The Effect of Working Memory Deficits on Academic Performances among Children with ADHD

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Abstract: This literature review focuses on the effect of working memory deficits on academic performance in children with ADHD. Many research studies cover the basic aspects of ADHD's impact on both working memory and school performance. However, many neglect the variance in academic performances that are affected. For example, many researchers have neglected the effects of ADHD on standardized testing. Many also conclude with biased experimental results that have been proven inaccurate. Many of the studies this literature review covers contain information from the past 20 years. ADHD is usually associated with a deficit in working memory. This leads to lower academic performances (SAT and standardized testing, especially in reading and math) compared to neurotypical children. This literature review can contribute to ADHD's development on an academic path, giving notice to parents and teachers for extra care and accommodations for children with ADHD. Increasing social awareness and emphasis on ADHD intervention and education is part of the goal of this review. Furthermore, it is recommended to research and experiment with larger samples from diverse cultures for a deeper understanding of this topic.

Keywords: ADHD, working memory deficit, school performances

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) has become a prominent subject of discussion within educational circles, particularly given its substantial prevalence of 11.3% among children aged 5-17 years. This condition significantly impacts academic outcomes, affecting both standardized test scores and achievement tests [1]. Arnold's research has investigated the academic challenges faced by students with ADHD, particularly focusing on attentional deficits as a central issue. Studies emphasize a strong positive correlation between working memory and attention, suggesting that these cognitive processes are crucial for academic success. According to the information processing model, attention is vital for the transfer of information to working and short-term memory, and without adequate attentional capacity, students struggle to retain and process information effectively [2].

Although recent studies have established a strong negative linear relationship between working memory deficits and academic achievements in students with ADHD, there remains significant ambiguity in defining what constitutes ''academic achievements.' Current research often conflates or does not distinctly differentiate between standardized test scores (such as SATs, which include reading and math) and achievement scores, leading to confusion about which aspects of academic performance are most affected by ADHD. While the impact of ADHD on academic performance is

well-documented, the specific academic areas most susceptible to impairment—whether they be in quantitative reasoning, reading comprehension, or other skills—haven't been conclusively identified.

This literature review focuses on the specific effects of working memory deficits on school-aged (8-18) children with ADHD and their academic performance. This literature explores the relationships and correlations between attention, working memory, and academic performance in the context of ADHD. This review will also explore the interplay between ADHD-related impairments in working memory and attention and their consequential impact on school performance, drawing on pivotal studies. The aim of this literature is to increase social awareness and embrace ADHD, aiming to provide reasonable understanding and self-efficacy to children and parents who are currently struggling academically with ADHD. Solutions and suggestions are expected to be identified at the end of this article.

2. What is Working Memory

Working memory is responsible for coordinating and acting upon information held in the short-term memory domain, which is essential for human executive function [3]. Working memory is originally defined as a memory system responsible for the temporary maintenance and processing of information. Working memory refers to the cognitive system responsible for temporarily holding and manipulating information needed for complex cognitive tasks such as reasoning, comprehension, and learning. Working memory is actively working in real-time, including reading, thinking, and chat-talks. This ability to actively manipulate and work with information in real time involves the active maintenance of a limited amount of information in a ready state for a short period of time [4]; it's a workshop that requires manipulation and simultaneous memory storage. The working memory function is essential for remembering reading materials and working materials from a few seconds ago.

There are a few models that can help explain working memory. Baddeley's Model from 1974 mentioned that working memory is composed of three main parts: First, the central executive part directs attention and coordinates information. Second is the phonological loop, the part where humans process verbal and auditory information. Third, the visual-spatial sketchpad handles visual and spatial data. This model explained working memory well and was known for being the most influential model. Working memory can be explained as a process where attention goes in like a spotlight, spots information, and coordinates it, then we process verbal information later, and spatial and visual information.

The central executive portion of working memory is the part of memory associated with memory attention and organization. Being the main controller of the visuospatial and phonological loop, this section can coordinate performance on two separated tasks (e.g., simultaneous storage and processing of information), switching between tasks, retrieval strategies, or operations (i.e., sequencing), correctly inhibiting unnecessary information and attending to selective information; and activating and retrieving information from long-term memory [5]. Visual Spatial working memory, as a slave of the central executive function of working memory, is the main component of visual memory or visual skills. The visual-spatial sketchpad involves temporary storage and rehearsal of visual and spatial information. Last, the phonological loop, working memory, is essential for the rehearsal of auditory and phonological function [6,7].

Despite these models of explanations, many parts of the working memory still aren't readily accessible. The simplest model to be explored is the phonological loop. Visual Spatial working memory is less tractable than phonological loop function; however, it's growing in progress and is often seen as linked with visual imagery. At the same time, the core executive part of working memory remains the least studied part, although it is almost certainly the most important component that has an overall impact on cognition.

Working memory can be measured in different ways. These working memory aspects are measured through different tasks. This task requires participants to recall information immediately without further processing. The others, testing for central executive function, require a complex span test in which deeper processing and manipulation of information is required [7]. These tasks are widely used to measure working memory capacity by requiring participants to engage in a secondary task (such as reading sentences or solving math problems) while maintaining a sequence of items in memory. Common examples include the "Reading Span" and "Operation Span" tasks. Meta-analysis emphasizes the reliability of these tasks and mentions a strong correlation between complex span tasks and other measures (n-back tests) [8]. N-back tests, another way of measuring working memory, are another influential measure tool for determining working memory. In this task, participants must identify whether the current stimulus matches the one presented in trials before. Variations include 1-back, 2-back, and 3-back tasks with increasing difficulty corresponding to the number of trials to remember. The task measures both response accuracy and reaction times, providing insights into the different facets of working memory performance, including speed and accuracy trade-offs [9].

However, some studies also show that N-Back tests and complex span tasks yield different results. While both tasks measure working memory, N-back tests exhibit variability in accuracy and reaction times that do not align with complex span measures. N-back tests might not be able to capture all aspects of working memory performance, potentially leading to an overestimation of working memory capacity. Another aspect to consider is that working memory is also influenced by other factors, such as emotional stimuli. For instance, while some studies have found that emotional stimuli can improve accuracy, others have reported no significant impact on working memory performance. Therefore, we cannot definitively ascertain the accuracy of working memory results. Research on affective working memory suggests that emotional stimuli can indeed influence working memory performance, with certain studies showing that positive or negative emotional content can enhance or impair working memory capacity [10].

3. What is ADHD?

ADHD is a developmental disorder that commonly occurs in children. Attention deficit hyperactivity disorder (ADHD) is a heterogeneous disorder of childhood onset, characterized by inattention, impulsiveness, and hyperactivity. It is a very common psychological disorder that about 5% of school-aged children are diagnosed within the United States. ADHD is commonly associated with impairment in peers, family, and academic functioning [11]. However, several aspects of ADHD are examined, and many different institutes give different definitions of them. From the most authoritative and internationally accepted medical measurement, DSM-IV, ADHD was diagnosed through specific and fixed criteria. These specific criteria can be categorized. For example, Children/Adults with ADHD often fail to hold attention and get distracted easily. ADHD also has trouble organizing tasks and activities [12]. Many other perspectives are also measured as a definition of ADHD. In an Egyptian study of ADHD students, it was written that ADHD is characterized by persistent patterns of inattention and/or hyperactivity-impulsivity that significantly interfere with social, academic, or occupational functioning in two or more settings (e.g., home or school). Inattention (e.g., difficulty concentrating on the task at hand) and hyperactivity-impulsivity (e.g., restlessness and inability to wait) are two core symptoms that define ADHD [13]. Others have used information processing models to define ADHD and arousal theory but have failed. Many claim that these theories cannot be used to expand and explain the causes of executive dysfunction in ADHD. ADHD can cause dysfunction in inhibition. Another experiment made in 1993 emphasizes another new dysfunction in ADHD. Logan found ADHD to have a slower than average initial inhibition of response inhibition and the inability to disengage or shift responding when signaled to do so in tasks.

Despite these clear definitions, the definition of ADHD still isn't complete enough. ADHD is overdiagnosed in many countries, including the U.S. and Canada. Many studies have been working to provide safe and restricted ADHD diagnoses to prevent overdiagnosis. In addition, laboratory tests cannot reliably predict ADHD [14]. Prevalence estimates of ADHD are sensitive to who is asked, what is asked, and how information is combined. ADHD symptoms are also easily confused and mixed with other psychological disorders such as dyslexia and anxiety. These disorders can mimic ADHD, leading to common misidentifications. The definition of ADHD is very unclear and uncertain; many studies only measure one aspect of the disorder or, like DSM-IV, provide broad and non-targeted definitions that can easily be mixed up with other disorders [15].

Another significant gap in ADHD research is the lack of longitudinal studies. Many studies and literature focus on small samples and school-aged children. While this has provided insights into the effect of ADHD on school performance, it cannot offer a long-term investigation into children's real development. With longitudinal research, we can identify how ADHD evolves and how it affects long-term success beyond academic performance.

4. How is Working Memory in ADHD

Working memory deficits are evident in children with ADHD. According to an article in Child, working memory is significantly reduced in both groups when working memory demands are heightened. The maintenance of activation in the interval between stimuli 'A' and 'X' provides a measure of working memory, which is thought to be related to the prefrontal cortex's memory activation. This activation is facilitated by the administration of methylphenidate (stimulant medication) in children with ADHD, suggesting that working memory may be a core deficiency in these children. Children with ADHD exhibit significant impairments in working memory, reordering, and updating but not in dual-processing tasks. Overall, 67%-71% of youth with ADHD exhibit impairments in at least one domain function in working memory. Many findings suggested that ADHD adults (after 18) are significantly less affected by ADHD symptoms (working memory). About 95% of the sample size of 3466 adolescents show an increase and complete working memory test results compared to school-aged children at 8-17 [16]. Finds suggested that a residual brain abnormality was seen on an fMRI scan on both brain structure and working memory.

After a sample of 83 young adults (11-20), it shows that the brain dysfunction shown in the fMRI scan is related to working memory. These findings are not secondary to stimulant treatment and emphasize the importance of taking a wider perspective on ADHD outcomes than simply whether or not a particular patient meets diagnostic criteria at any given point in time [17]. In a comparison of reading accuracy and speed between young adults with Attention Deficit Hyperactivity Disorder (ADHD) and those with Normal Development (ND), research indicates that individuals with ADHD exhibit significantly lower levels of both reading accuracy and speed compared to their ND counterparts. The results suggest that the primary contributor to the disparities in reading speed and accuracy among ADHD young adults is working memory dysfunction. This deficit in working memory makes individuals with ADHD repeatedly review previously read material, resulting in slower reading speed and accuracy [18].

In cooperation with working memory, many different working memories were measured. One includes verbal working memory. The working memory model, in contrast to Barkley's inhibition model, argued that the main dysfunction in working memory models is the verbal working memory section for ADHD children. The model also argued that the inhibition response deficit is also part of the verbal working memory deficit in ADHD children.

Several gaps and holes have been found in this research; for example, Barkley (According to his inhibition model) argued that the problem with ADHD is its response inhibition instead of working memory or other executive functions. The inefficient response inhibition causes executive function

deficiency, which also causes a lack of working memory. Mentioning that the main problem is response inhibition instead of working memory [19]. But then, it was identified as a problem involved inside the working memory. The majority of the literature focused too much on correlational associations, but some contradictory literature also supports that there is a non-significant worsening of working memory in ADHD children. Some studies also employed that the samples are mainly composed of white females. More general and broad research on different genders and different races should be considered to make future research more specific.

The synthesis of recent findings presents a coherent and convincing narrative about the profound impact that working memory deficits have on children with ADHD. The reports reviewed consistently suggest that these deficits compromise not only academic achievement but also social functioning, illustrating a multifaceted challenge. Notably, the differential impacts on reading comprehension highlighted by Kofler et al., along with the specific impairments in spatial versus verbal working memory capacities identified by Martinussen et al., indicate that these deficits are not uniformly experienced but are task-specific. The study's working memory tests also demonstrate a strong correlation to ADHD-related impairments in areas such as peer functioning, reading comprehension, parent-child relationship quality, academic success/productivity, and organizational skills. Psychiatry Psychology, a significant number of children with ADHD, exhibit working memory deficits. Working memory has also been linked to peer functioning and executive function, indicating underdevelopment in executive functions. Furthermore, increased working memory demands have been shown to cause disproportionate function in reading comprehension for children with ADHD compared to non-ADHD children.

5. Kinds of Academic Performances that are Affected by ADHD

Working memory is closely related to academic performance. Children with ADHD consistently exhibit a core deficit in working memory, which consequently has a negative impact on their school performance. Some studies have proven that ADHD significantly impacts both academic performance and performance outcomes, such as GPA and standardized test scores [20]. For instance, Arnold 2020 mentioned that children with untreated ADHD perform worse than children with ADHD on standardized testing such as the SAT. Some studies also mentioned that ADHD affects reading, writing, and math. For example, ADHD students always have a hard time writing properly; some also experience a difficult time writing and expressing their thoughts properly. Which can influence their school assignments and tests [21]. Students with ADHD tend to have weaker than normal working memories, which then can be reflected in achievement tests such as AP or IB courses. These exams measure students' ability to remember and understand large amounts of course materials. In order for students to achieve success on these exams, students are required to organize their daily tasks and memorize to understand the topic. However, children with ADHD are proven to have a lower capacity in working memory, causing a short-term memory deficit, therefore experiencing a difficult time mastering course material and receiving lower than normal grades. For example, to solve math problems, children need to remember and work with relevant information. For instance, breaking down a problem like 7×12 into smaller steps, such as 7×10 and 7×2, requires keeping track of partial answers before combining them to get the final result. Similarly, solving multi-digit addition or subtraction problems like $27 + 59$ or $47 - 19$ involves carrying or borrowing digits, which also demands attention to intermediate steps. Research shows that children with better working memory tend to excel in mathematics [7]. Gearry found that overall, the long-term academic outcomes for students with ADHD, such as high school graduation rates and post-secondary education attainment, are generally found to be lower compared to peers without ADHD. This is attributed to the persistent nature of ADHD symptoms that continue to affect learning and academic engagement over time.

While academic performance varies among children with ADHD, some excel in certain subjects compared to their neurotypical peers. This demonstrates that ADHD is not necessarily a determining factor in academic performance [21]. Therefore, it's inaccurate to generalize academic outcomes for children with ADHD as various subjects and individual factors must be considered. Furthermore, there are uncertainties and limitations to these measurement tools. Tools like the Conners' Rating Scales and the Behavior Rating Inventory of Executive Function (BRIEF) are used very often; they usually rely on subjective reports from parents and teachers. These reports can be biased or inaccurate because these reports are vastly based on the observer's expectations and experiences, leading to potential biases and inconsistent results. Another contradiction is that environmental factors can also shape children's performances despite ADHD or any developmental disorders. Factors such as teaching style, classroom settings, and seating arrangements can also be important determining factors for school performance changes. For example, students may perform better in smaller, more supportive classroom settings, but this improvement might not be reflected in standardized tests that do not account for these contextual differences.

Overall, standardized and achievement test scores (reading and math) are often affected by ADHD. However, research gaps reveal that these measurements might be inaccurate due to outside factors that can also disrupt results, such as environmental factors or talents. These cannot be omitted when measuring ADHD's school performance.

6. Academic Difficulties

Academic difficulties are a common problem in ADHD and are often the reason for a child's initial referral for clinical evaluation. Challenges with schoolwork can significantly contribute to future functional impairments. Earlier studies have classified academic outcomes into two main types: those connected to the information and skills acquired (academic achievement, best assessed through standardized academic tests) and those related to success within the school environment. These two types of outcomes are often viewed separately because succeeding in school involves a broader range of skills beyond just acquiring knowledge. For example, completing homework or successfully submitting a college application requires organizational and time management skills, while effective participation in group projects requires social skills.

The scores assigned by teachers may be influenced by bias, which may be influenced by students' social skills. Both types of academic achievements are thought to be negatively affected by ADHD. Various disabilities, including ADHD, can hinder academic performance, and higher cognitive skills are consistently linked to better academic outcomes. However, cognitive skills can be compromised by core symptoms of ADHD: inattention, hyperactivity, or both. Many studies have shown that early attention difficulties are associated with future challenges in reading, math, and overall school performance. Working memory impairment, inattention, and ADHD can all lead to lower grades on exams and lower academic success rates for students with ADHD. Learning disabilities can also play a role. (language, reading, and math) are common comorbidities of ADHD, and these may also affect academic outcomes in an additive manner.

7. Conclusion

This literature review offers an overall insight into the question: "What is the effect of working memory deficits on academic performance." This research can conclude a relationship between ADHD and working memory and their effect on academic performance. For instance, working memory (including central executive, phonological loop, and visuospatial sketchpad) is usually seen as a deficit in ADHD children. Gathercole and Alloway emphasize that working memory is 'essential for learning and academic achievement' as it enables students to process, understand, and retain new

information, follow instructions, and apply knowledge effectively. ADHD's working memory is intercorrelated with their academic performances, showing major deficits in reading and math skills. Children with ADHD often have lower grades than their peers, both in overall GPA and specific subjects like reading and math.

There are also future directions that literature might want to address. Literature should consider involving larger and more representative samples. For example, many researches are based on small samples that are not the representation of a population; some only used 30-50 children from one local high school, which is not sufficient evidence to support the claim. Furthermore, many other factors can influence school performance, not specifically ADHD. For instance, parenting style, school academic settings, and teaching styles. These are all different factors that can influence test results. Therefore, we cannot conclude that the results from the samples pulled solely depend on ADHD. More research can be directed to remove outside factors that lead to inaccuracy. Cultural influences on ADHD's school performance are also a plausible direction. ADHD children's school performances also vary among different cultures, and this is a possible explanation to unlock more about ADHD.

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