=22), while seven involved young adults. The mean sample size per study was 49.4±22.6 participants. The gender ratio was skewed towards males (approximately 4:1), consistent with known ASD prevalence. Intervention duration varied from 4 to 24 weeks, with sessions lasting between 20 and 60 minutes and occurring 2-4 times per week. Interventions used immersive VR (N=12), semi-immersive desktop-based VR (N=8), and gamified mobile/tablet applications (N=9).

Outcomes and Effectiveness

The primary outcomes measured were social communication (N=18 studies), emotion recognition (N=15), attention/engagement (N=12), and adaptive behavior (N=8).

- **Social Communication Skills:** Pooled effect size across 18 studies showed a moderate-to-large improvement (Hedges' g=0.62; 95% CI: 0.45-0.79; $p<0.001$). Random-effects meta-analysis indicated moderate heterogeneity ($I^2=41.7\%$), suggesting variability in study designs but consistent overall benefits.
- **Emotion Recognition:** VR-based training significantly improved facial emotion identification, with a pooled

standardized mean difference (SMD=0.48; 95% CI: 0.31-0.66; p<0.001). Subgroup analysis revealed immersive VR interventions were more effective (SMD=0.61) compared to gamified 2D applications (SMD=0.32).

- **Attention and Engagement:** Twelve studies reported improvements, with intervention groups showing 25-35% higher task completion rates compared to controls. A one-way ANOVA confirmed significant differences between immersive VR, semi-immersive VR, and gamified mobile apps (F(2,29)=6.72, P=0.004). Post-hoc Tukey tests revealed immersive VR > gamified mobile apps (p<0.01).
- **Adaptive Behavior:** Although less frequently assessed, eight studies found moderate improvements (pooled SMD=0.39; 95% CI: 0.18-0.61; P=0.002). However, long-term follow-ups beyond 6 months were rare, and retention effects remain uncertain.

Quality Assessment

Using the Cochrane RoB 2 tool, 11 RCTs were rated as "low risk of bias," 6 as "some concerns," and 1 as "high risk." Non-randomized studies (N=11) assessed via JBI checklists showed generally adequate methodological quality but lacked blinding and standardized outcome measures.

Examination and Interpretation

Overall, findings indicate that VR and gamification significantly enhance social and cognitive rehabilitation outcomes in individuals with ASD. The strongest evidence was observed for social communication and emotion recognition, especially in immersive VR contexts, suggesting that ecological validity and immersion contribute to therapeutic gains. Gamified mobile apps, while less impactful, provided cost-effective and scalable alternatives. However, moderate heterogeneity highlights the diversity of intervention designs, participant ages, and outcome metrics. Statistical analyses (meta-analysis effect sizes, ANOVA comparisons, and heterogeneity testing) confirm the robustness of results while acknowledging methodological variability.

Discussion

The present systematic review critically evaluated 29 studies comprising 1,432 participants to examine the impact of virtual reality (VR) and gamification in autism spectrum disorder (ASD) rehabilitation. Our findings suggest that immersive VR and gamified interventions demonstrate significant improvements in social communication, emotion recognition, engagement, and adaptive behaviors among individuals with ASD. The outcomes align with and extend existing literature on innovative, technology-driven therapies for neurodevelopmental conditions.

Social Communication Outcomes

The pooled analysis indicated a moderate-to-large improvement in social communication (g=0.62), which is consistent with prior research emphasizing the value of VR in simulating realistic yet controlled environments for social training [9-12]. For example, Parsons and Cobb [9] earlier noted that VR could reproduce authentic social contexts without overwhelming sensory demands, a finding echoed by Didehbani *et al.* [10], who demonstrated gains in conversational turn-taking and joint attention. Our synthesis strengthens this evidence base by showing these benefits are replicable across diverse age groups and settings. Notably, the higher impact of immersive VR compared to gamified 2D applications suggests that ecological validity and sensory engagement are crucial mediators of therapeutic success. This finding resonates with Gabrielli *et al.* [17], who highlighted the importance of co-designed multiplayer VR settings for enhancing adolescent social skills.

Emotion Recognition and Engagement

The improvements in emotion recognition (SMD=0.48) highlight VR's ability to deliver repetitive and adaptive practice in reading facial cues, a persistent difficulty in ASD populations. Lahiri *et al.* [11] and Bekele *et al.* [19] reported similar results, where adaptive VR environments adjusted emotional stimuli complexity to match the learner's ability, thereby minimizing frustration and maximizing learning. Likewise, Farashi *et al.* [20] showed VR-based emotion recognition training outperformed traditional computer-based programs. Our findings also confirm the superiority of immersive VR interventions (SMD=0.61) over mobile-based gamified applications, although the latter still improved attention and engagement by increasing task adherence by 25-35%. This supports Wang *et al.* [14], who systematically reviewed gamified approaches and found that reward-based reinforcement sustains motivation but may be limited in depth of cognitive transfer.

Adaptive Behavior and Long-Term Retention

Moderate gains in adaptive behavior (SMD=0.39) are consistent with Carneiro *et al.* [13], who reported that serious games improved daily living skills through structured reinforcement. However, our review identified a lack of long-term follow-up studies, making it difficult to confirm sustained benefits. Thakur [4, intro sequence] emphasized that skill generalization remains a persistent challenge in ASD interventions. This concern applies equally to VR and gamified tools, which may require integration with caregiver-mediated or real-world practice sessions [23].

Critical Analysis of Methodological Quality

Despite promising outcomes, critical appraisal revealed methodological variability. Eleven RCTs demonstrated low risk of bias, but several non-randomized studies lacked blinding or standardized outcome measures. This heterogeneity (I^2=41.7%) is similar to the inconsistencies reported by López-Bouzas *et al.* [21], who reviewed gamified interventions and found diverse study designs limited comparability. Moreover, while many interventions showed efficacy in children and adolescents, relatively few targeted adults with ASD, despite evidence suggesting social-communication challenges persist across the lifespan [5, 24].

Comparison with Broader ASD Intervention Literature

Our results complement earlier evidence-based practices for ASD, such as the Early Start Denver Model and parent-mediated behavioral programs [4, 7, 23]. Unlike traditional therapies, VR and gamification allow scalable, personalized, and immersive interventions that may address accessibility barriers [6, 8]. However, their success depends on thoughtful integration into broader therapeutic frameworks, as standalone gamified tools may not achieve the depth of behavioral change required [16]. Importantly, Ameis *et al.* [25]

stressed that psychosocial interventions must balance efficacy with feasibility, a principle directly relevant to VR, where high costs and equipment requirements could restrict clinical adoption.

Conclusion

The present systematic review highlights the significant potential of virtual reality (VR) and gamification as transformative tools in autism spectrum disorder (ASD) rehabilitation, demonstrating consistent improvements in social communication, emotion recognition, engagement, and adaptive behavior. Synthesizing evidence from 29 studies involving 1,432 participants, our analysis confirmed that immersive VR interventions yielded moderate-to-large effect sizes, particularly in social communication and emotion recognition, while gamified mobile and desktop-based applications contributed to enhanced attention, engagement, and task adherence. These findings collectively validate our hypothesis that immersive, feedback-rich environments provide individuals with ASD unique opportunities to rehearse social and cognitive skills in safe, motivating, and ecologically valid contexts. Importantly, the integration of gamification principles such as rewards, progression mechanics, and interactive storytelling was shown to sustain engagement, which has historically been a challenge in traditional therapy approaches. However, despite these promising outcomes, methodological heterogeneity, limited long-term follow-ups, and the underrepresentation of adult populations with ASD highlight the need for more robust, longitudinal, and demographically inclusive research designs. Practical recommendations derived from these findings emphasize that VR and gamification should not be perceived as standalone therapies but as complementary interventions to evidence-based behavioral and educational strategies. Clinicians and educators are encouraged to integrate VR sessions into structured therapeutic frameworks, using immersive simulations to complement real-world social practice, while gamified mobile platforms may serve as effective homework tools to reinforce skills outside the clinical setting. Policymakers and healthcare administrators should invest in infrastructure that makes VR equipment more accessible to special education schools, rehabilitation centers, and low-resource communities, given the technology's potential to reduce therapist burden and expand access to underserved populations. Equally critical is the need for the co-design of interventions with input from caregivers, teachers, and individuals with ASD themselves, ensuring that interventions remain developmentally appropriate, culturally sensitive, and tailored to the unique needs of each learner. Future studies must address the absence of standardized outcome measures by adopting validated assessment tools that facilitate cross-study comparability, while large-scale randomized controlled trials across diverse contexts will help clarify the cost-effectiveness and scalability of these technologies. From a training perspective, therapists and educators should receive formal instruction in VR and gamified platform integration to avoid superficial or inconsistent use and instead maximize therapeutic fidelity. Furthermore, technology developers should prioritize creating low-cost, portable, and user-friendly VR systems to address barriers of affordability and accessibility while also embedding adaptive features such as real-time feedback, progress tracking, and individualized difficulty adjustments. Considering the well-documented challenges of skill generalization in ASD, hybrid models combining VR practice with real-world application—supported by caregiver mediation and community-based exposure—may enhance the durability of intervention effects. On a policy level, government health agencies and research councils should prioritize funding to support multicentric trials and technology transfer partnerships between academia, clinical institutions, and industry, ensuring innovations reach the communities that need them most. Finally, ethical considerations must remain central, particularly around screen time, privacy of user data, and the potential for sensory overload in highly immersive VR environments; hence, interventions must include monitoring protocols and customization options to safeguard user well-being. In conclusion, this systematic review demonstrates that VR and gamification hold immense promise in bridging existing gaps in autism rehabilitation, and with deliberate integration into existing care models, thoughtful attention to accessibility, and rigorous long-term evaluation, these tools have the potential to evolve from experimental innovations into essential components of evidence-based practice for individuals with ASD, thereby improving their quality of life, independence, and inclusion in society.

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