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The Impact of Virtual Reality Games on Reducing Motor and Cognitive Disorders in Children with Autism Spectrum: A Meta-Analytical Review

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A B S T R A C T

Autism spectrum disorder (ASD) is one of the neurodevelopmental disorders (NDs) characterized by poor social skills, delayed speech development, and a tendency towards engaging in repetitive and stereotypical behaviors which make the participation of affected individuals difficult in educational settings. This disorder includes a wide range of neurodevelopmental issues such as Asperger's syndrome and autism. The present research is a meta-analysis review that involved collecting, categorizing, and summarizing scientific works related to the effects of virtual reality (VR) games and exergames on the motor skills of children with ASD and NDs, spanning from 2011 to 2022, derived from scientific databases including Google Scholar, Scopus, and PubMed using keywords such as NDs, ASD, VR games and exergames. The search method involved entering the mentioned keywords for papers published between 2011 and 2022 and those without full-text accessibility were excluded from the study. Consequently, ten highly cited papers were selected for review and analysis. According to the conducted studies, the results indicate a positive impact of VR games on the symptoms of participants with ASD. Exergames and VR can be utilized as therapeutic interventions to reduce symptoms in individuals with ASD.

Keywords: *Developmental disorders, autism spectrum, virtual reality games, and exergame*

1. Introduction

Some motor problems in children such as balance disorders, cognitive-motor disorders, or poor motor coordination (Geuze, 2005) are challenges that these children face not due to medical, intellectual, or environmental issues, nor are they indicative of intellectual disability, but primarily stem from difficulties in motor skills necessary for everyday life (Barnett et al., 1998). Based on reported data, boys are three to seven times more likely than girls to experience developmental disorders (Kadesjö & Gillberg, 1999). Children with these disorders may show reluctance to participate in physical education programs which could be due to intolerance to failure and low self-esteem (Missiuna, 1999). Additionally, they encounter difficulties in completing tasks, haptic perception, and perceptual skills (Cantell et al., 2003; Schoemaker et al., 2001). Developmental disability is a set

of variables that hinder standard physical, cognitive, and emotional growth, leading to disorders in personal, social, educational, and occupational functioning (American Psychiatric Association & Association, 2013; Zablotsky et al., 2015). These disorders typically occur during developmental ages and before school initiation. Often starting with learning limitations and motor disorders, they may then progress to cognitive and social limitations. Furthermore, these disorders may co-occur in individuals; for instance, children with ASD often experience intellectual disabilities and hyperactive children may have learning disorders. Developmental disorders in diagnostic and statistical manuals of mental disorders such as the American Psychiatric Association's Diagnostic and statistical manual of Mental Disorders, fifth edition (DSM-5), are classified into six main categories including specific learning disorders, attention-deficit/hyperactivity disorder (ADHD), intellectual disabilities, motor disorders, autism spectrum disorders and communication disorders (American Psychiatric Association, 2022).

ASD is an NDS characterized by poor social skills, delayed speech development, and a tendency towards engaging in repetitive and stereotypical behaviors that hinder the participation of the affected individual in educational environments (The Berkley Publishing Group, 1989). This disorder encompasses a broad spectrum of neurodevelopmental issues such as Asperger's syndrome and autism (Payakachat et al., 2012). The development of children and families affected by autism has underscored the importance of studies in this area and the variables involved in ASD (Homanian & Khezri, 2016). According to published statistics, in the United States, one child out of every 150 is affected by ASD, while in South Korea the prevalence is 3.7% among males and 1.5% among females (2002; Kim et al., 2011). Globally, it's estimated that one in 160 children is affected by ASD (Lauritsen, 2013). A child with ASD may exhibit either very poor or exceptionally high performance in a particular area (Rosenthal-Malek & Mitchell, 1997). The symptoms of children on the autism spectrum are numerous and complex with the most common symptoms diagnosed based on observable behaviors (Happe & Frith, 1996). The most significant indication of this disorder is severe social isolation along with obsessive-compulsive disorder (OCD) such as arranging objects in a specific order and self-stimulatory movements (Nekar et al., 2022). One of the prevalent indications associated with ASD is the performance of repetitive and stereotypical behaviors such as hand-flapping or even making repetitive noises which can lead to distraction from external stimuli and disrupt the learning process (Rosenthal-Malek & Mitchell, 1997). Hence, researchers are seeking ways to control or eliminate these behaviors to improve the quality of life and learning for individuals on the spectrum (Levinson & Reid, 1993). Generally, diagnostic features utilized to identify individuals with this disorder comprise limited communication skills, difficulties in social interactions, restrictive behavioral patterns, speech disorders, aggression, attention problems, and sleep disorders (Lang et al., 2010). Additionally, motor coordination limitations and levels of both gross and fine motor skills are also indicative symptoms of individuals affected by this spectrum.

Children with ASD exhibit undesirable levels of physical activity (Must et al., 2014; Tyler et al., 2014). Often, the challenges faced by children with ASD due to low levels of physical activity include issues related to balance, body posture stability, flexibility, and speed which generally lead to inconsistent physical growth and reduced physical readiness (Jansiewicz et al., 2006; Todd, 2012). Previous studies have also shown that children with autism tend to have a higher prevalence of overweight compared to their non-autistic peers (Broder-Fingert et al., 2014; Curtin et al., 2014). Engaging in physical activity, based on research findings, leads to a reduction in repetitive behaviors (Lang et al., 2010; Petrus et al., 2008), improvement in cognitive performance (Anderson-Hanley et al., 2011) and physical readiness (Getchell et al., 2012; Golden & Getchell, 2017).

However, exercise methods that encourage individuals to participate in sports may not yield results for individuals with ASD. Therefore, it is imperative to replace traditional physical education programs with innovative methods to encourage individuals on the spectrum to adhere to sports programs (lopaipwid; Must et al., 2015).

One approach that has recently garnered attention from researchers for enhancing physical activity levels is VR gaming. VR games neutralize negative environmental factors like weather and traffic that hinder individuals' participation in physical activities (Ng et al., 2019). These games are typically executed using commercial consoles like PlayStation and Microsoft Kinect, bridging the gap between gaming and physical activity. They are commonly known as exergames which are utilized for therapeutic or recreational purposes and physical activity (bin Song & cho Park, 2015; Donath et al., 2016). research study explored

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the effects of VR exercises using Xbox on the balance, walking ability, depression, and interpersonal relationships of stroke patients. The results indicated improvements in these factors for both groups (bin Song & cho Park, 2015). A review study that analyzed 17 research papers regarding the effects of video gaming on mental health suggested that this tool could be introduced as a therapeutic method for individuals with mental disorders (Byrne & Kim, 2019). Another research focused on the effects of exergaming on self-esteem and self-efficacy in overweight children, showing improvement in the mentioned variables after the intervention (Andrade et al., 2019).

For this reason, active interventions have received attention from researchers in recent years so that children can freely and purely use all their muscles through play (Truelove et al., 2017). Recently, the incorporation of video games as exergames and VR has expanded, attracting not only youth but also children with developmental disorders. Active video games, or exergames have been developed to improve physical readiness levels and overcome children's sedentary behaviors (Sween et al., 2014), as during the play of these games, children use their entire body muscles instead of just engaging their fingers (Kooiman & Sheehan, 2015). Research has indicated that video games can serve as exercises to enhance the cognitive performance and cognitive skills of individuals affected (Owen et al., 2010) and improve social skills in children with ASD (Trepagnier et al., 2005). However, behavioral aspects have shown contradictory results in research, as Johnson (2018) suggested that active gaming does not lead to changes in motor skill components (Lin et al., 2018).

In the last few years, numerous studies have been conducted on the impacts of active video games on both typically developing children and those with disorders, each examining various variables. The current study aims to review these conducted studies and propose a novel approach to engage children with ASD in physical activity.

2. Methods and Materials

2.1. Study Design

The present review adhered to the guidelines of selected reporting items for systematic reviews and meta-analyses.

2.2. Search Strategy

A thorough exploration was conducted across electronic databases including Google Scholar, PubMed, and Scopus. These databases were chosen for their repository of studies about health. Two researchers collaborated to develop and execute the search strategy. This strategy involved querying keywords related to developmental disorders, autism spectrum, VR games, and exergames. Ultimately, randomized clinical trials were incorporated into the study.

2.3. Study selection

Subsequently, two authors independently scrutinized the titles and abstracts of the retrieved studies. The researchers assessed the selected studies based on two evaluation criteria: 1) the utilization of VR technology or exergames in the study, and 2) whether participants were characterized as individuals with ASD.

2.4. Data Collection

To ensure precise and methodical data extraction, the researchers innovated an extraction form to organize cognitive method variables and the resultant findings. The final dataset earmarked for analysis in the study was corroborated by two researchers.

2.5. Data Analysis

The data analysis was conducted using SPSS version 28. The results revealed an amelioration in the symptoms of children diagnosed with ASD (P=0.684).

Inclusion criteria (Shahmoradi & Rezayi, 2022):

Studies incorporating the use of VR technology and incorporated the following topics:

- Studies utilizing VR methodologies for cognitive treatment and rehabilitation.
- Research works presenting efficacy outcomes.
- Target demographic: children.
- Various forms of VR technologies including desktop setups or mobile devices.

Exclusion criteria (Shahmoradi & Rezayi, 2022):

- Studies lacking complete English text were excluded.
- Studies solely concerned with evaluation or diagnosis were excluded.
- Studies solely focused on social skills were excluded.
- Studies lacking reports on efficacy were excluded.

3. Findings and Results

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Initially, 9684 studies were retrieved from searches across three databases. Duplicate studies and papers lacking full-text accessibility were excluded from the research.

Following a thorough evaluation based on inclusion and exclusion criteria and a form devised by the researchers, 9 research works were selected for inclusion in the study.

Table 1

Articles used in the present study categorized by interventions, results, and year

Authors and Year	Intervention	Results
(Anderson-Hanley et al., 2011)	Exergame	The intervention resulted in reduction of symptoms such as repetitive movements.
(Hilton et al., 2014)	Exergame	The results indicated an improvement in the subjects' performance.
(Hamideh et al., 2018)	Exergame	Basic movement skills can be developed by designing traditional games and exergames in the educational environment.
(Ye et al., 2018)	Exergame	The findings show that the combined exercise program can have a positive effect on BMI and musculoskeletal fitness of children.
(Ghobadi et al., 2019)	Xbox Kinect	In order to create balance in children with autism spectrum disorders, the use of active video games is suggested.
(Rafiei Milajerdi et al., 2021)	Exergame	Improves motor performance in children with ASD
(Dana et al., 2021)	Exergame	The result of the study emphasizes the importance of using active games and exergames to improve and strengthen the components of selective attention and working memory.
(Kwon et al., 2022)	Exergame	The results showed improvement in the implementation of fundamental skills
(Nekar et al., 2022)	Virtual reality	With the present findings, it can be suggested that cognitive-motor training using VR game-based content has positive effects on improving executive function reaction time and response accuracy.

Table 1 summarizes the articles included in the meta-analytical review, detailing their interventions, results, and publication years. The studies span from 2011 to 2022 and explore various interventions primarily involving exergames and VR-based activities targeted at children with autism spectrum disorder (ASD). For instance, a 2011 study by Cay Anderson-Hanley demonstrated that exergames reduced symptoms such as repetitive movements in children with ASD. ClaudiaListHilton's 2014 study indicated an improvement in the subjects' performance using similar interventions. In 2018, Hamideh Soltani showed that basic movement skills could be enhanced through traditional games and exergames in educational settings. Sunyue Ye's 2018 research highlighted the positive impact of combined exercise programs on BMI and musculoskeletal fitness in children. Additionally, Neda Ghobadi's 2019 study suggested using active video games like Xbox Kinect to create balance in children with ASD. The 2021 studies by Homa Rafiei Milajerdi and Amir Dana emphasized the improvement in motor performance and executive functions, respectively, while Hyunjin Kwon's 2022 study reported enhanced fundamental skills through exergame interventions. Lastly, Daekook M. Nekar's 2022 research concluded that VR game-based cognitive-motor training positively affects executive function, reaction time, and response accuracy in children with ASD.

Table 2

Effect size of articles used in the article

	Effect size	Std. error	t	Sig(2-tailed)	Lower (95% CI)	Upper (95% CI)	Lower (99%CI)	Upper (99%CI)
Overall	.068	.1661	.411	.684	-.274	.410	-1.457	1.594

Table 3

Effect Size Estimates for Individual Studies

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Study ID	Effect Size	Std. Error (a)	t	Sig. (2-tailed)	95% Confidence Interval Lower	95% Confidence Interval Upper	Weight	Weight (%)
ClaudiaLia2014	-0.562	0.3931	-1.430	0.153	-1.333	0.208	1.486	3.7
HomaRaifeiMilajerd2021	0.816	0.3448	2.367	0.018	0.140	1.492	1.569	3.9
HomaRaifeiMilajerd2021	0.042	0.3299	1.126	0.900	-0.605	0.688	1.594	4.0
HomaRaifeiMilajerd2021	-0.143	0.3304	-0.432	0.666	-0.790	0.505	1.593	4.0
HomaRaifeiMilajerd2021	-0.530	0.3363	-1.575	0.115	-1.189	0.129	1.583	4.0
Cay Anderson-Hanley2011	-0.301	1.1430	-2.109	0.035	-0.582	-0.021	1.855	4.7
Amir Dana2021	-2.195	0.5129	-4.279	<0.001	-3.200	-1.190	1.279	3.2
Amir Dana2021	-1.865	0.4824	-3.866	<0.001	-2.810	-0.920	1.331	3.3
Hyunjin2022	1.107	0.4262	2.597	0.009	0.272	1.942	1.428	3.6
Hyunjin2022	0.815	0.4110	1.983	0.047	0.010	1.621	1.454	3.7
Hyunjin2022	1.327	0.4401	3.014	0.003	0.464	2.189	1.404	3.5
Hyunjin2022	0.917	0.4158	2.205	0.027	0.102	1.732	1.446	3.6
Daekook M. Nekar2022	-0.519	0.4164	-1.247	0.213	-1.335	0.297	1.445	3.6
Daekook M. Nekar2022	-0.080	0.4084	-0.195	0.846	-0.880	0.721	1.459	3.7
Daekook M. Nekar2022	-0.402	0.4131	-0.973	0.331	-1.212	0.408	1.451	3.6
Daekook M. Nekar2022	0.030	0.4083	0.074	0.941	-0.770	0.830	1.459	3.7
Daekook M. Nekar2022	-0.598	0.4190	-1.427	0.153	-1.419	0.223	1.440	3.6
Daekook M. Nekar2022	-0.381	0.4127	-0.923	0.356	-1.190	0.428	1.452	3.6
Hamideh Soltani2018	1.123	0.3427	3.275	0.001	0.451	1.794	1.572	3.9
Hamideh Soltani2018	1.137	0.3434	3.312	<0.001	0.464	1.810	1.571	3.9
Sunyue Ye2018	-0.116	1.270	-0.910	0.363	-0.365	0.133	1.870	4.7
Sunyue Ye2018	-0.069	1.269	-0.541	0.588	-0.317	0.180	1.870	4.7
Sunyue Ye2018	-0.124	1.270	-0.974	0.330	-0.373	0.125	1.870	4.7
Sunyue Ye2018	-0.228	1.273	1.791	0.073	-0.022	-0.478	1.870	4.7
Neda Ghobadi2019	1.157	0.5528	2.094	0.036	0.074	2.241	1.213	3.0
Neda Ghobadi2019	0.955	0.5365	1.780	0.075	-0.096	2.006	1.240	3.1

Table 4

Forest plot analysis

	ID	Hedges' g	Std.Error	Lower	Upper	p-value	Weight	Weight	Forest Plot
1	Claudial 2014	-0.56	0.39	-1.33	0.21	0.15	1.49	3.73	
2	Homa rafieimilajerd 2021	0.82	0.34	0.14	1.49	0.02	1.57	3.94	
3	Homa rafieimilajerd 2021	0.04	0.33	-0.61	0.69	0.90	1.59	4.00	
4	Homa rafieimilajerd 2021	-0.14	0.33	-0.79	0.50	0.67	1.59	4.00	
5	Homa rafieimilajerd 2021	-0.53	0.34	-1.19	0.13	0.12	1.58	3.98	
6	Cay Anderson-hanley 2011	-0.30	0.14	-0.58	-0.02	0.03	1.86	4.66	
7	Amir dana 2021	-2.19	0.51	-3.20	-1.19	0.00	1.28	3.21	
8	Amir dana 2021	-1.86	0.48	-2.81	-0.92	0.00	1.33	3.34	

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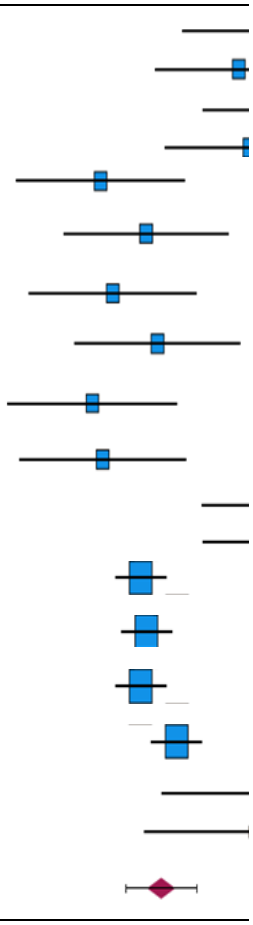
9	Hyunjin 2022	1.11	0.43	0.27	1.94	0.01	1.43	3.59
10	Hyunjin 2022	0.82	0.41	0.01	1.62	0.05	1.45	3.65
11	Hyunjin 2022	1.33	0.44	0.46	2.19	0.00	1.40	3.53
12	Hyunjin 2022	0.92	0.42	0.10	1.73	0.03	1.45	3.63
13	Deakook m. nekar 2022	-0.52	0.42	-1.34	0.30	0.21	1.45	3.63
14	Deakook m. nekar 2022	-0.08	0.41	-0.88	0.72	0.85	1.46	3.67
15	Deakook m. nekar 2022	-0.40	0.41	-1.21	0.41	0.33	1.45	3.64
16	Deakook m. nekar 2022	0.03	0.41	-0.77	0.83	0.94	1.46	3.67
17	Deakook m. nekar 2022	-0.60	0.42	-1.42	0.22	0.15	1.44	3.62
18	Deakook m. nekar 2022	0.38	0.41	-1.19	0.43	0.36	1.45	3.65
19	Hamideh soltani 2018	1.12	0.34	0.45	1.79	0.00	1.57	3.95
20	Hamideh soltani 2018	1.14	0.34	0.46	1.81	0.00	1.57	3.95
21	Sunyue ye 2018	-0.12	0.13	-0.36	0.13	0.36	1.87	4.70
22	Sunyue ye 2018	-0.07	0.13	-0.32	0.18	0.59	1.87	4.70
23	Sunyue ye 2018	-0.12	0.13	-0.37	0.13	0.33	1.87	4.70
24	Sunyue ye 2018	0.23	0.13	-0.02	0.48	0.07	1.87	4.70
25	Neda Ghobadi 2019	1.16	0.55	0.07	2.24	0.04	1.21	3.05
26	Neda Ghobadi 2019	0.96	0.54	-0.10	2.01	0.08	1.24	3.12
	Overall	0.07	0.17	-0.27	0.41	0.68		



Blue: Effect size of each study; Red: Estimated overall effect size; Open Line: Confidence interval of effect size; Closed Line: Estimated overall confidence interval

Table 2 presents the overall effect size and statistical significance of the articles included in the meta-analysis. The overall effect size is 0.068 with a standard error of 0.1661 and a t-value of 0.411, indicating no statistically significant effect (p=0.684). The 95% confidence interval ranges from -0.274 to 0.410, while the 95% prediction interval extends from -1.457 to 1.594, suggesting considerable variability among individual studies' effect sizes. These results imply that while some studies reported significant positive outcomes, the overall pooled effect of VR and exergames on reducing motor and cognitive symptoms in children with ASD is not statistically significant.

Table 3 details the effect size estimates, standard errors, t-values, significance levels, and confidence intervals for each study included in the meta-analysis. The studies show a range of effect sizes, with some demonstrating significant positive effects and others indicating no significant impact. For example, Claudia Lia's 2014 study has a negative effect size of -0.562 (p=0.153), indicating no significant improvement. In contrast, Homa Rafiei Milajerdi's 2021 study reports a positive effect size of 0.816 (p=0.018), highlighting significant improvements. Amir Dana's 2021 studies also show large negative effect sizes (-2.195 and -1.865, p<0.001), indicating substantial negative impacts. Hyunjin's 2022 studies generally report positive effect sizes, with one study showing an effect size of 1.327 (p=0.003). These variations underscore the diverse outcomes of VR and exergame interventions across different studies.

Table 4 provides a forest plot analysis of the effect sizes of individual studies, displaying the hedges' g values, standard errors, confidence intervals, p-values, and weights. The overall estimated effect size is small and not statistically significant (Hedges' g = 0.07, p=0.68), with a wide confidence interval (-0.27 to 0.41), suggesting heterogeneity in the study outcomes. The forest plot visually represents the variability in effect sizes, with some studies showing positive effects and others indicating negative or no significant effects. For instance, studies by Homa Rafiei Milajerdi (2021) and Hyunjin (2022) show positive effect sizes with relatively narrow confidence

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intervals, indicating consistent positive outcomes. Conversely, studies like Amir Dana's (2021) show large negative effect sizes, highlighting potential adverse effects or limitations in the intervention designs. The overall analysis indicates that while individual studies may report significant results, the aggregated data does not support a uniformly positive impact of VR and exergames on children with ASD.

4. Discussion and Conclusion

The present study aimed to investigate the roles of VR-based games in reducing cognitive and motor symptoms in children with ASD. Studies published over the past decade were searched using the aforementioned keywords. The majority of studies supported the positive effects of VR games. A study conducted in 2011 examined the effects of VR and video games and designed a game and environment based on participants' symptoms. Children were able to practice addressing their weaknesses and reducing symptoms in a simulated real-world environment. Conversations and situations were provided in the VR game setting, encouraging children with ASD to engage socially to continue playing. To attract participants, popular sports or cinematic characters were utilized. This approach was designed to address the common symptoms of social communication deficits and isolation among children with ASD. The results obtained from the studies suggest that VR games can be utilized as a therapeutic approach to improve social functioning (Lahiri et al., 2012). Generally, VR and exergames can be beneficial depending on the symptoms and type of disorder. VR games can be designed with high variability and diverse scenarios which allow individuals with disorders to work on their weaknesses in a non-real environment and transfer acquired skills to the simulated world. Children with ASD who are overweight or have excessive standard body composition can engage in active sports-based games focused on fundamental movements. Similarly, children with social communication abilities can be provided with a platform to engage in social and interactive tasks with other game characters within VR games.

Despite the promising results, it is crucial to acknowledge the variability in the efficacy of VR games based on individual differences among children with ASD. Factors such as the severity of symptoms, personal interests, and prior exposure to technology can significantly influence outcomes. For instance, children with severe motor impairments may require tailored VR experiences that specifically target their unique needs, while those with milder symptoms might benefit from more generalized game-based interventions. Additionally, the engagement level of children in VR activities can be enhanced by incorporating their interests, making the therapeutic process more enjoyable and effective. This individualized approach is supported by studies indicating that personalized interventions are more successful in achieving desired outcomes in children with developmental disorders (Homanian & Khezri, 2016).

Furthermore, the implementation of VR and exergames in therapeutic settings must consider the potential challenges and limitations. One of the primary concerns is the accessibility and cost of VR technology, which may limit its widespread adoption in under-resourced settings. Moreover, the effectiveness of VR interventions relies heavily on the proper training of therapists and educators in utilizing these technologies. Inadequate training could lead to suboptimal use of VR games, diminishing their therapeutic potential. Therefore, it is essential to develop comprehensive training programs and provide adequate resources to support the integration of VR-based therapies in diverse settings. Future research should also focus on developing cost-effective and user-friendly VR systems to ensure broader accessibility (Lahiri et al., 2012).

Lastly, while the current meta-analysis highlights the positive impact of VR games on reducing motor and cognitive symptoms in children with ASD, further longitudinal studies are necessary to assess the long-term effects of these interventions. Understanding the sustainability of improvements in motor skills and cognitive functions over extended periods is critical for determining the true efficacy of VR-based therapies. Additionally, future studies should explore the potential for VR games to facilitate broader developmental gains, such as improvements in academic performance and social relationships. By addressing these gaps in the literature, researchers can provide more comprehensive insights into the role of VR in supporting the development of children with ASD (Ng et al., 2019).

Authors' Contributions

A.M. conceptualized the study, designed the research methodology, and conducted the literature search and data collection from scientific databases. A.T., the corresponding author, performed the meta-analysis,

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interpreted the results, and took the lead in drafting and revising the manuscript. Both authors were involved in categorizing and summarizing the scientific works included in the review. They collaboratively discussed the findings, critically reviewed the manuscript for important intellectual content, and approved the final version for publication.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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