NEU PRESS

JGEHES Journal of General Health Sciences
GENEL SAĞLIK BİLİMLERİ DERGİSİ

Cilt/Volume:8 Sayı/Issue:2 Yıl:2026 Derleme/Review e-ISSN: 2687-5403

Scoping Review of Gamification Strategies to Support Occupational Performance in Children with Motor Disabilities

Veselin MEDENICA[1] Lidija IVANOVIC[1]
Emina BORJANIC BOLIC[1] Sasa STEPANOVIC[1]

[1] College of Human Developent, Occupational Therapy, Belgrade, Serbia

Article Info

Article History
Received: 16.04.2025
Accepted: 16.07.2025
Published:26.08.2026

Keywords
Review,
Motor Skills,
Social Participation,
Disabled Persons,
Video Games.

ABSTRACT

This scoping review examines the use of gamified interventions in motor rehabilitation for children with developmental disabilities, linking outcomes to ICF-CY and OTPF frameworks. A total of 30 studies were included, investigating various technologies such as virtual reality, augmented reality, motion sensors, and mobile applications. These studies targeted different motor disabilities and applied game-based interventions to enhance patient engagement during therapy and improve occupational outcomes. The most frequently addressed ICF-CY domains were d920 (recreation and leisure), d450 (walking), d440/d445 (fine and gross hand use), and d820 (school education), reflecting a strong emphasis on functional mobility and meaningful participation. Interventions incorporated adaptive feedback systems, real-time monitoring, and individualized difficulty adjustments. Outcomes were assessed using motor performance metrics as well as measures of user engagement and participation, with improvements observed in occupational domains including mobility, fine motor skills, and leisure activities. The review highlights that gamified interventions in pediatric rehabilitation support functional development through play-based, learning-oriented, and socially interactive tasks. Mapping ICF-CY domains to occupational performance areas provides valuable insights for guiding the development of future interventions grounded in occupational therapy principles and child-centered care.

Motor Engelli Çocuklarda Okupasyonel Performansı Desteklemeye Yönelik Oyunlaştırma Stratejilerine Dair Bir Kapsam İncelemesi

Makale Bilgisi

Makale Geçmişi
Geliş: 16.04.2025
Kabul: 16.07.2025
Yayın:26.08.2026

Anahtar Kelimeler
Derleme,
Motor Beceriler,
Sosyal Katılım,
Engelli Bireyler,
Video Oyunları.

ÖZET

Bu çalışma, gençlerin pandemi sonrası sağlık davranışlarını değerlendirmek amacıyla Heo ve ark. (2023) tarafından geliştirilen "Dijital Çağda Gençlerin Pandemi Sonrası Sağlık Davranışı Ölçeği"nin Türkçe formunun geçerlik ve güvenirliğini incelemek amacıyla gerçekleştirilmiştir. Ölçek; bireysel sağlık yönetimi, dijital sağlık bilgisi kullanımı, sosyal etkileşim, fiziksel aktivite ve psikolojik iyilik hâli gibi boyutlar altında gençlerin pandemi sonrası sağlıkla ilişkili davranışlarını ölçmeyi amaçlamaktadır. Araştırma metodolojik türdedir. . Çalışmaya 18-25 yaş arası 300 genç gönüllü olarak katılmıştır. Veri toplama aracı olarak Google Forms üzerinden oluşturulan anket kullanılmıştır. Veriler SPSS 25.0 ve AMOS 22.0 programlarıyla analiz edilmiştir. Uzman görüşlerine dayalı olarak hesaplanan kapsam geçerlik katsayısı en düşük 0.60, kapsam geçerlik indeksi ise 0.87 olarak bulunmuştur. Açımlayıcı faktör analizine uygunluğu test etmek amacıyla yapılan KMO değeri 0.84 ve Bartlett testi sonucu x^2=2210.926 ($p<0.001$) olarak belirlenmiştir. Açımlayıcı faktör analizinde, standart faktör yükü 0.30'un altında kalan üç madde çıkarılmış; kalan 24 madde beş alt boyutta toplanmış ve toplam varyansın %55.16'sını açıklamıştır. Doğrulayıcı faktör analizi sonucunda elde edilen model uyum indeksleri anlamlı bulunmuştur ($p<0.001$). Ölçeğin iç tutarlılığı Cronbach alfa değeriyle değerlendirilmiş ve toplam ölçek için 0.85 olarak hesaplanmıştır. Elde edilen bulgular doğrultusunda, "Dijital Çağda Gençlerin Pandemi Sonrası Sağlık Davranışı Ölçeği"nin Türkçe formunun Türk gençleri için geçerli ve güvenilir bir ölçüm aracı olduğu sonucuna varılmıştır.

To cite this article
Medenica, V., Ivanovic, L., Borjanic Bolic, E., & Stepanovic, S. (2026). Scoping review of gamification strategies to support occupational performance in children with motor disabilities. *Journal of General Health Sciences, 8*(2), 420-451. https://doi.org/10.51123/jgehes.2026.263

***Sorumlu Yazar:** Veselin MEDENICA, veselin.medenica@ahr.edu.rs

This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0)

INTRODUCTION

Children who have motor disabilities experience numerous obstacles that prevent them from participating in meaningful activities such as play, education and daily functional tasks. Such challenges typically stem from impairments in mobility, coordination, and strength, which restrict independent action capabilities and diminish social interaction and learning possibilities (Blank et al., 2012; Novak et al., 2020). Gamification has emerged as a promising method to improve participation in pediatric rehabilitation in recent years (Lohse et al., 2013; Bonnechère et al., 2016). Gamified interventions combine therapeutic exercises with game-like elements such as scoring systems, visual and auditory rewards, and adaptive challenges to boost motivation and enhance motor outcomes (Janssen et al., 2012).

The implementation of gamified systems shows strong relevance for pediatric motor rehabilitation because conventional therapy struggles to maintain children's interest and motivation during repetitive exercises (Huang, 2011). The combination of virtual reality (VR), augmented reality (AR), motion capture systems, and wearable sensors allows for interactive platforms that deliver enjoyable experiences while adapting to individual children's abilities and treatment objectives (Zhang et al., 2024). These tools create opportunities for personalized therapy, because they target essential functional areas of a child's daily activities.

Although interest in gamification for pediatric rehabilitation is growing rapidly, the published research in this field remains quite diverse. Research limitations stem from heterogeneous population samples, varied technology choices, and differing intervention objectives, which result in diverse measurement approaches, making it difficult to create evidence-based guidelines (Molina et al., 2014). The functional importance of gamified interventions often does not align with rehabilitation frameworks such as the International Classification of Functioning, ICF-CY, which prioritizes participation and activity alongside contextual factors (Damyanov, 2024).

The purpose of this scoping review is to investigate the implementation of gamification methods in pediatric motor rehabilitation by evaluating their alignment with ICF-CY domains and their benefits for occupational performance in children with motor disabilities. The objectives of this review are to identify prevalent gamification methods and technological implementations, determine which ICF-CY domains these interventions target, and evaluate their effects on occupational performance, as well as suggest directions for future research.

METHOD

This scoping review was conducted following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines (McGowan et al., 2020) to ensure methodological transparency and rigor throughout the review process. The objective of this review was to explore how gamification is applied in support of occupational performance among children with motor disabilities, using the ICF-CY as the guiding framework (World Health Organization, 2007) for mapping interpretation interventions and interpreting outcomes.

During the screening phase, two reviewers independently assessed the titles and abstracts for eligibility. Disagreements were resolved through discussion and consensus. Although a formal risk of bias assessment is not required in scoping reviews, measures were taken to minimize selection bias by applying predefined inclusion criteria and using independent parallel screening. No formal

review protocol was registered for this scoping review. However, the methodology, including eligibility criteria, search strategy, and data extraction procedures, was developed a priori and is fully detailed in the Methods section to ensure transparency and replicability.

The eligibility criteria were defined to include peer-reviewed articles, doctoral theses, and conference proceedings that addressed gamified interventions aimed at improving motor skills, participation, or functional performance in children with diagnosed motor disabilities. Interventions had to incorporate explicit game-based elements, such as feedback, reward systems, narrative, or progression mechanics, and be linked to rehabilitation or therapeutic outcomes. Studies that targeted general populations or focused solely on cognitive or language skills without clear motor rehabilitation objectives were excluded.

The literature search was conducted between June 1 and July 15, 2024, and covered studies published from January 1, 2014, to May 31, 2024. The search strategy was designed to capture a wide range of literature across multidisciplinary databases, including KobSON, PubMed, Scopus, IEEE Xplore, SpringerLink, and IScienceDirect. Serach terms included combinations of "gamification," "serious games," "motor disabilities," "children," "rehabilitation," "occupational performance," and diagnostic terms such as "cerebral palsy," "developmental coordination disorder," and "motor impairments." Boolean operators and controlled vocabulary terms (e.g., MeSH in PubMed) were used where applicable to refine the search.

To ensure transparency and reproducibility, the full electronic search strategy for PubMed was as follows: ("gamification"[Title/Abstract] OR "serious games"[Title/Abstract] OR "game-based rehabilitation"[Title/Abstract]) AND ("motor disabilities"[Title/Abstract] OR "cerebral palsy"[Title/Abstract] OR "developmental coordination disorder"[Title/Abstract]) AND ("children"[Title/Abstract] OR "pediatric"[Title/Abstract]). Limits applied: Publication date from 2014/01/01 to 2024/05/31; Language: English, Serbian.

After removing duplicates, all records were screened by title and abstract to assess their relevance. Full texts of potentially eligible studies were then retrieved and assessed against the inclusion criteria. A total of 30 studies were selected for in-depth review and data extraction. Extracted data included author(s), year, population characteristics, type of motor impairment, type of gamified intervention, technological platform used, feedback and reward mechanisms, targeted ICF-CY domains, occupational performance outcomes, and evaluation tools. To enhance the consistency of data analysis, a coding framework was developed iteratively and applied to all studies by the primary reviewer.

In the process of organizing the discussion section, all four reviewers independently analyzed each included study using a structured checklist designed to identify common elements across the literature. This checklist included items related to the types of gamification strategies, outcome measures and their purposes, technological platforms (e.g., VR, AR, sensors, mobile games), personalization and adaptive features, feedback and motivational mechanisms, user and therapist roles, and the functional domains addressed through ICF-CY and occupational performance frameworks. After individually extracting and summarizing these elements from all studies, the reviewers compared findings and reached a consensus on the key recurring themes. These themes—considered most relevant to understanding gamification in the context of pediatric motor impairments—served as the foundation for structuring the discussion section of this review.

The process of coding and linking the reviewed studies to the ICF-CY framework was conducted by a team of four independent reviewers. Each reviewer independently analyzed the extracted intervention descriptions and outcome focuses of the included studies, with the goal of identifying which specific domains of the ICF-CY classification were addressed by the gamified interventions. Reviewers used the official ICF-CY terminology and domain structure as a reference to ensure consistent coding across studies.

Where discrepancies in domain assignment occurred, particularly in complex or multi-domain interventions, reviewers engaged in collaborative discussion until consensus was reached. This consensus-based coding process ensured that each domain attribution reflected not only the literal content of the intervention, but also its functional intent and therapeutic relevance. In addition to assigning ICF-CY domains, reviewers evaluated how the targeted functions and activities aligned with the definitions of occupational performance domains (according to OTPF-4 (Occupational Therapy Practice Framework, 4th edition)), including mobility, play, self-care, and social participation (Boop et al., 2020). This interpretive linking was grounded in occupational therapy literature and aimed to highlight how gamified interventions contributed to meaningful participation and function from an occupational perspective.

The review did not aim to assess the quality or risk of bias of the included studies, in accordance with scoping review methodology, which prioritizes mapping the existing evidence base rather than evaluating the effectiveness of interventions. The analysis was structured around three main axes: gamification strategies, the relevance to ICF-CY domains and occupational performance, and methodological limitations with implications for future research.

RESULTS

The research review included 30 studies examining the implementation of gamification to enhance motor disability rehabilitation for children (Figure 1.). A group of four independent reviewers independently evaluated each study. The reviewers applied ICF-CY codes to intervention results and goals by using the information from each study regarding targeted skills, performance indicators, and the types of activities, which were grounded in the ICF-CY framework from the World Health Organization (2007).

Each member of the team applied ICF-CY codes autonomously during the initial stage. When reviewers disagreed about coding, they held meetings to achieve consensus on their assignments. The reviewers used this method to create final mappings that combined their shared understanding while reducing personal biases. The studies primarily focused on mobility and movement domains, which included walking (d450) and hand use (d440, d445), along with motor control domains like control of voluntary movement (b760), and recreational engagement domains, including recreation and leisure (d920) and play (d880).

The reviewers applied ICF-CY codes to determine which domains were most relevant for occupational performance assessment. The reviewers compared these ICF-CY domains to categories found in the OTPF, which included leisure, mobility, fine and gross motor skills, education, and social participation. This analysis demonstrated the practical links between gamified interventions and occupational needs of children with motor disabilities. The research showed that balance and coordination studies were mostly linked to the mobility domain, and interactive recreational technology interventions were primarily linked to leisure and social engagement domains.

The heatmap provided (Figure 2.) offers additional evidence to support findings by showing the distribution of ICF-CY domains relative to OTPF categories. According to the heatmap results, the

domain d920 within leisure was the most common target area for occupational performance. The ICF-CY domains of mobility and motor function, included d450 (walking) and d440 and d445 (fine and gross motor use), appeared frequently. Studies targeting educational domains (d820) and social domains (d750) appeared less often but remained significant. The research excluded remunerative work domain (d850) because the population fell within the age exclusion criteria. The majority of intervention studies targeted between one and three ICF-CY domains, indicating a focused approach in their design.

The study presented findings through systematic tables (Table 1, Table 2) alongside a visual heatmap (Figure 1.) which offered an extensive understanding of gamification applications in pediatric rehabilitation for achieving meaningful occupational goals.

Figure 1

PRISMA Process Diagram

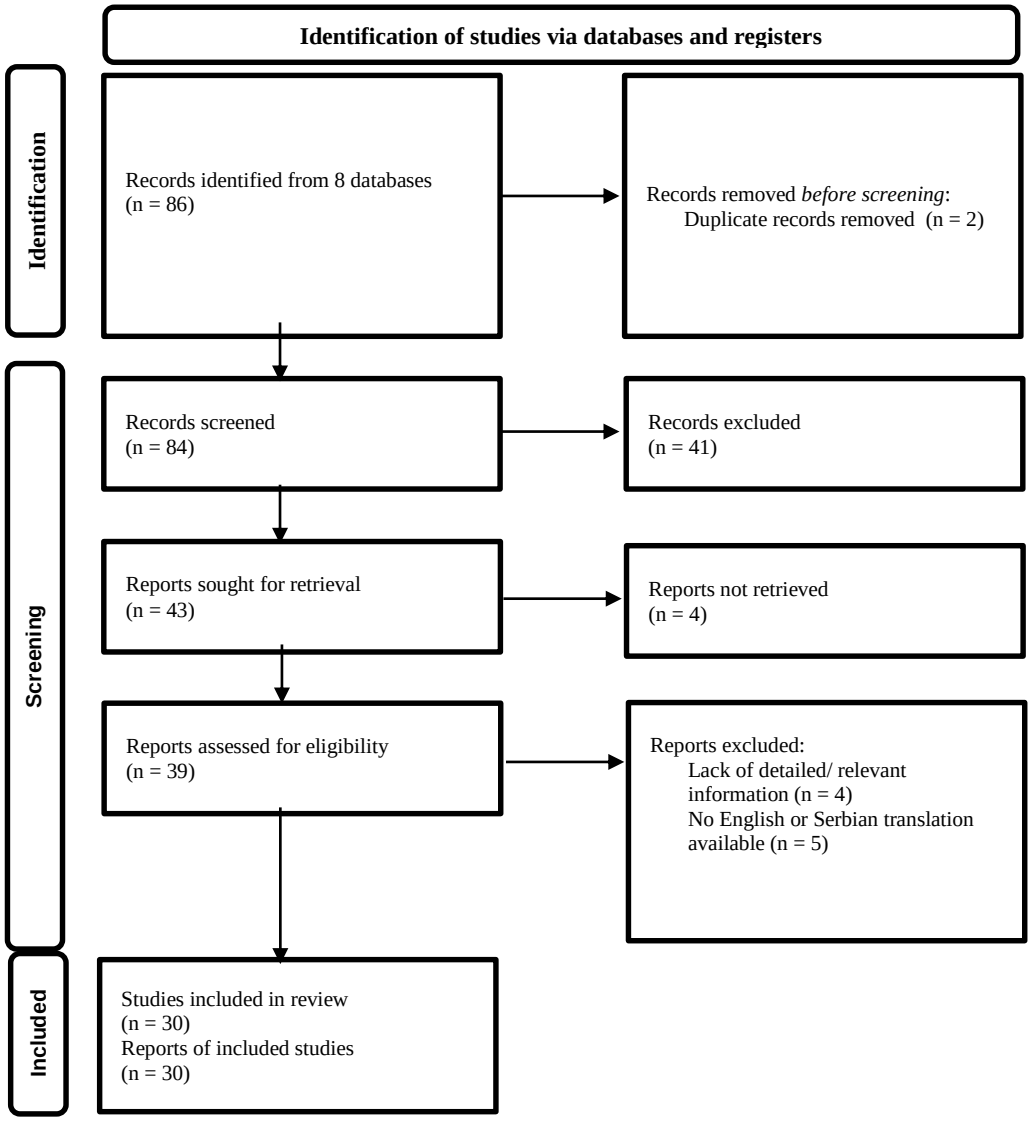


Table 1

PRISMA report on selected sources

Author (Year)	Population	Type of Intervention	Gamification Elements	Outcome Measures	Main Findings	Study Design
Afyouni et al. (2017)	Individuals with motor impairments of the hand; 5 participants	An adaptive serious game platform using Leap Motion technology, tailored to therapeutic hand movements in a 3D virtual environment.	Levels of difficulty, real-time feedback, personalized maps, virtual flights, adaptive challenges, points, in-game obstacles, progress visualization	Range of motion (ROM), angular speed, acceleration, gesture precision, user satisfaction.	The personalized gamified therapy system increased patient motivation and engagement, and enabled real-time adaptation based on individual progress. Improvements were observed in ROM and interaction quality.	Pilot technical and usability study with 5 participants; quantitative and qualitative evaluation.
Nossa et al. (2021)	Children with neuromotor impairments (mainly cerebral palsy, some with acquired brain injury); 56 families surveyed	Survey-based needs assessment for designing inclusive, accessible, and enjoyable videogames for children with neuromotor impairments.	Not directly tested in a specific game but explored in design preferences: reward systems, adaptive difficulty, feedback, cooperative vs. competitive play, preferred game environments and characters	Survey responses on children's motor and cognitive function, gaming habits, device accessibility, emotional responses to games, and preferences for game content and controllers.	Children with neuromotor disabilities show high interest in technology-based play. Parents prefer game designs that include bi-manual tasks, symbolic and intuitive controls (e.g., steering wheels), and short, goal-directed sessions. Cooperative play is favored over competitive.	Cross-sectional online survey with both quantitative (Likert scales) and qualitative (open-ended) questions.
Vidal et al. (2023)	Children with epileptic encephalopathy (rare developmental disorder with fine motor impairments); 4 participants	A serious game called Pizza Game using Leap Motion Controller for rehabilitation of fine motor control through simulated object manipulation tasks.	Goal-directed tasks, auditory feedback (bells and horns), time tracking, virtual object manipulation, adaptive session progression	Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition (BOT-2), Fine Motor Precision (FMP), Fine Motor Integration (FMI), Manual Dexterity (MD), Upper-Limb Coordination (ULC), Pittsburgh Rehabilitation Participation Scale (PRPS), User Satisfaction Evaluation Questionnaire (USEQ).	Significant improvements were observed in FMP ($p = .009$) and FMI ($p = .002$). MD and ULC did not significantly improve. Participation scores were rated good to very good. High satisfaction was reported, indicating the system was engaging, effective, and usable. Participants reduced task time over sessions and increased interaction success.	Pilot intervention study with pre-post assessment over 10 sessions (5 weeks); quantitative outcomes with t-test analysis.

Altilio et al. (2015)	Children and adults with various motor disabilities (stroke, cerebral palsy, multiple sclerosis, Parkinson's disease, etc.)	Overview of telerehabilitation (TRH) systems using low-cost technologies (e.g., Kinect, IMU sensors, RGB-D cameras) combined with serious games and multimedia interfaces for home-based motor therapy.	Rehabilitation games include: levels, feedback, avatar movement, performance tracking, scoring, mini-games, and challenges (exergames)	Review of kinematic performance (ROM, coordination), usability, clinical utility, technological feasibility; no original data collected.	The paper highlights how affordable, game-based TRH platforms can improve accessibility to rehabilitation for patients at home. It showcases systems like Rewire, Jintronix, and Rehab@Home and emphasizes their role in increasing engagement, extending therapy beyond clinical settings, and enabling remote tracking and personalization.	Narrative review / technical overview.
Hussein et al. (2023)	Students with special needs, including intellectual disability, learning disabilities, Down syndrome, autism spectrum disorder, and motor impairments; 15 empirical studies included in the review	Various gamified tools and environments aimed at skill development for children with disabilities; focus on learning, cognitive, behavioral, and emotional skills.	Points, badges, levels, feedback systems, structured interactive environments, motivational mechanics (as abstracted from the included studies)	Diverse – ranging from academic performance, reading and math ability, emotional intelligence, and behavioral improvements to subjective measures like satisfaction and engagement.	Gamification enhances a wide array of skills in children with special needs, with most studies showing effects on learning skills (46.7%) and cognitive abilities (33.3%). Fewer studies addressed behavioral (13.3%) and life skills (6.7%). The authors identified a gap in diversity of target populations and skill domains.	Systematic review using PRISMA methodology.
Tosto-Mancuso et al. (2022)	Stroke survivors with motor impairments (primarily adults; focus on chronic stroke recovery)	Gamified neurorehabilitation strategies, including non-robotic, robotic, and immersive virtual reality-based interventions for post-stroke motor recovery.	Feedback, task-specific movement repetition, immersive environments, avatar-based interaction, reward systems, goal-oriented play, exergames, serious games	Review of existing literature on rehabilitation outcomes (arm function, balance, motivation, adherence), focusing on systematic reviews and includes discussion of effectiveness, neuroplasticity, user engagement, cost-effectiveness, and scalability.	Gamified neurorehabilitation is a promising and engaging method for promoting motor recovery post-stroke. It enhances intensity, enjoyment, motivation, and adherence, especially when compared to traditional methods. However, barriers remain for large-scale adoption, including clinician skepticism, high cost, technological literacy, and infrastructure needs. There is limited distinction in the literature between gamified and non-gamified robotic therapies, which complicates evidence synthesis.	Narrative (topical) review with critical synthesis of recent literature (including meta-analyses and RCTs).

Eckert et al. (2023)	Children aged 5–12 with physical disabilities: 5 with cerebral palsy (CP) and 1 with obstetric brachial plexus palsy (OBPP); 6 children	Use of a customizable exergame ("Phiby's Adventures") embedded in the Blexer system, tailored to train upper limb function via Kinect-based motion capture.	Game avatars, story-based progression, movement-based challenges, adaptive difficulty, reward feedback, player decision-making (free path selection)	Box and Block Test (BBT) and Jebsen Taylor Hand Function Test (JTHFT); In-game performance metrics: % of achieved movements and % of time used.	Moderate game difficulty settings (where children completed 70–100% of objectives within time limits) led to better engagement and greater functional improvement. Children improved significantly in hand function (JTHFT) and fine motor coordination (BBT). Children with more severe impairments benefited more from JTHFT; those with better baseline function improved more in the BBT.	Small-scale observational case study with repeated measures; embedded in school-based physiotherapy sessions.
Pinos Cisneros et al. (2023)	Children with cerebral palsy (ages 2–18), with a focus on hand motor impairments 54 studies analyzed (participants in the reviewed studies range from 1 to 80 children per study)	Technology-supported hand therapy using both therapeutic-specific and consumer-grade technologies (e.g., smart toys, Kinect, Wii, Leap Motion).	Playfulness mapped via "Lenses of Play" framework including: Play structures: Goals, rules, structured challenges/ Forms of play: Physical/active play, creative play, pretend play Playful experiences: Challenge, control, competition, completion, fantasy, expression	Reported improvements in hand motor skills, motivation, engagement, adherence, and sometimes social-emotional outcomes; most interventions aimed at increasing therapy compliance through enjoyable activity.	Gamified and playful technologies in therapy for children with CP show strong potential to enhance engagement and effectiveness. Most interventions favor structured play with goal-oriented tasks (Ludus), while fewer utilize open-ended or improvisational forms of play (Paidia). Use of consumer technologies (Nintendo Wii, Kinect, etc.) was prevalent due to accessibility and familiarity. Wearables and smart tangibles allowed nuanced feedback and adaptive interaction. The diversity of playful elements and combinations of tech highlight the importance of tailored therapy solutions.	Scoping review following PRISMA-ScR, including 54 studies from 2009–2022.

Hassan, L (2024)	People with disabilities – including motor, cognitive, auditory, visual, mobility impairments, and elderly users; 162 studies reviewed (published between 2016–2020)	General review of game technologies' accessibility — including serious games, gamification, exergames, VR/AR, and mobile games across diverse domains (education, health, entertainment, etc.).	Gamification is one of the categories reviewed (alongside serious games, mobile games, etc.) but the article is more about mapping accessibility across these approaches.	Not empirically assessed — this is a thematic mapping study. Main indicators are types of technologies used, types of disabilities addressed, and use domains (health, education, etc.).	Motor, auditory, and mobility disabilities are significantly underrepresented in accessibility-related game research. Gamification, exergames, and immersive technologies (VR/AR) also receive limited accessibility-focused attention. Most research is utility-driven (focused on education and health), neglecting entertainment and leisure as valid participation goals. Suggests stronger theoretical framing and cross-domain synthesis (e.g., combining accessibility with design theory). Research gaps include accessibility in VR/AR, for motor impairments, and in non-utilitarian contexts.	Systematic literature review with thematic mapping and qualitative meta-analysis.
Demers et al. (2021)	Children and adolescents with cerebral palsy (CP); 26 studies (from 30 publications), sample sizes in individual studies ranged from 1 to 30	Virtual reality–based rehabilitation targeting upper limb function; both commercial and custom VR systems were analyzed.	Enhanced feedback (visual, auditory, haptic). Variable and task-specific practice; Motivation through game-like environments; Challenge progression (in custom systems more than commercial ones);Reward systems (scores, performance displays).	Motor function assessments (e.g., upper limb kinematics, functional tests); Motivation (participant reports, therapist observations); Retention and transfer (rarely assessed); Use of motor learning components (feedback, task variability, difficulty progression).	VR interventions for children with CP commonly include motivational elements and enhanced feedback Custom VR systems were better aligned with motor learning principles than commercial games There was limited integration of difficulty progression and poor reporting on motor skill retention and transfer Commercial systems were engaging but not always adapted to the capacities of children with CP. The therapeutic potential of VR can be significantly improved by systematically embedding motor learning principles.	Systematic review (PRISMA-based) with critical appraisal using the Downs and Black checklist.

Tresser (2019)	Children aged 7–11 with 20 children with CP 60 children with typical development	A novel, personalized virtual reality game system (iVG4Rehab) designed to support upper-limb motor training through real-time dynamic difficulty adaptation based on individual performance.	Personalized feedback and challenge level; Real-time difficulty adjustments based on kinematics; Playful, engaging environment using Kinect and gesture recognition; Embedded task goals and success metrics; Dwell vs. accuracy mode comparisons	Performance: percent success, level increase, task duration Usability: perceived effort, perceived enjoyment; Kinematics: path length, movement duration, curvature, overshoot.	Personalized gaming led to greater effort but not lower enjoyment among TD children. Children with CP performed similarly across conventional and personalized versions. Accuracy mode produced higher success rates than dwell mode. Children with CP showed similar performance in accuracy mode as TD children. Weighted play affected performance in TD but not in CP children. Real-time adaptation improved challenge precision and usability, potentially improving clinical outcomes.	Experimental design with within- and between-group comparisons.
Roxo, Nóbrega & Madeira (2022)	Children with various developmental disabilities (cerebral palsy, global developmental delay, autism spectrum disorder, spinal muscular atrophy); 10 participants (ages 3–11)	Participatory design and evaluation of four exergames using a dance mat for physical therapy, motor training, and engagement in children with developmental disabilities.	Visual feedback, symbolic targets, and score tracking; Task variety and progression (e.g., symbol matching, reaction games, obstacle dodging); Flexibility of use (standing, seated, laying down); Game themes: Matchmat, Left or Right?, Crazy Car, Fishing; Game customization: difficulty level, input mapping, layout configuration	Usability: System Usability Scale (SUS) for children and therapists; Game metrics: accuracy (Manhattan distance), play duration, interaction tracking; Observational feedback: therapists rated integration feasibility per child.	Games were highly accepted by children and therapists; average SUS score of 68.75 (children) and 77.5 (therapists). Children with GMFCS ≤ III benefited most; those with more severe motor impairments required too much therapist assistance. The dance mat proved to be a flexible, affordable, and versatile controller adaptable to various physical abilities. Participatory design led to meaningful game experiences and better therapeutic alignment. Therapists expressed intention to integrate games into regular therapy for several children. One game (Fishing) was deemed too cognitively demanding and was excluded from extended testing.	User-centered participatory design; mixed-methods evaluation; design thinking framework.

Ennis et al. (2016)	Children with physical impairments who use postural aids or have limited mobility (potential for future child studies; initial technical validation done on healthy adults); 2 un-impaired adults in prototype testing (planned future testing on children)	Gamified step-counting system using wearable sensor (Shimmer3) and a mobile application for collecting kinematic data to track and analyze treatment outcomes over time.	Daily step targets; Unlockable achievement badges; Progress tracking and positive reinforcement; Customizable step goals (set by therapist); Notifications and visual incentives	Step count accuracy (compared to human-observed ground truth); Accelerometer waveform analysis (raw and threshold-based step detection); Usability and feedback system for therapists via web portal Plans for future gait metric extraction: cadence, stride length, balance, trunk control.	The gamified system successfully increased user engagement with step tracking. Without postural aids, step counts were within 1–2 steps of actual; with postural aids, algorithm overcounted (due to lower motion magnitude). Authors propose algorithmic improvements for better accuracy in pediatric populations with assistive devices. The system is seen as a promising tool for quantitative and longitudinal evaluation of mobility-focused interventions.	Prototype development with engineering validation (sensor calibration and algorithm testing); future clinical implementation planned.
Antunes (2021)	Children with special needs, particularly those with cerebral palsy and motor impairments. The study does not isolate a specific age bracket but is focused on pediatric users in therapeutic settings.	Development and testing of a web-based therapeutic game design platform named PLAY, with integration of serious games for rehabilitation Framework includes model-driven game design, integration of smart sensors, NUI devices, and use of adaptive actions based on patient profiles.	Game mechanics based on levels and sequences of therapeutic actions; Real-time feedback loops, scoring, and progress tracking; Use of character avatars, narrative, and reward systems; Tools for therapists to model games based on specific motor exercises and goals.	Qualitative therapist feedback; Usage data collected from game sessions (joint angles, task completion rates, time-on-task, interaction frequency); Validated therapeutic goals cross-referenced with QUEST and GMFCS scales.	The platform successfully allows therapists to create personalized rehabilitation games using a high-level modeling interface. It supports smart environments through the use of NUI sensors, actuators, and machine learning for data analytics. Therapists can visualize, analyze, and compare patient progress across sessions and even between clinics. API allows integration with external applications and devices. Pilot results suggest high usability and therapist satisfaction; games were engaging for children.	Mixed-methods: platform development, technical validation, therapist evaluation, and preliminary patient testing.

Hassan (2024)	People with various disabilities in educational settings, particularly: visual impairments (blindness, low vision, color blindness), motor impairments (e.g., cerebral palsy), cognitive/emotional disabilities (including autism, Down syndrome, learning disabilities), auditory impairments; Systematic review of 66 articles published between 2016–2020	Review of various game-based educational technologies, including: serious games, mobile games audio games, gamification VR and AR applications.	Not reported	Not reported	Motor disabilities are underrepresented in accessibility research compared to cognitive or visual impairments. Educational games often fail to accommodate multiple disabilities simultaneously. Few studies involved co-design with people with disabilities. Accessibility issues in emerging tech (AR/VR) require urgent attention. There's a need to compare user experience between disabled and non-disabled users to avoid creating new digital divides. Most work focused on children, while adults with disabilities were rarely addressed.	Systematic literature review using SCOPUS and thematic coding over 66 manuscripts.
Ikebara (2021)	Children aged 9–16 years with cerebral palsy (GMFCS Levels I–II; 8 children with CP from 7 families.	Robot-mediated exergaming system (PedBotHome) targeting: ankle rehabilitation (dorsiflexion, plantar flexion, inversion, eversion), stretching and strengthening therapy delivered via a game interface.	Flying game controlled by foot movement via robotic footplate; Progressive difficulty, feedback, scores; Remote monitoring by therapist; Game goals as proxy for therapeutic goals; Immersive and child-friendly game scenario.	Qualitative thematic analysis of in-depth interviews; Structured alignment of findings with: Home Exercise Program (HEP) adherence theories; Exergame engagement literature; PYTHEIA evaluation instrument for robotic A/RTs.	PedBotHome is feasible and engaging, but adherence and enjoyment decline with repetition. Families value in-home therapy for logistical reasons. A major design challenge is balancing game enjoyment and therapy efficacy. Subjective experience (motivation, autonomy, frustration) is critical to adoption and sustained use. Existing instruments like PYTHEIA cover many relevant dimensions but miss some pediatric-specific and engagement-related factors. A new framework is proposed to develop a validated tool to assess subjective experience in child users of robotic/gamified rehabilitation technologies.	Descriptive study with qualitative thematic analysis

Kachmar et al. (2021)	Individuals with Cerebral Palsy (CP), primarily children and young adults with motor disabilities affecting movement and posture; 25 children (13 experimental, 12 control).	Use of personalized serious games from the GABLE platform over a two-week period, with a focus on trunk control and dynamic balance through weight-shifting tasks on a Wii Balance Board. Customizable games were tailored to each child's motor level.	mmediate feedback; Achievements and progression; Custom avatars and gameplay personalization; Simplified control schemes (single-button interaction, sweep control, sliders); Adaptive difficulty and configuration options; Use of Kinect and mechanical switches; Social interaction (leaderboards, two-player modes); Games Developed: Footb-all – simple soccer game using mechanical switches - Formula Chair – racing game controlled via Kinect -Fisio Run – running/jumping game emphasizing therapy goals	Trunk Control Measurement Scale (TCMS) – primary Dynamic Balance Test (DBT) Timed Up & Go Test (TUG); Center of Pressure Path Length (COP-PL).	Statistically significant improvement in TCMS (+4.5 points, $p < 0.05$) and DBT scores (+0.88 points, $p < 0.05$) in the experimental group. No significant improvement in TUG or COP-PL scores. Games effectively matched players' developmental levels, supporting engagement and effective motor learning. Suggested need for longer interventions and larger sample size for more definitive results. The pilot study served as a base for designing future RCTs.	Pilot quasi-experimental study with two groups and pre-post measurement; random group allocation based on medical record number.
Parise et al. (2023)	Children aged 2–18 years with various motor disabilities, including: Cerebral Palsy (CP) Ataxia Spina Bifida Complex Regional Pain Syndrome (CRPS) Other movement disorders Participants varied in physical ability from needing trunk support in sitting to independent standing; 16 participants, assessed across 176 therapy trials.	Development and testing of ADAPT, a large-screen smart, touch-based therapeutic gaming system designed to increase participation and engagement in reaching and balance exercises. Primary game used: "Bubble Popper".	Interactive and personalized gameplay (e.g., theme selection, bubble color, difficulty); Progressive task difficulty; Visual and auditory rewards; Motivational messages; Game mechanics based on Self-Determination Theory (SDT): Autonomy, Competence, Relatedness; Therapist-adjustable modes (e.g., Obstacle, Quadrant) Pop-to-touch scoring metrics	Qualitative: Pre-test: Hopkins Rehabilitation Engagement Rating Scale (HRERS); Post-test: Custom therapist-reported engagement questionnaire (9 items); Quantitative (from ADAPT system): Total game play time, Number of screen touches Inter-touch interval (ITI), Pop-to-touch ratio, Spatio-temporal distribution of touches (reaching diversity).	High engagement across all age groups, with over 200 reaches per session. No significant differences between younger (2–7 years) and older (12–18 years) in engagement or play time. Therapists reported that the system increased fun, autonomy, and therapy goal alignment. The system enables therapists to customize the experience, facilitating engagement and targeted training. Positive reception from both therapists and children; suitable for clinical and potentially home use. Demonstrated feasibility and utility of gamification for pediatric motor rehab.	Mixed-methods feasibility study (qualitative and quantitative evaluation)

Guinet et al. (2022)	25 children aged 12–18 years with spastic cerebral palsy (GMFCS I–III), able to walk with or without aids, and capable of understanding instructions.	Use of Microsoft HoloLens AR headset delivering visual feedback during walking under different conditions, aiming to influence gait speed.	AR-based interactive visual stimuli (round colored shapes, gradients) Real-time feedback on performance Variability in feedback based on color, position, motion, and persistence Personal challenge (e.g., shapes disappear if not caught on time); Use of engaging, immersive design principles.	Mean walking speed (condition MAX and INTER); Percentage of time above/around target speed; Time to reach target speed; User experience questionnaire (usability, engagement, comfort).	Scenario 6 (gradient color, world-locked, fading stimuli) led to the highest walking speeds and greatest success in exceeding target speed. Scenario 6 outperformed control (no feedback) in all measures. Time to reach target speed was shortest in scenarios 5 and 6. Children reported high immersion, ease of use, and enjoyment. Personalization of feedback and scenario enhanced therapy outcomes. Study supports AR visual feedback as a viable gamified intervention in pediatric rehabilitation.	Experimental study (repeated measures)
Jadavji et al. (2022)	10 children aged 6–16 years with severe motor disabilities (mostly quadriplegic cerebral palsy, GMFCS V), non-verbal and non-ambulatory, but cognitively intact	Implementation and evaluation of a clinical BCI (Brain-Computer Interface) program using non-invasive EEG-based systems (EPOC+, g.tec intendiX, mindBEAGLE). Activities included: control of video games (driving, jumping, shooting), robot control (Sphero), creating art, smart home commands (via iPad), communication interfaces (spelling, yes/no), motor imagery for object control.	Real-time interactive feedback; Personalized challenges (art creation, robot driving); Turn-taking and competitive play with family members; Customization of goals and tools per user; Engaging interfaces with visual and motion-based tasks,	Completion of individualized BCI tasks; Amount of training time per participant; Qualitative caregiver and therapist feedback; Participant performance across multiple activity types; Motivation levels across different BCI paradigms (motor imagery vs. spelling).	Most children were able to successfully use the BCI for various tasks (motor imagery being the most reliable strategy). Motivation was highest during gamified tasks like driving or painting, and lowest in spelling. Families reported enthusiastic support for continuing and expanding the program BCI allowed children to achieve first-time experiences of autonomous play, communication, and creativity. Challenges included attention span and maintaining engagement, suggesting a need for more game-based options. The study underscores the critical role of gamification in sustaining motivation in complex rehabilitation technologies.	Descriptive clinical program report with individual case analyses, qualitative outcomes, and narrative feedback from families and therapists.

Whittinghill & Brown (2014)	21 children with pediatric cerebral palsy (CP) Note: This pilot study used a convenience sample of 21 participants aged 6 to 34, mainly undergraduate students, in preparation for deployment with children with CP	Prototype evaluation of "Burnie," a Kinect-based serious game simulating upper extremity physical therapy poses for children with CP. The player controls a bird by performing calibrated therapeutic movements.	Roleplay as a bird named; Burnie navigating an obstacle course; Therapy poses reframed as game actions: Flap (arm lift), Strafe (balance), Dive (rest pose); Positive reinforcement only—no penalties; Reward system: collection of fun items (bugs, balloons), humorous effects (e.g., jet of fire after eating pepper); Calibrated movements per user's ability; Visually immersive and whimsical environment; Operant conditioning model (ABC: Antecedent–Behavior–Consequence),	Likert-scale questionnaire after 15–20 minute gameplay: visual aesthetics and overall enjoyment.	Participants found the game visually appealing and generally enjoyable. Control scheme rated lowest, suggesting either physical fatigue or poor input responsiveness. The approach of reframing therapy movements as play actions is promising Individual calibration of poses is critical to enable inclusivity across ability levels. Further clinical testing with actual pediatric CP users is needed. The system holds potential to increase therapy adherence and motivation via gamification and positive reinforcement.	Pilot usability study
Romeo et al. (2024)	Children and adolescents aged 0–18 years diagnosed with cerebral palsy (CP), with varying GMFCS levels (I–IV), involved in non-rehabilitative recreational sports or game-based activities; 15 studies included, covering a total of 401 children with CP	Participation in sports activities (dance, swimming, martial arts, basketball, soccer, tennis, adaptive cycling, baseball) and game-based training (Nintendo Wii, personalized balance games, computer-based dual-task training, virtual golf).	Video games used for physical training; Game-based dual-task protocols (balance + cognition) Wii Fit balance games; Immersive platforms with visual and motion feedback; Use of adaptive and accessible sports formats.	GMFM-88 Pediatric Balance Scale (PBS); CoP sway (postural stability); Child Behavior Checklist (CBCL); Trunk Control Measurement Scale (TCMS); Quality of life; questionnaires Enjoyment and adherence ratings.	Dance and swimming consistently improved balance, gait, and gross motor function. Wii Fit and virtual reality-based training showed significant gains in balance, postural control, and upper-limb coordination. Sports participation was associated with increased enjoyment, engagement, and quality of life. Virtual golf and personalized balance games yielded improvements in flexibility, strength, and postural control. Significant biopsychosocial benefits noted in sports participation (especially in children with diplegia). No adverse effects reported, even in children with higher levels of impairment. The review emphasized integration of recreational sport as a complement to traditional rehab.	Systematic review

Lerma Lara et al. (2016)	Children with Cerebral Palsy (CP), especially those with significant gait impairments and motor control deficits. The system is designed with young children in mind, capitalizing on neuroplasticity in early development.	Development of a top-down robotic rehabilitation system (CPWalker) that integrates: Smart Walker with body-weight support, wearable exoskeleton Multimodal human-robot interface (MHRI) combining EEG, EMG, and IMU sensors. Repetitive, intensive gait training based on volitional motor planning and feedback.	Real-time biofeedback during training; Auditory and visual rewards for completing motor tasks; Planned integration of parallel gamification layer for tracking progress and increasing participation; Motivational triggers such as task mastery, progress tracking, and interactive control	Not reported	Argues for the necessity of combining CNS and PNS feedback in robot-assisted rehabilitation for CP. Introduces a new framework for cognitive-motor interaction using robotic platforms. Highlights motivation and engagement as essential components of neuroplasticity and effective therapy. Provides conceptual foundation for randomized clinical trials using CPWalker platform. Suggests that gamification and volitional control mechanisms can enhance therapy adherence, engagement, and motor learning.	Conceptual framework and system design
González-González et al. (2019)	Uunspecified number of individuals undergoing motor or cognitive rehabilitation, including children and adults with neurological or motor impairments. While not limited to any one condition, it is relevant to populations with cerebral palsy, traumatic brain injury, or developmental disorders.	Development and testing of TANGO:H, a gamified rehabilitation platform using Kinect-based gesture recognition and a recommender system to adapt therapy tasks dynamically to individual performance and needs.	Personalized exergames with real-time feedback; Difficulty scaling and adaptive progression; Visual and auditory rewards and encouragement; Competitive and cooperative multiplayer game modes; Therapist-designed and user-preferred exercises; Recommender system suggesting optimal exercises based on user profile and task history	Comparison of task performance over sessions; Therapist evaluation of patient progress; System usability and engagement analysis; Performance prediction and personalization efficacy via recommender system; Indirect improvement in compliance, motivation, and motor planning.	The recommender system successfully suggested exercises aligned with user progress and engagement. Patients demonstrated improved adherence and greater participation in therapy compared to standard routines. Therapists valued the flexibility and customization options. The platform enabled real-time adaptation of difficulty, helping to maintain the “flow” experience. The system is feasible for clinical use and shows promise for scaling up in neurorehabilitation programs.	Pilot feasibility study

Sedini et al. (2024)	Children aged 4–12 years, including children with cerebral palsy and children without disabilities, involved in participatory design and testing of a digital motor rehabilitation tool; Experimentation Lab 1: 6 children (ages 4–8) Experimentation Lab 2: 20 children (ages 4–8) Online/offline co-development tests: 10 children (4–8 y.o.) School test 1: 20 children (4–12 y.o.) School test 2: 40 children (8–10 y.o.)	Co-design and iterative testing of BODYSOUND, a gamified, motion-activated system for motor reactivation using sound-based feedback. The system translates body movement into melodies and scores using gesture recognition and visual avatars.	Movement-to-sound feedback loop; Avatar interaction that mirrors child's movements; Points and levels system; Music and rhythm-based progression Use of narrative (Halloween version); Cooperative and competitive multiplayer play; Game personalization and difficulty calibration per child.	Observation (direct and video-recorded) of engagement and movement execution; Parental feedback via diaries and interviews; Usability, pleasure, and enjoyment ratings; Movement calibration and task completion success; Feedback from therapists and co-participants; Learning effect and system intuitiveness.	Children easily engaged with the system, understood rules independently. Movement feedback through music significantly increased enjoyment and motivation. Avatars and sound-guided motion improved interaction and expressiveness. Co-design process enabled personalization and real-world relevance. Technology adapted to children's physical capacities (automatic calibration). Offline and online testing both viable, but hardware limitations in home use noted. Co-creation revealed importance of tangible, low-tech prototypes during early stages. Children contributed as informants and testers, influencing design decisions directly.	Participatory design and formative usability study (mixed methods)
Rodriguez (2015)	4 children aged 13–16 with multiple disabilities (defined as a combination of motor and severe cognitive impairments, resulting in extreme limitations in autonomy and communication)	Design and initial testing of a virtual reality wheelchair simulator developed in Unity3D, intended to teach wheelchair navigation skills in a safe, controlled, and low-cognitive-load digital environment.	Positive reinforcement (fireworks, smiley face) when children stay on course Level-based progression; Simple, high-contrast graphics to reduce perceptual overload; Sound feedback (e.g., applause at end of task); Customized joystick hardware for accessible input; Realistic simulation of wheelchair physics (directional response, acceleration).	Qualitative observation of engagement, attention, and emotional response; Reports from educators and therapists; Usability feedback on joystick and scene simplicity; Time spent using simulator; Degree of distraction and recognition of visual cues while driving.	Children were interested and curious about the simulator. Some managed 2–3 minutes of continuous driving before fatigue. Simplicity of graphics and sound was effective in maintaining engagement. Traditional joystick use was difficult for longer sessions → need for adaptive interfaces. Highlighted the challenge of evaluating user experience in children with minimal verbal or gestural expression. Simulator showed potential for training, especially when embedded in individualized learning plans. Collaboration with a multidisciplinary team (therapists, orthoptists, educators) proved essential.	Pilot usability study with qualitative observation

Saimaldahar (2016)	3 children aged 4–12 years diagnosed with spastic quadriplegic cerebral palsy, presenting with severe motor disabilities and some cognitive or communicative challenges	Development of a gamified assistive technology system consisting of: A Virtual Pet Companion app for Android tablets, an AR physical cube for tactile interaction, a hybrid interface supporting touch, voice, and gesture inputs.	Tamagotchi-like virtual pet requiring care and attention; Leveling system based on interaction frequency; Visual and auditory feedback based on success/failure; Mini-games for feeding, walking, and playing with the pet; Personalization of pet's appearance and environment; Reward system and in-game progression.	Observed interaction time and engagement duration; Feedback from caregivers and therapists; Qualitative evaluation of motivation, independence, and usability; Child-reported enjoyment and willingness to repeat tasks; Noted improvement in hand movement and task initiation.	Children displayed increased motivation and emotional engagement during use. The AR cube encouraged bilateral hand interaction, even in children with limited reach. Visual feedback helped sustain attention during task repetition. The pet's responsive behavior supported empathy and social interaction. Hybrid design enabled inclusive access for children with differing levels of ability. Highlights importance of designing for agency and autonomy in therapeutic play tools.	Pilot usability and interaction study (qualitative case series)
Salem, Alfandi & Al-kfairy (2024)	Students with diverse developmental, sensory, motor, and cognitive disabilities, with examples including autism spectrum disorder (ASD), dyslexia, motor impairments, and hearing loss. Targeted group: children and adolescents under age 18.	Design of a conceptual inclusive educational metaverse system using: AI for personalized learning, federated learning for privacy-preserving training, blockchain for secure transactions, gamification to promote engagement, cloud computing for data analysis and scalability. Includes motivational scenario of a child with ASD using the metaverse for school, therapy, and social interaction with avatars.	Adaptive difficulty through AI Reward-based progression (e.g., puzzle-solving in math games); Customizable avatars and environments; Social scenarios and simulations; Role-based participation: student, teacher, therapist, parent; Game-like learning challenges tied to academic content; Sensory-adjusted learning (visual/audio personalization).	Theoretical framework; no empirical outcomes, but outlines metrics for future research: AI-derived progress metrics (learning rate, error rate); Engagement logs (session frequency, task completion); Feedback from parents, therapists, and teachers; Use of secure reporting and visualization dashboards.	Identifies gaps in existing inclusive metaverse systems: lack of personalization, limited teacher/therapist integration, and weak data security. Proposes a robust architecture integrating AI, FL, blockchain, and cloud services. Emphasizes gamification and avatar-based interaction as tools to enhance learning and therapy. Advocates for co-participation of parents, teachers, and therapists in educational experiences. Stresses importance of customization, accessibility, and privacy. Highlights research challenges such as data heterogeneity, FL security, and user training.	Conceptual framework and system design (non-empirical)

Kushnir, A., Kachmar, O & Bonnechère (2024)	Children and adults with motor disabilities, with emphasis on those with cerebral palsy and similar neurodevelopmental or musculoskeletal impairments. Focus on individuals in telerehabilitation settings, including low-resource environments.	Development and pilot evaluation of STASISM, a modular serious gaming platform integrating: multiple low-cost sensors (e.g., Wii Balance Board, webcam, IMU sensors), machine learning algorithms for movement tracking and adaptation, real-time personalized rehabilitation exercises via gamified interface, telemonitoring capabilities for therapists and remote care.	Adaptive game difficulty and task personalization; Real-time visual and auditory feedback; Game modes targeting specific therapeutic goals (e.g., balance, trunk control); High-score tracking and performance dashboards; Engagement through interactive avatars and game scenarios; Progress reports accessible to therapists and patients.	Center of pressure (COP) and range of motion (ROM); Balance assessment protocols (e.g., tandem stance, single-leg stance); Therapist evaluations of usability, performance, and engagement; GDPR-compliant data collection and cloud-based performance analytics; Qualitative feedback from children, caregivers, and therapists.	STASISM showed high engagement and usability in low-resource and home settings. Children with cerebral palsy demonstrated improved trunk control and balance. Modular design allowed for easy adaptation to various impairments and environments. Gamified elements were critical for sustained attention and therapy adherence. Therapists appreciated remote monitoring features and ease of session setup. Platform validated as cost-effective, scalable, and cross-culturally adaptable.	Pilot mixed-methods feasibility and usability study
Khaksar (2023)	Children and adults with motor disabilities, including cerebral palsy and spinal cord injuries, requiring joint-specific rehabilitation (particularly upper limbs and wrists)	Development and validation of a gamified rehabilitation framework using: non-invasive inertial sensors (IMUs), custom Unity-based games with motion tracking, therapist-driven calibration and monitoring system, emphasis on joint movement analysis, smoothness, and accuracy.	Game scenarios (e.g., Monster Chase, Aeroplane, Skiing); Real-time visual and auditory feedback; Progression tracking, levels, and scores; Adaptive challenge levels based on movement quality; Reward mechanisms to maintain motivation and adherence; Personalization of task difficulty based on user performance.	Kinematic indicators: SPARC (Spectral Arc Length), LDLJ (Log Dimensionless Jerk); Joint range of motion and movement smoothness; Time to task completion; Therapist and user feedback; Engineering validation: accuracy of sensor system, software responsiveness.	The framework effectively supported adaptive remote rehabilitation with accurate motion tracking. Gamified activities improved engagement and were feasible for children with CP. Sensor setup and calibration could be tailored for each user. The platform bridged engineering reliability with playful user experience. Demonstrated potential for scalable and personalized therapy in underserved contexts.	Pilot validation study (biomechanical + user feedback)

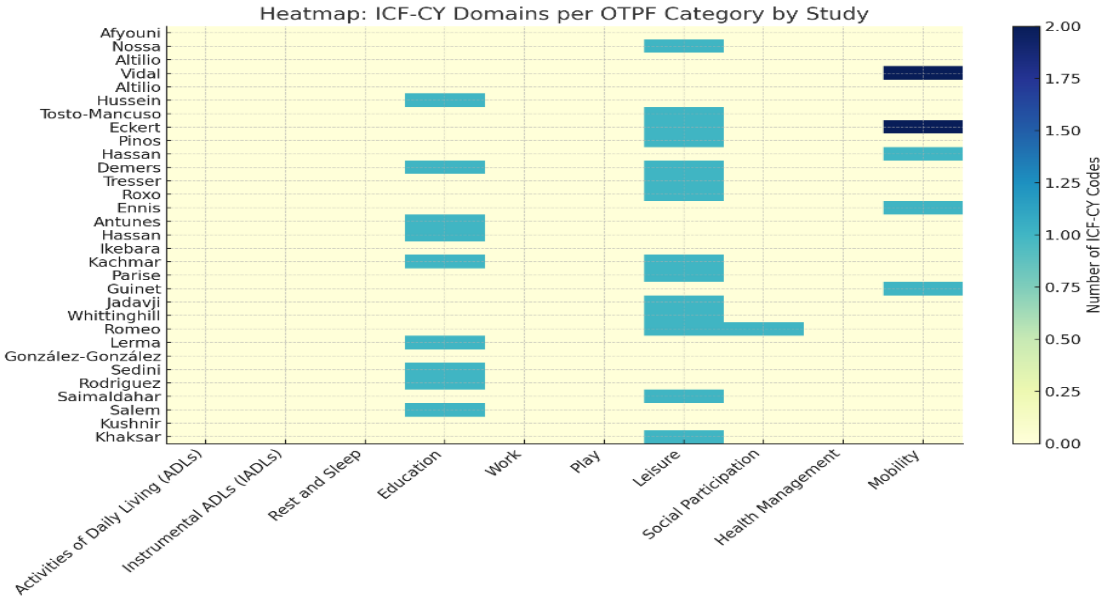
Table 2

Mapping of ICF-CY and occupational performance domains

Author (Year)	ICF-CY Domains Targeted	Occupational Performance Domain
Afyouni et al. (2017)	b710, b765	Mobility, Motor Skills
Nossa et al. (2021)	b144, b710, d920	Leisure
Altilio et al. (2015)	b710, b760	Gross Motor Skills, Mobility
Vidal et al. (2023)	b760, d440, d445	Fine Motor Skills, Gross Motor Skills
Hussein et al. (2023)	b144, b710, d820	Education
Tosto-Mancuso et al. (2022)	b710, b760, d920	Mobility
Eckert et al. (2023)	b710, b760, d440, d445, d920	Fine Motor Skills, Gross Motor Skills
Pinos Cisneros et al. (2023)	d920	Leisure
Hassan (2024b)	b144, d450	Leisure, Mobility
Demers et al. (2021)	d820, d920	Education
Tresser (2019)	d920	Gross Motor Skills, Leisure
Roxo, Nóbrega & Madeira (2022)	b144, b710, d920	Leisure
Ennis et al. (2016)	b710, b760, d450	Mobility
Antunes (2021)	b710, d820	Education
Hassan (2024a)	b144, b710, d820	Education
Ikebara (2021)	b710	Mobility
Kachmar et al. (2021)	b760, d820, d920	Education, Gross Motor Skills, Leisure, Mobility
Parise et al. (2023)	b710, d920	Gross Motor Skills, Leisure
Guinet et al. (2022)	b765, d450	Mobility
Jadavji et al. (2022)	b144, d920	Leisure
Whittinghill & Brown (2014)	b710, d920	Gross Motor Skills, Leisure
Romeo et al. (2024)	b760, d750, d920	Gross Motor Skills, Mobility, Social Participation
Lerma Lara et al. (2016)	b144, b760, d820	Education, Mobility
González-González et al. (2019)	b144, b710	Education, Mobility
Sedini et al. (2024)	b710, d820	Education, Gross Motor Skills
Rodriguez (2015)	b144, b710, d820	Education
Saimaldahar (2016)	b144, b710, d920	Gross Motor Skills, Leisure
Salem, Alfandi & Al-kfairy (2024)	b144, b710, d820	Education
Kushnir, A., Kachmar, O. & Bonnechère (2024)	b144, b710, b760	Mobility
Khaksar (2023)	b710, d920	Gross Motor Skills, Leisure

Figure 2

ICF CY domains per OTPF



DISCUSSION

Gamification Strategies in Pediatric Motor Rehabilitation

The application of gamification techniques in pediatric motor rehabilitation continues to develop through multiple technological approaches and design strategies, enhancing child participation and treatment success for motor disability patients. The research indicates that motion-sensing Technologies, like Microsoft Kinect and Nintendo Wii, function as main interfaces for child interaction. The systems deliver live body movement tracking, enabling therapists as well as users to receive instant feedback during therapeutic activities (Ennis et al., 2016).

VR and AR environments have become widespread because they provide immersive experiences through either the simulation of real-life activities or the creation of completely new interactive settings. Children participate in virtual therapeutic tasks through head-mounted displays or screen-based projections that immerse them in controlled interactive environments (Sedini et al., 2024; Parise et al., 2023). These environments combine motivation for children with adjustable difficulty settings, which correspond to their current abilities and development.

Wearable sensors along with pressure-sensitive devices serve to enhance rehabilitation programs by providing gamification elements. The data obtained from postüre, limb movement, and pressure distribution are converted into game mechanics to both reward correct child movements and refine execution errors (Kachmar et al., 2021; Hassan, L, 2024). The research focused on creating personalized games through which therapeutic objectives were integrated with game mechanics to achieve optimal motor rehabilitation outcomes (Compán-Rosique et al., 2019; Bortone et al., 2020).

Custom game mechanics have become a significant trend in the field. Multiple research projects have employed algorithmic systems that adapt game challenges or feedback delivery methods according to individual child performance levels, thereby creating personalized and dynamic rehabilitation processes (Elias, Batumalai, & Azmi, 2019; Saimaldahar, 2016). The customized approach enhances both children's engagement and goal achievement in therapy.

Several interventions integrate social play with multiplayer features to promote peer interaction while keeping motor skill development as their primary focus (Ennis et al., 2013; Parise et al., 2023). Theses features utilize visual and auditory feedback mechanisms that recognize achievements and provide corrective guidance, creating an enhanced immersive experience.

Outcome Measures Used in Reviewed Studies

Multiple studies have employed different outcome measures to evaluate motor performance and child engagement following gamified interventions for children with motor disabilities. The assessments varied between studies but aimed to measure occupational performance from functional and motivational perspectives depending on their design and chosen platform.

Quantitative motor performance metrics were frequently used. The Gross Motor Function Measure (GMFM), Trunk Control Measurement Scale (TCMS), and Pediatric Balance Scale (PBS) served as standardized assessment tools to evaluate the effectiveness of interventions in several studies (Romeo et al., 2024; Kachmar et al., 2021). Motion capture systems and wearable sensors tracked objective measures, including range of motion (ROM), movement smoothness through SPARC and LDLJ, and center of pressure (CoP) in sensor-based platforms, according to Khaksar (2023) and Kushnir, Kachmar, and Bonnechère (2024).

The digital feedback systems built into games tracked performance data by recording user reaction time, and accuracy, as well as task completion rates, and successful movement frequencies. The in-game metrics delivered immediate user feedback during gameplay while also generating longitudinal data that therapists could use to track student progress (González-González et al., 2019). The systems provided learning analytics dashboards, which both clinicians and families could use to track performance patterns (Kushnir, Kachmar, & Bonnechère, 2024).

Numerous studies evaluated both functional and motivational measures, as well as subjective outcomes such as user engagement, and enjoyment, usability, and adherence. Researchers used Likert-scale questionnaires, child and caregiver interviews, and observational assessments to measure these outcomes (Whittinghill & Brown, 2014; Sedini et al., 2024). Several studies documented increased autonomy and social interaction, which led to participation outcomes that aligned with ICF-CY categories (Rodriguez, 2015; Saimaldahar, 2016).

The main research constraint lies in the lack standardized methods to evaluate gamified therapy results. Research often employs assessment tools tailored to particular contexts, which makes results hard to compare across studies. Multi-dimensional assessment frameworks that combine motor, cognitive, and emotional engagement indicators have demonstrated effectiveness in pediatric rehabilitation according to cumulative evidence.

Technological Platforms and Accessibility

Different technological platforms are used to deliver gamified motor rehabilitation to children with disabilities based on the reviewed studies. The platforms vary in terms of their complexity level, and infrastructure requirements, and their ability to meet the unique needs of users. Motion capture systems, virtual and augmented reality (AR) environments, wearable sensors, and mobile or tablet-based applications represent the most commonly used technologies.

The implementation of motion-sensing devices like Microsoft Kinect, Nintendo Wii, and customized sensor-based systems has become common because they enable real-time, full-body movement tracking. Children participated in therapeutic activities by controlling their avatars through limb movements in Kinect games, which helped develop postural control, balance, and limb coordination, according to Ennis et al. (2016) and Compán-Rosique et al. (2019). Wii Balance Board systems supported patients by helping them practice posture while performing weight shifts at home or in school settings, according to Romeo et al. (2024) and Kushnir, Kachmar, and Bonnechère (2024).

The implementation of VR and AR platforms has enabled the creation of immersive therapeutic experiences. Sedini et al. (2024) developed BODYSOUND through AR technology, which transformed child movements into musical sounds to boost engagement and physical perception. Rodríguez (2015) designed a basic virtual wheelchair simulator that supported children with profound disabilities through an accessible design featuring joystick controls. The platforms are most effective for replicating real-world scenarios that cannot be safely or practically recreated in physical environments.

Wearable sensors using inertial measurement units (IMUs) have served as standard tools for tracking joint motion as well as trunk stability during upper limb rehabilitation programs. The gamified framework developed by Khaksar (2023) employed wearable sensors to track fine motor skills with high precision and provided real-time kinematic feedback that enabled remote self-paced therapy sessions. These systems incorporate gamified interfaces built using Unity or comparable engines to display progress visualization while keeping users engaged.

Mobile applications and tablet solutions provide cost-effective and user-friendly options, making them well-suited for low-resource areas as well as home-based therapy. Saimaldahar (2016) created a mobile-based virtual pet game with augmented reality cube features for children with spastic cerebral palsy, which supported multimodal interaction through touch, sound, and voice while using minimal hardware. Such approaches demonstrate potential to improve accessibility when conventional rehabilitation services remain scarce.

All platforms need to prioritize accessibility features. Various systems require individual adjustments for setup, calibration, and difficulty settings,as well as hardware modifications, such as simplified controllers and enlarged interface elements, to help children with severe motor and cognitive disabilities (Rodríguez, 2015; Sedini et al., 2024). Research highlighted the necessity of implementing systems that function across different cultural contexts while keeping costs affordable. Kushnir, Kachmar, and Bonnechère (2024) developed the STASISM platform as an affordable solution with modular architecture to serve international locations with restricted access to advanced medical tools.

Personalization and Adaptivity of Gamified Content

The research studies demonstrate how personalized, adaptive game content targets specific abilities and therapeutic requirements of individual users as a main theme. Multiple interventions implemented dynamic difficulty adjustment systems that automatically adjusted task difficulty levels according to user performance in real time. The TANGO:H platform employed a recommender system that adjusted exercise levels based on user profiles, motor abilities, and past performance data to deliver progressive challenges and sustained user engagement (González-González et al., 2019).

Personalization occurred through calibration protocols that matched game mechanics with the precise motor capacities of each user. The Kinect-based bird flight game “Burnie” required individual calibration of therapeutic movements, which translated rehabilitation poses into gameplay mechanics that included flapping and diving motions (Whittinghill & Brown, 2014). The system enabled children with varied motor disabilities to participate in shared gaming activities that helped them reach personalized therapeutic targets.

The systems gave therapists the ability to customize task complexity, pace, and task types directly from gameplay observation of a child’s responses. Through Khaksar's (2023) framework, therapists created customized movement tasks using Unity-based games, which provided real-time kinematic analysis along with performance feedback to patients.

Gamified systems were designed with various customization options that included visual and auditory elements and avatar modification capabilities. Children in Saimaldahar’s (2016) study personalized their virtual pet companion through appearance adjustments and environment selection, while the system chose interaction methods according to individual physical capabilities. The personalized features improved accessibility while strengthening the emotional bond between users and the system.

The implementation of adaptive gamification approaches led to better outcomes in pediatric motor rehabilitation by boosting motivation levels, while enabling goal advancement and improving therapy participation. These systems tailored their responses to individual child capabilities and performance progress to enable meaningful participation in rehabilitation activities and skill development.

Types of Feedback and Motivational Mechanisms

Children with motor disabilities require feedback mechanisms combined with motivational strategies to sustain engagement and enhance the effectiveness of gamified interventions. All reviewed studies incorporated feedback mechanisms delivered through visual, auditory, or haptic channels, providing users with performance guidance, error correction, and recognition of success.

The most common type of visual feedback appears in the form of screen animations that include color-coded signals, progress bars, and avatar behavior responses dependent on child's input (Rodríguez, 2015; Ennis et al., 2013). Various systems reward children with colorful visual effects and level progression when movements are performed correctly (Whittinghill & Brown, 2014; González-González et al., 2019). When errors occure, the system generates neutral or corrective alerts rather than punitive responses, thereby maintaining the therapeutic goal of continuous engagement without discouragement.

Auditory feedback operated alongside visual cues in systems designed for younger users or children with cognitive impairments. Successful task completion often triggers applause sounds, encouraging phrases, and musical cues to promote emotional engagement (Sedini et al., 2024; Saimaldahar, 2016). These multimodal feedback systems aim to stimulate multiple sensory channels, thereby accommodating children with varied preferences and abilities.

Motivational strategies often combine point systems with level progression features and unlockable rewards. These game mechanics are designed to foster a sense of achievement and progresst in therapeutic activities that involve repetition and physical effort (Khaksar, 2023; González-González et al., 2019). For example, in the game Burnie, players were required to successfully repeat motor poses to advance within the game world and earn humorous rewards (Whittinghill & Brown, 2014).

Research has shown that personalized, real-time feedback can be adapted to users' performance, fatigue, and attention levels in certain studies. For instance, STASISM employed adaptive game feedback to adjust gameplay flow according to the user's ability and recovery status, making the experience both therapeutic and enjoyable (Kushnir, Kachmar, & Bonnechère, 2024).

Therapist and User Roles in Game Interaction and Design

Therapists in gamified rehabilitation systems perform roles that extend beyond system implementation, as they actively participate in designing therapeutic games and calibrating them to achieve personalized outcomes. The alignment of therapeutic objectives with gameplay mechanics requires therapist involvement as emphasized in several studies. In multiple interventions, therapists customized system parameters and adapted exercises to individual children according to their movement abilities and therapeutic needs (Khaksar, 2023; Saimaldahar, 2016; Kachmar et al., 2021).

Therapists also acted as facilitators of engagement by guiding children through tasks, encouraging participation, and providing immediate support during activities. According to Romeo et al. (2024) and Kushnir, Kachmar, and Bonnechère (2024), therapist supervision was particularly crucial in studies involving complex motor disabilities, as it ensured both safety and the optimal execution of therapeutic exercises.

Several systems provided clinicians with tools to monitor student progress and performance data while enabling real-time adjustments to the game sequence. For example, the STASISM system provided therapists live trunk control and balance assessment through its performance dashboard (Kushnir, Kachmar, & Bonnechère, 2024). Similarly, the *CPWalker* project illustrated how EEG and EMG feedback, combined with therapist-defined goals, were integrated into the system to guide interventions (Lerma Lara et al., 2016).

Research studies have increasingly involved children as active participants in the design process. For instance, the *BODYSOUND* engagement model implemented co-creation and testing with children, who acted as users, informants, and evaluators throughout the development of the interactive system. This participatory design approach led to improved user needs, improved system usability, and increased user motivation (Sedini et al., 2024).

The platform enabled users to exercise control through in-game choices, avatar customization, and free-play functionality. These features allowed children to maintain autonomy over their experiences, which is particularly important for populations who face daily restrictions (Saimaldahar, 2016; Rodriguez, 2015).

Targeted ICF-CY Domains and Occupational Performance Outcomes

Children with motor disabilities participated in gamified interventions whose primary objectives aligned with voluntary movement control, physical mobility, and recreational engagement, as outlined in the ICF-CY framework. Across multiple studies, the main areas of focus—voluntary movement control, and physical mobility, and recreational engagement—consistently reflected established therapeutic goals for pediatric rehabilitation.

A total of 15 studies reported that the d920 (recreation and leisure) domain was the most frequently addressed in their research samples. Most interventions employed digital games with interactive systems to foster intrinsic motivation, thereby sustaining patient participation in leisure activities. Research by Nossa et al. (2021), Tosto-Mancuso et al. (2022), and Eckert et al. (2023) demonstrated how gamification elements can create create engaging experiences that enhance therapeutic adherence through meaningful leisure activities.

The d450 (walking) domain, along with several other mobility-related categories, was frequently addressed in the reviewed studies. Research employing sensor-based platforms with motion-tracking systems specifically targeted these domains to enhance balance, gait, and postural transitions. Interactive stepping games and trunk stability challenges were shown to improved ambulatory function in children with physical impairments (L. (2023) and Ennis et al. (2022).

The ICF domains d440 (fine hand use) and d445 (gross hand use) are closely related, representing fine and complementary aspects of hand function. Interventions targeting these domains emphasized hand-eye coordination and object manipulation. Research by Vidal et al. (2023) and Eckert et al. (2023) demonstrated that gesture-based and sensor-guided activities effectively improved grasp precision and upper limb control, directly supporting occupational performance in fine motor skills.

The control of voluntary movement domain b760 emerged as a primary objective in interventions utilizing Kinect, IMUs, and VR for full-body motion tracking. Altilio et al. (2015), Vidal et al. (2023), and Tosto-Mancuso et al. (2022) implemented movement control programs that employed gamified feedback systems and performance tracking to enhance voluntary movement.

Some studies also adressed the d820 (school education) domain, although not consistently across all interventions. Research by Hussein et al. (2023), Demers et al. (2021), and Antunes (2021) analyzed gamified environments designed to enhance academic outcomes, including aattention, learning, and virtual task completion. Theses findings suggest that gamification can support educational objectives, extending its benefits beyond motor function to cognitive development.

Romeo et al. (2024) targeted the social participation domain (d750) by incorporating collaborative elements that promoted peer interaction and communication.

The final group of studies focused on cognitive-affective domains, specifically b144 (memory functions) and d155 (acquiring skills). Research by Nossa et al. (2021), Hussein et al. (2023), and Roxo et al. (2022) developed systems that combined BCI-controlled environments with gamified learning sequences and attention/memory training modules.

Research findings indicate that gamified interventions primarily target leisure activities, mobility, fine motor skills, education, voluntary movement control, and selected social and cognitive abilities. These patterns highlight how gamification can address multiple dimensions of occupational performance challenges in pediatric rehabilitation.

The reviewed research demonstrates a clear correlation between gamified interventions and occupational performance in children with motor disabilities. These interventions primarily focused on enhancing functional activities related to daily life participation, particularly in the domains of leisure, education, and mobility.

More than half of the studies focused on improving fine and gross motor skills relevant to occupational engagement. For example, interventions involving grasping, reaching, bilateral coordination, or hand tracking—such as those by Vidal et al. (2023), González-González et al. (2019), and Eckert et al. (2023)—were associated with the ICF-CY domains d440 (fine hand use) and d445 (hand and arm use), and functionally linked to OTPF domains such as dressing, writing, and tool use. These game-based movements supported the performance of activities of daily living and enhanced fine motor precision, both of which are critical areas in pediatric occupational therapy.

Many studies targeted recreational and leisure activities, with the d920 (recreation and leisure) domain appearing in more than half of the dataset. Examples of such interventions include Nossa et al. (2021), Sedini et al. (2024), and Tosto-Mancuso et al. (2022), who integrated therapeutic objectives into engaging activities such as dance simulations, interactive musical games, and game-based exploration. These approaches not only enhanced movement but also promoted sustained attention, emotional engagement, and the development of positive attitudes toward play, aligning with the Leisure domain in the OTPF.

Several studies also focused on enhancing mobility and postural control within daily routines. For example, gamified environments designed to improve balance, trunk stability, and stepping (e.g., Hassan, 2023; Ennis et al., 2022) were associated with the ICF-CY domains d450 (walking) and d455 (moving around), aiming to enhance children's ability to navigate home, school, or therapy environments. These tasks fall under Occupational Performance, specifically the Mobility domain, and are related to functional ambulation, environmental transitions, and engagement in environment-based activities.

Some interventions also addressed cognitive and behavioral aspects, particularly those involving goal-directed repetition, routine initiation, or attention cues. Systems such as *STASISM* and *CPWalker* (Kushnir, Kachmar, & Bonnechère, 2024; Lerma Lara et al., 2016) not only targeted motor training but also structured game flow to support executive functions in real-world activities, including turn-taking,

activity sequencing, and task completion. These correspond to the ICF-CY domains d230 (carrying out daily routines) and d570 (taking care of one's health), and relate to Health Management and Routines in the OTPF.

Some studies extended their focus to educational and social performance by using gamified systems that simulated classroom activities or encouraged social collaboration. For instance, Hussein et al. (2023) and Romeo et al. (2024) incorporated tasks requiring cognitive attention and peer interaction, thereby supporting the ICF-CY domains d820 (school education) and d750 (informal social relationships). Although less common, these interventions highlight the growing potential of gamification to enhance occupational participation beyond motor skills.

Although all the studies primarily focused on motor rehabilitation, their gamified interventions often incorporated real-world occupational tasks. This suggests that gamification, when combined with purposeful, goal-directed activities, can support not only clinical outcomes but also children's participation in daily occupations. Strategically aligning game mechanics with occupationally relevant tasks enhances both the ecological validity and therapeutic value of gamified rehabilitation for pediatric populations.

CONCLUSION AND SUGGESTIONS

This scoping review provides an integrative overview of the use of gamification in the rehabilitation of children with motor impairments, highlighting its functional relevance through the framework of ICF-CY and occupational performance. The findings indicate that gamified interventions primarily target motor skill development, educational engagement, and social or leisure participation. The wide range of technologies employed—including VR, AR, motion sensors, and mobile platforms—demonstrates considerable potential to deliver accessible and motivating therapeutic activities. Although the reported outcomes emphasize functional gains, their classification and contextualization remain inconsistent across studies.

The systematic analysis revealed variability across studies in terms of personalization, adaptivity, and the extent of user and therapist involvement in game-based interventions. While most interventions align with occupational therapy principles, only a few explicitly connect gamified activities to clearly defined occupational performance goals and ICF-CY domains. This gap underscores the need for clearer functional framing and more systematic integration of classification frameworks in future research and practice.

Multiple research studies featured in this review demonstrate that rehabilitation interventions require better technological and methodological development in gamified approaches. Researchers frequently propose the integration of artificial intelligence (AI) and adaptive learning algorithms as a future direction to customize difficulty levels and game content and feedback in real time based on current abilities and progress (Khaksar, 2023; González-González et al., 2019). The application of intelligent systems would customize therapy sessions while minimizing the requirement of ongoing therapist monitoring.

Multiple studies included in this review indicate that rehabilitation interventions could benefit from further technological and methodological advancements in gamified approaches. Researchers frequently suggest integrating artificial intelligence (AI) and adaptive learning algorithms to dynamically adjust difficulty, game content, and feedback in real time according to the user's abilities and progress (Khaksar, 2023; González-González et al., 2019). The use of intelligent systems could personalize therapy sessions while reducing the need for continuous therapist supervision.

The field has identified two key directions for future development: cross-platform accessibility and scalability. For example, the *STASISM* system operates on affordable hardware while accommodating diverse cultural settings, enabling the global implementation of gamified rehabilitation programs (Kushnir, Kachmar, & Bonnechère, 2024). This approach addresses economic and infrastructural barriers that often limit access to rehabilitation services in under-resourced regions.

The co-creation and participatory design model has emerged as a major trend in gamified rehabilitation. Several researchers emphasize the importance of involving children and their families, alongside clinicians and researchers, in the development process (Sedini et al., 2024; Saimaldahar, 2016). Including pediatric users with motor impairments in the design process helps ensure that the final product is engaging, accessible, and tailored to their specific needs.

Future research should explore hybrid therapeutic approaches that combine gamification with robotic-assisted therapy, virtual reality, and telehealth services. BCI-based programs, such as those by Jadavji et al. (2022) and *CPWalker*, demonstrate the potential benefits of integrating multiple systems to support home-based or remote care delivery.

The research community should develop standardized outcome measures and conduct clinical trials with larger, more diverse participant samples. Longitudinal studies are needed to assess not only immediate task performance and motor function but also the progression of occupational performance over time, providing more comprehensive insights for the field (Romeo et al., 2024; Rodríguez, 2015).

In conclusion, gamification represents a promising and increasingly valuable approach in pediatric rehabilitation. To fully realize its therapeutic potential, future studies should adopt consistent reporting practices, clearly define functional targets, and explicitly situate interventions within occupation-based and developmentally appropriate classification frameworks.

LIMITATIONS

Many studies included in this review employed pilot or proof-of-concept designs with small participant groups and short intervention periods. For example, Whittinghill and Brown (2014) tested the gamified system *Burnie* using a convenience sample of 21 adult participants who modeled pediatric experiences, but children with cerebral palsy were not included. This highlights a persistent gap between technological prototype development and clinical validation. Similarly, Sedini et al. (2024) described an extensive co-creation process but did not conduct formal clinical evaluation, limiting the generalizability of their findings beyond qualitative insights.

The reviewed studies reported inconsistent results in their quantitative outcome measurements. While some studies employed validated motor performance metrics, such as GMFM and SPARC (Khaksar, 2023), others primarily relied on behavioral observations and user feedback (Saimaldahar, 2016; Sedini et al., 2024). The absence of standardized outcome frameworks aligned with motor rehabilitation goals and ICF-CY domains complicates comparisons of intervention efficacy. Most research focused on validating technology rather than assessing clinical or behavioral effects. For instance, Khaksar's (2023) doctoral thesis used IMU sensor-derived motion smoothness metrics and SPARC/LDLJ measurements to validate sensor accuracy and software performance, rather than evaluating patient improvement over time. This engineering-driven approach indicates a tendency to prioritize technical validation over functional rehabilitation outcomes and occupational relevance.

Although many systems offered adaptable and personalized features, few demonstrated sustained therapeutic effects or included long-term patient follow-up (Kushnir, Kachmar, & Bonnechère, 2024; Kachmar et al., 2021). Testing sessions in various studies ranged from minutes to hours, limiting the ability to assess adherence, long-term engagement, and skill transfer to real-world environments.

The majority of gamification-based motor rehabilitation studies also lacked diversity in their clinical populations. Most interventions targeted children with cerebral palsy who had mild motor disabilities (GMFCS levels I–III), while children with severe disabilities and complex medical conditions remained underrepresented (Khaksar, 2023; Kushnir et al., 2024). This restricted focus hinders generalization and overlooks children with multiple disabilities, including cognitive and sensory impairments (Rodríguez, 2015). Despite growing interest in inclusive design, diagnostic variety has not substantially increased. Research has mostly focused on cerebral palsy and hemiplegia, with only a few studies including spinal cord injury or other motor dysfunctions (Sedini et al., 2024). Children with rare degenerative neurological conditions remain entirely unrepresented, leaving intervention development for these populations largely unexplored.

Geographical bias is another limitation. Most system development and testing occurred in Western or high-resource settings, with few studies addressing low- and middle-income countries or culturally diverse populations. Given the digital divide and disparities in technological infrastructure, it is crucial to deploy sensor-based and VR/AR gamified rehabilitation platforms globally (Kushnir, Kachmar, & Bonnechère, 2024; Sedini et al., 2024).

Future research should broaden diagnostic categories and participant profiles to include children with complex and severe motor disabilities, and ensure cultural and contextual inclusivity in the design and implementation of gamified rehabilitation systems.

Ethical Approval

At all stages of the study, including preparation, information presentation, literature review, and writing, the study was conducted in accordance with scientific and ethical rules. Care was taken to cite all data and information used within the scope of the study. The study complies with all the terms of the Committee on Publication Ethics (COPE) and was conducted in accordance with the World Medical Association (WMA) Declaration of Helsinki.

Conflict of Interest

There is no conflict of interest.

Financial support

There is no financial support.

Authorship Contributions

Design: V.M., Data Collection or Processing: S.S, V.M., L.I., E.B.B., Analysis or Interpretation: S. S., V.M., Literature Search: S. S., V.M., L. I., E. B. B., Writing: V.M., L.I.

REFERENCES

Afyouni, I., Rehman, F. U., Qamar, A. M., Ghani, S., Hussain, S. O., Sadiq, B., ... & Basalamah, S. (2017). A therapy-driven gamification framework for hand rehabilitation. *User Modeling and User-Adapted Interaction, 27*, 215–265. https://doi.org/10.1007/s11257-017-9191-4

Altilio, R., Liparulo, L., Panella, M., Proietti, A., & Paoloni, M. (2015). Multimedia and gaming technologies for telerehabilitation of motor disabilities [leading edge]. *IEEE Technology and Society Magazine, 34*(4), 23–30. https://doi.org/10.1109/mts.2015.2494279

Antunes, A. M. N. C. (2021). *Computational framework to support serious games design for therapy of children with special needs* (Master's dissertation, Escola Superior de Tecnologia de Setúbal, Instituto Politécnico de Setúbal).

Blank, R., Smits-Engelsman, B. O. U. W. I. E. N., Polatajko, H., & Wilson, P. (2012). European Academy for Childhood Disability (EACD): Recommendations on the definition, diagnosis and intervention of developmental coordination disorder (long version). *Developmental Medicine and Child Neurology, 54*(1), 54. Portico. https://doi.org/10.1111/j.1469-8749.2011.04171.x

Bonnechère, B., Jansen, B., Omelina, L., & Jan, S. V. S. (2016). The use of commercial video games in rehabilitation: a systematic review. *International Journal of Rehabilitation Research, 39*(4), 277–290. https://doi.org/10.1097/mrr.0000000000000190

Boop, C., Cahill, S. M., Davis, C., Dorsey, J., Gibbs, V., Herr, B., ... & Lieberman, D. (2020). Occupational therapy practice framework: Domain and process fourth edition. *AJOT: American Journal of Occupational Therapy, 74*(S2), 1–85. https://doi.org/10.5014/ajot.2020.74s2001

Bortone, I., Barsotti, M., Leonardis, D., Crecchi, A., Tozzini, A., Bonfiglio, L., & Frisoli, A. (2020). Immersive virtual environments and wearable haptic devices in rehabilitation of children with neuromotor impairments: a single-blind randomized controlled crossover pilot study. *Journal of Neuroengineering and Rehabilitation, 17*, 1–14. https://doi.org/10.1186/s12984-020-00771-6

Compañ-Rosique, P., Molina-Carmona, R., Gallego-Durán, F., Satorre-Cuerda, R., Villagrá-Arnedo, C., & Llorens-Largo, F. (2019). A guide for making video games accessible to users with cerebral palsy. *Universal Access in the Information Society, 18*, 565–581. https://doi.org/10.1007/s10209-019-00679-6

Damyanov, K. (2024). International Classification of Functioning, Disability, and Health for Children and Youth (ICF-CY) as a Framework for Early Intervention Planning in Inclusive Education. *Open Journal of Social Sciences, 12*(11), 85–98. https://doi.org/10.4236/jss.2024.1211006

Demers, M., Fung, K., Subramanian, S. K., Lemay, M., & Robert, M. T. (2021). Integration of motor learning principles into virtual reality interventions for individuals with cerebral palsy: systematic review. *JMIR Serious Games, 9*(2), e23822. https://doi.org/10.2196/23822

Eckert, M., Domingo Soria, B., & Terroso Gil, N. (2023). Finding Effective Adjustment Levels for Upper Limb Exergames: Focus Group Study With Children With Physical Disabilities. *JMIR Serious Games, 11*, e36110. https://doi.org/10.2196/36110

Elias, Z. M., Batumalai, U. M., & Azmi, A. N. H. (2019). Virtual reality games on accommodation and convergence. *Applied Ergonomics, 81*, 102879. https://doi.org/10.1016/j.apergo.2019.102879

Ennis, A., Cleland, I., Nugent, C., Finney, L., Trainor, D., & Bennett, A. (2016). The Use of Gamification Techniques in a Clinical Setting for the Collection of Longitudinal Kinematic Data. In *Ubiquitous Computing and Ambient Intelligence: 10th International Conference, UCAmI 2016* (pp. 267–273). Springer. https://doi.org/10.1007/978-3-319-48746-5_27

González-González, C. S., Toledo-Delgado, P. A., Muñoz-Cruz, V., & Torres-Carrion, P. V. (2019). Serious games for rehabilitation: Gestural interaction in personalized gamified exercises through a recommender system. *Journal of Biomedical Informatics, 97*, 103266. https://doi.org/10.1016/j.jbi.2019.103266

Guinet, A. L., Bouyer, G., Otmane, S., & Desailly, E. (2022). Visual Feedback in Augmented Reality to Walk at Predefined Speed Cross-Sectional Study Including Children With Cerebral Palsy. *IEEE Transactions on Neural Systems and Rehabilitation Engineering, 30*, 2322–2331. https://doi.org/10.1109/tnsre.2022.3198243

Hassan, L. (2024). Accessibility of educational games and game-based approaches to people with learning and physical disabilities: a systematic literature review. Proceedings of the 57th Hawaii International Conference on System Sciences. https://doi.org/10.24251/hicss.2024.203

Hassan, L. (2024). Accessibility of games and game-based applications: A systematic literature review and mapping of future directions. *New Media & Society*, *26*(4), 2336–2384. https://doi.org/10.1177/14614448231204020

Huang, J. D. (2011). Kinerehab: a kinect-based system for physical rehabilitation: a pilot study for young adults with motor disabilities. In *The proceedings of the 13th international ACM SIGACCESS conference on Computers and accessibility* (pp. 319–320). https://doi.org/10.1145/2049536.2049627

Hussein, E., Kan'An, A., Rasheed, A., Alrashed, Y., Jdaitawi, M., Abas, A., ... & Abdelmoneim, M. (2023). Exploring the impact of gamification on skill development in special education: A systematic review. *Contemporary Educational Technology*, *15*(3), ep443. https://doi.org/10.30935/cedtech/13335

Jadavji, Z., Zewdie, E., Kelly, D., Kinney-Lang, E., Robu, I., & Kirton, A. (2022). Establishing a clinical brain-computer interface program for children with severe neurological disabilities. *Cureus*, *14*(6). https://doi.org/10.7759/cureus.26215

Janssen, J., Verschuren, O., Renger, W. J., Ermers, J., Ketelaar, M., & Van Ee, R. (2017). Gamification in physical therapy: More than using games. *Pediatric Physical Therapy*, *29*(1), 95–99. https://doi.org/10.1097/pep.0000000000000326

Kachmar, O., Kushnir, A., Fedchyshyn, B., Cristiano, J., O'Flaherty, J., Helland, K., ... & Puig, D. (2021). Personalized balance games for children with cerebral palsy: A pilot study. *Journal of Pediatric Rehabilitation Medicine*, *14*(2), 237–245. https://doi.org/10.3233/prm-190666

Khaksar, S. (2023). *A Framework for Gamification of Human Joint Remote Rehabilitation, Incorporating Non-Invasive Sensors* (Doctoral dissertation, Curtin University).

Kushnir, A., Kachmar, O., & Bonnechère, B. (2024). STASISM: A versatile serious gaming multi-sensor platform for personalized telerehabilitation and telemonitoring. *Sensors*, *24*(2), 351. https://doi.org/10.3390/s24020351

Lerma Lara, S., Martínez Caballero, I., Bayón, C., del Castillo, M. D., Serrano, I., Raya, R., ... & Rocon, E. (2016). Can robotic-based top-down rehabilitation therapies improve motor control in children with cerebral palsy? A perspective on the CPWalker project. *Biomedical Research and Clinical Practice*, 22–26. https://doi.org/10.15761/brcp.1000106

Lohse, K., Shirzad, N., Verster, A., Hodges, N., & Van der Loos, H. M. (2013). Video games and rehabilitation: using design principles to enhance engagement in physical therapy. *Journal of Neurologic Physical Therapy*, *37*(4), 166–175. https://doi.org/10.1097/npt.0000000000000017

McGowan, J., Straus, S., Moher, D., Langlois, E. V., O'Brien, K. K., Horsley, T., ... & Tricco, A. C. (2020). Reporting scoping reviews—PRISMA ScR extension. *Journal of Clinical Epidemiology*, *123*(177), e9. https://doi.org/10.1016/j.jclinepi.2020.03.016

Molina, K. I., Ricci, N. A., de Moraes, S. A., & Perracini, M. R. (2014). Virtual reality using games for improving physical functioning in older adults: a systematic review. *Journal of Neuroengineering and Rehabilitation*, *11*, 1–20. https://doi.org/10.1186/1743-0003-11-156

Novák, I., Morgan, C., Fahey, M., Finch-Edmondson, M., Galea, C., Hines, A., ... & Badawi, N. (2020). State of the evidence traffic lights 2019: systematic review of interventions for preventing and treating children with cerebral palsy. *Current Neurology and Neuroscience Reports*, *20*, 1–21. https://doi.org/10.1007/s11910-020-1022-z

Nossa, R., Porro, M., Picciolini, O., Malosio, M., Pittaccio, S., Valoriani, M., ... & Biffi, E. (2021). What children with neuromotor disabilities need to play with technological games. *Applied Sciences*, *11*(21), 9886. https://doi.org/10.3390/app11219886

Parise, S., Lee, K., Park, J., Sullivan, C., Schlesinger, R., Li, M., ... & Keller, J. (2023). Customized gaming system engages young children in reaching and balance training. *Journal of Rehabilitation and Assistive Technologies Engineering*, *10*. https://doi.org/10.1177/20556683231160675

Pinos Cisneros, T. V., Brons, A., Kröse, B., Schouten, B., & Ludden, G. (2023). Playfulness and new technologies in hand therapy for children with cerebral palsy: Scoping review. *JMIR Serious Games*, *11*(1), e44904. https://doi.org/10.2196/44904

Rodriguez, N. (2015). Development of a wheelchair simulator for children with multiple disabilities. In *2015 3rd IEEE VR International Workshop on Virtual and Augmented Assistive Technology (VAAT)* (pp. 19–21). IEEE. https://doi.org/10.1109/vaat.2015.7155405

Romeo, D. M., D'Amario, G., Brunozzi, G., Napoli, V., Villa, M., Arpaia, C., ... & Brogna, C. (2024). Sports activities in children with cerebral palsy: a narrative review. *Medicina, 60*(3), 457. https://doi.org/10.3390/medicina60030457

Roxo, G., Nóbrega, R., & Madeira, R. N. (2022). Dance mat fun—a participatory design of exergames for children with disabilities. In *International Conference on Pervasive Computing Technologies for Healthcare* (pp. 513–527). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-34586-9_34

Saimaldahar, D. (2016). *Virtual Pet Companion: A digital console to enhance the experience of children with cerebral palsy* (Doctoral dissertation, OCAD University).

Salem, R., Alfandi, O., & Al-kfairy, M. (2024, September). Conceptualizing an inclusive metaverse for enhanced learning among students with disabilities. In *Proceedings of the 2024 the 16th International Conference on Education Technology and Computers* (pp. 69–75). https://doi.org/10.1145/3702163.3702173

Sedini, C., Maffei, S., Cipriani, L., & Bianchini, M. (2024). Co-create and co-develop with children. The BODYSOUND Engagement Model. *Diid Disegno Industriale Industrial Design, (82)*. Sedini, C., Cipriani, L., Maffei, S., & Bianchini, M. (2024). Co-create and Co-develop With Children. The BODYSOUND Engagement Model. Diid, 1(82). https://doi.org/10.30682/diid8224g

Tosto-Mancuso, J., Tabacof, L., Herrera, J. E., Breyman, E., Dewil, S., Cortes, M., ... & Putrino, D. (2022). Gamified neurorehabilitation strategies for post-stroke motor recovery: challenges and advantages. *Current Neurology and Neuroscience Reports, 22*(3), 183–195. https://doi.org/10.1007/s11910-022-01181-y

Tresser, S. (2019). *Personalization of virtual gaming system for children with motor impairments: Usability performance and kinematics* (Doctoral dissertation, University of Haifa (Israel)).

Vidal, E., Castro-Gutierrez, E., Arisaca, R., Paz-Valderrama, A., & Albiol-Pérez, S. (2023). Serious game for fine motor control rehabilitation for children with epileptic encephalopathy: Development and usability study. *JMIR Formative Research, 7*(1), e50492. https://doi.org/10.2196/50492

Whittinghill, D. M., & Brown, J. S. (2014). Gamification of physical therapy for the treatment of pediatric cerebral palsy: A pilot study examining player preferences. In *2014 ASEE Annual Conference & Exposition* (pp. 24–638). https://doi.org/10.18260/1-2--20529

World Health Organization. (2007). *International Classification of Functioning, Disability, and Health: Children & Youth Version: ICF-CY*. World Health Organization. https://doi.org/10.1037/t76403-000

Zhang, W., Xiong, K., Zhu, C., Evans, R., Zhou, L., & Podrini, C. (2024). Promoting child and adolescent health through wearable technology: A systematic review. *Digital Health, 10*. https://doi.org/10.1177/20552076241260507