



REVIEW

Computerised Executive Function Training in ADHD: A Systematic Review of Academic Outcomes

Carolina Mele^{1,*}, Lucia Miranda¹, Vincenzo Martone², Anna Trifonova³ and Angelo Rega¹

¹Department of Psychology and Health Sciences, Pegaso University, Naples, 80143, Italy

²Italian Association of Cognitive Technologies, Naples, 00185, Italy

³CreaTIC Academy, Barcelona, 08028, Spain

*Corresponding Author: Carolina Mele. Email: carolina.mele@unipegaso.it

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ABSTRACT: Background: Attention deficit/Hyperactivity disorder (ADHD) is frequently associated with executive functions (EF) impairments (working memory, inhibitory control, planning, attention, and cognitive flexibility), underlying self-regulation, learning, and academic problems. In recent years, computerised executive function training (CCT) has been proposed as a non-pharmacological intervention tool designed to specifically stimulate EF through adaptive digital tasks. These programs are based on the hypothesis that repeated and progressive training of executive components can produce generalised improvements in cognitive functioning and, consequently, a positive impact on academic performance and school behaviour. However, the scientific literature on the effectiveness of CCT in individuals with ADHD shows heterogeneity in terms of methodologies, protocols, and outcomes considered. Furthermore, it remains unclear whether any cognitive benefits observed translate into an effective transfer of school skills and whether such training can induce structural or functional changes in the brain. **Methods:** This study aims to conduct a systematic review of recent literature on CCT in children and adolescents with ADHD, with the objective of examining whether improvements in EF are associated with measurable benefits in academic and school-related outcomes. Following PRISMA 2020 guidelines and Cochrane recommendations, a systematic search was conducted in December 2025 across the PubMed and Scopus databases. Eligible studies evaluated adaptive CCT interventions targeting core EFs and report objective, standardized academic outcomes. Study quality and risk of bias were systematically assessed using the Cochrane RoB 2 and ROBINS-I tools. **Results:** The synthesis of the 66 selected studies reveals that the effectiveness of CCT is highly domain-specific, showing significant improvements in mathematics, particularly when the training targets the Central Executive. In contrast, literacy benefits often follow a “sleeping effect,” emerging only months post-intervention. While results are promising for classroom engagement and “readiness-to-learn,” gains may be influenced by rater expectancy effects and methodological heterogeneity. **Conclusion:** CCT appears to display significant domain-specific effectiveness in helping improve academic performance in individuals with ADHD, especially in maths, while literacy benefits require long-term follow-up to be detected. However, the high methodological heterogeneity and possible rating biases indicate that further research is necessary to elucidate the exact circumstances where cognitive training can help achieve academic success.

KEYWORDS: ADHD; executive functions; computerised training; systematic review; academic outcomes

1 Introduction

Attention Deficit and Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by pervasive patterns of inattention, hyperactivity, and impulsivity that interfere with functioning or development. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) [1], indicates that

about 5–7% of school-age children worldwide suffer from ADHD, with symptoms often persisting into adolescence and adulthood [1,2]. Beyond core behavioural symptoms, ADHD is increasingly conceptualised as a disorder of cognitive control and self-regulation, with significant implications for academic achievement, social functioning, and long-term life outcomes [3,4].

In recent years, research has highlighted the central role of executive functions (EF) in ADHD. Rather than isolated processes, executive functions refer to a set of higher-order cognitive processes that enable goal-directed behaviour, including working memory, inhibitory control, cognitive flexibility, planning, and sustained attention [5,6]. Deficits in these domains are among the most consistently reported neuropsychological features of ADHD, although with substantial interindividual variability [7,8]. Meta-analytic evidence indicates moderate to large impairments in working memory and inhibitory control, and smaller but significant deficits in planning and cognitive flexibility [9,10].

It is fundamental to recognize that these executive dysfunctions are not merely laboratory findings but have direct functional consequences in daily life. Impairments in working memory and inhibitory control have been linked to difficulties in classroom behaviour, task completion, reading comprehension, mathematical problem solving, and overall academic performance [11–13]. From a developmental perspective, executive functions play a central role in learning processes, self-monitoring, and adaptive behaviour, making them a key target for early intervention in children and adolescents with ADHD [14,15].

While pharmacological treatments, specifically stimulant medications, remain the first-line intervention for ADHD and have demonstrated robust short-term effects on core symptoms and certain aspects of executive functioning [16,17]. However, rather than being curative, medication effects tend to be symptomatic, they frequently fail to translate into academic skills and may be associated with side effects or limited long-term adherence [18,19]. These limitations have promoted an increasing interest in non-pharmacological and complementary interventions, such as cognitive training approaches which focus on improving executive functions [20].

Within this context, computerised executive function training (CCT) has emerged as a promising intervention strategy. Specifically, CCT is defined as a structured intervention consisting of adaptive, repetitive digital tasks designed to train core executive components—most commonly working memory, attention, and inhibitory control—based on principles of neuroplasticity [21,22]. Unlike generic educational software, these programs rely on three fundamental pillars: adaptivity, intensity, and core targeting. Adaptivity is achieved through ‘staircase’ algorithms that adjust task difficulty in real-time based on the user’s performance, ensuring a constant cognitive challenge. Intensity requires a high frequency of sessions to trigger neuroplastic changes, while core targeting focuses on the underlying building blocks of cognition, such as the central executive, rather than specific academic content. The underlying assumption is that such systematic practice can foster durable improvements in executive functioning, which may subsequently transfer to untrained cognitive domains and real-world outcomes, such as academic performance and behavioural regulation [23].

Neuroimaging studies involving both typically developing and clinical cohorts offers encouraging, albeit preliminary, support for this hypothesis. Findings suggest that cognitive training can induce functional and structural brain changes, particularly in fronto-parietal and fronto-striatal networks implicated in executive control [24–26]. In ADHD specifically, atypical development of these neural circuits has been consistently documented, reinforcing the theoretical plausibility of EF-focused interventions [27,28].

A crucial, yet often overlooked, theoretical construct in the evaluation of cognitive interventions is the ‘sleeper effect’. This phenomenon suggests that the transfer of improved executive capacities to complex academic skills, such as reading comprehension or written expression, is not necessarily immediate.

From a neurodevelopmental perspective, while computerized training may rapidly enhance core ‘building blocks’ like working memory or inhibitory control (near-transfer), these cognitive resources require a period of consolidation and sustained interaction with authentic classroom instruction before they can be effectively ‘proceduralized’ into academic achievement (far-transfer). Consequently, the benefits of CCT may remain latent at post-intervention assessments, only becoming statistically significant during delayed follow-up evaluations, typically two to six months later [29].

Despite the rapid growth of interest and commercial availability of CCT programmes, evidence regarding their effectiveness in ADHD remains mixed and controversial. While some studies report improvements in trained tasks and parent- or teacher-rated attention, others fail to demonstrate meaningful transfer to academic skills or everyday functioning [20,23,30]. Moreover, significant heterogeneity exists across studies in terms of sample characteristics, training protocols, outcome measures, and follow-up duration, complicating the interpretation of findings and their clinical relevance [31,32].

Given the inconsistent evidence and substantial methodological heterogeneity in current literature on computerised executive function training in children and adolescents with ADHD, there is a clear need for a critical and up-to-date synthesis that specifically targets academic and school-related outcomes. In particular, it remains unclear whether improvements in executive functioning following computerised training extend beyond trained cognitive tasks and translate into functionally meaningful benefits within educational contexts.

Therefore, the present systematic review aims to examine recent literature on computerised executive function training in children and adolescents with ADHD, with the specific objective of evaluating whether such interventions are associated with measurable improvements in academic and school-related outcomes. Specifically, the review focuses on the effects of CCT on indicators of academic achievement (e.g., grades and standardised assessments in reading, writing, and mathematics), learning-related skills, and broader aspects of school functioning, including classroom behaviour, homework management, and academic engagement.

Ultimately, this review aims to provide an integrated and critical overview of the effectiveness and limitations of computerised executive function training in promoting academic outcomes in individuals with ADHD. By identifying key methodological strengths and weaknesses of existing studies, this work aims to inform future research and support the development of more rigorous, ecologically valid, and educationally relevant intervention approaches.

2 Methods

To ensure this synthesis is both reproducible and inherently unbiased, the methodology of this review has been built upon a foundation of rigorous scientific standards.

The research protocol was carefully drafted following the methodological recommendations of the Cochrane Handbook for Systematic Reviews of Interventions [33] and is reported in full compliance with the PRISMA 2020 Statement [34]. Adopting these international standards ensures that every stage of the process, from the initial identification of primary studies to the critical assessment of the risk of bias, is documented with total transparency, thereby allowing for the verification of results and the replicability of the selection procedure. The completed PRISMA checklist is available as Supplementary Material S1.

During the preparation of this manuscript, the authors used AI-assisted tools for language polishing, grammatical corrections, and technical editing.

2.1 Search Strategy and Information Sources

To ensure comprehensive literature coverage and minimize the risk of publication bias, we adopted a multi-channel search strategy.

The search involved the electronic databases Scopus and PubMed, which were selected for their academic relevance in the fields of neuropsychology, clinical medicine, and educational sciences.

The search was initiated in December 2025 and was restricted to studies published between 2005 and 2025 to focus the analysis on the most recent digital technologies and intervention protocols.

It is important to clarify that in this review, the term “computerized cognitive training” (CCT) is used as an umbrella term to refer to adaptive digital interventions, which include computerized working memory training (CWMT), central executive training (CET), and computerized executive function training. These terms are used interchangeably in the literature to describe software-based activities targeting fundamental executive components.

The search query was formulated using Boolean operators (AND, OR, NOT) to combine terms related to the diagnosis, the type of technological intervention, and academic outcomes.

The final query used was as follows:

(ADHD OR “Attention Deficit Hyperactivity Disorder”) AND (“computerized” OR “computer-based” OR “digital” OR “software-based” OR “web-based” OR “online” OR “gamified” OR “tablet-based” OR “app-based”) AND (“cognitive training” OR “working memory training” OR “executive function training” OR “CCT”) AND (“academic performance” OR “school achievement” OR “academic success” OR “learning outcomes” OR “school marks” OR “academic skills”) AND (“primary school” OR “elementary school*” OR “child*” OR “school-age*”) AND (“randomized controlled trial” OR “RCT” OR “randomised controlled trial” OR “randomized” OR “randomised” OR “clinical trial” OR “controlled trial”) AND NOT (“paper-and-pencil” OR “manualized” OR “traditional training” OR “classroom-based intervention”).

While the search was focused on Scopus and PubMed, Scopus was specifically prioritized due to its extensive indexing of interdisciplinary literature. This ensured a high degree of sensitivity for digital intervention protocols in school-age populations.

2.2 Eligibility Criteria

To ensure the relevance and quality of the evidence, we established a set of specific inclusion criteria. This review includes studies focusing on children aged 5 to 12 years with a clinical diagnosis of ADHD. In terms of interventions, our analysis was limited to computerized cognitive training (CCT) aimed at enhancing executive functions.

The selection primarily targeted randomized controlled trials (RCTs). However, to provide a comprehensive overview of the current technological landscape, high-quality non-randomized controlled trials and quasi-experimental studies were also included and subsequently assessed using the ROBINS-I framework to account for potential methodological differences.

A fundamental requirement for inclusion was the presence of objective and standardized academic outcomes, such as performance in reading, writing, and mathematics. Furthermore, the search was limited to English-language publications released between 2005 and 2025 to focus on the most recent digital intervention protocols and technological developments.

2.3 Quality Assessment and Risk of Bias

To ensure a rigorous evaluation of the evidence, the methodological quality of the included studies was assessed using two distinct frameworks tailored to the specific design of each study. For studies utilizing a

randomized design, two reviewers independently evaluated the risk of bias using the Cochrane Risk of Bias Tool for Randomized Trials (RoB 2). This tool allows for a structured assessment of five key domains:

1. Selection and Randomization: Evaluation of the methods used to generate the allocation sequence and conceal it until participants were assigned.
2. Performance and Intervention: Assessment of potential bias due to deviations from the intended computerized protocols or lack of blinding of participants and personnel.
3. Attrition: Analysis of the completeness of outcome data and whether the exclusion of participants (dropouts) was balanced across groups.
4. Detection: Evaluation of the blinding of outcome assessors, with specific consideration for the distinction between objective standardized tests and subjective teacher/parent ratings.
5. Reporting: Assessment of whether the results were reported selectively based on their significance or in accordance with pre-registered protocols.

Each domain was categorized as having a “Low risk of bias”, “Some concerns”, or a “High risk of bias”. Any disagreements between the two reviewers were resolved through discussion or, if necessary, by consulting a third senior reviewer.

For non-randomized studies, which present various methodological challenges—particularly the lack of inherent balance between groups—the ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) tool was used. This tool assesses the risk of bias by comparing the study’s methodology with a hypothetical “reference study”. The assessment covered seven areas of bias grouped into three phases:

1. Pre-intervention bias: focused on bias due to confounding factors (e.g., pre-existing differences in ADHD subtype, medication use, or IQ) and bias in the selection of study participants (e.g., self-selection of highly motivated families).
2. Bias during the intervention: ensuring that the intervention (the computer program) was clearly defined and that participant classification was not influenced by information received after the intervention began.
3. Post-intervention bias: assessment of bias due to deviations from planned interventions, missing data (attrition), and bias in outcome measurement. Particular attention was paid to outcome measurement, as the lack of blinding in non-randomized designs significantly increases the risk of “detection bias” in subjective behavioral reports. Finally, the selection of reported outcomes was assessed to ensure transparency.

3 Results

3.1 Study Selection and Flow Diagram

The initial systematic search across electronic databases yielded a total of 717 records (715 from Scopus and 2 from PubMed). Following the identification phase, 73 duplicate records were identified and removed using reference management software, leaving 644 unique records for the initial screening process.

During the first stage of screening, which involved a rigorous evaluation of titles and abstracts, 458 records were excluded as they clearly did not meet the primary inclusion criteria (e.g., unrelated to ADHD, outside the 5–12 age range, or non-digital interventions). This resulted in 186 reports being sought for more detailed retrieval and evaluation.

This 186 reports underwent a comprehensive eligibility assessment through full-text reading. At this stage, a further 119 reports were excluded for various methodological reasons. The primary reasons for exclusion were the lack of objective and standardized academic outcome measures ($n = 45$), the population age outside the 5–12 range or absence of a formal ADHD diagnosis ($n = 34$), the non-adaptive or non-digital intervention protocols ($n = 25$) and studies lacking a control group ($n = 15$).

Ultimately, 66 studies met all eligibility requirements and were included in the final systematic review and qualitative synthesis. The complete selection process is visually summarized in the PRISMA 2020 flow diagram (Fig. 1).

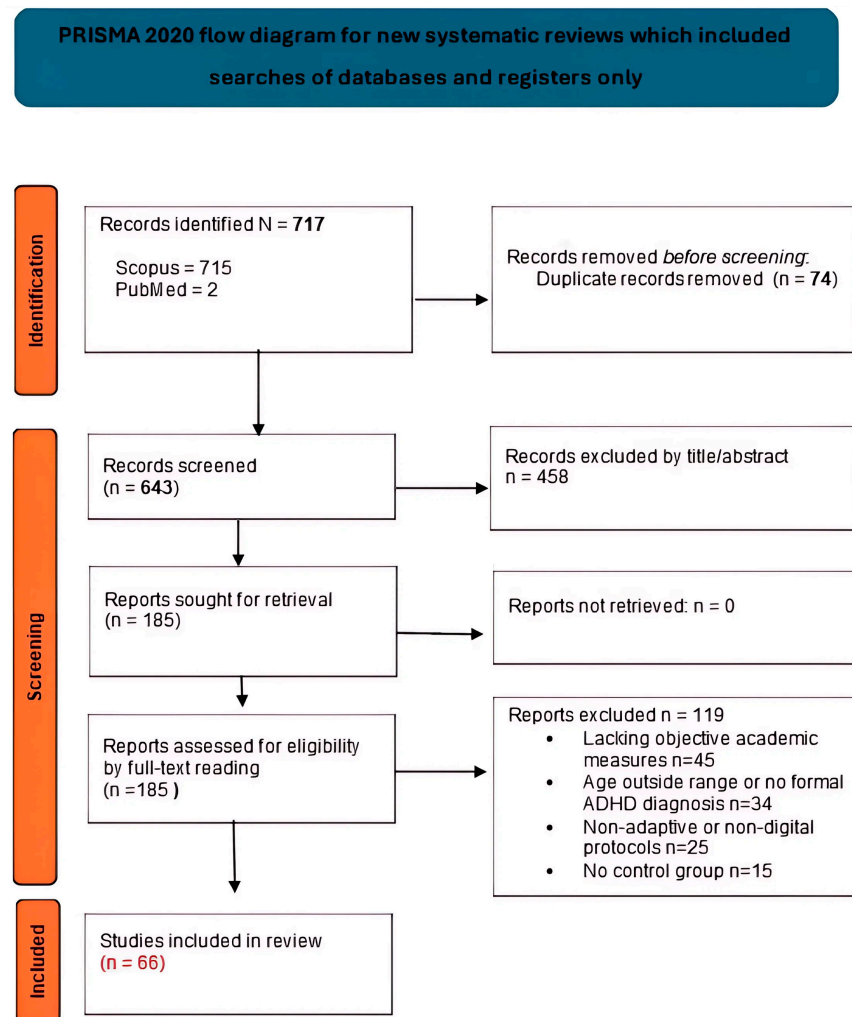


Figure 1: PRISMA2020 Flow Chart.

3.2 General Characteristics of the Studies

The systematic synthesis included 66 sources published between 2010 and 2026, primarily originating from the Netherlands, USA, China, and Spain. The total population analysed across the included studies exceeds 1800 participants, and individual randomized controlled trials (RCTs) focused on children aged 5–12 with a formal ADHD diagnosis.

Interventions were characterized by a high degree of technological variety, predominantly utilizing Computerized Working Memory Training (CWMT) and Central Executive Training (CET) protocols. The average intervention “dosage” consisted of 25 to 40 sessions, typically distributed over 5 to 8 weeks, with each session lasting between 30 and 45 min.

Detailed characteristics of the studies selected for final synthesis, including authors, sample sizes, study types, and key findings, are summarized in Table 1.

Table 1: General Characteristics of Included Studies.

Study	Study Type	Sample Size	Country	Follow-Up Duration	Main Outcomes	Effect Size
Bigorra et al., 2016 [35]	RCT	66	Spain	6 months	- Improvements in teacher-rated executive functioning, specifically within metacognition and planning/organization - long-term enhancement of working memory - Reduction in ADHD symptoms	d = 0.53 to 0.87
van der Donk et al., 2015 [36]	RCT	102	The Netherlands	6 months	- Improvements in working memory and ADHD symptoms - moderate-to-large advantage in visuospatial memory	d = 0.50 to 0.80
Chacko et al., 2014 [37]	RCT	85	United States	3 weeks	no significant, generalized clinical benefits	d = -0.24
Trinczer et al., 2024 [38]	RCT	80	Israel	3 months	- reduced inattentive symptoms - significant improvements in sustained attention	d = 0.82
Green et al., 2012 [39]	RCT	26	United States	Not reported in original study	- change in off-task behavior during a structured academic task - improvements in working memory	Off-Task Behavior d = 0.82 Working Memory d = 0.52 to 1.39
van der Donk et al., 2020 [40]	RCT	101	The Netherlands	6 months	- improvements in broad neurocognitive measures - No significant improvements for academic performance	Neurocognitive measures d = 0.40 to 0.6. Accademic Outcomes d = <0.20
Li et al., 2025 [41]	RCT	60	China	8 weeks	- Significant gains in attention span and impulse control - Substantial progress in Mathematics, reading comprehension	Maths d = 0.92 Reading comprehension = 0.65
Ponomarev et al., 2023 [42]	RCT	90	Kazakistan	1 month	- significant delayed effect (sleeper effect)	Inattention d = 0.70–0.85 Hyperactivity d = 0.65 Executive Functions d = 0.75
van der Donk et al., 2013 [43]	RCT	100	The Netherlands	6 months	Improvement in working memory	d = 0.81
Steiner et al., 2014 [44]	RCT	104	United States	5 months	Significant improvements in ADHD symptoms	Inattention d = 0.85 Hyperactivity d = 0.69 Executive Function d = 0.58
Egeland et al., 2013 [45]	RCT	67	Norway	8 months	- Significant improvement in working memory tasks similar to the training - No significant improvement in maths and reading	Working Memory d > 0.80 Maths d = 0.11 Reading d = 0.05

Table 1: *Cont.*

Study	Study Type	Sample Size	Country	Follow-Up Duration	Main Outcomes	Effect Size
Dovis et al., 2015 [46]	RCT	89	The Netherlands	3 months	No significant treatment effects	Maths d = 0.12 Reading d = 0.05
Bioulac et al., 2020 [47]	RCT	51	France	6 to 8 weeks	Improvement in Attention and Impulsivity	Attention d = 0.86 Impulsivity d = 0.55
Zheng et al., 2024 [48]	RCT	138	Hong Kong	2 months	- Reducing ADHD symptoms - Improved academic achievement in reading, writing and maths	d = 0.50
Gollier-Briant et al., 2024 [49]	RCT	360	France	6 months	Improvement in homework autonomy and organizational skills	d = 0.50 to 0.70
Richmond et al., 2022 [50]	RCT	104	Australia	3 months	Improvement in Maths and Reading and Writing Skills	d = 0.35
Bikic et al., 2018 [51]	RCT	70	Denmark	24 weeks	No significant improvement in reading or spelling	d = 0.13
Luo et al., 2023 [52]	RCT	121	China	3 months	Significant improvement in the school domain	d = 0.52
Wexler et al., 2021 [53]	RCT	93	United States	15 weeks	- Improvement in Working Memory and Inhibitory Control - Significant Improvement in Reading and Math scores	Working Memory d = 0.55 Inhibitory Control d = 0.50 Academic Outcome d = 0.42
Chan et al., 2023 [54]	RCT	73	United States	2–4 months	Improvements in academic organization	d = 0.67
van Dongen-Boomsma et al., 2014 [55]	RCT	51	The Netherlands	Not reported in original study	No significant improvement in academic skills	d = 0.02
Poon et al., 2024 [56]	Controlled trial	120	China	5 weeks	Significant improvement in reading fluency and Word recognition	d = 0.42
Hovik et al., 2013 [57]	RCT	67	Norway	8 months	No significant long-term improvement in reading or maths	d < 0.15
Wu et al., 2023 [58]	RCT	127	China	Not reported in original study	Significant improvement in school-related functioning and productivity	d = 0.58
Bilan et al., 2025 [59]	RCT	41	Spain	12 weeks	- Significant reduction in academic functional impairment - Improved Cognitive Control	Impulsivity d = 0.88 Academic functional improvement d = 0.61

Table 1: *Cont.*

Study	Study Type	Sample Size	Country	Follow-Up Duration	Main Outcomes	Effect Size
Bach-Morrow et al., 2022 [60]	RCT	46	Spain	13 weeks	- Enhanced executive control efficiency - Improved Mental Flexibility	d = 0.72 d = 0.58 to 0.65
McDermott et al., 2020 [61]	RCT	46	United States	3 months	Significant improvements in reading and Maths	Reading Performance d = 0.62 Maths Performance d = 0.58
Sandberg et al., 2021 [62]	RCT	40	Canada	3 months	Significant improvement in Working Memory	d = 0.91
Carrillo, 2024 [63]	Pilot study	41	Spain	Not reported in original study	- Improvement in Attention and Inhibitory Control	Attention d = 0.78 Inhibitory Control d = 0.62
Revollo Carrillo et al., 2024 [64]	Quantitative study	41	Spain	Not reported in original study	- Significant improvement in Working Memory and Inhibitory control - Improvements in Academic regulation	Working memory d = 0.58 Inhibitory Control d = 0.52 Academic regulation d = 0.48
van der Donk et al., 2016 [65]	RCT	105	The Netherlands	6 months	No significant improvement in academic scores	d < 0.15
Abdeldaym et al., 2022 [66]	Clinical Trial	60	Egypt	Not reported in original study	Improved academic productivity and better engagement in school task	d = 0.54
Singh et al., 2022 [67]	Two clinical trials	108	United States	2–4 months	Improvement in Maths and reading achievement	Math d = 0.74 Reading d = 0.62 to 0.68
Rabiner et al., 2010 [68]	RCT	77	United States	1+ year	Significant improvement in reading fluency and word recognition	d = 0.41
Azami et al., 2016 [69]	RCT	34	Iran	3 months	Significant improvement in educational functioning and classroom focus	d = 0.58
Steiner et al., 2011 [70]	RCT	41	United States	4 months	Significant improvements in Visual Attention	d = 0.54
van der Oord et al., 2014 [71]	RCT	40	The Netherlands	9 weeks	Significant improvement in task planning and organization	d = 0.70
Jones et al., 2020 [72]	RCT	108	United States	3 months	No effect for academic-related cognitive transfer	d = 0.05
Singh et al., 2021 [73]	RCT	108	United States	2–4 months	Significant gains in Math and reading achievement	Math d = 0.72 to 0.78 Reading d = 0.65
Ahmadi et al., 2017 [74]	RCT	30	Iran	Not reported in original study	Significant improvement in math achievement and problem solving skills	Math d = 0.68 Problem Solving d = 0.75

Table 1: *Cont.*

Study	Study Type	Sample Size	Country	Follow-Up Duration	Main Outcomes	Effect Size
van der Donk et al., 2017 [75]	Pilot Clinical Study	164	The Netherlands	6 months	No significant result in academic achievement	$d < 0.15$
Chu et al., 2022 [76]	RCT	145	China	8 weeks	Significant improvement in school-based functional performance and academic productivity	$d = 0.61$
Pérez-Rodríguez et al., 2025 [77]	RCT	76	Spain	6 months	Improvement in Academic Organization	$d = 0.50$ to 0.70
Sohrabi, 2013 [78]	Quasi-experimental	23	Iran	3–6 months	Improvement in Educational functioning	$d = 0.56$
Klingberg et al., 2005 [79]	RCT	53	Sweden	3 months	Significant enhancement of reasoning and working memory capacity	$d = 0.40$ – 0.45
Tamm et al., 2013 [80]	RCT	105	United States	12 weeks	Improvement on-task behavior and classroom focus	$d = 0.84$
Lloyd et al., 2010 [81]	RCT	38	United Kingdom	Not reported in original study	Improved classroom focus and on-task behavior	$d = 0.72$
Hasslinger et al., 2016 [82]	RCT	200	Sweden	6 months	Improvement in Academic Productivity and classroom behavior	$d = 0.30$ to 0.40
Kofler et al., 2018 [83]	Sequential design	54	United States	2–4 months	Significant gains in Math and Reading scores	Math $d = 0.75$ to 0.82 Reading $d = 0.69$
Badia-Aguarón et al., 2024 [84]	RCT	120	Spain	5 months	Improvement in academic engagement	$d = 0.50$
Lim et al., 2023 [85]	RCT	20	Singapore	8 weeks	Significant improvement in school-based functional performance	$d = 0.56$
Rajender et al., 2011 [86]	Pre-post design	20	India	Not reported in original study	Significant improvement in academic productivity	$d = 0.58$
Gallen et al., 2021 [87]	Prospective trial	28	United States	4 weeks	Significant improvement in school-related functional impairment	$d = 0.51$
Nejati et al., 2023 [88]	RCT	30	Iran	1 month	Improved academic self-regulation, task organization and cognitive control	$d = 0.58$
Kermani et al., 2016 [89]	Controlled trial	60	iran	6 months	Improvement in classroom productivity	$d = 0.64$

Table 1: *Cont.*

Study	Study Type	Sample Size	Country	Follow-Up Duration	Main Outcomes	Effect Size
Molazamani et al., 2023 [90]	RCT	30	Iran	45 days	Improved management of simultaneous classroom demands (e.g., listening and writing)	d = 0.78
Papanastasiou et al., 2022 [91]	RCT	36	Greece	Not reported in original study	- Improvement in on-task behavior - Reduction in academic-related impairment during school activities	Attention d = 0.75 Academic-related productivity d = 0.62
Roording-Ragetlie et al., 2017 [92]	RCT	52	The Netherlands	6 months	No significant improvement in word reading and maths scores	d < 0.10
Kollins, 2019 [93]	RCT	345	United States	4 weeks	Improvement in academic achievement	d = 0.15 to 0.25
Soleimani et al., 2014 [94]	RCT	38	Iran	1 month	Improved academic productivity	d = 0.54
Bikic et al., 2024 [95]	RCT	70	Denmark	8 weeks	No significant improvement in academic achievement	d < 0.20
Giannakopoulou et al., 2025 [96]	RCT	158	United States	10 weeks	Significant improvement in reading and math skills	d = 0.48
Qian et al., 2017 [97]	RCT	86	China	1 year	Significant improvement in school functional performance, homework management and classroom productivity	d = 0.64
Zhao et al., 2023 [98]	RCT	90	China	4 weeks	Significant improvement in metacognition and global executive functioning	d = 0.61
Minder et al., 2019 [99]	Clinical trial	31	Switzerland	12 weeks	No significant result in academic performance or classroom behavior	d < 0.20
Korpa et al., 2020 [100]	Controlled trial	52	Greece	3 months	Improved academic readiness and the ability to follow complex school instructions	d = 0.58

3.3 Methodological Quality and Risk of Bias

The methodological quality of the the 66 included randomized controlled trials was systematically evaluated using the Cochrane Risk of Bias tool (RoB 2). This assessment aimed to establish the internal validity of the evidence and to identify potential systematic errors that could influence the interpretation of academic outcomes. The results of this evaluation are summarized in Table 2, which provides a study-by-study breakdown of the five assessment domains (Traffic Light Plot).

Table 2: Results of Rob2 of Included Studies.

Study	D1: Random-ization	D2: Deviations	D3: Missing Data	D4: Measurement	D5: Reporting	Overall Risk
Bigorra et al. (2016) [35]	Low Risk	Low Risk	Some Concerns	Some Concerns	Low Risk	Low Risk
van der Donk et al. (2015) [36]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk
Chacko et al. (2014) [37]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk
Trinczer et al. (2024) [38]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Some Concerns
Green et al. (2012) [39]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
van der Donk et al. (2020) [40]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Some Concerns
Li et al. (2025) [41]	Some Concerns	Low Risk	Some Concerns	Some Concerns	Low Risk	Some Concerns
Ponomarev et al. (2023) [42]	Some Concerns	Some Concerns	Low Risk	Some Concerns	Some Concerns	Some Concerns
van der Donk et al. (2013) [43]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Steiner et al. (2014) [44]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Egeland et al. (2013) [45]	Low Risk	Some Concerns	Low Risk	High Risk	Low Risk	High Risk
Dovis et al. (2015) [46]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Bioulac et al. (2020) [47]	Low Risk	High Risk	Low Risk	Some Concerns	Low Risk	High Risk
Zheng et al. (2024) [48]	Low Risk	High Risk	Low Risk	Some Concerns	Low Risk	High Risk
Gollier-Briant et al. (2024) [49]	Low Risk	High Risk	Low Risk	High Risk	Low Risk	High Risk
Richmond et al. (2022) [50]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Bikic et al. (2018) [51]	Low Risk	Some Concerns	High Risk	Some Concerns	Low Risk	High Risk
Luo et al. (2023) [52]	Low Risk	High Risk	High Risk	Some Concerns	Low Risk	High Risk

Table 2: Cont.

Study	D1: Random- ization	D2: Deviations	D3: Missing Data	D4: Measurement	D5: Reporting	Overall Risk
Wexler et al. (2021) [53]	Low Risk	High Risk	High Risk	Some Concerns	Low Risk	High Risk
Chan et al. (2023) [54]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Low Risk
van Dongen- Boomsma et al. (2014) [55]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Hovik et al. (2013) [57]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Wu et al. (2023) [58]	Some Concerns	Low Risk	Some Concerns	Low Risk	Low Risk	Some Concerns
Bilan et al. (2025) [59]	Some Concerns	Low Risk	Low Risk	Some Concerns	Low Risk	Some Concerns
Bach-Morrow et al. (2022) [60]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
McDermott et al. (2020) [61]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Sandberg et al. (2021) [62]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Carrillo (2024) [63]	High Risk	Some Concerns	Some Concerns	Some Concerns	Low Risk	High Risk
van der Donk et al. (2016) [65]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Rabiner et al. (2010) [68]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Azami et al. (2016) [69]	Low Risk	High Risk	Low Risk	High Risk	Some Concerns	High Risk
Steiner et al. (2011) [70]	Low Risk	Some Concerns	Some Concerns	High Risk	Low Risk	High Risk
van der Oord et al. (2014) [71]	Low Risk	Some Concerns	Low Risk	High Risk	Low Risk	High Risk
Jones et al. (2020) [72]	Low Risk	Low Risk	Some Concerns	Some Concerns	Low Risk	Some Concerns
Singh et al. (2021) [73]	Some Concerns	Low Risk	Low Risk	Some Concerns	Low Risk	Some Concerns
Ahmadi et al. (2017) [74]	High Risk	Low Risk	Some Concerns	High Risk	Low Risk	High Risk
Chu et al. (2022) [76]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk
Pérez-Rodríguez et al. (2025) [77]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Klingberg et al. (2005) [79]	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk	Low Risk

Table 2: Cont.

Study	D1: Random-ization	D2: Deviations	D3: Missing Data	D4: Measurement	D5: Reporting	Overall Risk
Tamm et al. (2013) [80]	Low Risk	Some Concerns	Low Risk	High Risk	Low Risk	High Risk
Lloyd et al. (2010) [81]	Some Concerns	High Risk	Some Concerns	Some Concerns	Some Concerns	High Risk
Hasslinger et al. (2016) [82]	Low Risk	High Risk	Some Concerns	Some Concerns	Low Risk	Some Concerns
Badia-Aguarón et al. (2024) [84]	Low Risk	Some Concerns	Low Risk	Some Concerns	Low Risk	Some Concerns
Lim et al. (2023) [85]	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Nejati et al. (2023) [88]	Some Concerns	Some Concerns	Low Risk	High Risk	Some Concerns	High Risk
Molazamani et al. (2023) [90]	Some Concerns	High Risk	Some Concerns	Low Risk	Some Concerns	High Risk
Papanastasiou et al. (2022) [91]	Low Risk	Some Concerns	Some Concerns	Low Risk	Low Risk	Some Concerns
Roording-Ragetlie et al. (2017) [92]	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk	Low Risk
Kollins (2019) [93]	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk	Low Risk
Soleimani et al. (2014) [94]	Low Risk	Some Concerns	Low Risk	High Risk	Some Concerns	High Risk
Bikic et al. (2024) [95]	Low Risk	Some Concerns	Low Risk	Low Risk	Low Risk	Some Concerns
Giannakopoulou et al. (2025) [96]	Low Risk	Low Risk	Low Risk	Some Concerns	Low Risk	Low Risk
Qian et al. (2017) [97]	Low Risk	Low Risk	Some Concerns	High Risk	Low Risk	High Risk
Zhao et al. (2023) [98]	Low Risk	Some Concerns	Some Concerns	High Risk	Low Risk	High Risk

For the non-randomized studies included in this review, the methodological quality was assessed using the ROBINS-I framework. The overall risk of bias for these studies ranged from “Low” to “Critical”, as summarized in Table 3.

3.4 Academic Outcomes

Synthesis of the extracted data shows a complex, domain-sensitive, and methodologically nuanced pattern regarding the efficacy of Computerized Cognitive Training (CCT) in generating far-transfer effects, defined as the generalization of training-induced cognitive gains to ecologically valid academic outcomes within real-world educational contexts. Across the majority of included randomized controlled trials, improvements were consistently observed in tasks closely resembling those practiced during training, confirming the presence of robust near-transfer effects. These gains were particularly evident in paradigms

targeting working memory updating, inhibitory control, sustained attention, and cognitive flexibility. The consistent evidence of near-transfer across diverse samples suggests that adaptive, high-intensity digital protocols are capable of strengthening specific executive processes when measured with structurally similar neuropsychological instruments. The translation of these gains into measurable scholastic competencies, such as standardized mathematics performance, reading comprehension, written expression, academic productivity, or classroom engagement, proved considerably less uniform. Far-transfer effects were neither automatic nor generalized. In fact, their magnitude varied significantly across studies. In several trials employing active control conditions and blinded outcome assessment, academic improvements were small, delayed, or statistically non-significant, highlighting the importance of methodological rigor when interpreting claims of educational impact. The architectural design of the intervention appears to be a decisive factor. Programs that utilize real-time adaptivity, progressive difficulty modulation, and explicit targeting of central executive processes demonstrated more promising academic transfer than protocols primarily focused on passive storage components of working memory. This makes theoretical sense: academic tasks such as mathematical reasoning, multi-step problem solving, and reading comprehension require active manipulation, monitoring, and inhibition of irrelevant information—functions primarily governed by central executive control rather than short-term storage capacity alone.

Table 3: Results of ROBIN-I of Included Studies.

Study	D1: Confounding	D2: Selection of Participants	D3: Classification of Interventions	D4: Deviations from Intended Interventions	D5: Missing Data	D6: Measurement Outcomes	D7: Selections of Reported Results	Overall Risk
Poon et al. (2024) [56]	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Revollo Carrillo et al. (2025) [64]	Moderate	Low	Low	Low	Moderate	High	Low	High
Abdeldaym et al. (2022) [66]	Critical	Moderate	Low	Moderate	Moderate	High	Moderate	High
Singh et al. (2022) [67]	Low	Low	Low	Low	Low	Low	Low	Low
van der Donk et al. (2017) [75]	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate
Sohrabi (2013) [78]	High	Moderate	Low	Moderate	Low	Critical	Moderate	Critical
Kofler et al. (2018) [83]	Low	Low	Low	Low	Low	Moderate	Low	Low
Rajender et al. (2011) [86]	Moderate	Low	Low	Low	Low	Critical	Low	High
Gallen et al. (2021) [87]	Critical	Low	Low	Low	Moderate	Critical	Low	Critical
Kermani et al. (2016) [89]	Low	Low	Low	Moderate	Low	Critical	Low	Moderate
Minder et al. (2019) [99]	Moderate	Low	Low	Low	Low	Moderate	Low	Moderate
Korpa et al. (2020) [100]	Critical	Low	Low	Low	Low	Critical	Moderate	Critical

Furthermore, intervention dosage and environmental context emerged as relevant variables. Studies implementing 25–40 sessions distributed over 5–8 weeks tended to report stronger behavioral and engagement-related outcomes compared to lower-intensity protocols.

Importantly, training delivered within supervised school contexts appeared more likely to facilitate transfer than unsupervised home-based interventions, suggesting that ecological scaffolding and adult mediation may help bridge the gap between cognitive exercise and academic application.

Another recurring pattern concerns the temporal dynamics of transfer. In literacy-related domains, several studies documented delayed improvements, often emerging only at follow-up assessments conducted

two to four months post-intervention. This “sleeping effect” suggests that executive gains may require consolidation and sustained academic exposure before becoming observable in complex scholastic tasks. Such findings challenge simplistic causal interpretations and instead point toward a mediated pathway in which cognitive strengthening enhances readiness-to-learn, which in turn supports gradual academic improvement. It is also essential to acknowledge that outcome measurement significantly influenced reported efficacy. Academic gains were more frequently detected when assessed through teacher-rated engagement scales or productivity indices than through standardized achievement tests. This raises the possibility that some observed improvements reflect enhanced behavioral regulation and task persistence rather than direct augmentation of domain-specific academic skills. While such behavioral changes are educationally meaningful, they should be conceptually distinguished from structural gains in reading or mathematics achievement.

Collectively, these findings suggest that CCT does not act as a universal “cognitive amplifier” capable of uniformly enhancing academic performance. Its impact appears conditional upon the alignment between the executive mechanisms trained and the cognitive architecture underlying the targeted academic domain, the methodological rigor of outcome assessment, the intensity and adaptivity of the protocol, and the ecological context in which training is embedded. Understanding these moderating factors is essential for accurately interpreting the educational relevance of computerized executive interventions in children with ADHD.

3.4.1 Mathematics and Numerical Skills

Of all academic domains, mathematics emerged as the most consistently responsive to the benefits of computerized cognitive training, especially when the intervention was explicitly designed to challenge high-level executive processes rather than mere short-term storage capacity. This aligns perfectly with contemporary models of mathematical cognition, which emphasize the central role of working memory updating, inhibitory control, and cognitive flexibility in multi-step calculation, problem solving, and numerical reasoning. The most encouraging results come from interventions grounded in Central Executive Training (CET), which directly target active manipulation, dual-task coordination, interference suppression, and goal maintenance. In these protocols, reported effect sizes for mathematical achievement reached substantial magnitudes ($d \approx 1.30$ in selected trials), suggesting that strengthening central executive control may enhance children’s capacity to manage the cognitive load inherent in arithmetic procedures and word problems. From a mechanistic perspective, children with ADHD often struggle with math not because of a conceptual deficit, but because their regulatory processes ‘misfire’ during complex tasks—often leading them to lose track of a sequence or fail to inhibit a misleading cue. Training paradigms that explicitly engage these regulatory components seem better aligned with the functional demands of mathematics. In contrast, traditional computerized working memory training programs primarily focused on phonological or visuospatial span—such as Cogmed—often failed to produce statistically significant improvements in standardized mathematics assessments when compared to active control conditions. Although these interventions reliably improved performance on trained span tasks, their limited impact on academic outcomes suggests that expanding storage capacity alone may be insufficient to influence complex scholastic skills.

Mathematical achievement depends not only on holding numbers in mind but on dynamically updating intermediate results, shifting between representational formats, and resisting distraction—all processes mediated by the central executive rather than passive storage buffers.

Importantly, the presence or absence of transfer effects also appeared contingent upon the methodological rigor of the studies. Trials incorporating blinded outcome measures and active control groups

tended to report more conservative academic gains, indicating that expectancy effects and rater bias may partially inflate findings in less controlled designs.

Nevertheless, even under stricter methodological conditions, interventions that targeted executive coordination rather than isolated memory rehearsal demonstrated comparatively stronger and more stable mathematical effects. Emerging neuroeducational approaches further support the relevance of executive modulation for mathematics in ADHD. EEG-guided adaptive learning paradigms, for example, dynamically adjust task difficulty based on real-time neural markers of cognitive load and attentional engagement. Preliminary evidence suggests that this closed-loop modulation enhances inhibitory stability and reduces performance variability, thereby facilitating more efficient numerical problem solving.

By keeping children in an optimal zone of cognitive challenge, neither under-stimulated nor overwhelmed, such systems may promote neural plasticity within fronto-parietal circuits implicated in both executive control and mathematical reasoning. Taken together, the available evidence suggests that mathematics represents a domain in which the alignment between executive training architecture and academic task demands is particularly strong. However, the durability of these effects remains insufficiently documented, and long-term follow-up data are still limited. Future research should therefore clarify whether executive-driven gains in mathematics reflect transient performance optimization or enduring restructuring of cognitive strategies applied to numerical reasoning.

3.4.2 Reading, Literacy, and Language

In the domain of reading, literacy, and language, the results appear more nuanced, temporally dynamic, and less immediately observable compared to mathematics. The data frequently describe what has been termed a “sleeper effect,” whereby measurable improvements in reading-related outcomes do not emerge at post-test but become statistically significant only at delayed follow-up assessments, typically conducted two to four months after the completion of training. Several randomized controlled trials reported that reading comprehension scores remained unchanged immediately following intervention but improved during subsequent evaluations. This temporal delay suggests that executive function gains doesn’t translate directly into linguistic performance; rather, they may first enhance regulatory capacities, such as sustained attention, interference control, and monitoring, that gradually facilitate more efficient engagement with text during ongoing classroom instruction. In other words, the executive strengthening may increase the child’s readiness-to-process linguistic information, but the observable academic benefit becomes apparent only after repeated exposure to authentic reading contexts.

From a cognitive standpoint, reading comprehension is a highly integrative process requiring the coordination of multiple systems: decoding, lexical access, syntactic parsing, semantic integration, inferencing, and metacognitive monitoring. Executive functions, in particular updating, inhibition, and cognitive flexibility, play a crucial role in maintaining coherence across sentences, suppressing irrelevant interpretations, and revising mental representations as new information is encountered. Therefore, it is theoretically plausible that training targeting central executive components may indirectly enhance comprehension by stabilizing these regulatory processes. The interventions explicitly focused on central executive engagement reported moderate effect sizes ($d \approx 0.78$) in reading comprehension, particularly in tasks requiring inferential reasoning and multi-sentence integration. These findings align with “top-down” models of reading, according to which executive monitoring supports the detection of inconsistencies and the allocation of attentional resources to semantically demanding segments of text.

The outcomes related to more automatized aspects of literacy, such as reading fluency, word decoding speed, and phonological processing, remained inconsistent and highly variable across studies. In many trials,

no significant improvements were observed in standardized fluency measures, even when comprehension gains were detected at follow-up. This gap is theoretically revealing: decoding and fluency rely heavily on overlearned phonological and orthographic mappings that are relatively automatized and less dependent on high-level executive coordination once mastery has been achieved. Consequently, training that strengthens executive control may have limited influence on the speed or accuracy of word-level processing, particularly in children without comorbid reading disorders.

Furthermore, variability in outcomes appears to be influenced by the architectural characteristics of the training software. Platforms emphasizing adaptive central executive tasks and multi-component engagement tended to produce more favorable literacy-related results than those limited to repetitive span-based exercises. Nevertheless, even with the best protocols, effect sizes were generally smaller and less predictable than those observed in mathematics, underscoring the greater structural complexity and multi-determined nature of reading performance.

Methodological considerations also warrant caution. In many studies, improvements in literacy were detected primarily through teacher- or parent-reported academic functioning rather than objective standardized tests, raising the possibility that enhanced behavioral regulation, such as improved task persistence and reduced distractibility, may mediate perceived gains in reading performance. While such behavioral changes are educationally meaningful, they should be analytically distinguished from direct enhancements in linguistic processing capacity. The evidence suggests that executive-focused CCT may contribute to reading outcomes through indirect and temporally mediated pathways. Rather than producing immediate structural changes in decoding or fluency, these interventions appear to enhance the regulatory infrastructure that supports comprehension, with academic improvements emerging gradually as children integrate strengthened executive control into authentic literacy experiences. Further longitudinal research with blinded outcome assessment is required to determine the stability, magnitude, and boundary conditions of these delayed transfer effects.

3.4.3 Writing and Learning-Related Behaviors

Writing is perhaps the least systematically investigated academic domain within the current literature on computerized cognitive training (CCT) in ADHD, and available findings remain fragmented and methodologically heterogeneous, emerging evidence suggests meaningful trends in broader indicators of school functioning that are indirectly related to written production.

Direct measures of writing quality, such as syntactic complexity, coherence, organization, spelling accuracy, or compositional length, have been inconsistently assessed across studies, and when included, results are often modest or statistically inconclusive. This variability likely reflects the multifactorial nature of writing, which requires the integration of linguistic formulation, planning, working memory maintenance, motor execution, and self-monitoring. Writing is not merely a language-based activity but a high-load executive task, especially in children with ADHD who frequently struggle with planning, sequencing, error monitoring, and sustained effort.

Consequently, improvements in executive functioning may not immediately manifest as measurable gains in standardized writing scores but may instead influence the regulatory processes that underpin productive engagement in written tasks.

The most consistent findings emerged in relation to learning-related behaviors and classroom functioning. Multi-component training protocols, particularly those combining central executive exercises with inhibitory control and attentional shifting tasks, were associated with a significant reduction in off-task behaviors, decreased impulsive responding, and improved task persistence during classroom activities.

These behavioral changes were frequently documented through teacher rating scales, structured classroom observations, and indices of academic productivity (e.g., number of completed assignments, on-time task initiation). Teacher evaluations consistently indicated increased academic engagement following intervention, including greater capacity to remain seated during written assignments, improved adherence to instructions, and more efficient management of transitions between tasks. In many cases, these improvements were described as enhancements in “work readiness” or “behavioral availability to learn.” Such changes, while not directly equivalent to structural improvements in writing skills, are educationally significant: they create the necessary regulatory conditions for sustained participation in cognitively demanding activities such as written composition. From a theoretical perspective, these findings are coherent with models that conceptualize ADHD-related academic impairment as partly rooted in deficits of goal maintenance and inhibitory regulation rather than purely domain-specific academic weakness.

Writing, in particular, requires sustained activation of a mental plan, inhibition of irrelevant ideas, monitoring of output, and sequential organization, all processes mediated by the central executive. Strengthening these regulatory mechanisms may therefore reduce disruptive behaviors and enhance productive engagement, even if immediate improvements in compositional quality are not yet observable.

It is important, however, to interpret these findings with methodological caution. Many behavioral outcomes were derived from teacher-reported measures, which, although ecologically valid, may be susceptible to expectancy effects in non-blinded designs. Furthermore, relatively few studies incorporated objective, standardized writing assessments or long-term follow-up data, limiting conclusions regarding the durability and magnitude of academic impact. Overall, while direct evidence for improvements in writing achievement remains limited, the broader pattern of results suggests that digital cognitive training may function as a facilitator of goal-directed classroom behavior. By enhancing inhibitory control, attentional stability, and task monitoring, CCT appears capable of increasing children’s functional engagement in school activities, thereby creating a more favorable context for academic development within the primary school environment.

4 Discussion

The present systematic review aimed to evaluate the effectiveness of computerized cognitive training (CCT) on academic and school-related outcomes in children with ADHD.

The results emerging from the synthesis of the 66 selected sources clearly indicate that CCT cannot be considered a monolithic intervention; rather, its ability to translate into significant scholastic improvements depends strictly on the nature of the cognitive functions targeted and the specific academic domain being assessed.

A central finding from the analysis is the high sensitivity of the mathematical domain compared to literacy. The evidence of large effect sizes ($d = 1.30$) associated with Central Executive Training (CET), as highlighted in the work of Ahmadi et al. [74], supports the theoretical premise that ADHD is primarily a disorder of cognitive control and the active manipulation of information rather than a simple deficit in working memory storage. This explains why traditional training programs focused exclusively on phonological or visuospatial working memory, such as the Cogmed protocol [101], often fail to produce tangible benefits in mathematics tests, which require high-level numerical reasoning processes that only the enhancement of the central executive seems capable of supporting.

Parallely, the impact on reading and literacy skills follows a more nuanced and less immediate trajectory. The “sleeper effect” found in several randomized controlled trials suggests that the integration of enhanced cognitive resources into text decoding and comprehension processes is not instantaneous.

The fact that improvements emerge with statistical significance only 2 to 4 months after the end of the intervention indicates that children require a period of consolidation and scholastic practice to apply the newly acquired cognitive control to complex linguistic tasks. While reading fluency appears to remain a more automated skill resistant to training, reading comprehension shows moderate benefits ($d = 0.78$) when the training targets central executive components, confirming that CCT can act as a catalyst for the top-down monitoring and regulation functions necessary for learning. These transfer mechanisms are supported by neuroimaging, which suggest that adaptive digital tasks can induce structural and functional changes in fronto-parietal networks.

However, we must contextualize these findings within the most recent meta-analytic evidence, which invites caution. Specifically, Westwood et al. (2023) [102], in a comprehensive analysis for the European ADHD Guidelines Group (EAGG), highlighted that when stringent ‘probably blinded’ (PBLIND) assessments and objective measures are applied, the significant effects of CCT on core ADHD symptoms and academic performance often vanish. This suggests that a portion of the perceived academic success in less controlled studies might be influenced by rater expectancy bias rather than stable cognitive improvements. Our synthesis emphasizes that such changes translate into “far-transfer” academic skills only when the training is sufficiently intensive and, above all, adaptive. The success of EEG-guided learning [41] demonstrates that real-time cognitive load modulation is fundamental to maintaining the child’s engagement and stimulating neural plasticity relevant to the school environment.

Beyond standardized test scores, the most recent literature (2020–2026) highlights significant improvements in classroom behavior and academic engagement [58]. This suggests that CCT may act as a “readiness-to-learn” intervention: by reducing impulsivity and improving inhibitory control, the intervention makes the child more “available” for frontal instruction, facilitating task management and participation in didactic activities. This positive evidence, methodological limitations remain regarding the heterogeneity of training dosages and the scarcity of studies focused on writing, which still represents a gap in current research despite its clinical relevance in ADHD. Furthermore, the role of supervision emerges as a determining factor for the successful transfer of cognitive gains to real life, suggesting that CCT is more effective when integrated into a context supervised by teachers or clinicians rather than as an isolated tool for home use. In addition to these factors, many existing studies lack active control groups, potentially introducing expectancy bias in behavioral ratings. There is also a notable absence of long-term longitudinal data, making it difficult to assess the permanence of academic improvements over time. Future research must therefore address these gaps by employing more rigorous double-blind designs and testing the ecological validity of these tools within real-world classroom settings.

In light of these findings, it is important to translate the evidence into practical guidelines for both clinical and educational contexts.

From a clinical perspective, practitioners should move away from recommending generic digital activities, focusing instead on protocols that specifically target the Central Executive through high levels of adaptivity. It is equally fundamental for clinicians to manage parental expectations, clarifying that CCT serves as a ‘readiness-to-learn’ tool rather than a standalone treatment; this includes explaining that while behavioral benefits may be immediate, academic improvements, particularly in literacy, often require a consolidation period of several months due to the ‘sleeping effect’. Moreover, the clinician’s role must extend beyond providing the software, involving active monitoring to help the child bridge the gap between digital tasks and daily scholastic challenges through metacognitive reflection.

At the same time, for school system, CCT should not be seen as an isolated laboratory task but as a strategic ‘warm-up’ for cognitively demanding subjects like mathematics. To maximize its impact, schools

must provide a supervised environment where teachers or tutors offer the motivational support necessary to stimulate neural plasticity—a component often missing in unsupervised home use. Teachers can further leverage the post-training window, during which inhibitory control is temporarily enhanced, to introduce complex instructions or tasks that require sustained focus. This operational synergy between clinical precision and educational application is what ultimately allows cognitive gains to be consolidated and successfully applied within the classroom environment.

Based on the evidence synthesized in this review, several practical recommendations can be made for clinical and educational practice. First, given the identification of the ‘sleeper effect’, school psychologists should avoid expecting immediate academic improvements; monitoring of the student’s progress should extend to at least 6–12 months post-intervention to accurately capture the delayed impact on academic skills. Second, educators should frame CCT as a tool to improve ‘learning readiness’, such as better focus and task persistence, rather than a direct replacement for academic instruction. It is recommended to combine these digital interventions with specific behavioral classroom management strategies. Finally, since objective test scores might not show immediate changes, teachers are encouraged to use qualitative observations to track improvements in the student’s ability to initiate tasks, follow multi-step instructions, and manage classroom distractions.

In conclusion, CCT represents a valuable complementary tool, especially for supporting mathematics and behavioral regulation, its implementation must be guided by the awareness that academic benefits require protocols specifically targeting the central executive, adaptive algorithms, and adequate time for the consolidation of gains to manifest fully within the educational context.

Limitations of the Study

Despite the rigorous methodology and the large number of studies synthesized, some limitations of the present review must be considered when interpreting the results. One of the limitations concerns the literature search process; where the database search was limited to the Scopus and PubMed databases. Although these sources are highly representative of the interdisciplinary intersection between clinical psychology, neurotechnology, and education, the exclusion of other specialized databases, as well as grey literature, may have led to the omission of some relevant trials.

Furthermore, the high degree of methodological heterogeneity among the included studies represented a significant challenge for the synthesis. The extreme variability in training protocols, dosages, and specific outcome measures precluded the possibility of conducting a formal meta-analysis. Consequently, a structured narrative synthesis was adopted to provide a comprehensive overview, although this approach inherently lacks the statistical pooling of effect sizes across all 66 studies.

Finally, while this review emphasizes the clinical importance of the “sleeper effect,” there remains an evident lack of research involving longitudinal studies that span longer than 12 months.

This gap in the literature makes it difficult to ascertain the long-term stability of academic gains or the potential need for “booster sessions” to maintain cognitive-scholastic transfer. Additionally, while mathematics and reading were extensively covered, writing skills remain significantly under-researched, representing a clear area for future investigation given its critical relevance for the functional autonomy of children with ADHD.

5 Conclusions

This systematic review indicates that the academic effects of Computerized Cognitive Training (CCT) in children with ADHD are neither uniform nor generalized, but depend on the alignment between the

executive functions targeted by training and the cognitive demands of specific academic domains. The strongest evidence of improvement was observed in mathematics, particularly in interventions targeting central executive processes, whereas literacy outcomes showed a delayed “sleeper effect,” with gains in reading comprehension emerging only during follow-up assessments. In contrast, automatized skills such as reading fluency and decoding remained largely unaffected.

Apart from its effects on academic achievement, CCT is thought to increase learning readiness through improvements in attention control, decreased distraction, and increased participation in class. These effects can foster an environment that facilitates learning regardless of the lack of immediate effects on academic performance. Nonetheless, care must be taken while interpreting the current findings. The large methodological variability, differences in treatment protocol, and the reduction of effect sizes in blinded trials have all pointed to the possibility that certain benefits observed may be due to placebo and bias. Future studies need to focus on sufficiently powered double-blind RCTs using active controls and objective academic performance measures, with long-term follow-ups, especially for less studied areas like written expression.

In conclusion, CCT alone does not have a sufficient impact on overcoming the challenges associated with ADHD-related academic problems. Instead, if implemented effectively by using appropriate strategies, it may be used as an important complementary intervention in helping individuals with ADHD become successful academically.

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Availability of Data and Materials: All data analyzed during this study are included in this published article. The primary sources utilized are publicly available in the Scopus and PubMed databases as documented in the methodology.

Ethics Approval: Not applicable. This study is a systematic review based on the analysis of previously published literature. It does not involve the direct participation of human or animal subjects, nor does it require the handling of sensitive personal data that would necessitate specific institutional ethics committee approval. All primary studies included in this review are assumed to have been conducted in accordance with the ethical standards of their respective institutions and the Declaration of Helsinki.

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