

# The Impaired Sustained Attention in Children with ADHD: Relevant Factors and Clinical Implications

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**Abstract.** Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental condition that profoundly disrupts a child's capacity to maintain focus, impacting various aspects of their daily existence. This article delves into the intricate realm of compromised sustained attention in children diagnosed with ADHD, offering an exhaustive examination of the contributing factors and their clinical implications. Employing extensive research, this research delves into the multifaceted facets of attention deficits associated with ADHD, encompassing distinct attentional components, susceptibility to distractions, attention patterns, processing speed, autonomic regulation, and developmental considerations. By unraveling these discoveries, the exploration acquires valuable insights into the hurdles confronted by children grappling with ADHD when it comes to sustaining attention. Furthermore, emphasizing the significance of tailored interventions aimed at addressing specific attention-related elements. By shedding light on the complexity of impaired sustained attention in ADHD, this article advances researchers' comprehension of this condition and lays the groundwork for more efficacious diagnostic and therapeutic approaches. This review can help improve the lives of children affected by ADHD by fostering a more nuanced understanding of the challenges they face in their daily lives.

**Keywords:** attention-deficit/hyperactivity disorder; sustained attention; clinical implications.

## 1. Introduction

Sustained attention is paramount, and it serves as a foundational cognitive skill that underpins academic achievement, professional success, and daily life functioning. In the context of children grappling with Attention-deficit/hyperactivity disorder ADHD, which is a neurodevelopmental condition. The main symptoms of ADHD are inattention, hyperactivity, and impulsivity. Therefore, understanding the intricate dynamics of impaired sustained attention becomes indispensable. Notably, sustained attention is central to academic pursuits, where students must maintain focus during lectures, sustain concentration during exams, and complete homework assignments consistently. Furthermore, in the professional realm, sustained attention is pivotal for productivity, efficient task completion, and maintaining professional relationships. To develop further into the fundamental aspects of ADHD, it is essential to first establish a solid understanding of the core components of attention. The research done by Knudsen and his colleagues established a conceptual framework for understanding attention, providing insight on the neural mechanisms behind this complex cognitive process [1]. The research identifies four key components of attention. Working memory can manipulate information, while top-down sensitivity control can direct attention according to goals and expectations. Competitive selection helps prioritize relevant information, and automated bottom-up filtering highlights important stimuli in the environment. These components work in concert to select and process information, with working memory functioning as the decision-maker, competitive selection determining what enters working memory, top-down control enhancing specific information, and automatic filtering identifying salient stimuli. The importance of this framework is its potential to guide future research and clinical applications. By exploring the neural mechanisms underlying each attention component, researchers can deepen their understanding of how attention operates in the brain. This knowledge can lead to breakthroughs in diagnosing and treating attention-related disorders, as different symptoms may point to specific components being affected. Additionally, a better grasp of attention mechanisms may enable the development of more targeted therapies [1].

Another fundamental aspect guiding ADHD research other than the mechanism of attention is the neurobiology of ADHD. The research discusses the neurobiological and behavioral aspects of ADHD and explores a theoretical framework known as the Dopamine Transfer Deficit (DTD) theory to understand the condition [2]. The DTD theory posits that certain symptoms may result from the inability of dopamine cell responses to shift towards early predictors of rewards. In individuals with ADHD, there is a defect in the response of dopamine cells to cues that predict reinforcement, resulting in delayed dopamine signaling at the cellular level [2]. This delayed reinforcement processing can explain various ADHD symptoms, including inattention and difficulties with sustained focus, as well as sensitivity to delayed reinforcement. This paper provides valuable insights into how dopamine function and reinforcement processing are related to ADHD symptoms and their treatment, indicating the importance of further research to fully elucidate the underlying mechanisms and develop more targeted treatments for individuals with ADHD.

Understanding the multiple facets of attention, particularly in the context of children and adolescents diagnosed with ADHD, is critical. Such comprehension forms the foundation for developing targeted interventions and support systems that cater to the unique needs of this population. While previous studies have predominantly concentrated on investigating ADHD during childhood and adolescence, exploring its effects on academic performance, social interactions, and the development of executive functions, there exists a conspicuous gap in research focusing on the long-term outcomes, persisting challenges, and necessary interventions as individuals with ADHD transition into adulthood. The extant body of literature has primarily revolved around the earlier phases of the disorder, leaving a significant void in researchers' understanding of how ADHD-related difficulties evolve with age and the subsequent impact on educational and occupational trajectories. Hence, this comprehensive review seeks to overcome this knowledge gap by systematically evaluating and synthesizing existing research. By doing so, it aims to offer a holistic perspective on the enduring nature of challenges associated with ADHD and how they adapt over time. This comprehensive understanding is not only crucial for the individuals themselves but also for researchers who are dedicated to crafting targeted interventions and support systems. Ultimately, these efforts can significantly enhance the life prospects and overall quality of life for individuals with ADHD as they navigate the complex journey into adulthood.

## **2. Atypical Patterns of Sustained Attention and Relevant Components in ADHD**

### **2.1. Impaired Components of Attention in ADHD**

Sustained attention, often referred to as the ability to maintain focus over an extended period, is essential for various daily activities and academic performance. For example, children with ADHD may struggle with tasks requiring continuous concentration, such as homework assignments or listening in class. In this research study, the primary goal was to investigate attention profiles in children diagnosed with ADHD and to explore potential differences among subtypes of ADHD [3]. The study aimed to address questions related to the specific attentional deficits exhibited by children with ADHD and how these deficits might vary depending on the ADHD subtype. The research focused on a population of children with ADHD, considering both inattentive and hyperactive-impulsive subtypes, to gain insights into the heterogeneity of attentional impairments within the disorder. To achieve these goals, the researchers employed a comprehensive set of methods, including the use of the Test of Variables of Attention (TOVA) and the Theory of Visual Attention (TVA)-based assessment, which provided a parametric measurement of attentional components [3]. The study utilized various neuropsychological measures and tests, including reaction time tasks and sustained attention tasks, to assess different aspects of attention in children with ADHD. The results of the study revealed that children with ADHD performed poorly on neuropsychological measures and tests, exhibiting distinct attentional deficits including slower perceptual processing speed, less accurate responses, and increased response variability, particularly in situations with low external stimulation. These deficits were found to be more pronounced in the inattentive subtype of ADHD,

highlighting the heterogeneity of the disorder. The research provided valuable insights into the relationship between attentional impairments and symptom severity, shedding light on the complex interplay between attention deficits and ADHD [3]. The study highlighted the critical importance of understanding the diverse attentional components at play in children with ADHD. The findings emphasize that ADHD is not a one-size-fits-all condition; rather, it manifests as a spectrum of attentional challenges that extend beyond mere inattention. Recognizing these distinct components, such as reaction time deficits and variable sustained attention, is pivotal in tailoring interventions and diagnostic approaches for children with ADHD.

Through the discussion and study of the previous research, the concept of attention has been severed to parts and view no longer as a whole. While identifying and defining various attentional components would be important, examining how these components manifest across different developmental stages and in response to distractors would be as valuable as such. The importance of focusing on various attentional components can be shown through the cross-sectional analysis, which examines participants spanning different age groups, offering a valuable insight of how distractibility varies across the developmental spectrum in individuals with ADHD. In the research conducted by Berger and colleagues, attention and distractibility in children and adolescents diagnosed with ADHD were examined using the MOXO-Continuous Performance Test (CPT) task. The study encompassed 839 participants aged 7 to 18 years, consisting of 478 individuals diagnosed with ADHD and 361 non-ADHD controls. Demographic variables, including age and gender, were examined separately within age groups—7 to 12 years old children and 13 to 18 years old teenagers. Remarkably, the ADHD group demonstrated a heightened occurrence of omission errors across all CPT conditions, which encompassed scenarios featuring visual, auditory, and combined distractors. The interaction between group and task demands revealed that the ADHD and control groups gained very different results which varied depending on the level of task difficulty. The ADHD group performed much poorly and exhibited the phenomenon of distraction [4].

The MOXO-CPT test utilized in this study included eight levels with varying degrees of distractors. The stimuli consisted of cartoon images of faces and animals, with visual and auditory distractors introduced to simulate real-world environmental distractions. For children from 7 to 12 years old, age significantly affected CPT performance, with older children performing better. Regardless of age and gender, ADHD children had significantly higher rates of omission errors compared with non-ADHD children across all CPT conditions. Notably, visual distractors were found to have a more significant impact on ADHD participants, potentially due to impaired visual attention. The study observed that age-related improvements in attention were evident in typically developing adolescents, while individuals with ADHD continued to exhibit distractibility, resembling younger control children [4]. The result of the study underscores the significance of considering age-related variations in distractibility, highlighting that distractibility in ADHD isn't a static phenomenon but evolves as children and adolescents grow. This insight strengthens the argument, emphasizing that the multifaceted nature of impaired sustained attention in ADHD extends beyond a single point in time. To comprehensively address this complexity, it is necessary to consider the evolving interplay between attention and distractibility, a crucial facet in the broader understanding of ADHD and its associated attentional challenges.

Berger's study focused on the variation of attention between different age groups, but the nature of the attention variation remains debatable. Attention allocation, defined as the process by which individuals distribute their cognitive resources to various stimuli and tasks, is a critical factor in sustained attention. Understanding these attention allocation patterns in children with ADHD not only informs researchers' comprehension of the disorder's nature but also opens avenues for refining diagnostic procedures and designing targeted interventions to enhance their sustained attention abilities. This study aims to investigate the abilities of children with ADHD to detect changes compared with typically developing (TD) children. It is regarding questions concerning how ADHD might impact change detection and whether this would differ from TD children. The study population included children diagnosed with ADHD and typically developing children. To achieve its goals, the

study employed a flicker task and eye movement analysis [5]. The results showed that children that are diagnosed with ADHD exhibited lower accuracy in change detection than TD children. This difference was attributed to ADHD children's tendencies towards rapid but inaccurate responses, possibly linked to impulsivity and difficulties in behavioral inhibition. Additionally, there were distinctions in attention allocation patterns between the two groups. TD children focused more on the changed area, contributing to their superior performance, while children diagnosed with ADHD were less focused and more likely to shift rapidly between different areas, potentially contributing to their lower accuracy in detecting changes [5].

In short, research suggests that children with ADHD exhibit poorer abilities in detecting changes compared with TD children. The findings suggest that ADHD-related difficulties in sustaining attention, impulsivity, and attention allocation strategies contribute to these differences. Understanding the cognitive processes underlying change detection in ADHD can shed light on the disorder's nature and may inform future diagnostic procedures and interventions. These insights strengthen the argument that the multifaceted nature of impaired sustained attention in ADHD is not limited to the ability to maintain focus but also involves the allocation of attentional resources. Gaining insight into these allocation strategies not only adds to researchers' knowledge of this disorder but also carries possible implications for the development of interventions intended to enhance sustained attention in children diagnosed with ADHD.

Sustain attention was one aspect of the attention components that was introduced, and in the study completed by McAvinue and her colleagues, a new dimension of attention components emerges, introducing the theory of TVA framework, defined as the cognitive mechanism through which individuals distribute their visual focus to different areas of a scene, is a critical factor in understanding sustained attention. The experiment sought to delve into attentional processes among children with ADHD in contrast to their typically developing counterparts, who constituted the control group. It involved assessing various aspects of visual attention using the TVA framework, measuring sustained attention using specific tasks, and evaluating self-reported alertness [6]. The goal was to better understand how children with ADHD differ in terms of attentional abilities, response consistency, and subjective alertness, pointing out the importance on the cognitive characteristics associated with this neurodevelopmental disorder. It was found that children with ADHD had significantly lower visual processing speed (C) compared to children in the control group, indicating slower processing of visual information. Additionally, children with ADHD made significantly more errors on the visual attention task, suggesting a more inconsistent response pattern. However, it's important to note that there were no substantial variations observed between the ADHD group and the control group in terms of perceptual threshold ( $t_0$ ) and visual short-term memory (VSTM) ability (K). Likewise, there was no significant divergence found in the efficiency of top-down attentional selection ( $\alpha$ ) between these two groups [6].

To sum up, the study that used the TVA paradigm revealed that children with ADHD exhibit specific attentional deficits characterized by slower visual processing speed and increased lapses in attention. While their perceptual threshold, VSTM capacity, and top-down attentional selection appear to be intact, these findings emphasize the importance of addressing attentional processing speed in understanding ADHD-related attention deficits. These findings align with the notion that sustained attention is intricately linked to multiple attentional processes, including visual processing speed, within the TVA framework. They underscore the significance of considering these nuanced attentional components in the context of ADHD and its associated attention deficits. The study reminds that, within the broader examination of impaired sustained attention, researchers must recognize the individual contributions of various attentional processes, as they collectively shape the landscape of attentional challenges in children with ADHD.

## **2.2. Different Aspects of Impaired Sustained Attention in ADHD**

As the exploration deepens, the direction shifts towards unraveling the intricate tapestry of attention in ADHD, recognizing that sustained attention holds the key to understanding the broader spectrum

of attentional challenges within this multifaceted disorder. An experiment was carried out by Yıldırım Demirdöğen and his team, where they utilized eye-tracking technology during a classroom streaming video task to assess the sustained attention of children diagnosed with ADHD. The research questions addressed attention patterns, the influence of distractors, and the relationship between eye-tracking parameters, learning outcomes, and the severity of ADHD symptom. The study's primary focus was on children with ADHD, a population known for attention-related challenges [7]. To achieve its objectives, the research utilized eye-tracking technology to measure eye movement parameters while children engaged in a simulated classroom environment. The study included children with ADHD and controls and used eye-tracking parameters for assessing sustained attention. Two types of distractors (relevant and irrelevant) were introduced to evaluate their effects on sustained attention, following previous research [7]. The study also examined correlations between eye-tracking data, learning outcomes, and ADHD symptom severity, as done in previous studies. Findings showed that children with ADHD showed lower test scores in relevant domains (e.g., teachers and whiteboards) and higher test scores in irrelevant domains. This suggests challenges in maintaining attention in the intended area of focus, and potentially related deficits in shifting attention [7]. Moreover, children with ADHD demonstrated improved sustained attention after relevant area distractors but experienced decreased performance following irrelevant area distractors.

This highlighted the importance of attention-shifting deficits and the potential benefits of relevant distractors in enhancing sustained attention in this population. Additionally, the study identified positive correlations between longer fixation duration in the relevant area and better learning outcomes, emphasizing the significance of sustained attention for academic achievement. Additionally, studies have shown that domain-related tasks and tests results are inversely associated with inattentive cognitive problems and oppositional defiant symptoms in children with ADHD, improving researchers' understanding of the severity of ADHD symptoms and their impact on attention [7]. The study underlines that sustained attention, as a topic, can't be adequately understood without considering the nuanced factors of attention allocation and the influence of distractors. By connecting this evidence, it reinforces the argument that a comprehensive exploration of impaired sustained attention in ADHD necessitates an examination of the intricate web of attentional processes that collectively shape the landscape of this complex neurodevelopmental disorder.

To understand the intricacies of sustained attention deficits in ADHD, the study employs the Diffusion Model (DM) parameter, a sophisticated cognitive framework that provides insights into how attention processes unfold over time. Within the DM, attention diffusion occurs as cognitive resources are allocated across different aspects of a task, affecting the speed and accuracy of decision-making. This research addressed the central question of whether children with ADHD exhibit deficits in sustaining attention in the diffusional aspect [8]. The research employs a comprehensive methodology, including the use of DM parameters to analyze performance in CPTs. The study utilizes target and non-target stimuli with low discriminability to enhance interpretability of Signal Detection Theory (SDT) parameters. Additionally, it explores the impact of event rate and the control of difficulties on performance, although it acknowledges limitations such as unequal sample sizes and suggests that larger samples are needed for future research. Moreover, the study highlights the significance of using two-choice tasks over one-choice tasks for investigating sustained attention [8].

The findings suggest that children with ADHD show a modest processing bias and reluctance to respond during vigilance, which may be indicative of persistent attentional deficits. However, the more substantial effect observed is characterized by slow drift rates throughout the tasks, reflecting a slower accumulation of evidence to make decisions. The research strengthens the importance of DM parameters in understanding individual differences in cognition and shows that a reduced capacity to maintain bias towards engagement may not be the primary issue; instead, the focus should be on slower evidence accumulation [8]. These findings strengthen the argument that it is critical to understand the cognitive complexity underlying impaired sustained attention. By revealing the subtle processes of attentional diffusion, this study contributes to a more comprehensive understanding of

the attentional challenges associated with ADHD and guides researchers in tailoring interventions to address the cognitive factors involved in maintaining attention in daily life.

While more and more psychological approaches are made to explore sustained attention, it is crucial to focus on the physiological dimension as well. The research group led by Griffith and her colleagues studied the relationship between cardiac autonomic regulation, as measured by heart rate variability (HRV), and ADHD. This study investigates the relationship between cardiac autonomic regulation, as measured by HRV, and ADHD in a cohort of un-medicated children and adolescents. It aims to uncover potential differences in resting HRV, HRV changes during cognitive tasks, and their associations with ADHD symptoms and sustained attention performance. This study involved a large sample of children and adolescents, including those with and without ADHD, to explore HRV patterns. The study assessed resting HRV measures, including Low Frequency/High Frequency (LF/HF) ratio, i.e., a marker of autonomic dysregulation [9]. Then, HRV patterns were measured again 2 minutes after participants completed a standardized cognitive battery consisting of 12 tasks, including a 6-minute CPT to assess sustained attention. It also examined the impact of age, gender, and emotional regulation on these HRV findings [9].

The results challenged previous assumptions and showed no significant differences in resting HRV between the ADHD and control groups. However, they highlight a consistent elevation in LF/HF ratio among individuals with ADHD, particularly in male children. This intriguing finding underscores the potential utility of LF/HF ratio as an indicator of autonomic dysregulation in ADHD and its association with sustained attention deficits in both groups [9]. By elucidating the connection between autonomic dysregulation and ADHD-related attention deficits, this study offers a unique perspective on sustained attention that complements the cognitive and behavioral aspects previously explored. It reinforces the argument that sustained attention deficits in ADHD encompass a broad spectrum of factors, including physiological ones, and calls for a comprehensive approach to understanding and addressing these challenges in individuals with ADHD.

### **3. A Developmental Perspective of Impaired Sustained Attention in ADHD**

Moving away from exploring different aspects of impaired sustained attention in ADHD, it is reasonable to turn the attention to understanding how this critical cognitive function evolves over time in patients diagnosed with ADHD. Shift the focus from immediate attentional challenges to a broader, longitudinal perspective. In the study by Lewis and colleagues, the focus was on describing developmental trajectories of sustained attention in a longitudinal community sample of children aged 9 to 14 years, spanning an average of 7 years. The study aimed to investigate differences in sustained attention among children with sustained ADHD, children with ADHD in remission and typical controls and achieved this goal by utilizing a longitudinal design with three specific time points to investigate sustained attention in children aged 9 to 14. Wave 1 occurred during a 3-year follow-up when participants were between 9 and 11 years old., and wave 3 was conducted at a 6-year follow-up when the participants were aged 12 to 14 years. This longitudinal approach enabled the researchers to track and analyze changes in sustained attention performance within the same group of children as they progressed through this critical developmental period [10].

Results showed that sustained attention showed linear improvements in late childhood and early adolescence in both children diagnosed with ADHD and typically developing control children [10]. However, it is worth noting that children with both persistent and remitting ADHD diagnoses displayed levels of sustained attention comparable to those observed in controls who were approximately 1 to 3 years younger than their chronological age. This data hints at the possibility that children diagnosed with ADHD may encounter difficulties in catching up with the control group in terms of their sustained attention development, thereby lending support to the hypothesis during this specific period. Furthermore, the study examined specific components of sustained attention using ex-Gaussian measures, sigma and tau. Tau, representing response time variability and attention lapses, displayed significant improvements with age, while children with ADHD consistently exhibited

higher tau values than controls, suggesting ongoing attention difficulties [10]. This longitudinal perspective adds depth to researchers' understanding of how sustained attention challenges evolve over time, strengthening the argument that sustained attention in ADHD cannot be fully comprehended without considering the developmental trajectory and the nuanced factors at play. It urges researchers to adopt a dynamic and developmental lens when addressing sustained attention deficits in individuals with ADHD.

#### **4. Conclusion**

In summary, this comprehensive exploration of ADHD and its complex relationship with sustained attention provides insights into the multifaceted nature of this neurodevelopmental disorder. Throughout the investigation, a range of different factors were studied, including specific attentional components, cognitive processes, physiological markers, and developmental trajectories. The convergence of these insights underscores the ongoing concern that ADHD is far from a single entity; rather, it is the result of a dynamic interplay of cognitive, physiological, and developmental factors. The investigation demonstrates that understanding and addressing the challenges associated with impaired sustained attention in ADHD requires a multifaceted approach that recognizes the heterogeneity of attention deficits and the importance of considering children's developmental trajectories. As these complexities are being navigated, it is likely that this newfound knowledge can guide future diagnostic procedures, interventions, and support systems to meet the individual needs of children with ADHD. In essence, this exploration transcends the traditional boundaries of sustained attention research and invites researchers to adopt a holistic perspective that acknowledges the many components that contribute to attentional challenges in ADHD.

Although previous findings reviewed in this article provide valuable insights into the multifaceted nature of sustained attention deficits in children with ADHD, certain limitations must be acknowledged. First and most importantly, the studies included in this analysis relied primarily on cross-sectional designs, which may limit the ability to draw causal relationships or track the developmental trajectory of sustained attention over time. Longitudinal approaches may provide a more comprehensive understanding of how sustained attention develops in children with ADHD. Additionally, the diversity of tools and methods across studies may lead to differences in findings. Future studies may benefit from standardized assessment protocols to ensure consistency and comparability across studies. Looking ahead, several promising directions emerge for further research in this area. Incorporating advanced neuroimaging techniques may shed light on a further understanding of the neural mechanisms underlying sustained attention deficits in ADHD. Longitudinal studies with larger sample sizes and diverse populations may reveal more nuanced developmental trajectories and subtypes of sustained attention deficits. Additionally, intervention studies aim for strengthening the sustained attention in children that have ADHD could provide practical insights for tailoring treatment approaches. By addressing these limitations and pursuing these future directions, researchers can continue to advance people's understanding of ADHD and ultimately pave the way for more effective diagnostic and intervention strategies.

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