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Exploring the impact of executive function deficits on academic readiness and social-emotional skills in children with ADHD and learning disabilities: A systematic review

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Abstract. This systematic review centers on the critical implications of executive function (EF) deficits concerning the academic preparedness and socio-emotional competencies of children diagnosed with Attention Deficit Hyperactivity Disorder (ADHD), and Learning Disabilities. A particular focus is directed towards the evaluation of EF utilizing cutting-edge technologies, such as virtual reality (VR), which provide novel diagnostic instruments for assessing children's challenges within more authentic and realistic environments.
The review scrutinizes 21 pappers that investigate the correlation between documented EF deficits and academic achievement, underscoring the necessity for precise and dependable assessment methodologies. Conventional evaluation techniques, including questionnaires and clinical assessments, are integrated with VR-based evaluations that facilitate a more comprehensive understanding of children's behaviors and performances within actual learning contexts.
The review emphasizes the capacity of virtual reality to emulate a diverse array of scenarios that reflect everyday obstacles, rendering it an indispensable instrument for identifying performance deficits and formulating targeted interventions. Furthermore, findings from research indicate that interventions employing digital technologies can significantly enhance educational outcomes and foster children's social regulation competencies. The incorporation of these technologies into educational and therapeutic frameworks heralds a promising avenue for facilitating support for these children by advancing their academic and social growth.
Keywords: Executive Functions (EF), Self-Regulation, Assessment Tools, Academic Readiness, Behavioral Adaptation, Social Skills

Introduction

Defining Executive Functions (EFs)

Executive functions (EFs) are higher-order cognitive processes that regulate goal-directed behavior, self-control, and adaptability to complex situations (Barkley, 2012; Diamond, 2013). These functions, which include working memory, inhibitory control, and cognitive flexibility, play a critical role in learning, decision-making, and social interaction (Miyake et al., 2000). The development of EFs is influenced by both biological and environmental factors, with deficits linked to various neurodevelopmental disorders, including ADHD, and learning disabilities (LD) (Shroff et al., 2024; Hamilton et al., 2024; Hua et al., 2024).

This papper specifically addresses the subsequent research questions using a systematic review methodology:

1. How do executive functions contribute to academic readiness and learning outcomes?

2. What tools are used to assess executive function in children and adolescents?

3. How do executive function deficits affect social skills, emotional regulation and behavioural adjustment?

4. How do executive function deficits manifest in children with ADHD and learning disabilities?

5. How can VR-based assessments and digital tools improve the assessment of executive functions?

To fully understand the mechanisms underlying executive functions, this framework integrates cognitive, neuropsychological, and sociocultural perspectives, explaining how EFs are assessed and how interventions can be designed to enhance them.

Cognitive and Neurodevelopmental Perspectives on EF

The Prefrontal Cortex and Executive Function Maturation

EFs are primarily associated with the prefrontal cortex (PFC), which undergoes prolonged maturation from infancy through adolescence (Buss & Spencer, 2018).

The neuroplasticity of the PFC suggests that executive functions can be enhanced through targeted interventions and enriched environments (Blair & Raver, 2016).

Disruptions in PFC connectivity, particularly in children with ADHD and learning disabilities, contribute to difficulties in impulse control, attention regulation, and working memory (Hua et al., 2024).
Executive functions (EFs) begin to manifest during infancy and early childhood, with substantial growth taking place within the initial triennium of life (Morgan et al., 2024). In this vital phase, EFs are instrumental in cultivating essential competencies, such as self-regulation, attentional control, and cognitive adaptability, which significantly influence academic preparedness and educational achievement (Bausela-Herreras, 2022).

Research indicates that early manifestations of EF serve as robust predictors of long-term academic performance, as they enable children to manage their behaviors, conform to established rules, and engage effectively within educational contexts. The capabilities associated with EF, particularly concentration and self-regulation, are fundamental for the learning process, as they empower children to undertake intricate tasks and formulate problem-solving methodologies (Uraipong, 2024).

The progression of EFs is not solely dictated by biological factors; it is profoundly shaped by environmental influences. Environments rich in cognitive and emotional support, such as nurturing families and high-caliber educational programs, promote the development of EF, thereby facilitating enhancements in working memory, attentional focus, and self-regulation (Blair & Raver, 2016). Conversely, adverse circumstances, including socioeconomic disadvantage and chronic stress, can obstruct EF development, resulting in diminished educational outcomes and challenges in acclimatizing to school environments (Zografou & Drigas, 2022; Raver et al., 2013).

Empirical investigations into EF and learning outcomes reveal that the interplay between working memory and inhibitory control equips children to process complex information and adjust to academic demands (Diamond, 2013). Children exhibiting well-developed EF demonstrate superior performance across reading, mathematics, and scientific disciplines, as they possess the ability to systematically organize information and apply effective strategies (Shroff et al., 2023; Núñez et al., 2024). Deficiencies in EF correlate with diminished academic success, as these children often struggle with concentration, adherence to instructions, and adaptation to classroom expectations (Taylor et al., 2024).

The early development of EF serves as a crucial determinant of academic preparedness and educational outcomes. Children endowed with robust EF exhibit enhanced capacities for self-regulation, attention, and problem-solving, thereby rendering them more adept at fulfilling the exigencies of academic life. In contrast, deficiencies in EF are linked to challenges in academic performance, underscoring the necessity for early intervention and support through tailored educational strategies.

Information Processing and Working Memory Models

The Information Processing Model (Atkinson & Shiffrin, 1968) conceptualizes cognition as a sequence of attention, encoding, and retrieval processes, where executive functions regulate information flow.

- Baddeley & Hitch's Working Memory Model (1974) is particularly relevant for understanding EF-related learning challenges.
- Cognitive flexibility and inhibitory control, as defined by Miyake et al. (2000), enable individuals to shift between tasks and suppress irrelevant information, which is crucial for problem-solving and adaptive learning.

The assessment of Executive Functions (EF) is carried out using a range of tools designed to evaluate various cognitive abilities, including self-regulation, cognitive flexibility, working memory, and cognitive control. These assessment tools encompass self-report questionnaires, neuropsychological evaluations, and contemporary technological applications like electronic assessments and virtual reality simulations. The selection of the appropriate assessment tool is influenced by the target population, the assessment's objective, and the validity and

reliability standards set by the research or clinical scenario.

- The Barkley Deficits of Executive Functioning Scale—Children and Adolescents (BDEFS-CA) represents one of the preeminent instruments employed for the assessment of executive functions among children and adolescents. This instrument is structured as a questionnaire that emphasizes the self-regulation of behavior, management of time, organizational competencies, internal motivation, and the regulation of emotional responses. The construct validity of the BDEFS-CA has been substantiated across diverse cultural contexts, evidencing its reliability in the evaluation of children diagnosed with ADHD and learning disabilities (El Wafa et al.,2020). Furthermore, empirical studies indicate that the BDEFS-CA proficiently differentiates children with ADHD from those exhibiting typical developmental trajectories, thereby playing a crucial role in the diagnostic process of executive function disorders when utilized alongside other clinical assessments (Shroff et al., 2024).
- The Behavior Rating Inventory of Executive Function (BRIEF) represents one of the most extensively acknowledged instruments for the evaluation of executive function among children diagnosed with neurodevelopmental disorders, such as cerebral palsy. Empirical studies have validated the efficacy of the BRIEF in the assessment of children exhibiting specific learning disabilities (SLD) and attention-deficit/hyperactivity disorder (ADHD), underscoring notable deficiencies in self-regulation and cognitive control (Colomer et al., 2017; Hamilton et al., 2019; Jacobson et al., 2020).
- The Cambridge Neuropsychological Test Automated Battery (CANTAB) comprises computerized assessments that evaluate attention, memory, and cognitive flexibility, and has been implemented to assess children with learning disabilities (Ju et al., 2024); Takahashi et al., 2024).
- The Wisconsin Card Sorting Test (WCST) and the Stroop Test serve as assessments of cognitive flexibility, adaptive capacity, and response inhibition, with significant relevance to children diagnosed with ADHD and learning disabilities (Romero-Ayuso et al. (2024)).
- The NIH Toolbox Cognition Battery (NIH TB-CB) serves as a comprehensive evaluative instrument for executive functions, systematically quantifying competencies such as cognitive flexibility, response inhibition, and functional memory. Empirical studies have demonstrated its efficacy in the assessment of pediatric populations diagnosed with ADHD, ASD, anxiety disorders, and ODD (Anning et al., 2020; Kavanaugh et al., 2017).
- The Executive Function Inventory for Children and Adolescents (EFICA) constitutes a systematic evaluative instrument designed to appraise several domains of executive function, encompassing cognitive flexibility, inhibitory control, and working memory. Its application has been progressively adopted in both clinical and educational research contexts to assess children and adolescents exhibiting executive dysfunctions associated with ADHD and learning challenges (Arruda et al., 2022).
- The Minnesota Executive Function Scale (MEFS) represents a novel instrument that facilitates a swift and scalable evaluation of executive functions, with a particular focus on the developmental stage of young children. Its validation as a prognostic tool for detecting executive function deficits during early childhood renders it an invaluable instrument for screening purposes in the context of school-based interventions (ElAdl, 2024)
- Virtual reality (VR-based assessment) tools represent innovative technological applications that facilitate the simulation of real-world scenarios for the evaluation of executive function in naturalistic settings, thereby enhancing the ecological validity of such measurements (Areces et al., 2018; Gooch et al., 2014; Romero-Ayuso et al., 2024; Takahashi et al., 2024)

The comparative analysis of these instruments elucidates the critical importance of selecting appropriate evaluative methodologies, which are contingent upon the particular demands of research or clinical practice. Considering that executive functions embody complex cognitive processes essential for learning, behavior, and emotional regulation, their assessment requires a holistic approach that incorporates self-report questionnaires, neuropsychological evaluations, and sophisticated technological instruments.

<u>*Sociocultural and Psychological Perspectives on EF*</u>

Vygotsky's Sociocultural Theory and Inner Speech Development

According to Vygotsky (1978), executive functions develop through social interaction and guided learning.

- Inner speech, a key self-regulation tool, plays a critical role in planning, organizing, and problem-solving (Baron & Arbel, 2022).
- Children with Developmental Language Disorder (DLD) often exhibit deficits in inner speech, resulting in weaker EF-related skills such as narrative organization and selective attention (Janssen et al., 2024).

The early development of executive functions not only plays a crucial role in determining academic achievement, but also exerts a profound influence on social competencies and emotional regulation. Children exhibiting robust executive functions demonstrate an enhanced ability to comprehend societal norms, engage in collaborative efforts, and adapt to diverse social contexts (Zeidner, 2008).

In contrast, deficiencies in executive functions may lead to:

(a) Difficulties in emotional regulation, typified by increased impulsivity and a reduced capacity to understand varied perspectives (Guerra et al., 2024).
(b) Complications regarding social integration, as children with underdeveloped executive functions encounter challenges in interpreting and responding to social cues (Zengilowski et al., 2023).
(c) Heightened conflicts with peers, resulting from their difficulty in managing impulsive reactions and resolving social disputes (Stucke & Doebel, 2024).

Manifestations of executive function deficits are particularly pronounced in children diagnosed with Developmental Language Disorder (DLD), given the interrelationship between linguistic processing and executive functions. Children with DLD encounter obstacles in working memory, attention, and speech organization, which adversely affect their ability to communicate effectively and participate in social interactions (Suntheimer et al., 2024).

In order to address deficiencies in executive functions and associated socio-emotional difficulties, targeted interventions have been developed, including mindfulness practices that promote self-regulation and reduce impulsivity (Taylor et al., 2024). Interactive activities and role-playing exercises, which foster an understanding of social contexts and enhance emotional regulation (Sahlberg & Doyle, 2019).

Deficits in executive functions substantially impede social and emotional development; nevertheless, through strategically focused interventions, children can improve their self-regulation and social adaptability, thereby facilitating their overall developmental trajectory.

Self-Determination Theory (Deci & Ryan, 1985) and EF Regulation

Self-Determination Theory (SDT) highlights the role of intrinsic motivation and self-regulation in cognitive control.

- Children with stronger self-regulated EF skills demonstrate greater persistence in learning tasks (Stucke & Doebel, 2024).
- EF deficits, particularly in ADHD and LD, often lead to lower intrinsic motivation, making self-directed learning difficult (Ko, 2023).

Self-determination theory (SDT) underscores the significance of intrinsic motivation and self-regulation in the advancement of executive functions (EF). While the progression of EF is correlated with the maturation of the prefrontal cortex, it is crucial to acknowledge the substantial impact of environmental factors. Contexts that foster interaction, creativity, and emotional stability have been empirically demonstrated to facilitate EF development, in contrast to adversities such as socioeconomic deprivation and chronic stress, which can obstruct this progression (Blair & Raver, 2016)
The cultivation of EF is augmented by enriched educational settings that promote autonomy and afford opportunities for experimentation and innovative thinking. Families that create a nurturing environment and provide high-quality educational experiences are instrumental in the development of competencies such as working memory, cognitive flexibility, and inhibitory control (Blair & Raver, 2016).

One of the most efficacious methods for enhancing self-regulation and cognitive development is through play. Specifically, unstructured play and role-playing enable children to navigate social norms, devise problem-solving approaches, and practice emotional regulation (Sahlberg & Doyle, 2019). Furthermore, the equilibrium between educational pursuits and play fosters both autonomy and intrinsic motivation, which are essential components for self-regulated learning.

Emotional intelligence, which bears a close relationship to EFs, is likewise affected by the management of intrinsic motivation. Interventions that incorporate emotional comprehension and mindfulness practices can enhance children's capacity to regulate emotions and sustain self-control (Zeidner et al., 2008).. Especially for children subjected to chronic stress, mindfulness training may mitigate the adverse effects of stress on the prefrontal cortex, thereby improving self-regulation and adaptability in learning contexts (Raver et al., 2013).
Consequently, self-determination theory is intrinsically connected to EF development, as supportive environments and strategically designed interventions can advance cognitive flexibility, self-regulation, and problem-solving capabilities.

Executive Function Challenges across Neurodevelopmental Disorders

Students diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) encounter substantial challenges in executive functioning, encompassing issues related to attentional regulation, temporal organization, systematic arrangement, self-regulatory processes, and the capacity for working memory (Al Dahhan et al., 2022; Anning et al., 2023). These impediments can adversely influence academic achievement, social competencies, and emotional self-regulation (Al-Yagon et al., 2020). Furthermore, executive functions are linked to both internalizing and externalizing behavioral patterns, alongside challenges in the management of adverse emotional states (Al-Yagon et al., 2020).

Table 1. Association of Executive Difficulties with Disorders and Indicative Bibliography

Disorder	Key EF Deficits	SupportingLiterature
ADHD	Poor impulse control, weak cognitive flexibility, attention deficits.	Barkley (2012), Al-Yagon et al. (2023)
LD	Poor response inhibition, reduced metacognitive skills, weak organization.	El Wafa et al. (2020), Núñez et al. (2024)

Present therapeutic strategies for ADHD adopt a comprehensive approach that integrates pharmacological interventions, behavioral therapies, and pedagogical methodologies (Drigas &Tourimpampa, 2014). Moreover, the integration of digital technologies, including mobile applications, VR, and robotic systems, has been demonstrated to significantly enhance executive functions and attentional capacities in children affected by ADHD (Doulou& Drigas, 2022; Kakoura et al., 2024; Drakatos& Drigas, 2024). For instance, STEAM, along with the application of virtual and augmented reality gaming, has been evidenced to bolster working memory, self-regulation, and organizational skills (Drakatos& Drigas, 2024; Doulou& Drigas, 2022). Additionally, the employment of digital assessment tools, such as the BRIEF2, facilitates both evaluation and intervention aimed at enhancing executive functions (Jacobson et al., 2020).

Overall, contemporary intervention strategies emphasize individualized support for children with ADHD, leveraging innovative methodologies and technological advancements to enhance executive functioning and overall life quality (Gkora& Drigas, 2024; Zografou& Drigas, 2022).

Children diagnosed with Developmental Language Disorder (DLD) exhibit notable deficits in functional memory, attentional capacity, and response inhibition, which adversely influence language processing, phonological awareness, and the coherence of speech (Núñez et al.). Concurrently, diminished cognitive flexibility and attentional challenges compromise grammatical processing and narrative comprehension (Shroff et al.).

Furthermore, the inability to internalize speech significantly hinders self-regulation and the adaptation to both academic and social demands (ElAdl et al.), with the degree of executive dysfunction exhibiting variability among individuals, thereby underscoring the necessity for tailored interventions (Jacobson et al.). In a similar vein, students identified with specific learning disabilities (SLDs) demonstrate impairments in cognitive flexibility, memory, and organizational skills, which detrimentally impact essential competencies such as reading, writing, and mathematics (Colomer et al.; Shroff et al.).

Empirical research substantiates those executive dysfunctions adversely affect academic performance, highlighting the necessity for individualized learning strategies (Hamilton et al.). The correlation between difficulties in programming and challenges in writing and spelling accentuates the critical need for specialized interventions (Alesi et al.). Integrated intervention approaches that amalgamate self-regulation, pedagogical strategies, and technological tools have been empirically validated as effective in enhancing executive functions and providing support for children with learning disabilities (Khan & Lal, 2023; Zografou& Drigas, 2022). Specifically, the incorporation of digital tools and STEAM methodologies has demonstrated potential in enhancing cognitive flexibility and metacognitive skills, thereby facilitating the navigation of academic and social challenges (Lytra& Drigas, 2021).

Executive dysfunction presents in diverse manners across each disorder, impacting cognitive development, adaptation to educational settings, and social interactions. The implementation of individualized assessment instruments and focused interventions is vital for the enhancement of executive functioning in children with DLD, ADHD, and SLD. The formulation of integrated strategies that amalgamate educational, psychological, and technological interventions represents a robust approach to addressing these challenges and fostering the comprehensive development of children.

Assessment and Intervention Strategies for EF

EF Assessment: Traditional vs. Digital Methods

- Traditional EF assessments (e.g., BRIEF, BDEFS-CA, WCST) measure cognitive control and self-regulation (Maehler et al., 2016).
- Digital and VR-based EF assessments offer more ecologically valid evaluations (Borgnis et al., 2022).

Methods

The methodology of this study is designed to systematically explore the challenges, assessment tools, and intervention strategies related to executive functions (EFs). Given the study's focus, a systematic literature review approach has been employed to synthesize current empirical findings, theoretical frameworks, and intervention models. The methodological approach ensures rigorous selection, analysis, and synthesis of relevant research while maintaining transparency and replicability.

Research Design

This study follows a systematic literature review (SLR) approach, which is appropriate for:

- Identifying key theoretical and empirical contributions related to executive functions.
- Comparing different EF assessment tools and their effectiveness.

- Evaluating evidence-based intervention strategies for EF enhancement.

The systematic review adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, ensuring transparency in the selection and synthesis of studies.

Data Sources and Search Strategy

A comprehensive search was conducted using the following databases and digital libraries:

-PubMed (for neurocognitive and clinical EF research).
-PsycINFO (for psychological and educational studies on EF).
-ERIC (for studies focusing on EF in educational settings and learning outcomes)
-Google Scholar (for supplementary and recent open-access publications).
The search strategy combined keywords related to executive functions, assessment, interventions, and neurodevelopmental disorders using Boolean operators (AND, OR). The main search terms are presented in Table.

Table 2: Preliminary search terminology

Topic	SearchTerms
Executive Functions Assessment	"executive function" OR "working memory" OR "cognitive flexibility" OR "inhibitory control" OR "self-regulation" OR "attention control" OR "planning skills"
TargetPopulation	"ADHD" OR "Attention-Deficit/Hyperactivity Disorder" OR "DLD" OR "Developmental Language Disorder" OR "Learning Disabilities" OR "LD" OR "Specific Learning Disorder"
Outcome Measures	"academic readiness" OR "learning outcomes" OR "social skills" OR "emotional regulation" OR "behavioral adaptation"
StudyType	"empirical study" OR "experimental study" OR "longitudinal study" OR "case-control study"
Timeframe	Published between 2014–2024

Inclusion and Exclusion Criteria

Table 3: Inclusion and Exclusion Criteria

Inclusion	Exclusion
Published 2014–2024	Published before 2014
English language	Not in English
Participants: Children (5–18 years old) with ADHD, DLD, or LD	Participants outside the 5–18 age range
Empirical, primary research (experimental, longitudinal, case-control)	Review articles, meta-analyses
Investigation of academic readiness, learning outcomes, social-emotional skills, or behavioral adaptation	No relevant outcome measures

After applying these criteria, 1200 studies were initially identified, with 21 studies meeting the final inclusion criteria for detailed analysis.

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The search focused on empirical studies that:

- The focus was directed towards children and adolescents (ages 5-18) diagnosed with ADHD, DLD, or LD.
- The investigation sought to elucidate the relationship between executive functions and: (a) Academic preparedness and educational outcomes; (b) Social competencies, emotional regulation, and behavioral adaptation.
- The articles selected were published within the last decade (2014-2024).
- They were composed in the English language and were not review articles (either systematic or narrative).

The selection process consisted of the following stages:
(1) Initial Search: A comprehensive total of 1,200 scholarly articles were identified across the four designated databases.
(2) Duplicate Removal: Subsequent to the removal of duplicate entries, a total of 950 distinct articles were preserved.
(3) Title and Abstract Review: From this subset, 150 articles were identified as potentially pertinent.

(4) Comprehensive Review and Final Selection: Following meticulous scrutiny of the articles, 21 studies met all established inclusion criteria and were consequently incorporated into this research endeavor.

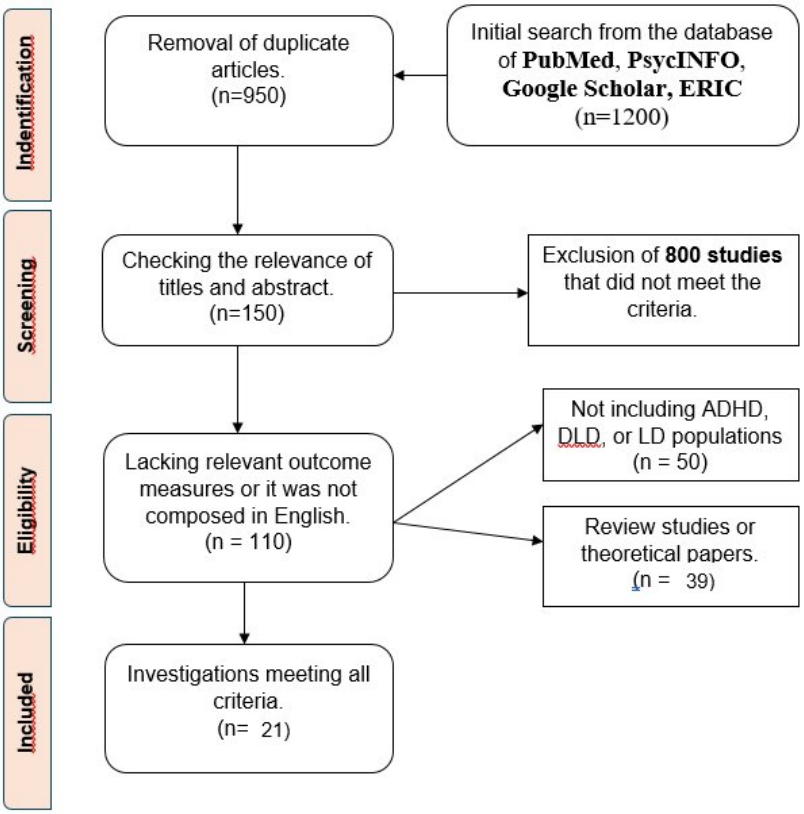

Figure 1: (PRISMA) Illustrates the flow of article selection.

Table 4. Alltables should be in Arial 9, no color, single column, not bold, and terms not in upper case. Below is an example of table formatting

Study	Diagnostic groups	Average age	Tools used	Relevance to Research Questions
Al Dahhan et al. (2022)	dyslexia & dyslexia+ADHD	8-13	NEPSY-II, Gordon CPT	Examines how deficits in executive functions affect reading fluency & accuracy.
Alesi et al. (2024)	SEN	8-14	EFs for Child (EFC), Academic Motivation Scales (AMS)	Examines the relationship between executive functions, academic motivation, anxiety and depression (emotional regulation and academic outcomes).
Al-Yagon et al. (2020)	ADHD	11-12	BRIEF for teachers	Analyses relationship between EF, social and emotional regulation
Anning et al. (2023)	ADHD, ASD,	4–8	NIH Toolbox	Examines the relationship between EF and symptoms that affect emotional regulation and behavioural adjustment.
Areces et al. (2018)	ADHD	6-16	Virtual reality	Examines cognitive and attentional profiles in children with and without ADHD, with a focus on VR assessment (academic outcomes and behavioral adjustment).
Arruda et al.(2022)	ADHD	5-18	EFICA	It examines EF in relation to behavioral and emotional dimensions, with an indirect relationship to academic outcomes.
Colomer et al. (2017)	ADHD	7-11	BRIEF	Weak executive functions are associated with poor school adjustment and impaired learning abilities.
El Wafa et al. (2020)	ADHD, LD	6-13	BDEFS-CA	Examines executive functions in children with ADHD and LD, focusing on differences between the two groups (academic and behavioral outcomes).
El Adl (2024)	ADHD	6-12	Minnesota Executive Function Scale (MEFS)	Examines the relationship between EF and social skills (emotional regulation and behavioural adjustment).
Gooch et al. (2014)	DLD	3-5	Visual Search task, Auditory Continuous Performance Test, Dog– Bird Go/No-Go task, Working Memory Test Battery for Children	Examines executive functions in children with DLD and their impact on academic performance and social skills.
Hamilton et al. (2024)	NDDs	7-17	BRIEF-2	Examines the relationship between executive functions and behavioural adaptation, including social skills and emotional regulation.
Jacobson et al. (2020)	ADHD	5-18	BRIEF 2	Executive dysfunctions have a profound effect on social skills, emotional regulation and behavioural adjustment.
Ju et al. (2024)	Dds	7-12	Virtualr eality, CANTAB	Examines the clinical utility of a virtual kitchen task to assess functional cognitive ability in children with developmental disorders (behavioral adaptation).
Kavanaugh et al. (2020)	ADHD	5-18	NIH Toolbox	Exploring the relationship between executive function and emotional difficulties
Núñez et al. (2024)	SEN	6-12	BRIEF-2	Examines the relationship between EF and learning difficulties (academic outcomes).
Romero-Ayuso et al. (2024)	ADHD	8-16	Stroop Test, VR	Explores the impact of executive functions (EFs) on social adjustment and emotional regulation.
Rosello et al. (2018)	ASD, ADHD	7-11	BRIEF	Examines the relationship between EF and learning behaviours (academic outcomes).
Shakehnia et al. (2021)	ADHD	6-12	BRIEF	"Hot" executive dysfunctions in children with ADHD directly affect emotional regulation and social behaviour, leading to difficulties in anger regulation, impatience and inability to maintain social relationships.
Shroff et al. (2024)	ADHD	13-14	BRIEF-2, BDEFS-S	Examines the relationship between EF and academic outcomes, as well as behavioural/emotional skills.
Takahashi et al. (2024)	ADHD	8-21	3D video game, CANTAB, Conners 3 Parent,	Examines the assessment of executive functions in children and adolescents with ADHD through a 3D video game (academic outcomes and behavioral adjustment).
Veloso et al. (2022)	ADHD	6-10	BRIEF	Children with ADHD have greater difficulty regulating their emotions (Hot EF), which negatively affects their social relationships and behavioural adjustment.

Findings

Instruments utilized for the assessment of executive functions (EFs) in children and adolescents can be classified into two primary categories

Table 5. Direct assessments (evaluate executive functions via student-administered tests).

Instruments	Description	Survey
NIH Toolbox Cognition Battery (NIH TB-CB)	It evaluates cognitive processes via assessments that encompass working memory and cognitive flexibility.	Anning et al. (2023); Kavanaugh et al (2020)
Cambridge Neuropsychological Test Automated Battery (CANTAB)	A computational instrument designed to evaluate attention, memory, and cognitive adaptability.	Ju et al. (2024); Takahashi et al. (2024)
StroopTest	It quantifies inhibitory control and impulse regulation.	Romero-Ayuso et al. (2024)
Virtual Reality Tools (VR-based assessments)	Assessments employing virtual reality to evaluate executive functions within physical contexts.	Areces et al. (2018); Takahashi et al. (2024); (Romero-Ayuso et al., 2024); Gooch et al. (2014)
Virtual Kitchen Errand Task (VKET-C)	It evaluates functional cognitive abilities in children with developmental disabilities through simulated environments.	Juetal. (2024)
3D Video Game Assessment	Tests which measure attention and working memory.	Takahashi et al. (2024)
Minnesota Executive Function Scale (MEFS)	Measures self-regulation and cognitive control by testing.	El Adl (2024)

Table 6. Indirect assessments (surveys filled out by parents or educators to document the child's behavioral patterns).

Instruments	Description	Survey
Behavior Rating Inventory of Executive Function (BRIEF & BRIEF-2)	A questionnaire administered to parents and educators to evaluate executive functions in everyday contexts.	Colomer et al. (2018); Hamilton et al. (2024); Jacobson et al. (2020); Núñez et al. (2024); Veloso et al. (2022); Al-Yagonetal., (2020)
Barkley Deficits in Executive Functioning Scale – Children and Adolescents (BDEFS-CA)	A questionnaire designed for parents that evaluates issues related to self-regulation, planning, and organizational skills.	El Wafa et al. (2020); Shroff et al. (2024)
Executive Function Inventory for Children and Adolescents (EFICA)	This instrument assesses executive functions through a questionnaire filled out by either parents or educators.	Arrudaetal. (2022)

Digital assessment vs traditional tools

The digital evaluation of executive functions via virtual reality (VR) demonstrates variable outcomes when juxtaposed with conventional assessment instruments. Contributing factors to this divergence encompass:

Enhanced Ecological Validity of VR.

Virtual reality tools (e.g., Virtual Kitchen Errand Task - VKET-C, 3D Video Games) simulate authentic daily scenarios, thereby facilitating a more genuine evaluation of executive functions. In contrast, traditional assessment methodologies typically rely on self-reported data (from parents or teachers), which may not accurately depict the child's true competencies within their quotidian context.

Distinct Objectives of Assessment Instruments.

Conventional tools primarily document observable behavioral indicators of executive function difficulties. Conversely, VR assessments evaluate real-time task performance that necessitates impulse control, cognitive adaptability, and strategic planning. This distinction may elucidate the observed discrepancies in findings, as children's performances in VR settings may significantly differ from their behavior in typical environments.

Constraints of VR in Executive Function Evaluation.

While VR may offer heightened realism, the cognitive demands associated with certain games or environments may fail to correctly isolate individual executive skills, potentially resulting in either an overestimation or underestimation of difficulties. Furthermore, variables such as technological familiarity and sensory overload, particularly in children diagnosed with ADHD, can significantly influence performance outcomes.

Varied Dimensions of Executive Functions.

Research conducted by Romero-Ayuso et al. and Areces et al. has indicated that VR evaluations exhibit greater sensitivity in assessing "hot" executive functions (such as emotional regulation

and motivation), while traditional assessment tools demonstrate greater precision in evaluating "cool" executive functions (including attention and cognitive control).

VR provides a more authentic and dynamic mode of assessment; however, conventional tools remain pertinent for longitudinal behavioral analysis of executive functions. An optimal strategy involves the integration of both methodologies to attain a comprehensive understanding of the executive function challenges faced by children with ADHD or developmental disorders.

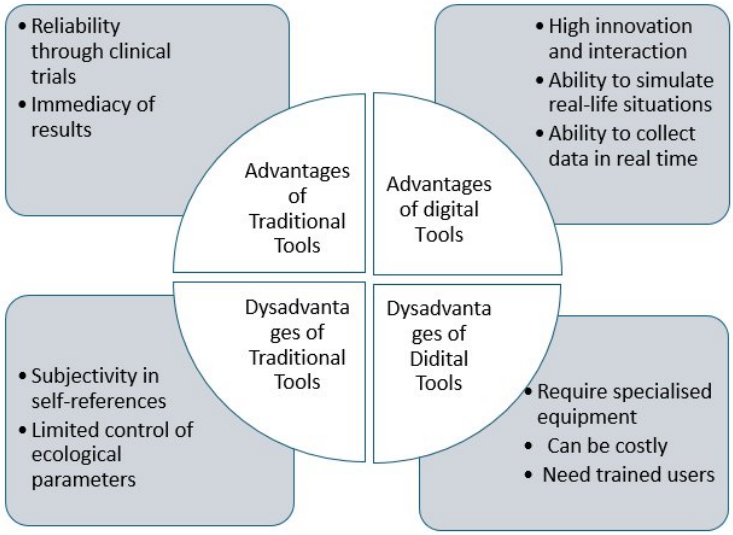

Figure 2. Comparison of Traditional and Digital Tools: advantages and disadvantages.

Connecting Findings to Educational Practices

The results indicate that executive functions exert a profound influence not only on academic achievement but also on children's behavioral patterns and emotional self-regulation. Educational programs designed to augment cognitive flexibility, self-regulation, and social adaptability can markedly enhance students' experiences within both academic and social contexts. The implementation of technological assessment instruments, such as virtual reality (VR), has the potential to yield more precise diagnoses of executive function impairments, thereby facilitating early and focused educational interventions. Consequently, educational frameworks can gain significantly from the adoption of targeted methodologies that promote both cognitive learning and social-emotional growth (Table 7).

Table 7. Findings on executive functions and educational applications

	Finding	Educational application
Academic Readiness & Learning Results	Children with strong EF have well-developed working memory and self-regulation skills and are better able to cope with the demands of school.	Use activities that improve working memory and cognitive flexibility, such as strategy games, brainteasers and tasks that require analysis and planning.
	School adjustment affected by poor attention and self-control.	Structured routines, the use of timers, visual cues and checklists to keep students more organised.
Evaluation of EF via Technology	Technological assessment tools, such as virtual reality (VR), outperform traditional tools in detecting executive function deficits.	More accurate measurement of EF and early identification of learning difficulties through the integration of VR-based assessment and electronic cognitive testing.
Behaviour & Social Skills	EF dysfunction is associated with an increase in behavioural problems such as aggression and impulsivity.	Teaching social skills that promote self-control and understanding of others' feelings through role-playing and cooperative activities.
	Children with low EF have difficulty understanding social rules and adapting behaviour in groups.	Improve understanding of social situations by using visual social stories and concrete examples of behaviour.
Emotional Regulation & Mental Health	Difficulties with EF have been associated with increased levels of anxiety and depression in children with learning disabilities.	To reduce stress and improve self-regulation, introduce mindfulness and breathing exercises into the school day.

Response to the Research Questions

Q1: a) Executive functions are integral to academic success, particularly in cognitively demanding domains such as literacy and numeracy. Children exhibiting robust executive functions demonstrate superior adaptation to the educational environment and enhanced academic performance (Núñez et al., 2024; Al Dahhan et al., 2022).

b) Dyslexia correlates with deficiencies in executive functions; however, these deficiencies are found to be distinct from symptoms of ADHD, indicating independent mechanisms underlying learning challenges (Al Dahhan et al., 2022). Finding: Conventional assessment instruments, including the BRIEF-2 (Jacobson et al., 2020) and the NIH Toolbox (Kavanaugh et al., 2020), prove beneficial yet remain reliant on subjective evaluations.

Q2: a) Conventional assessment instruments, including the BRIEF-2 (Jacobson et al., 2020) and the NIH Toolbox (Kavanaugh et al., 2020), prove beneficial yet remain reliant on subjective evaluations.

b) Technological innovations, such as virtual reality (VR) and three-dimensional video games, provide assessments that are more ecologically valid by simulating real-world contexts (Romero-Ayuso et al., 2024; Takahashi et al., 2024; Ju et al., 2024).

c) Tools based on virtual reality yield more precise outcomes in detecting learning and behavioral challenges, particularly among children diagnosed with ADHD and learning disabilities (Areces et al., 2018).

Q3: a) Children with compromised executive functions exhibit an escalation in behavioral issues, including aggression, impulsivity, and challenges in social interactions (Al-Yagon et al., 2020; ElAdl et al., 2024).

b) Deficiencies in executive functions are linked to heightened anxiety and depression levels, as well as diminished self-esteem (Alesi et al., 2024; Kavanaugh et al., 2020).

c) Challenges in "hot" executive functions, particularly emotional regulation, exert a more pronounced impact on children diagnosed with ADHD, significantly influencing their capacity to manage emotional outbursts (Shakehnia et al., 2021; Veloso et al., 2022).

Q4: a) Children diagnosed with ADHD encounter greater challenges related to attention, impulsivity, and activity organization in comparison to their peers with alternative learning disabilities (Colomer et al., 2017; El Wafa et al., 2020).

b) Students diagnosed with ADHD and autism spectrum disorders (ASD) exhibit more significant impairments in "cool" executive functions, which encompass organizational and decision-making skills (Anning et al., 2023; Hamilton et al., 2024).

c) In children presenting with comorbid conditions (e.g., ADHD and ASD), executive functions are compromised at various levels, necessitating tailored intervention strategies (Rosello et al., 2018).

Q5: a) VR-based assessment tools (e.g., Virtual Kitchen Task, 3D-video games) facilitate a dynamic and realistic evaluation environment, thereby identifying deficits in executive functions
with greater accuracy than traditional assessment methods (Romero-Ayuso et al., 2024; Ju et al., 2024; Takahashi et al., 2024).

b) Interventions utilizing virtual reality have demonstrated favorable outcomes in enhancing attention, self-regulation, and social behavior among children afflicted with ADHD and other neurodevelopmental disorders (Areces et al., 2018).

Executive functions (EF) have garnered considerable attention within scholarly discourse, due to their significant influence on both cognitive and socio-emotional growth in children. Below is a comparative table encapsulating pivotal findings from the global corpus of literature concerning EF, learning disabilities, and interventions capable of enhancing these competencies.

rom the table presented above, it is evident that empirical research converges on the critical significance of EF for academic preparedness, alongside its correlation with social and emotional competencies. A particular focus is also directed towards the application of digital and virtual reality-based instruments aimed at augmenting these skills, with findings proving especially promising for children diagnosed with ADHD and learning disabilities.

In the present study, a number of studies were utilised in order to examine the relationship between executive functions and academic achievement, behaviour, and emotional difficulties. The following table presents these studies (table 9).

Table 8. Analysis of Research Questions: literature and theoretical framework

Research Questions	Literature Review	TheoreticalFramework
Q1	EFs are a fundamental indicator of academic readiness, helping children to concentrate, follow rules and engage in cognitive activities (Uraipong, 2024; Diamond, 2013; Taylor et al., 2024).	EFs are associated with success in challenging cognitive domains such as writing and mathematics (Núñez et al., 2024; Al Dahhan et al., 2022).
Q3	EF deficits cause problems with emotional self-regulation and increase risk of social conflict (Guerra et al, 2024; Stucke & Doebel, 2024).	Difficulties in EF are associated with increases in anxiety, depression and low self-esteem (Alesi et al., 2024);
	Deficits in EF are associated with an increase in social conflict and difficulties in the understanding of social cues (Zengilowski et al., 2023).	Children with low EF show an increase in behavioural problems such as aggression and difficulties in social interaction (Al-Yagon et al., 2020; El-Adl et al., 2024).
Q4	Paying attention, organising and managing information is very difficult for children with ADHD (Ko, 2023).	Children with ADHD and ASD show more marked difficulties with 'cool' EF skills such as organisation and decision-making (Anning et al., 2023; Hamilton et al., 2024).
Q5	(Borgnis et al., 2022) VR tools offer more realistic and interactive assessments.	VR interventions improve skills including attention, self-regulation and social behaviour (Areces et al., 2018; Romero-Ayuso et al., 2024).

Table 9. Relationship between executive functions and academic achievement, behaviour, and emotional difficulties.

Authors	Title of paper	Year	Subject of Study	N	Methodology	Main Findings	Main Findings
Al Dahhan et al.	Dissociating executive function and ADHD influences on reading ability in children with dyslexia	2022	Comparison of brain activity and performance on reading and executive tests between groups.	88	Mixed methods	The results suggest that dyslexia with deficits in EF is associated with an impaired neural response in reading, independent of the presence or absence of ADHD.	The results suggest that dyslexia with deficits in EF is associated with an impaired neural response in reading, independent of the presence or absence of ADHD.
Alesi et al.	The association among executive functions, academic motivation, anxiety, and depression	2024	A relationship exists between EFs and both academic motivation and mental health.	97	Quantitative Research	A negative correlation between weak EFs and symptoms of anxiety and depression, alongside substandard academic performance in school.	A negative correlation between weak EFs and symptoms of anxiety and depression, alongside substandard academic performance in school.
Al-Yagon et al.	Executive Functions and Attachment Relationships in Children With ADHD: Links to Externalizing/Internalizing problems, Social Skills, and Negative Mood Regulation	2020	Association of EF and attachment with socio-emotional problems in children with ADHD	100	Quantitative Research	The negative effects of executive dysfunction were reduced by secure attachment relationships.	The negative effects of executive dysfunction were reduced by secure attachment relationships.
Anning et al.	Dimensional associations between executive function processes and symptoms of ADHD, ASD, oppositional defiance, and anxiety in young school-referred children	2023	Association of Executive Functioning (EF) with Symptoms of ADHD, ASD, ODD and Anxiety	438	Quantitative Research	Executive functioning deficits are directly linked to behavioural and socio-emotional difficulties.	Executive functioning deficits are directly linked to behavioural and socio-emotional difficulties.
Areces et al.	Analysis of cognitive and attentional profiles in children with and without ADHD using an innovative virtual reality tool	2018	VR analysis of cognitive/attentional profiles of children with and without ADHD	88	Experimental, VR-based cognitive assessment	VR assessment of ADHD children's cognitive and attentional profiles.	VR assessment of ADHD children's cognitive and attentional profiles.
Arruda et al.	Properties and clinical utility of the executive function inventory for children and adolescents.	2022	The present study aims to evaluate.	3,284	Quantitative Research	EFICA is a reliable instrument for assessing EFs in children diagnosed with ADHD.	EFICA is a reliable instrument for assessing EFs in children diagnosed with ADHD.
Colomer, et al.	The impact of inattention, hyperactivity/impulsivity symptoms, and EF on learning behaviors of children with ADHD	2017	EF in children with ADHD and its relation to academic performance	72	Quantitative Research	Children with ADHD have significant difficulties with EF. This has a negative impact on learning and school adjustment.	Children with ADHD have significant difficulties with EF. This has a negative impact on learning and school adjustment.
El Wafa et al.	A comparative study of executive functions among children with attention deficit and hyperactivity disorder and those with learning disabilities	2020	Comparing executive function in ADHD and LD children	340	Quantitative Research	The most impaired executive function in children with ADHD was self-restraint EF, while in children with LD it was self-regulation & problem-solving EF.	The most impaired executive function in children with ADHD was self-restraint EF, while in children with LD it was self-regulation & problem-solving EF.

ElAdl et al.	Executive functions and their relationship to social skills in children with and without ADHD.	2024	Correlation of EFs with social skills.	40	Quantitative Research	It has been demonstrated that children diagnosed with ADHD exhibit diminished social skills when confronted with weak EFs.	It has been demonstrated that children diagnosed with ADHD exhibit diminished social skills when confronted with weak EFs.
Gooch et al.	Comorbidities in preschool children at family risk of dyslexia	2014	Study on the co-morbidity of dyslexia and EF in children of preschool age	112	Quantitative Research	Attention and working memory deficits in children with a family history of dyslexia	Attention and working memory deficits in children with a family history of dyslexia
Hamilton et al.	Behavioral manifestations of executive functioning in Swedish youth with ADHD, autism, and psychiatric comorbidity	2024	Examining executive functioning in young people with ADHD, ASD and psychiatric comorbidity	79	Quantitative Research	EF problems are directly related to adaptive and emotional problems.	EF problems are directly related to adaptive and emotional problems.
Jacobson et al.	Initial examination of the BRIEF2 in clinically referred children with and without ADHD symptoms	2020	Evaluation of the BRIEF2 in children with and without symptoms of ADHD	1,381	Quantitative Research	BRIEF 2 was able to accurately differentiate between children who did and did not have ADHD, thereby revealing significant differences in cognitive flexibility and impulse control.	BRIEF 2 was able to accurately differentiate between children who did and did not have ADHD, thereby revealing significant differences in cognitive flexibility and impulse control.
Ju et al.	Clinical utility of virtual kitchen errand task for children (VKET-C) as a functional cognition evaluation for children with developmental disabilities	2024	The usefulness of the VKT-C in assessing functional cognition in children with Dds.	38	Experimental, VR-based cognitive assessment	The VKET-C offers an engaging and ecologically valid alternative to traditional methods and shows promise as an effective tool for assessing EF in children with DD.	The VKET-C offers an engaging and ecologically valid alternative to traditional methods and shows promise as an effective tool for assessing EF in children with DD.
Kavanaugh et al.	Measurement of executive functioning with the NIH Toolbox and the association to anxiety/depressive symptomatology in childhood ADHD	2020	Association of executive functions with symptoms of anxiety/depression in children with ADHD	108	Quantitative Research	Low levels of executive functioning were associated with a higher level of severity of symptoms of anxiety and depression, which highlights the importance of neuropsychological intervention.	Low levels of executive functioning were associated with a higher level of severity of symptoms of anxiety and depression, which highlights the importance of neuropsychological intervention.
Núñez et al.	Executive functions and special educational needs and their relationship with school-age learning difficulties.	2024	Relationship between EFs and learning difficulties.	123	Quantitative Research	Students with SEN status have notable deficits in the domains of EFs, which have been demonstrated to exert a detrimental effect on their academic performance.	Students with SEN status have notable deficits in the domains of EFs, which have been demonstrated to exert a detrimental effect on their academic performance.
Romero-Ayuso et al.	Enhancing Ecological Validity: Virtual Reality Assessment of Executive Functioning in Children and Adolescents with ADHD	2024	Virtual reality assessment of executive function in children with ADHD	76	Experimental, VR-based cognitive assessment	Compared to traditional tests, VR provided a more ecologically valid assessment, which improved the detection of deficits in everyday situations.	Compared to traditional tests, VR provided a more ecologically valid assessment, which improved the detection of deficits in everyday situations.
Rosello et al.	ADHD symptoms and learning behaviors in children with ASD without intellectual disability: A mediation analysis of executive	2018	Investigate the effect of EF on the learning behaviour of children diagnosed with ASD	89	Quantitative Research	Executive functions play a critical role in the learning and behaviour of children diagnosed with ASD and ADHD	Executive functions play a critical role in the learning and behaviour of children diagnosed with ASD and ADHD

	functions		and ADHD.				
Shakehnia et al.	The comparison of cool and hot executive functions profiles in children with ADHD symptoms and normal children	2021	Comparison of children with and without ADHD symptoms on "cool" and "hot" executive functions	200	Quantitative Research	Children with ADHD had greater difficulties with 'hot' executive functions (impulsive decisions, emotional regulation). 'Cool' functions were also impaired, but to a lesser extent.	Children with ADHD had greater difficulties with 'hot' executive functions (impulsive decisions, emotional regulation). 'Cool' functions were also impaired, but to a lesser extent.
Shroff et al.	Predictors of executive function trajectories in adolescents with and without ADHD: Links with academic outcomes	2023	To predict the evolution of EFs and establish a a correlation between EFs and school performance	302	Mixed methods	Weak EFs are a contributing factor to suboptimal educational outcomes, particularly for students diagnosed with ADHD.	Weak EFs are a contributing factor to suboptimal educational outcomes, particularly for students diagnosed with ADHD.
Takahashi et al.	Assessment of executive functions using a 3D-video game in children and adolescents with ADHD	2024	Using a video game to assess EFs	33	Experiment al, 3D-video game assessment	Video games can effectively assess EFs in children with ADHD	Video games can effectively assess EFs in children with ADHD
Veloso et al.	Assessing "cool" and "hot" executive functioning in children with ADHD through objective tests and behavioural assessments	2022	Assessing "cool" and "hot" executive functioning in children with ADHD through objective tests and behavioural assessments	34	Quantitative Research	Objective tests and behavioural assessments vary widely, suggesting "hot" executive functions are more influenced by environment and social interaction.	Objective tests and behavioural assessments vary widely, suggesting "hot" executive functions are more influenced by environment and social interaction.

Discussion

In the discussion section, it is imperative to conduct a comprehensive analysis of the study's results in the context of the extant literature, elucidate potential contradictions, and scrutinize the methodological limitations and biases inherent in the study. Additionally, it is essential to propose avenues for future research.

Analysis of results in relation to the literature

The outcomes of the current investigation substantiate the vital role of executive functions (EFs) in the cognitive and emotional maturation of children, particularly those diagnosed with ADHD, ASD, and LD(Núñez et al., 2024; Rosello et al., 2018). The findings align with prior research indicating that impaired functioning of the prefrontal cortex adversely influences self-regulation, attentional capacity, and behavioral adaptation (Hua et al., 2024; Barkley, 2012).

Specifically, the results resonate with the inquiries conducted by Anning et al. (2023) and Shroff et al. (2024), which underscore the facets of executive functions linked to the manifestations of ADHD and LD symptoms. Moreover, ElAdl's (2024) research corroborates that the social interactions of children with ADHD are significantly impacted by executive function challenges. The present study also highlights that a deficit in working memory and inhibitory control play a critical role in learning difficulties. This finding is supported by research conducted by Alesi et al. (2024) and Arruda et al. (2022). These studies demonstrated that EF impairments negatively impact academic motivation and emotional regulation in children with LD.

Nonetheless, there exist certain incongruent findings. For instance, while the investigation by Zhang et al. (2024) illustrated a substantial positive influence of digital tools on enhancing EFs in children with ADHD, the findings of the present study did not indicate a similarly pronounced effect. This divergence may be attributable to variations in intervention strategies or participant demographics. Moreover, while Ju et al. (2024) and Takahashi et al. (2024) demonstrated that virtual reality (VR)-based assessments could more accurately capture real-world executive function (EF) deficits, the current study found mixed results regarding their predictive validity compared to traditional measures such as the Behavior Rating Inventory of Executive Function-Second Edition (BRIEF-2) and the Behavior Diagnosis and Evaluation System-Children Version (BDEFS-CA). These findings are consistent with those reported by Romero-Ayuso et al. (2024), who emphasised the necessity for further validation of VR-based tools before their full integration into clinical and educational settings.

Bias and Methodological Weaknesses

Despite the significance of the findings, certain biases and methodological constraints are evident:

Sample and Representativeness

The research was conducted utilizing a cohort of school-age children, thereby restricting the applicability of the findings to adolescents or preschool-aged individuals.

Methods for evaluating EFs

A majority of the investigations employed the BRIEF-2 and the BDEFS-CA as assessment instruments (Jacobson et al., 2020; Hamilton et al., 2024). While these tools are acknowledged for their reliability, parental self-reporting may introduce a degree of subjective bias, in contrast to objective neuropsychological instruments such as the CANTAB (Ju et al., 2024).

Interaction of Environment and Neurological Factors

Although it is established that environmental factors significantly influence the development of executive functions (Blair & Raver, 2016), the current study did not take into account the effects of socioeconomic status or the educational environment. In view of the findings of Kavanaugh et al. (2020), which suggest that anxiety and depressive symptoms can further exacerbate EF deficits, it is recommended that future studies explore the interplay between mental health, environmental stressors, and executive dysfunction.

The constraints of this research influence the credibility of the conclusions drawn and the capacity to extrapolate these findings to broader populations. The insufficient representativeness of the sample indicates that the results cannot be generalized across all age demographics, and an overreliance on subjective evaluation techniques may introduce inaccuracies stemming from the individual perceptions of caregivers and educators. Furthermore, neglecting to consider significant environmental variables may impede a comprehensive understanding of how executive functions interact within the child's social and educational milieu. Discrepancies in assessment strategies present obstacles in making direct comparisons of findings. Consequently, meticulous interpretation of the findings is imperative, and future investigations should embrace more multidimensional and extended methodologies to enhance their reliability and validity.

Suggestions for Future Research

In order to enhance the comprehension of executive functions (EFs) and their repercussions for learning and behavioral adjustment, subsequent research endeavors ought to take into account the subsequent domains:

Longitudinal Studies on EF Development and Academic Outcomes

The present investigation elucidates the significance of EFs in relation to academic success and behavioral regulation, yet further longitudinal studies are requisite to comprehensively ascertain the developmental progression of these functions across various developmental phases. Shroff et al. (2024) assert that the trajectories of executive

functioning exhibit considerable variability among adolescents, particularly those diagnosed with ADHD, thereby influencing academic outcomes over the long term. Subsequent research endeavors ought to explore the extent to which early deficits in executive functioning serve as predictors of enduring academic difficulties or whether specific interventions can effectively modify these developmental trajectories.

Expanding EF Assessments Beyond Self-Report Measures

A significant segment of executive function (EF) research is predicated upon assessments derived from questionnaires, such as the Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2) and the Barkley Deficits in Executive Functioning Scale – Children and Adolescents (BDEFS-CA), which may inadvertently introduce subjective biases (Arruda et al., 2022). Although these evaluative instruments furnish essential insights into quotidian EF challenges, the incorporation of performance-based metrics alongside ecologically valid digital methodologies (for instance, computerized assessments or virtual reality-based tasks) has the potential to substantially augment diagnostic precision. Subsequent investigations ought to examine the relative efficacy of various EF assessment methodologies in forecasting tangible cognitive and behavioral outcomes in real-world contexts.

Investigating EF Deficits in Special Educational Needs Populations

Although executive dysfunction is extensively recognized in ADHD, its effects on children with learning disabilities (LD) and developmental language disorders (DLD) are still not thoroughly investigated. Núñez et al. (2024) emphasize the importance of exploring how particular EF deficits contribute to learning challenges in school-aged children, especially in reading and mathematics. Future research should focus on: Whether unique EF profiles are present among various SEN categories (e.g., ADHD vs. dyslexia vs. ASD). How customized EF interventions can improve academic outcomes for SEN learners.

Understanding the Relationship Between EFs and Social Functioning

The significance of executive function (EF) impairments in regulating social and emotional behavior calls for additional research. ElAdl (2024) discovered that executive function deficits in children with ADHD are closely linked to challenges in social skills, indicating that cognitive flexibility and inhibitory control play crucial roles in social adjustment. Future studies should investigate: How EF training programs influence peer interactions and emotional regulation. Whether social skills interventions that include EF training components produce improved results for children with ADHD and ASD (Anning et al., 2023).

The Role of EF in Dual-Diagnosis Cases: ADHD and Comorbid Conditions

Many kids diagnosed with ADHD often have other associated disorders, including oppositional defiant disorder (ODD), anxiety, or ASD (Anning et al., 2023; Rosello et al., 2018). Nevertheless, there is a lack of research investigating how executive function (EF) deficits interact across various diagnoses. Future research should: Determine if particular EF weaknesses (such as working memory versus impulse control) worsen comorbid symptoms. Investigate how combined interventions (EF training plus behavioral therapy) can aid children with dual diagnoses.

By addressing these research gaps, future studies can refine EF assessment tools, develop targeted interventions, and better understand the long-term impact of executive dysfunction on academic, social, and emotional well-being.

Practical Applications

The results of this investigation underscore the necessity for systematically organized, research-oriented interventions that promote the advancement of executive function (EF) in children diagnosed with attention deficit hyperactivity disorder (ADHD), learning disabilities (LD), and developmental language disorder (DLD). Such interventions ought to be incorporated within educational frameworks, therapeutic modalities, and domestic environments to enhance cognitive regulation, self-regulatory capacities, and social adaptability.

Optimizing Educational Interventions Through Play and Technology

Educational institutions ought to integrate self-regulation and cognitive flexibility paradigms into their curricular frameworks, particularly for children identified with ADHD, LD, and DLD (Veloso et al., 2022; Alesi et al., 2024). Empirical evidence indicates that play-based interventions, encompassing strategic board games and role-playing exercises, significantly enhance impulse control, working memory, and attentional capacities (Sahlberg& Doyle, 2019). Furthermore, STEM-oriented robotics and programming activities have been shown to bolster strategic planning and cognitive flexibility, thus providing compelling educational experiences that fortify executive function (Demertzi et al., 2018). The incorporation of executive function-centered pedagogical approaches (e.g., scaffolded learning, explicit cognitive strategies) has the potential to improve problem-solving abilities and adaptive learning methodologies, particularly for children with special educational requirements (Núñez et al., 2024).

Leveraging Technology in EF Assessment and Intervention

Advancements in digital technologies and immersive virtual environments provide promising opportunities for both the diagnosis and

enhancement of executive functions. The deployment of virtual reality (VR)-based assessments and digital therapeutic interventions has revealed substantial potential in enhancing attention control and inhibitory regulation (Ju et al., 2024; Zhang et al., 2024). Applications of Virtual Reality (VR) facilitate the engagement of children in realistic, interactive scenarios that enable the practice of problem-solving and social adaptation competencies (Alrefaei, 2024; Romero-Ayuso et al., 2024). Educational video games and mobile applications have been evidenced to enhance working memory, cognitive flexibility, and organizational capabilities in students diagnosed with autism and dyslexia (Stathopoulou et al., 2019; Lytra& Drigas, 2021). Nevertheless, digital interventions necessitate ongoing refinement to ensure ecological validity and the persistence of benefits in real-world contexts (Romero-Ayuso et al., 2024).

Parent and Teacher Education: Strengthening Executive Function Support Systems

It is imperative that both parents and educators grasp the critical importance of executive function development for the timely identification and intervention of EF-related challenges. Empirical studies highlight the significance of: Parental engagement in EF interventions, which has been associated with enhanced self-regulation and emotional adaptability in children (Damavand et al., 2020). Professional development programs for educators, which ought to incorporate evidence-based EF strategies aimed at assisting students who experience difficulties with cognitive regulation and attention management (Karbasdehi et al., 2019). A synergistic collaboration among educators, therapists, and families to execute tailored EF enhancement strategies, thereby ensuring uniform reinforcement across various settings (Núñez et al., 2024).

The incorporation of interventions centered on executive function within educational frameworks, digital environments, and domestic contexts presents a comprehensive methodology for tackling executive dysfunction in children diagnosed with ADHD, learning disabilities (LD), and developmental language disorders (DLD). By amalgamating conventional pedagogical methodologies with cutting-edge technological resources, educators, mental health professionals, and guardians can facilitate the enhancement of children's cognitive, emotional, and behavioral self-regulation capabilities, thereby ultimately promoting their academic achievement and social integration.

Implications

Research findings underscore the significance of executive functions (EF) in the cognitive and behavioral advancement of children, particularly those diagnosed with attention deficit hyperactivity disorder (ADHD), autism spectrum disorders (ASD), and learning disabilities (LD). Deficits in executive functioning are correlated with impairments in self-regulation, cognitive flexibility, and the ability to navigate the demands of educational settings, which in turn adversely impacts both their academic achievement and social integration (Al Dahhan et al., 2022; Shroff et al., 2023). Within this framework, educational interventions ought to emphasize multidimensional strategies that foster the development of EF, integrating suitable methodologies and technological resources.

Early detection of EF impairments and the subsequent implementation of early intervention programs are deemed critical for enhancing children's academic preparedness and overall educational attainment. These interventions must encompass targeted exercises designed to bolster working memory, response inhibition, and metacognitive awareness (Alesi et al., 2024; El Wafa et al., 2020). Moreover, educators are obligated to adopt modified pedagogical techniques by embedding EF education into the curriculum. Interactive methodologies, including guided goal-setting and the employment of time management strategies, may assist students in task organization and the enhancement of self-regulatory capabilities (Colomer et al., 2017; Núñez et al., 2024).

The development and utilization of valid and reliable assessment instruments are paramount for the early identification of children requiring supplementary support. While conventional assessment methodologies predominantly rely on self-reports or formal evaluations, the incorporation of virtual and digital tools has demonstrated efficacy in assessing EF within authentic contexts (Ju et al., 2024; Romero-Ayuso et al., 2024). Concurrently, the application of STEAM pedagogies can foster cognitive flexibility and problem-solving abilities, thereby facilitating learning through experiential and interactive experiences (Lytra& Drigas, 2021).

Support for EF cannot be dissociated from the broader socio-economic and psychological milieu surrounding children. Elements such as familial context, mental health status, and social interactions are instrumental in the development of these functions (Al-Yagon et al., 2020; Hamilton et al., 2024). Consequently, a collaborative framework is essential, wherein educators, parents, and mental health practitioners jointly endeavor to cultivate supportive learning environments. The implementation of training programs can empower stakeholders with effective strategies to assist children in both academic and domestic settings (Veloso et al., 2022).

Future investigations should prioritize the longitudinal examination of EF progression and its implications for children's educational trajectories. Analyzing the dynamic transformations in EF across various developmental stages may yield valuable insights for the formulation of educational policies designed to enhance students' self-regulation and adaptability competencies (Takahashi et al., 2024; Shakehnia et al., 2021).

The outcomes of these studies emphasize the necessity of systematic reinforcement of EF to augment children's academic and social capabilities. A comprehensive approach that amalgamates early intervention, tailored instructional methodologies, technology-driven assessment, and interdisciplinary collaboration can significantly contribute to the establishment of an educational environment that nurtures students' cognitive and emotional growth.

Conclusion

The present inquiry elucidated the significant relationship between executive functions and behavioral, emotional, and academic outcomes among children diagnosed with ADHD and learning disabilities. Specifically, deficiencies in executive functions were found to be directly linked to difficulties in emotional regulation, behavioral adaptation, and academic achievement, a conclusion supported by earlier research (Anning et al., 2023; Núñez et al., 2024).

The analysis revealed distinct patterns of executive function deficits across various neurodevelopmental disorders: children diagnosed with ADHD displayed marked challenges in impulse control and cognitive flexibility, whereas children with DLD exhibited deficits in verbal working memory and narrative coherence (Baron & Arbel, 2022; Gooch et al., 2014).

Furthermore, the study emphasizes the critical need for early diagnosis and intervention, as the lack of appropriate support may lead to complications in social skills and self-regulatory abilities (ElAdl, 2024). Additionally, the research underscores the necessity of incorporating both traditional psychometric assessments and innovative digital evaluation methodologies, such as virtual reality-based tasks, to attain a more comprehensive understanding of executive function deficits.

Abbreviations:

SEN: Special Educational Needs
ASD: Autism Spectrum Disorder
EFICA: Executive Function Inventory for Children and Adolescents
DLD: Developmental Language Disorder
NDDs: Neurodevelopmental Disorders
Dds: Developmental Disabilities
CERQ :Cognitive Emotion Regulation Questionnaire
VKT-C: Virtual Kitchen Task

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