Visual Memory Deficits in Children With ADHD

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Abstract
Attention Deficit Hyperactivity Disorder (ADHD) is a common developmental disorder that occurs in childhood and is characterized by attention deficit, with or without high levels of hyperactivity-impulsivity. ADHD in children is accompanied by a variety of difficulties and problems related to language, higher executive functions such as working memory and emotion self-regulation, behavior and socialization. The purpose of this study was to investigate possible differences in visuomotor organization and visual memory between children with ADHD and typically developing children. The experimental group consisted of 54 children with ADHD symptoms (36 boys and 18 girls, mean age 9.2 years, range 6-11 years), who were matched in age, gender and handedness with an equal number of typically developing children who formed the control group. To assess visuomotor organization and visual memory, both groups were administered the Rey-Osterrieth complex figure and tested on its replication and mnemonic reproduction. The analysis revealed no significant differences in the performance of the two groups in copying the complex figure, but the ADHD students showed significantly lower performance than typically developing children in its mnemonic reproduction. This lower performance was observed regardless of whether the children of the ADHD group belong to the inattentive, hyperactivity-impulsivity, or the combined subtype. These results suggest that children with ADHD are likely to experience cognitive deficits that affect the visual memory system much more than that of visuomotor organization.

Keywords: ADHD, Children, Visual Memory, Visuomotor Skills

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common neuro-developmental disorders in school age children (Doernberg & Hollander, 2016; Price & Raffelsbauer, 2012). The core symptoms relate to inattention and/or hyperactivity/ impulsivity. Therefore, diagnosis is classified into three potential subtypes: inattentive, hyperactive-impulsive, and combined (American Psychiatric Association, 2013). The disorder can cause considerable impairment in essential domains of social, academic, and behavioral functioning (Beljan, Reuter, Ganas, & Hoover, 2012). More specifically, associated features of the disorder commonly include academic underachievement and language/learning disabilities (Carames, Irwin, & Kofler, 2022; Carruthers, Taylor, Sadiq, & Tripp, 2022), behavioral and social problems (Classi, Milton, Ward, Sarsour, & Johnston 2012; Modesto-Lowe, Chaplin, & Godsay, 2014), diminished fine/gross motor skills (Fliers et al., 2008) and perceptual skills (Racine, Majnemer, Shevell & Snider, 2008; Rosa Neto et al., 2015). ADHD also affects a range of cognitive functions, including visual memory (Barnett, Maruff, & Vance, 2005; Cortese et al., 2012; Shang & Gau, 2011) and visuomotor skills (Carames et al., 2022; Fabio, Andricciola, & Caprì, 2022).

Visual memory refers to the ability to store, retain, and recall visual information (Luck & Vogel, 2013). Children with ADHD often experience difficulties in maintaining and recalling visual information, which can affect their academic performance and social interactions (Alloway, Gathercole, Kirkwood, & Elliot, 2008). Visual memory deficits were also demonstrated in the study of Shang and Gau (2011), which involved 279 adolescents, their siblings who did not display the disorder, and typically developing peers. The ADHD group performed significantly lower on all visual memory tests compared to the other two groups. Barnett et al. (2005) examined children with ADHD of the combined type and found deficits in their visuospatial memory. Additionally, deficits in visual memory in children with ADHD appear to be confirmed by studies using fMRI. Cortese et al. (2012) in a meta-analysis of 55 studies examining the structure and function of the brain in children with ADHD, supported the presence of dysfunctions in brain areas related to visual memory.

In recent decades, scientific interest has also focused on the connection between visual-motor skills and ADHD. Studies have shown that children with ADHD experience difficulties in controlling visual stimuli (Jung, Woo, Kang, Choi & Kim, 2014) and in adapting their movements to these stimuli (Farhangnia, Hassanzadeh, & Ghorbani, 2020). Deficits in visual-motor skills were also indicated in a very recent study (Carames et al., 2022). Specifically, children with ADHD appear to have lower visual-motor cohesion and possibly issues with motor coordination, but they do not differ from typically developing children in terms of visual perception. Another very recent study (Şahan, Atasavun, & Çak, 2023) evaluated visual-motor skills in children with ADHD who had comorbidity with learning or psychiatric disorders and found deficits in motor skills and visual perception. These deficits were observed both in children with ADHD with comorbidity and in those with ADHD without comorbidity. The study by Mayes, Breaux, Calhoun, and Frye (2019) reports a high rate of dysgraphia in students with ADHD and autism, which could be attributed to deficits in visual-motor integration.

Based on these findings, the current study designed to compare the performance of children diagnosed with ADHD to that of their typically developing peers in areas such as visual memory and visuomotor skills. This comparison was made using the Rey-Osterrieth Complex Figure (ROCF) test, a tool originally crafted in 1941 by Rey for evaluating visual-

spatial construction skills and visual memory. Over the years, the ROCF test has become a preferred method in neuropsychological evaluations for both adults and children due to its complexity and efficacy in drawing upon visual-motor skills and memory (Lezak, 1983). The test requires children to copy and then recall from memory a complex design, serving as a multifaceted measure of various cognitive processes including perceptual and spatial skills, as well as metacognitive and memory functions. The ROCF test is particularly valued for its ability to generate detailed data and has been used extensively to investigate both typical (Vlachos & Karapetsas, 1994; Waber & Holmes, 1985) and atypical developmental patterns in children (Brandys & Rourke, 1991). Research has shown that while the ROCF test poses significant challenges to younger primary school children, older children and adults find it increasingly manageable, illustrating its developmental sensitivity (Karapetsas & Vlachos, 1997; Vlachos, Gaillard, Vaitsis & Karapetsas, 2013).

The purpose of this study was to investigate potential differences in visual memory and visuomotor skills between children with ADHD and typically developing children. Specifically, based on the results of previous research (Barnett et al., 2005; Cortese et al., 2012; Shang & Gau, 2011) we expected that children with ADHD would exhibit deficits in visual memory *(1st hypothesis)*. Additionally, according to other studies (Carames et al., 2022; Mayes et al., 2019; Şahan, Atasavun, & Çak, 2023) we hypothesized that children with ADHD would show deficits in visuomotor skills *(2nd hypothesis)*.

Method

Participants

In the experimental group, there were 54 children exhibiting symptoms of ADHD (36 boys and 18 girls, mean age 9.2 years, SD 1.7, age range 6-11 years) who met the diagnostic criteria according to the DSM-V (American Psychiatric Association, 2013). Of these, 24 children ($N = 24$) belonged to the Inattentive subtype, which meets the criterion of inattention but not hyperactivity/impulsivity, 9 children ($N = 9$) to the Hyperactive-Impulsive subtype, which meets the criterion of hyperactivity/impulsivity but not inattention, and 21 children ($N = 21$) displayed the Combined subtype, meeting both the criteria of inattention and hyperactivity-impulsivity.

The children in the experimental group were matched by age and gender with an equal number of typically developing children who formed the control group (36 boys and 18 girls, mean age 9.1 years, SD 1.8, age range 6-11 years). The participants of the control group were selected from the same schools attended by children with ADHD.

Materials and Procedure

To assess visual-motor skills and visual memory, the Rey-Osterrieth Complex Figure (ROCF) was administered using guidelines set forth by Osterrieth (1944) and Rey (1941, 1959). The figure was presented on a 30cm x 21cm white sheet of paper, with the base rectangle of the figure measuring 8.0cm x 5.5cm. Each child tested received an identical piece of paper to ensure uniformity.

Testing was conducted on an individual basis. After presenting the ROCF, the children were instructed to replicate the figure as accurately as possible, paying close attention to its intricate details. There were no time limits imposed. After the completions of the copying, the

paper was taken away. Subsequently, children were provided with a new sheet and asked to recreate the figure from memory.

Scoring

To analyze the data as outlined by Osterrieth (1944), the complex figure was segmented into 18 individual parts, each valued equally. The analysis involved counting the parts that children managed to reproduce, noting their locations relative to the overall figure, and assessing how accurately they were replicated. The scoring approach used was as follows: If a part was reproduced precisely and positioned correctly, it received a score of 2. A score of 1 was given if the part was correct but misplaced or if it was distorted or incomplete yet still recognizable and correctly positioned. A score of 0.5 was assigned if a part, though distorted or incomplete, was misplaced. A part that was unrecognizable or missing received a score of zero. The maximum score for each reproduced figure was 36 points. The duration taken to complete the figure was not considered in the scoring. Two judges independently evaluated all the drawings using these criteria, achieving an interrater reliability of 96%.

Results

In Table 1, the means, and standard deviations of the performances of children with ADHD and their typically developing peers during the copying and recall of the ROCF are presented. The statistical analysis revealed no significant differences in performance between typically developing children and the three subtypes of the ADHD children, in copying the complex figure ($F_{3,104} = 2.39$, $p > .05$). However, the students with ADHD showed statistically lower performance than their typically developing peers during the recall of the ROCF ($F_{3,104} = 14.18$, $p < .001$).

Group	Copy		Recall		Recall/Copy ratio
	M	*SD*	*M*	*SD*	%
ADHD-Inattentive subtype	22.46	8.65	12.67**	8.13	56.4%
ADHD- Hyperactive-Impulsive subtype	26.23	9.80	14.44**	8.21	55.1%
ADHD- Compined sybtype	23.48	8.16	11.50**	8.70	48.9%
Control	26.63	4.69	21.53**	5.57	80.8%

**$p < .001$

Table 1. Means and Standard Deviations of ROCF Copying and Recall Performance by Children With ADHD and Typically Developing Children.

Table 1 also displays the recall score relative to the copy score, expressed as a percentage. The ratio was significantly lower in all three subtypes of ADHD compared to typically developing children, indicating that children with ADHD faced more difficulties in the mnemonic reproduction of the ROCF than their controls. Specifically, the ratio shows that children with ADHD who exhibit the Inattentive subtype recall 56.4% of the information they have already copied, children of the Hyperactive-Impulsive subtype recall 55.1%, and children with the Combined subtype recall 48.9%, whereas children in the control group recall 80.8%.

Conclusions

The aim of the current research was to investigate potential differences in visual memory and visuomotor skills between children with ADHD and typically developing children. The results of our study showed that students with ADHD exhibited significantly lower performance than typically developing children in the mnemonic reproduction of the complex figure, confirming our first hypothesis. This lower performance was observed regardless of the predominant subtype of disorder the students with ADHD had.

Our findings align with those of recent studies (Andersen et al., 2012; Barnett et al., 2005; Shang & Gau, 2011) which report the presence of deficits in visual memory among children with ADHD. As argued by Swanson and Alloway (2012), these deficits manifest as difficulties in recognizing, storing, and recalling visual information, often affecting the students' ability to perform academic skills, such as reading and solving mathematical problems.

According to our second research hypothesis, we expected that children with ADHD would exhibit deficits in visuomotor skills. Although children with ADHD did perform slightly lower than typically developing children during the copying of the complex figure, the analysis did not reveal a statistically significant difference between the two groups, and thus did not confirm our second hypothesis. Our results do not align with those of recent studies (Carames et al., 2022; Mayes et al., 2019; Şahan, Atasavun, & Çak, 2023) that report the existence of visuomotor deficits in individuals with ADHD.

This discrepancy may indicate that while visuomotor deficits can be a characteristic of ADHD, they may not be consistently observable in every context. Specifically, the variations between our results and those of other studies could be attributed to differences in the age of the sample. In the study by Mayes et al. (2019), the sample included both children and adolescents, whereas our study exclusively involved children with an average age of 9.2 years. Another reason for the differences in our results might be the diagnoses received by the participants. For example, all children in our study met the criteria for ADHD diagnosis, while the study by Mayes et al. (2019) also included children with autism.

These factors highlight the complexity of ADHD as a disorder and suggest that its manifestations, particularly in visuomotor skills, may vary as a function of individuals' developmental stage and the specific methodologies used for assessment. This underscores the importance of considering these variables when designing studies and interpreting results in ADHD research. Additionally, it suggests the need for more nuanced approaches to understand the full scope of visuomotor impairments across different ages and settings.

The deficits in visual memory observed in our study, along with the visuomotor organization deficits highlighted in the literature review, may suggest that children with ADHD experience cognitive difficulties that predominantly affect visual memory more than visuomotor skills. This interpretation could be related to the role of working memory and processing speed. Children with ADHD appear to have limited capacity in working memory, which is crucial for the temporary storage and processing of information (Alloway & Alloway, 2010; Baddeley, 2012). This limitation may hinder their ability to retain and efficiently process visual information, thereby affecting visual memory and visuomotor skills.

Furthermore, the behavioral inhibition deficit theory suggests that individuals with ADHD struggle to inhibit irrelevant or unwanted information, which might explain the difficulties in visual memory and visual processing (Barkley, 1997). This inability to "filter out" extraneous visual information could make it difficult for them to focus on specific visual tasks and impact their visual memory.

It is important to note that our study has two limitations that prevent us from drawing more definitive conclusions. First, we should have matched the children with ADHD and the typically developing peers for their intellectual potential and general abilities. Second, the strategies used during the drawing tasks were not studied, although the copying and recall performances of the children with ADHD and the control subjects may have been influenced by these strategies. Despite these limitations, the results support the view that the two tests (copy and recall) of the Rey-Osterrieth Complex Figure test can contribute significantly and independently to the neuropsychological assessment of children with developmental disabilities (Vlachos & Karapetsas, 2003; Waber & Bernstein, 1995).

In summary, the results of our study suggest that children with ADHD might face cognitive deficits that affect the visual memory system more profoundly than the visuomotor organization system and reflect the organizational difficulties encountered by children with ADHD, confirming previous studies on deficits in higher executive functions, particularly in working memory (Barkley, 1997). Given the different aspects of visual memory, such as implicit versus explicit memory, which can both be assessed, it is recommended that further research with various mnemonic tasks should explore in depth the relationship between neurodevelopmental disorders like ADHD and the visual memory system. Understanding the relationships between visuomotor skills, visual memory, and ADHD in children could provide critical information for developing educational approaches. Integrating strategies that enhance visual memory and visuomotor skills, such as visualized instructions, organized visual materials, and specialized educational programs, could improve the academic performance and daily functioning of children with ADHD. This holistic approach underscores the importance of targeted interventions that respond to the specific cognitive profiles of these children, potentially leading to better educational outcomes and improved quality of life.

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