Working Memory Among Children with and Without ADHD: a Comparative Study

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Abstract

Children with Attention Deficit/Hyperactivity Disorder (ADHD) often experience serious cognitive deficits that can negatively impact their academic performance, which may lead in many cases to school dropout and Failure to attend school. Children with ADHD performance in different cognitive tasks probably represents impaired working memory components. The current study aimed to evaluate working memory components performance among children with and without ADHD. Using two different methodologies as the nature of this study necessitated, consisting of case study and statistical analysis, this study included a sample of 90 participants (30 typically developing children, and 60 children divided equally between mild and moderate ADHD), between the ages of 7 and 9, with an average age of around 8 years. Participants with ADHD were registered in several associations dedicated to supporting children with neurodevelopmental disorders in Beni Mellal region. Participants performance in all working memory components were assessed using four different tests dedicated to evaluate working memory components. The current study outcomes confirmed the presence of significant statistical differences between the scores of typically developing children and those with mild ADHD, then between typically developing children and those with moderate ADHD, and between children with mild ADHD and those with moderate ADHD.

Keywords: attention deficit/hyperactivity disorder (ADHD), working memory; phonological loop, visuo-spatial sketchpad, central executive

Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is a frequently diagnosed neurodevelopmental disorder, that is often diagnosed in childhood and usually persists into adolescence and adulthood (Salari et al., 2023). People with ADHD, and more specifically children, struggle to focus, often has difficulty sustaining attention in tasks and activities, and easily distracted. In addition, children with ADHD frequently suffer from lack of self-control and impulsive behaviors (APA, 2022).

Although ADHD is currently considered a lifelong condition (Klefsjo et al., 2021), symptoms of ADHD usually disappear with aging, so that the prevalence of this disorder among adults is approximately 2.5% (Simon et al., 2009), compared to 7.2% among children.

Baddeley (1992) indicated that the term working memory identifies a brain system that provides temporary storage and processing of the information for complex cognitive tasks such as learning, language comprehension, and reasoning. This definition has evolved from the earlier notion short-term memory system. This system can be divided into three components: the central executive, the visuospatial sketch pad, and the phonological loop. It appeared from previous studies that working memory participates in cognitive functioning, for example in reading (El-Mir, 2017, 2020, 2022; Naciri & El-Mir, 2019), reading comprehension ((Bouayad & El-Mir, 2022), and academic achievement (El-Mir, 2019). It has also been shown that its functioning declines in some neurodevelopmental disorders such as autism (Guennach & El-Mir, 2019) and specific developmental language disorders (Kriblou & El-Mir, 2021, 2024). Research has shown that working memory is one of the memory structures most affected by depression (Dahbi & El-Mir, 2020) and aging (El-Mir, 2021). In addition, it has been revealed that working memory functioning is affected by emotional state (Bousbaiat & El-Mir, 2021; El-Mir, 2018). Working memory training improves working memory capacity in children with autism spectrum disorder (Sedjari & El-Mir, 2021, Sedjari, El-Mir & Souirti, 2023), and children with dyslexia (Ammour & El-Mir, 2023). The effect of cognitive training on several cognitive processes, including working memory, has also been confirmed (El-Mir & Sedjari, 2022). Cognitive training has also been shown to improve working memory performance in people with schizophrenia (El-Haddadi & El-Mir, 2022).

The central executive in this model facilitates the performance of working memory through directing attention to relevant information only, and suppressing irrelevant information, as well as switching attention between different processes and inhibiting reactions to irrelevant information (Miller-Cotto & Gordon, 2024). While visuospatial sketch pad refers to a system that allows us to hold and manipulate visual and/or spatial information accessed from long-term memory or received from our senses (McGonnell et al., 2024). Hughes (2024) acknowledged that the phonological loop is a short-term system dedicated for verbal or verbalizable information, and includes the phonological store, which is a core passive component that maintains representations of verbal items in their phonological form for approximately 2 seconds.

Bullard and others (2024) mentioned that children with attention-deficit/hyperactivity disorder (ADHD) often experience deficits in working memory, as well as behavioral inhibition and self-control (Alaoui Belghiti & El-Mir, 2023). Children with ADHD usually demonstrate difficulties on many different neuropsychological tests, However, this does not mean necessarily that this pattern reflects a large number of distinct deficits, while this may represent a broad impact of small number of deficits (Kofler et al., 2024).

Study Aims and Importance

In this study we aim to evaluate the performance of working memory among children with and without Attention Deficit/Hyperactivity Disorder, taking into consideration the

importance of studying the relationship between ADHD and working memory, and the lack of Arabic studies about this topic. This study would be a value added to the Arabic academia and would probably provide clearer and more accurate information about this subject in order to facilitate the research and clinical interventions for children with ADHD.

Throughout this study we will try to figure out:

- Evaluating the performance of working memory among children with and without ADHD;
- Examining the main working memory challenges faced by children with ADHD compared to their typically developing peers;
- promoting the potential for more clinical studies;
- Identifying some tests and pointing out their applicability and difficulties for these specific participants.

Study Problematics

Day to day life and clinical practice in Morocco prove that children with ADHD face severe difficulties in different contexts (especially at school), which makes their academic performance far below the expected from them. Hyperactivity represents a fundamental element in school dropout and Failure to attend school at some cases, while besides attention, other intellectual functions deficits (such as working memory, inhibition, concentration, decisions making) are probably a corner stone in this case as well, knowing that attention requires coherent working memory performance. Children with ADHD are usually considered naughty and undisciplined students, and these judgments make the present topic a priority for psychologists.

The present study focuses on early educational periods, as this period necessitates good cognitive and meta-cognitive performance, while working memory deficits constitute many behavioral symptoms of ADHD (Al-Saad et al., 2021).

The current study took into consideration some older studies outcomes about working memory and ADHD, as Ramos and others (2020) conducted a meta-analysis study on forty-nine other studies comparing children and adolescents with and without ADHD, and the outcomes indicated poorer verbal working memory performance in those with ADHD. In the same vein, Kofler and others (2020) have confirmed in their study that ADHD is associated with profoundly impaired central executive functioning, as well as the significant smaller impairment in visuospatial short-term memory, while the phonological short-term memory deficits was not significantly impaired as mentioned in this study. Children with ADHD showed impairments in working memory reordering and updating (Fosco et al., 2020). Another study conducted by Schweitzer and others (2006) compared adults with and without ADHD, and confirmed that gender differences in performance of working memory were evident on some measures, and regardless of group (participants with ADHD and Normal Control adults) males performed better than females.

This study aims to answer the following questions:

Are there any statistical differences in working memory performance between children with mild Attention Deficit/Hyperactivity Disorder (ADHD) and typically developing children?

Are there any statistical differences in working memory performance between children with moderate ADHD and typically developing children?

Are there any statistical differences in working memory performance between children with mild and moderate ADHD and typically developing children?

Study Hypotheses

Hypothesis 1: We assume that there are statistically significant differences between the scores of typically developing children and children with mild ADHD on tests of working memory components.

Hypothesis 2: We assume that there are statistically significant differences between the scores of typically developing children and children with moderate ADHD on tests of working memory components.

Hypothesis 3: We hypothesize that there are statistically significant differences between the scores of children with mild and moderate ADHD on tests of working memory components.

Materials and Methods

Sample Characteristics

The current study's sample consisted of 90 children, divided into three groups, every group included 30 participants; the first group consisted of 30 children diagnosed with mild attention deficit hyperactivity disorder (ADHD), including 18 boys and 12 girls, and the second group consisted of 30 children diagnosed with moderate ADHD, 21 of them are males and 9 females, while the third group comprised 30 typically developing children, randomly selected as a control group in this study.

It is important to note that participants exclusion took into consideration any signs of autism spectrum disorder (ASD) or intellectual disability, because these cases may represent ADHD as comorbidity, and impairments in working memory could be related to other disorders than ADHD.

The participants in the current study were already diagnosed with ADHD by psychiatrists, and the ages in all three groups ranged from 7 to 9 years. Children with ADHD were registered in four associations dedicated to supporting children with neurodevelopmental disorders in Beni Mellal region and the Fquih Ben Salah province, and more specifically in Al-Youssoufia Federation of Associations for People with Motor Disabilities in Morocco; Al-Raihan Association for Special Needs in Souk Sebt Ouled Nemma; Sidi Aissa Association for Disabled Persons; and Al-Raafa Association for Special Needs.

Methodology

The present study necessitated the usage of two different methodologies, starting with case study approach, in which we confirmed the diagnosis of children with Attention Deficit Hyperactivity Disorder (ADHD), and determined their disorder's severity based on the criteria mentioned in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders-Text Revised (DSM-5-TR) by the American Psychiatric Association (APA), in this stage we used various techniques, including direct and indirect observation, clinical interviews with the participants, their parents, and specialized educators (knowing that these cases had been previously diagnosed with ADHD). The second methodology used in this study was statistical analysis, in order to evaluate the performance of different components of working memory among the sample, which was conducted using Statistical Package for the Social Sciences program (SPSS), and more specifically, utilizing Independent Samples T-Test to identify statistical differences between the scores of these three groups (typically developing children, children with mild ADHD, and children with moderate ADHD).

Tools and Techniques

The current study executed a range of tools and techniques, described as follows:

Observation: using both direct and indirect observation methods.

Medical files: these files contain medical and quasi-medical information and reports about the participants' conditions.

Clinical Interview: in order to collect case study data and tests conduction.

Working Memory Tests: This study used working memory tests developed by Dr. Mohamed El Mir, obtained from the website (elmirmohammedmemorypsy.com). These tests measure the performance of subcomponents of working memory based on Baddeley and Hitch's (1974) model, including Phonological Loop Test, Visuospatial Sketchpad Test, and Central Executive Tests, all of which were administered to the study sample.

Tests Description

In order to assess the capacity of working memory components in terms of storage and processing phonological and visuospatial information in the present study we conducted four tests:

Digit Span Test: This test is the part of Wechsler Intelligence Scale that evaluates the capacity of phonological loop, this involves presenting sequences of numbers ranging from two to nine digits, at a rate of one digit per second. The number of digits in the sequence increases with each successful trial, and the test ends when the participant fails to recall the sequences correctly in two consecutive attempts. The participant must remember and recite the digits in the order they were presented. So that, the capacity is determined by the longest sequence of digits recalled accurately (Bousbaiat & El-Mir, 2021).

Corsi Block-Tapping Test: This test measures the capacity of the visuospatial sketchpad, another component of working memory. This component assesses the ability of tracking the spatial sequence of objects. The test consists of nine cubes arranged randomly on a board. In this test the researcher indicates a sequence of cubes, and the participant must recall the cubes in the same order, while it starts with practice trials before the actual test, which ends if the participant fails to recall the sequence correctly in two consecutive attempts. The capacity is determined by the number of cubes correctly recalled in the final successful attempt (Bousbaiat & El-Mir, 2021).

Digit Span Backwards Test: This test is dedicated to measure the working memory's ability to process and reorganize information, and is part of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV). This involves presenting sequences of numbers, starting from two digits and extending up to nine digits. The researcher askes the participant to recall the numbers in reverse order. The participant's performance is evaluated based on the last sequence of numbers correctly recalled in reverse (Bousbaiat & El Mir, 2021).

Adaptive Digit Span Test: This test is designed to provide an accurate measurement of working memory capacity, independently of any strategies or skills used by the participant. This test measures the working memory's ability to store and process information while minimizing the use of memory strategies, such as verbal repetition. This involves presenting sequences of letters ending with a number, and the participant required to remember the number. After several sequences, the participant must recall the numbers in the same order they were given, and the test ends if the participant fails to recall the sequences correctly in

two consecutive attempts. The result of this test is based on the number of digits correctly recalled (El Mir, 2022).

Study Limits

Spatial limits: This study was conducted in several associations dedicated to children with neurodevelopmental disorders in Beni Mellal region and the Fquih Ben Salah province, and exactly within the following associations: Al-Youssoufia Federation of Associations for People with Motor Disabilities in Beni Mellal, Al-Raihan Association for Special Needs in Souk Sebt Oulad Nemma, Sidi Aissa Association for Disabled Persons, and Al-Ra'fa Association for Special Needs.

Temporal limits: This study took place between December 12, 2023, and May 23, 2024. During this period, we reassessed the children to verify the diagnostic criteria outlined in the revised Fifth Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR), as well as the assessment of working memory capacities among children with ADHD alongside with typically developing children.

Human limits: Recognizing that a larger sample size enhances the accuracy and reliability of results, we included as many children as possible in this study. The sample consisted of 90 children, evenly distributed among those with mild ADHD, moderate ADHD, and typically developing children.

Results

Reminder of the first study hypothesis

We assume that there are statistically significant differences between the scores of typically developing children and children with mild ADHD on tests of working memory components.

After applying working memory components tests on the sample to assess their capabilities, we collected the outcomes and calculated the statistical significance of the differences between the average scores of typically developing children and those with mild ADHD on these tests. The aim was to evaluate the participants' capacity to store and process information in working memory. This analysis was conducted using the Statistical Package for the Social Sciences (SPSS), specifically using the independent samples t-test. After analyzing the data, we came up with several findings, which are described in the following table.

Table 1

Results of t-test for the significance of differences between typically developing children and children with mild ADHD in working memory tests

Components of working memory	Sample	Average	Standard deviation	T-test	Sig (bilateral)	Level of Sig
Phonological loop (Normal)	Mild ADHD	3,73	,69	-9,30	,000	**0,01**
	Normal children	5,37	,67			
Visuospatial sketchpad (corsi)	Mild ADHD	3,37	,72	-7,64	,000	**0,01**
	Normal children	4,63	,56			
Central executive (Inverse)	Mild ADHD	2,33	,48	-6,55	,000	**0,01**
	Normal children	3,37	,72			
Central executive (Modified)	Mild ADHD	2,20	,41	-9,82	,000	**0,01**
	Normal children	3,77	,77			

The table above represents the results of an independent samples t-test, comparing the scores of typically developing children and children with mild Attention Deficit Hyperactivity Disorder (ADHD) on tests assessing components of working memory. The results can be described as follows:

Phonological Loop Test Results

The results of phonological loop test (Digit Span Test) indicate that the average number of correct responses among children with mild ADHD was (3.73), with a standard deviation of (0.69). In contrast, typically developing children had an average of (5.37) correct responses, with a standard deviation of (0.67). This indicates a statistically significant difference in the average scores between the two groups for this component, with a t-test value of (-9.30) and a highly significant p-value of (0.00), at the (0.01) significance level.

Visuo-Spatial Sketchpad Test Results

The results of the visuo-spatial sketchpad test (Corsi Block-Tapping Test) show that children with mild ADHD had an average of (3.37) correct responses, with a standard deviation of (0.72). Meanwhile, typically developing children scored an average of (4.63) correct responses, with a standard deviation of (0.56). This suggests a statistically significant difference in mean scores between the two groups in terms of this component, with a t-test value of (-7.64) and a highly significant p-value of (0.00), at the (0.01) significance level.

Central Executive Tests Results

First Test (Digit Span Backwards Test)

The first central executive test reveals that children with mild ADHD had an average of (2.33) correct responses, with a standard deviation of (0.48), compared to an average of (3.37) correct responses among typically developing children, with a standard deviation of (0.72). This indicates a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-6.55) and a highly significant p-value of (0.00), at the (0.01) significance level.

Second Test (Adaptive Digit Span Test)

In this central executive test, children with mild ADHD scored an average of (2.20) correct responses, with a standard deviation of 0.41. On the other hand, typically developing children had an average of (3.77) correct responses, with a standard deviation of (0.77). This highlights a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-9.82) and a highly significant p-value of (0.00), at the (0.01) significance level.

The previous results confirm the first hypothesis, which assumed the existence of statistically significant differences between the scores of typically developing children and those with mild ADHD. These differences observed in the performance of the phonological loop, visuo-spatial sketchpad, and central executive functions reflect the specific cognitive challenges faced by these children in tasks requiring working memory. Supported by statistical significance, including t-test and p-values, these outcomes emphasize the need for

targeted interventions aimed at enhancing these cognitive dimensions for children with mild ADHD.

Reminder of the second study hypothesis

We assume that there are statistically significant differences between the scores of typically developing children and children with moderate ADHD on tests of working memory components.

Throughout conducting working memory components tests on the study sample to assess their abilities, we collected the results and calculated the statistical significance of differences between the average scores of typically developing children and those with moderate ADHD on these tests. The aim was to evaluate the participants' ability to store and process information in working memory. This was done using SPSS program, and more specifically, independent samples t-test. Data analysis showed several findings, as described in the following table:

Table 2

Results of t-test for the significance of differences between typically developing children and children with moderate ADHD in working memory tests

Components of working memory	Sample	Average	Standard deviation	T-test	Sig (bilateral)	Level of Sig
Phonological loop (Normal)	Moderate ADHD	2,73	,98	-12,16	,000	**0,01**
	Normal children	5,37	,67			
Visuospatial sketchpad (corsi)	Moderate ADHD	2,37	,49	-16,75	,000	**0,01**
	Normal children	4,63	,56			
Central executive (Inverse)	Moderate ADHD	1,40	,50	-12,32	,000	**0,01**
	Normal children	3,37	,72			
Central executive (Modified)	Moderate ADHD	1,20	,41	-16,08	,000	**0,01**

This table represents the results of an independent samples t-test, comparing the scores of typically developing children and children with moderate ADHD on tests assessing components of working memory. The main findings are as follows:

Phonological Loop Test Results

The results of the phonological loop test (Digit Span Test) indicate that the average number of correct responses among children with moderate ADHD was (2.73), with a standard deviation of (0.98). In contrast, typically developing children had an average of (5.37) correct responses, with a standard deviation of (0.67). This indicates a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-12.16) and a highly significant p-value of (0.00), at the (0.01) significance level.

Visuo-Spatial Sketchpad Test Results

The results of the visuo-spatial sketchpad test (Corsi Block-Tapping Test) show that children with moderate ADHD had an average of (2.37) correct responses, with a standard deviation of (0.49). Meanwhile, typically developing children scored an average of (4.63) correct responses, with a standard deviation of (0.56). This suggests a statistically significant difference in mean scores between the two groups for this component, with a t-test value of (-16.75) and a highly significant p-value of (0.00), at the (0.01) significance level.

Central Executive Tests Results

First Test (Digit Span Backwards Test): The first central executive test used reveals that children with moderate ADHD had an average of (1.40) correct responses, with a standard deviation of (0.50), compared to an average of (3.37) correct responses among typically developing children, with a standard deviation of (0.72). This indicates a statistically significant difference in mean scores between the two groups for this component, with a t-test value of (-12.32) and a highly significant p-value of (0.00), at the (0.01) significance level.

Second Test (Adaptive Digit Span Test): In the second central executive test, children with moderate ADHD scored an average of (2.20) correct responses, with a standard deviation of (0.41), in comparison with typically developing children who had an average of (3.77) correct responses, with a standard deviation of (0.77). These outcomes highlight a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-16.08) and a highly significant p-value of (0.00), at the (0.01) significance level.

These findings confirm the second hypothesis, which suggested the existence of statistically significant differences between the scores of typically developing children and those with moderate ADHD. These findings indicate that children with moderate ADHD show significantly lower performance across various working memory components compared to typically developing children. These important differences observed in the phonological loop, visuo-spatial sketchpad, and central executive functions suggest that the challenges are even clearer in this group. The strong statistical significance of these results confirms the need for specific interventions to enhance working memory capacities in children with moderate ADHD, particularly in the dimensions where they show the most substantial deficits.

Reminder of the third study hypothesis: We hypothesize that there are statistically significant differences between the scores of children with mild and moderate ADHD on tests of working memory components.

After the application of working memory components tests on the study sample to evaluate their abilities, we could collect the outcomes and calculate the statistical significance of the differences between the average scores of children with mild ADHD and those with moderate ADHD on these tests. The goal in this case was to evaluate the participants' capacity to store and process information in working memory. This analysis was conducted using the SPSS, and specifically using independent samples t-test. After the data analysis, we could get several findings as described in the following table:

Table 3

Results of the t-test for the significance of differences between children with mild ADHD and children with moderate ADHD in working memory tests

Components of working memory	Sample	Average	Standard deviation	T-test	Sig (bilateral)	Level of Sig
Phonological loop (Normal)	Mild ADHD	3,73	,69	4,57	,000	**0,01**
	Moderate ADHD	2,73	,98			
Visuospatial sketchpad (corsi)	Mild ADHD	3,37	,72	6, 30	,000	**0,01**
	Moderate ADHD	2,37	,49			
Central executive (Inverse)	Mild ADHD	2,33	,48	7,39	,000	**0,01**
	Moderate ADHD	1,40	,50			
Central executive (Modified)	Mild ADHD	2,20	,41	9,52	,000	**0,01**
	Moderate ADHD	1,20	,41			

The previous table represents the results of an independent samples t-test, comparing the scores of children with mild ADHD and those with moderate ADHD on tests assessing components of working memory, and the results are as follows:

Phonological Loop Test Results

The results of phonological loop test (Digit Span Test) indicate that the average number of correct responses among children with moderate ADHD was (3.73), with a standard deviation of (0.69). On the other hand, children with mild ADHD had an average of (2.73) correct responses, with a standard deviation of (0.98). This indicates a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-12.16) and a highly significant p-value of (0.00), at the (0.01) significance level.

Visuo-Spatial Sketchpad Test Results

The results of visuo-spatial sketchpad test (Corsi Block-Tapping Test) show that children with moderate ADHD had an average of (3.37) correct responses, with a standard deviation of (0.72). Meanwhile, children with mild ADHD scored an average of (2.37) correct responses, with a standard deviation of (0.49). This suggests a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-16.75) and a highly significant p-value of (0.00), at the (0.01) significance level.

Central Executive Tests Results

First Test (Digit Span Backwards Test): The first central executive test reveals that children with moderate ADHD had an average of (2.33) correct responses, with a standard deviation of (0.48), compared to an average of (1.41) correct responses among children with mild ADHD, with a standard deviation of (0.50). This indicates a statistically significant difference in average scores between the two groups for this component, with a t-test value of (-12.32) and a highly significant p-value of (0.00), at the (0.01) significance level.

Second Test (Adaptive Digit Span Test): In the second central executive test, children with moderate ADHD scored an average of (2.20) correct responses, with a standard deviation of (0.40). Similarly, children with mild ADHD had an average of (2.20) correct responses as well, yet with a standard deviation of (0.41). Despite the identical average scores, there is still a statistically significant difference between the two groups, with a t-test value of - (16.08) and a highly significant p-value of (0.00), at the (0.01) significance level.

Based on the outcomes showed above, we conclude that the third hypothesis is confirmed, indicating statistically significant differences between the scores of children with mild ADHD and those with moderate ADHD. The results show that children with mild ADHD perform relatively better on working memory tasks compared to children with moderate ADHD, as confirmed through the significant differences in their scores across various components. These results suggest that the severity of ADHD symptoms may be directly related to certain aspects of working memory performance, with worse performance associated with greater severity of the disorder. This underscores the need for differentiated intervention strategies that address the varying cognitive challenges faced by children according to the severity of their ADHD.

Discussion

The outcomes of this study could provide fairly clear answers to the main problematic that this investigation aimed to address, and the hypotheses we assumed in this study were confirmed. Starting with the first hypothesis, which assumed statistically significant

differences between the scores of typically developing children and those with mild ADHD in tests of working memory components (the phonological loop, visuospatial sketchpad, and central executive), and the outcomes validated this assumption. The four tests taken from Dr. El-Mir Mohamed's website showed that the minimum and maximum number of correct answers for typically developing children in the phonological memory test ranged between 3 and 7 correct answers out of 10 attempts, with an average of 5.37 correct answers.

In the Corsi test for the visuospatial sketchpad, correct answers ranged between 3 and 6, with an average of 4.63 answers, while in the digit span backwards test for the central executive, correct answers ranged between 3 and 5, with an average of 3.37 answers. In the adaptive digit span test for the central executive, correct answers ranged between 3 and 5, with an average of 3.77 answers. In contrast, the correct answers for children with mild ADHD in the same tests ranged between 2 and 5 correct answers in the phonological memory test, with an average of 3.73 answers. In the Corsi test for the visuospatial sketchpad, correct answers ranged between 2 and 4, with an average of 3.37 answers, while in the digit span backwards test for the central executive, correct answers ranged between 2 and 3, with an average of 2.33 answers. Meanwhile, in the adaptive digit span test, correct answers ranged between 3 and 5, with an average of 2.20 answers.

The comparison of average scores of the two groups in these tests, showed statistically significant differences favoring typically developing children, with a p-value of 0.00 at the 0.01 significance level. These results align with previous studies that have shown impaired working memory performance in children with ADHD compared with typically developing children, as the meta-analysis study conducted by Ramos and others (2020) on 49 previous studies confirmed the presence of deficits in the phonological loop among children suffering from this disorder. Similarly, the study done by Fusco and others (2020) demonstrated a working memory deficit in the same vein, particularly in updating and reorganization. However, the study of Kofler and others (2020) concluded that ADHD is significantly associated with impairment in the central executive, with less impairment in the visuospatial sketchpad and no statistically significant deficits in the phonological loop, which does not accurately match our study's findings, while our study showed a deficit in the performance of the phonological loop, and this may be due to differences in the sample's age or the tests used.

The results of the current study had confirmed the second hypothesis as well, as it showed statistically significant differences between the scores of typically developing children and those with moderate ADHD. The correct answers scores of children with moderate ADHD in these tests ranged between 2 and 3 correct answers, with an average of 2.73 in the phonological memory test, between 2 and 3 correct answers, with an average of 2.37 in Corsi test for the visuospatial sketchpad, between 1 and 3 correct answers, with an average of 1.40 in the digit span backwards test, and between 1 and 2 correct answers, with an average of 1.20 in the adaptive digit span test. When comparing the average scores of typically developing children with those of children with moderate ADHD in these tests, the significant difference between the two groups is clearly evident, with statistically significant differences favoring typically developing children, with a p-value of 0.00 at the 0.01 significance level. These results support previous studies that confirmed impaired working memory performance in children with ADHD, including the studies mentioned previously and related to the first hypothesis.

The present study findings showed a significant difference between the scores of children with mild ADHD and those with moderate ADHD in working memory tests, which confirmed the third and final hypothesis. These differences were statistically significant, favoring children with mild ADHD, with a p-value of 0.00 at the 0.01 significance level. It is important to recognize that this hypothesis provides qualitative and novel data on the impact of ADHD symptom severity (mild vs. moderate) on the performance of working memory

components, which has not been extensively covered in previous studies (based on the research we conducted). These results contribute to enriching scientific knowledge on the impact of ADHD severity on working memory performance and enhance our understanding of working memory performance in children with ADHD, which has not been adequately addressed in previous studies.

Conclusion

The aim of this study was to investigate the capacity of working memory components in storing and processing phonological and visuospatial information in a sample of children with Attention-Deficit/Hyperactivity Disorder (ADHD) compared with typically developing children, besides determining the impact of symptoms severity on these memory components' performance. In order to achieve this goal, we visited several associations dedicated to children with neurodevelopmental disorders and reviewed the medical files of participants diagnosed with ADHD. Subsequently, we invested case study approach to confirm their diagnosis of ADHD, excluding other neurodevelopmental disorders such as autism spectrum disorder (ASD) and intellectual disability.

A sample of 60 children was selected, divided into two groups: 30 children with mild ADHD and 30 children with moderate ADHD, aged between 7 and 9 years, in addition to 30 randomly selected typically developing children of the same age range as a control group.

Statistical analysis of the current study outcomes of working memory components tests for the three groups confirmed all three hypotheses assumed in this study. Significant statistical differences were evident between the scores of typically developing children and those with mild ADHD, and the results were the same for the comparison between typically developing children and those with moderate ADHD, in the same vein, the findings proved the existence of significant statistical differences between the performance children with mild and moderate ADHD on the same tests.

Moving forward, future studies conducted under more favorable conditions may yield even more reliable and practical outcomes. Subsequent research would open to more extended research in terms of larger sample sizes, the disorder severity, and gender variable.

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