Game Nexus

Effectiveness of Serious Game on Cognitive and Motor Functions in Children and Adults with Neurodevelopmental Disorders

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ABSTRACT

Neurodevelopmental disorders (NDDs) are increasingly being recognized as a leading cause of morbidity in children, causing great suffering for patients and their families and large costs for society and prompting considerable interest in its management. Numerous methods of treating NDDs have been put out in recent decades in an effort to improve their treatment. Although pharmacological treatments are the most successful, it is more crucial to create alternative therapies due to their side effects and unclear long-term usefulness. Game-based treatment offers self-paced, individualized learning and portability. Objective: The purpose of this study is to look at the most recent data about the benefits of serious games for both adults and children with neurodevelopmental problems in terms of their cognitive and motor abilities. Methods: To find research evaluating the efficacy of serious games in children and adults with neurodevelopmental problems, a thorough literature search was carried out in the PubMed /MEDLINE, Scopus, Google Scholar and Science Direct databases. Results: Ten pertinent research involving neurodevelopmental problems and serious gaming were found. Three research looked at how serious games affected the cognitive and motor abilities of adults with NDDs, while seven studies looked at how serious games affected the cognitive and motor abilities of children with NDDs. Conclusion: Serious games appear to improve the severity of cognitive and motor functions in children and adults with NDDs. But given the limitations of the available data, such as methodological flaws and the wide variation in adult methods used, it is crucial to elucidate their efficacy in further research.

Keywords: serious game, cognitive functions, motor functions, Children and adults, neurodevelopmental disorders

Introduction

According to the Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (DSM-5), neurodevelopmental disorders (NDDs) are a new diagnostic category for a variety of neurological and psychiatric disorders, including attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), intellectual disability, specific learning disorder, communication disorders, and motor disorders (e.g., developmental coordination disorder) (1). The overlap between these disorders and their constituent symptoms is high (2), supporting the argument for examining them together, especially in children and adolescents, where intellectual disability, ASD, and learning and motor difficulties frequently have concomitant ADHD. Individuals with NDDs frequently experience difficulty with motor abilities, learning, memory, language, nonverbal communication, and other neuropsychiatric domains (3).

When NDD is diagnosed and treated late in a child's life, it leads to poorer health for both the child and the family. It is frustrating for parents when they do not understand their child's behavior or how to provide the best support. Late identification reduces developmental possibilities for children and may also have an impact on their well-being (4).

Pharmacological treatments are the most successful of the available solutions, but their adverse effects and unknown long-term efficacy highlight the significance of discovering alternative therapy. To date, no pharmaceutical approaches, including behavioral therapy, exercise, diet, and cognitive therapy, have demonstrated even small efficacy, and their therapeutic effects are inferior to pharmacological treatments (5). Digital game-based training programs have lately been employed to improve the cognitive ability of children with neurodevelopmental problems (6).

Another advantage of game-based treatment is its user-friendly (touchscreen) interface, portability, and self-paced and tailored learning. Finally, implementing therapy at home makes intervention more accessible and lasts longer, requiring less parental effort (7). The number of SGs created for educational and training reasons has expanded over the previous decade, owing to the advancement of information and communication technologies such as mobile technologies and healthcare systems. Furthermore, a meta-analysis demonstrated that SGs boost learning across domains when compared to conventional techniques (8).

SGs can contextualize the player's experience in challenging, realistic contexts, hence facilitating situated cognition (9). A serious game (CGR) is a game-based format that combines fine or gross motor training and visual-spatial cognitive activities suitable for children with cerebral palsy (10). SGs have been employed both in usually developing individuals and in children with NDDs (8). However, while some studies appear to suggest the efficacy of utilizing SGs as a treatment for patients with NDDs, their methodological quality is poor, and more study is required. The purpose of this study is to determine the effectiveness of serious games in improving cognitive and motor abilities in children and adults with neurodevelopmental problems. The purpose of this narrative review is to assess the efficacy of serious games as digital therapeutic tools for children with NDDs.

Thus, this narrative review aims to assess the efficiency of serious games as digital treatments, including cognitive function and motor function, in children and adolescents with NDDs.

Methods and Materials

The purpose of this narrative review was to find and analyze relevant contemporary material on the efficacy of serious games on cognitive and motor functioning in children and adults with neurodevelopmental disorders. Two independent reviewers extracted data from all eligible studies using a duplicate extraction approach to reduce errors and potential biases in result interpretation. When consensus could not be achieved, a third reviewer checked for any potential differences to verify data extraction accuracy and consistency. Reviewers evaluated the overall quality of scientific evidence by examining each study's methods, including study design robustness and result validity. A search was conducted in four databases: PubMed/MEDLINE, Scopus, Google Scholar, and Science Direct, utilizing combinations of the following key words: serious game, cognitive and motor functions, Children and adults, neurodevelopmental disorders (NDDs).

Inclusion criteria

Articles were chosen based on the following inclusion criteria: (1) NDDs as the study topic, (2) evaluation of the efficacy of (serious) gaming therapies, and (3) publication between 2015 and 2025.

Exclusion criteria

We rejected publications with at least one of the following characteristics: (1) individuals above the age of 40, (2) case studies, (3) any type of "gray" literature.

Quality assessment of the included studies

The quality of the included studies was assessed using the physiotherapy evidence-based (PEDro) scale (Table 1), which is considered as a valid approach for evaluating clinical trial methods in narrative reviews. This scale uses a 10-point rating system, with each criterion assessed as yes or no, and each affirmative response worth one point. A higher PEDro score indicates higher research quality (11).

Table 1: Pedro scale total scores of the included studies

Study	Eligibility criteria	Random allocation	Allocation was concealed	Baseline comparability	Blind subjects	Blind therapists	Blind assessors	Adequate follow-up	Intention-to-treat analysis	Between-group comparisons	Point estimates and variability	Total score
Crosbie and Claude Bedard 2023 (12)	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	6/10
Vonthron et al. 2024 (8)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7/10
Toki et al. 2024 (13)	Yes	Yes	No	No	Yes	No	No	Yes	No	Yes	Yes	5/10
Hutson and McGinley 2023 (14)	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	6/10
Robb et al. 2018 (15)	Yes	Yes	Yes	No	Yes	No	No	Yes	No	Yes	Yes	6/10
Rouhi et al. 2019 (16)	Yes	Yes	No	No	Yes	No	No	Yes	No	Yes	Yes	5/10
Gelsomini et al. 2021 (17)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10
Löytömäki, Ohtonen and Huttunen 2024 (18)	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes	6/10
Stewart, Houghton and Macqueen 2025 (19)	Yes	Yes	No	No	Yes	No	No	Yes	Yes	No	Yes	5/10
Hayo et al. 2017 (20)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7/10

Findings and Results

The search method resulted in the inclusion of 10 screened articles. The narrative synthesis of the outcomes was used to extract as many insights as possible for understanding and interpreting the investigations.

Serious game affects cognitive and motor abilities in children with neurodevelopmental problems

This evaluation comprised seven studies that investigated the effects of serious games on cognitive and motor abilities in children and adults with neurodevelopmental disorders (Table 2). These studies contrasted serious games with a control group. Specifically, one research examined the effectiveness of Mega Team (a video game) (12). Another study looked at the effectiveness of a serious game for developing rhythmic ability (8). Three studies investigated the effectiveness of serious games for learning about emotions (16, 18, 20). Furthermore, the supportive framework for children and parental intention to support were explored using serious games (13, 15). The primary characteristics and conclusions of the included research are explained below and summarized in Table 2.

Crosbie and Bedard (12) conducted a randomized controlled experiment to determine the effectiveness of Mega Team, a video game on a portable device designed to promote executive functioning in children with ADHD and ASD. Participants with ADHD (n = 168) and ASD (n = 62) aged 6 to 12 years were randomized to one of the following: 1) 5 weeks of Mega Team training that includes multiple executive function games (e.g., reaction inhibition and working memory); or 2) therapy as normal. To date, results demonstrate significantly increased accuracy on working memory spatial n-back tasks (OR = 1.12; 95% CI, 1.07-1.18; p <.001) and decreased response variability (slope = 0.7; 95% CI, 0.1-1.3; p =.02) as a function of game duration and difficulty levels. Increasing play time has improved. The study indicates considerably better response variability (p <.001) within the Stop Task, and a tendency (p =.07) towards increased response inhibition as a function of playing time.

Vonthron et al. (8) sought to study a serious game for training rhythmic abilities in youngsters with dyslexia. They created Mila-Learn, an SG that uses unity to make training remotely accessible and reliably replicable while adhering to an educational goal. The SG's creation was influenced by two studies undertaken during the French COVID-19 lockdowns. Study 1 was a feasibility study that assessed the autonomous use of Mila-Learn with 2500 children who had reading difficulties. Data were evaluated from a subsample of 525 youngsters who played at least 15 games (median 42). Research 2, conducted in the same real-world scenario as research 1, assessed the usefulness of an upgraded version of Mila-Learn throughout a 6-month period in a sample of 3337 youngsters.

The analysis involved 98 children with accessible diagnoses. Linear mixed models demonstrated that performance improved with time. Scores were higher for older children (P<.001), children with attention-deficit/hyperactivity disorder (P<.001), and children with dyslexia (P<.001). Children with ADHD showed quicker improvement (β=.06; t3754=3.91; P<.001), whereas dyslexic children showed slower improvement (β=−.06; t3816=-5.08; P<.001).

Hayo et al. (20) assessed 'Emotiplay', a serious game for learning about emotions in autistic youngsters. Participants were 6-9-year-olds with high functioning ASC who used the SG for 8 to 12 weeks. The measures included face, voice, body, and integrated ER tasks, as well as parent-reported autistic symptoms and adaptive socializing. In the United Kingdom, fifteen youngsters were evaluated before and after using the SG. Children in Israel (n = 38) and Sweden (n = 36) were randomly assigned to either the SG or the waiting list control group.

In the United Kingdom, studies found that 8 weeks of SG usage significantly enhanced participants' performance on ER body language and integrative tasks. Parents also claimed that their children had improved their adaptive socializing skills. In Israel and Sweden, individuals who used the SG performed much better than controls on all ER measures. In addition, parents in the Israeli SG group claimed that their children had less autistic symptoms after using the SG. To summarize, Emotiplay's

SG is a successful and compelling psycho-educational intervention for children with high functioning ASC that teaches ER from faces, voices, and body language and integrates it in context.

Löytömäki, Ohtonen, and Huttunen (18) investigated whether the serious game Emotion Detectives improves the social-emotional abilities of children with neurodevelopmental impairments. This study looked at whether 6-10-year-old children with autism spectrum disorder, attention deficit hyperactivity disorder, and developmental language impairment may enhance their emotion discrimination abilities by participating in a serious game. Six emotion discrimination tasks were performed by intervention (n = 30) and control groups (n = 20) of children with neurodevelopmental problems, as well as a group of normally developing (TD) peers (n = 106).

The ABA research design was used in this study. Prior to the game intervention, children with neurodevelopmental problems were far behind their TD age counterparts in all skills. After two months of playing the game, the intervention group's youngsters had considerably improved their emotion discernment abilities in four activities, while the control group had only made significant progress in one test without practice. The intervention improvements were sustained during the one-month follow-up. Parents stated that the children in the intervention group had somewhat better emotion awareness and behavioral abilities in daily life than the control group.

Rouhi et al. (16) sought to examine Emotify, an emotional game for children with autism spectrum disorder. The study presents a spoken educational game that uses machine learning techniques to assist children with ASD learn how to accurately recognize and express emotions. The game focuses on four emotional states (happy, sorrow, rage, and neutrality) and is separated into two phases of increasing difficulty: the first step teaches the user how to perceive and express feelings, while the second phase tests and evaluates the user's emotional abilities. The program has a multilingual emotion recognition system based on voice pitch.

Toki et al. (13) examined a supportive framework for neurodevelopmental disorders. This study's premise is that self-adaptation of games can help students improve their well-being and performance by recommending individualized activities (for example, emphasizing stimuli to enhance attention or selecting a difficulty level that fits students' ability). The goal is to investigate how AI may help tackle this challenge. The findings would not only contribute to a better understanding of the problems of NDD children and their teachers, but would also assist psychologists in validating the findings against their clinical knowledge, improving communication with patients, and identifying areas for further investigation, such as explaining the decision made and protecting the children's private data during the learning process.

Robb et al. (15) examined parents' willingness to approve the use of computerized cognitive training for children with hereditary neurodevelopmental problems. They created a questionnaire based on the theory of planned behavior, which states that a person's intention to engage in a behavior is predicted by (1) their attitude toward the behavior, (2) their perception of subjective norms related to the behavior (i.e., perceived social pressure), and (3) their perceived control over the behavior.

Parents of children with NDDs completed the questionnaire, and 58 unique responses were preserved for analysis. Parents indicated minimal levels of understanding and familiarity with CCTs. However, our findings indicate that parents of children with NDDs have favorable ideas about the potential benefits of CCT and want to support their children's use of CCT. Linear modeling revealed that, of the three elements in the theory of planned behavior, only attitudes substantially predicted intention. Finally, parents' perceptions of the advantages of CCT were positively connected with their attitudes toward such training.

Serious game on cognitive and motor functions in adults with neurodevelopmental disorders

Based on our study, we discovered three studies that investigated the effects of serious games on cognitive and motor functioning in children and adults with neurodevelopmental problems and included them in this review. One of them addresses cognitive bias in teenagers with neurodevelopmental problems through the use of 3-D animated serious games (19). Another

study looked into fulfilling the physical requirements of persons with neurodevelopmental disorders (17). Finally, collaborative games in wearable virtual reality for individuals with neurodevelopmental problems was evaluated (14) (Table 2).

Stewart, Houghton, and Macqueen (19) investigated the use of 3-D animated serious games to reduce cognitive bias in adolescents with neurodevelopmental problems. Minds Online, a 10-episode 3-D animated serious game with CBM-I embedded, was presented in a classroom context using a three-phase multiple baseline design. Eight teenagers with an NDD finished all ten episodes. Real-time data demonstrated that seven of the eight teens switched from a negative interpretative bias to a benign one.

However, pre- and post-test standardized measurements found no significant changes in the expected direction for mental health. Visual analyses of 308 daily self-reported assessments of stress about academics, worry about peer relationships, and feelings of loneliness revealed no repeatable intervention impact. However, when the interrupted time series data were statistically evaluated, substantial individual improvements were found. Engagement with Minds Online was high, as was commitment to daily data collecting. Conclusions: Minds Online appears to be quite successful in changing the negative interpretative biases of adolescents with NDDs, which is encouraging given that such cognitive biases are implicated in the origin and maintenance of psychopathology.

Gelsomini al. (17) produced another article that addresses the requirements of persons with neurodevelopmental disorders using a physical approach. It launched Reflex, a mirrored camera mobile training software for those with neurodevelopmental disorders (NDD). The game, which is available as a cross-platform software for smartphones and tablets, connects the digital and physical worlds by monitoring tangible objects on the table using a bottom-looking mirror mounted on the device's camera. This interaction paradigm, known as phygital, its co-designed features, and the first pilot research indicate hitherto untapped learning potential.

Finally, Hutson and McGinley (14) sought to determine the efficacy of VR (virtual reality) for individuals with neurodevelopmental problems. The VR programs delivers a series of games co-designed with NDD professionals to improve communication skills. In VR programs, several users wearing virtual reality visors work together to execute collaborative activities in shared virtual worlds that need them to communicate with one another. The research offers an exploratory empirical study aimed at determining the potential of VR games for people with NDD to improve their speech-based conversational abilities.

Their findings show that the VR gaming experience was useful and entertaining, and it improved higher conversational skills when compared to its equivalent in the physical context.

Table 2: Basic characteristics and results of the included studies

Study	Intervention type/duration	Participants (N)	Results
Crosbie and Claude Bedard (2023) (12)	5 weeks of training on MegaTeam involving several executive function games.	230	Significantly improved accuracy on working memory spatial n-back tasks (OR = 1.12; 95% CI, 1.07-1.18; $p <$ .001) and decreased response variability (slope = 0.7; 95% CI, 0.1-1.3; p = .02) as a function of game play time and difficulty levels.
Vonthron et al. (2024) (8)	Children spontaneously played at least 15 (median 42) games. Study 2, following the same real-life setting as study 1, evaluated the usability of an enhanced version of Mila-Learn over 6 months.	Study 1 with 2500 Study 2 with 3337	Performance improved significantly faster in children with attention-deficit/hyperactivity disorder (β=.06; t_{3754}=3.91; P<.001) and slower in children with dyslexia (β=−.06; t_{3816}=−5.08; P<.001).
Toki et al. (2024) (13)	The children played a SG that was part of the SmartSpeech system. The game dataset included variables that were child responses quantified from two sources: hand movements on the touch screen (such as solving puzzles, manipulating	473	It will support teachers by providing the users performance assessment and enabling self adaptation of games to improve students' performance and learning capabilities.

	items on the touchscreen, or identifying images and forms) and verbal responses to questions or executing commands (such as recalling names/events, recognizing emotions, or answering with vocal replies).		
Hutson and McGinley (2023) (14)	We organized participants in 2 groups, one playing a game in VR and one playing a similar game in the real world, and assessed likability, usability, and a number of conversational performance metrics.	24	Our results indicate that the game experience in VR was usable and enjoyable, and boosted higher conversational skills with respect to its counterpart in the physical setting.
Robb et al. (2018) (15)	Once an organization agreed to assist with recruitment, they were asked to circulate a link to the questionnaire via email, social media, and organizations' own websites. All data was collected anonymously.	58	parents intend to support the use of CCT by their children; their behavioral beliefs about CCT are positive, as are their attitudes toward CCT; parents perceive that social norms regarding CCT are positive; they also believe that they could control how often their child uses CCT.
Rouhi et al. (2019) (16)	The paper proposes a spoken educational game, exploiting Machine Learning techniques, to help children with ASD to understand how to correctly identify and express emotions. The game focuses on four emotional states (happiness, sadness, anger and neutrality) and is divided in two levels with increasingly difficulty: the first step is to learn how to recognize and express feelings and in the second phase emotional skills by the user are examined and evaluated.	850	The evaluation of the developed automatic emotion recognition algorithm shows a positive accuracy of 72%.
Gelsomini et al. (2021) (17)	Reflex was placed on the table in front of the subject and participants were instructed to use only the space defined by the board and to interact with items within the working space.	17	We shed a light on phygital-based activities in terms of functioning level among the broad NDD population. Evidences from the study suggests that subjects with "Moderate" or "Mild" Cognitive Functioning Level might benefit the most from the phygital approach.
Löytömäki, Ohtonen and Huttunen (2024) (18)	Play the game at home, at school or in a clinical setting for two months (weekly one hour at a minimum and two hours, at a maximum).	50	Parents reported that the children in the intervention group somewhat improved their emotion recognition and behavioural skills in daily life in comparison to the control group.
Stewart, Houghton and Macqueen (2025) (19)	Minds Online, a 10-episode 3-D animated serious game that embeds CBM-I was introduced using a three phase multiple baseline design in a school setting.	8	Minds Online seems to be highly effective in altering the negative interpretive biases of adolescents with NDDs, which is promising because such cognitive biases are involved in the onset and maintenance of psychopathology.
Hayo et al. (2017) (20)	Participants were 6-9 year olds with high functioning ASC who used the serious games for 8-12 weeks.	24	Emotiplay's SG is an effective and motivating psycho-educational intervention, cross-culturally teaching ER from faces, voices, body language, and their integration in context to children with high functioning ASC.

SG: Serious Game; VR: Virtual Reality; CCT: Computerized cognitive training; ASD: Autism Spectrum Disorder; NDD: Neurodevelopmental Disorder; ASC: Autism Spectrum Conditions.

Discussion and Conclusion

The goal of this research was to look at the impact of serious games on cognitive and motor abilities in children and people with neurodevelopmental problems, which poses a multifaceted issue that need careful selection and deployment of appropriate methodologies. Thus, it is critical to investigate the efficacy of serious games in terms of game type, frequency, length, and impacts on cognitive and motor function. According to the findings of the included studies, serious games appear to improve the severity of cognitive and motor functions by increasing motivation and learning through the addition of specific features such as customization, storylines, humor (8), socialization (20), and demonstrating performance when using an appreciated interaction mode and an adapted task (13, 17).

They also helped youngsters recognize emotions and enhance their behavioral abilities in everyday situations (16, 18, 20). Furthermore, Reflex (a cross-platform program) demonstrated the potential of physical techniques in increasing motivation, reducing annoyance, and ultimately boosting performance when employing an appreciated interaction style and an adapted task (12, 14, 17, 21). Furthermore, the findings of this analysis support the notion that serious games are useful and engaging, improve conversational skills [21] and bridge the digital and real worlds (17).

These findings are consistent with Vonthron et al.'s (8) feasibility and usability research, which concluded that Mila-Learn improves motivation and learning by including particular characteristics such as customisation, stories, comedy, and increasing complexity. Robb et al.'s findings also indicate that parents of children with NDDs have favorable ideas about the potential benefits of computerized cognitive training (CCT) for their children and want to support their children's usage of CCT (15).

The duration of therapies in the studies considered ranged from 4 sessions (each lasting 12.5 minutes) to > 6 months, indicating substantial variation among the research. However, older children's scores increased substantially quicker in the same span (15, 17). The study has significant drawbacks. The various procedures used varied significantly in terms of length and frequency.

Furthermore, the vast number of research concentrating on children with NDDs may provide the perception of bias. However, this disparity reflects the fact that children's NDDs have been investigated more thoroughly. We have attempted to present the findings honestly, based on the available data, and recognize this as a potential weakness in the current review. Future research using more rigorous and well-designed trials in people with neurodevelopmental problems may give additional evidence of their efficacy.

Our review's findings suggest that serious games can improve cognitive and motor abilities in children and people with neurodevelopmental problems. According to the theory of planned behavior, a person's intention to engage in a behavior is predicted by (1) their attitude toward the conduct, (2) their perception of subjective norms surrounding the behavior (i.e., perceived social pressure), and (3) their perceived control over the behavior (15). The advantages of serious games corresponded strongly with the notion of planned conduct. However, because to the small number of studies, methodological flaws, and substantial variation in adult procedures used, further research must clarify their usefulness

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Authors' Contributions

Mafi H participated in the conception, design, search and interpretation of results. Ghayour Najafabadi M participated as advisor, reviewer and interpretation of results. Sheikh M participated as a researcher, conception, design and writing of the scientific article. Gharayagh Zandi H participated as a researcher and scientific article writing.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

Ethical code received from Ethical Committee of Tehran University (IR.UT.SPORT.REC.1404.018).

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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