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**Assessment of Working Memory in Students with Attention-Deficit/Hyperactivity Disorder (ADHD)**

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**Abstract:**

**This study aims to evaluate the working memory of children with ADHD. To achieve this goal, the study tested the hypothesis that students with ADHD experience impairments in working memory. A quasi-experimental design was employed. The Conners Scale and Baddeley's Working Memory Test were administered to a sample of five primary school students aged 8–10. The study found that students with ADHD exhibit working memory impairments.**

**Keywords: working memory, attention-deficit/hyperactivity disorder (ADHD).**

**Introduction:**

Memory is one of the most important factors influencing all aspects of human behavior. It enables people to retain past experiences and draw on them throughout their lives. Memory enables people to take in experiences, encode and process them, store them and retrieve them when needed. Memory plays a key role in many areas of behavior, such as speaking, writing, reading and performing various tasks and skills.

Baddeley defines memory as 'the process by which an individual stores and retrieves information'. There are several types of memory, including working memory. (Robert(1999- 2004), p160) defines this as 'a core mental function that clearly relies on frontal systems', evident when patients with frontal lobe damage exhibit weaknesses in the brain areas responsible for language.

Working memory comprises three components: the central executive, the phonological loop and the visuospatial sketchpad. The central executive coordinates the different processes operating within working memory. It allocates cognitive resources between processing and storage by using and monitoring two subsidiary systems. The phonological loop stores spoken language material in an organized way for a limited time. This system has two parts: a phonological storage component (the

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phonological register), which temporarily holds verbal information that has been read or heard; and a rehearsal system (the articulatory rehearsal component), which subvocally refreshes and phonologically encodes information in the phonological store. Verbal control involves the activation and planning of verbal material.

Phonological storage refers to the phonological representation held in memory and activated when listening to and understanding spoken language. The visuospatial sketchpad is responsible for retaining and processing visual and spatial information, as well as handling mental imagery. This system itself comprises two subsystems: a visual window and a system that activates mental images.

In a study of working memory, Marusiak and Janzen examined the abilities of children with Attention-Deficit/Hyperactivity Disorder (ADHD). They measured working memory using the Stanford-Binet, Fifth Edition (SBV). Their main finding was that children with ADHD performed much worse than typically developing children on working memory tasks, particularly on visuospatial working memory tasks compared with verbal ones (Marusiak (2005), p 20).

Working memory impairments may result from disorders associated with attention difficulties. Attention is the first step in acquiring educational experiences; it enables pupils to focus on information presented during lessons. Any distraction can cause a loss of focus, making self-regulation difficult and leading to hyperactive behavior, which is a major factor in poor academic performance.

ADHD is defined as ‘a neurobiological behavioral disorder characterized by chronic, developmentally inappropriate levels of inattention and impulsivity, and in some cases, hyperactivity’. It is thought to result from reduced levels of certain neurotransmitters, which lower the brain’s efficiency in core functions such as attention and behavioral regulation (Maktoum (2011), p15). It often persists into adulthood. Shard, Naglaa, Raslan and Soma El-Fishawy (2011) define it as “a neurobehavioral disorder caused by dysfunction in brain structure and function that affects behavior, thoughts and emotions”. It is a disorder that can be managed, and whose symptoms can be alleviated to help children learn self-control and boost their self-confidence. Children with ADHD are most often identified between the ages of 5 and 9” (Moussa ( 2007), p9).

“ Kamal, (2001)” conducted a study examining the impact of attention disorders on verbal working memory in a group of primary school pupils. He employed the Clinical Observation Checklist for Child Behavior (DSM-III) and the Digit Pairing Test, which was developed by Al-Samadoni (1990). The sample comprised two groups of pupils identified as having attention problems: the first group included 36 boys and girls who scored highly on the diagnostic instruments, and the second group included 36 boys and girls who scored low. Both groups were given individually administered tests of auditory word and digit recall sequences to measure verbal working memory.

The results showed statistically significant differences between pupils with attention disorders and those without on the verbal working memory measures. The findings

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indicated that attention disorder negatively affects the working memory system of affected pupils (Kamal, (2001)).

Based on previous studies, theoretical background and field observations, the current research was prompted by the following question:

**-Do pupils with attention deficit/hyperactivity disorder (ADHD) suffer from working memory impairment?**

### **1. Hypothesis:**

To answer this question, the following hypothesis was formulated:  
Pupils with ADHD suffer from working memory impairment.

### **2. Study objectives:**

This study aims to:

- assess working memory in pupils with attention-deficit/hyperactivity disorder (ADHD).
- Highlight ADHD and its effect on working memory.
- Identify behaviors and strategies that can help parents and teachers to reduce hyperactivity and inattention.

### **3. Significance of the study:**

This study addresses a widespread problem among primary school pupils: attention-deficit/hyperactivity disorder (ADHD), as noted by many studies.

The primary stage is critical to a pupil's academic success or failure; therefore, early attention to and intervention in problems is necessary in order to treat them and reduce their severity.

### **4. Definition of terms:**

**4-1. Attention-deficit/hyperactivity disorder (ADHD):** A pattern of purposeless motor activity manifested by restlessness, an inability to concentrate or pay attention, and impulsive problem-solving without focus. This can lead to poor communication skills, difficulty forming successful social relationships and lower academic achievement (Hatem (2008)).

Operational definition: Scores obtained on the Conners Rating Scale, as completed by parents and teachers.

**4-2. Working memory:** Working memory is a flexible and complex information-processing system. Baddeley (Baddeley(1992), p51) defines it as a mental system in which information currently in use is temporarily stored and processed for reasoning, comprehension, and learning.

Operational definition: Scores obtained by participants on Baddeley's working memory test.

### **5-Methodological procedures of the study:**

**5-1. Preliminary (pilot) study:** This study involved visiting several educational

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Institutions in the Tizi Ouzou province to test the suitability of the instruments, identify any difficulties with their application, and find appropriate solutions. The aim was to identify weaknesses in the procedures for administering the data-collection tools, revise the instructions, estimate the time needed for the fieldwork and confirm the presence and accurate formulation of the problem under study. We also assessed teachers' willingness and readiness to cooperate with the study procedures.

Finally, we selected Muhammad Bouchiba Primary School in Tibcharine, Mizrana municipality, Tigzirt district, Tizi Ouzou province. There, we met the available teachers and arranged for their assistance with test administration and verifying the availability of the study population.

### **5-2. Research design:**

As the research design determines how the study is conducted, we adopted a descriptive approach. This is a systematic scientific method of analyzing and interpreting a specific phenomenon or problem, and portraying it quantitatively by collecting, classifying and analyzing quantified data about the phenomenon. We chose this method because it is suitable for assessing the working memory of pupils with attention-deficit/hyperactivity disorder.

### **5-3. Study sample:**

The sample was purposively selected and consisted of five cases aged 8–10 years . Selection was based on the Conners scale.

**Table 1: shows the characteristics of the sample:**

| <b>Cases</b> | <b>Age</b> | <b>Gender</b> | <b>Grade</b>               | <b>Conners scale results:</b> | <b>Comorbid disorders</b> |
|--------------|------------|---------------|----------------------------|-------------------------------|---------------------------|
| Case 1       | 10 years   | Male          | level: 5th grade (primary) | 48.77%                        | none                      |
| Case 2       | 8 years    | Female        | 3rd grade (primary)        | 59.52%                        | none                      |
| Case 3       | 10 years   | Male          | 5th grade (primary)        | 75.04%                        | none                      |
| Case 4       | 10 years   | Male          | 5th grade (primary)        | 73.02%                        | none                      |
| Case 5       | 8 years    | Male          | 3rd grade (primary)        | 65.38%                        | none                      |

From Table 1, we can see that the participants are between 8 and 10 years old and in years 3 to 5 at school. Case 1 scored 48.77%, Case 2 scored 59.52%, Case 3 scored 75.04%, Case 4 scored 73.02% and Case 5 scored 65.38% on the Conners scale, which are all high scores. We also observed that most cases do not have comorbid disorders.

## **6. Scope of the study:**

**6-1. Spatial scope:** The field study was conducted at the Muhammad Bouchiba Primary School in the village of Tibcharine, in the municipality of Mizrana, in the province of Tizi Ouzou.

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**6-2. Temporal scope:** Fieldwork, including the pilot study, took place from early September until 2 November 2021.

## **7 -Research instruments:**

**7-1. Conners Rating Scale:** Developed by Conners in 1969 to assess attention-deficit/hyperactivity disorder (ADHD), it is one of the most widely used instruments for identifying behavioral disorders in children and adolescents. It is designed for children aged 6–18 and is commonly used to evaluate ADHD. The scale is easy to use and takes approximately 20–30 minutes to complete. Consisting of statements rated on a 0–3 scale, it is divided into two forms: a 48-item parent form describing the child’s behavior and a 28-item teacher form. Instructions are provided to guide parents and teachers through the process.

- **Administration:** The clinician asks the parents questions during an interview and asks them to complete the Conners Parent Form. The teacher completes the Teacher Form. Respondents mark an ‘X’ for each item using the following response options: ‘rarely’, ‘sometimes’, ‘often’, ‘always’. They also record the child’s school, name, surname, age and grade.

- **Scoring: Response scores are rated as follows:**

Rarely: 0; Occasionally: 1, Often: 2, Always: 3.

- **Points:** In the teacher-rated scale, the minimum possible score is 0 and the maximum is 57. On the parent-rated scale, the minimum possible score is 0, and the maximum possible score is 84.

- **Psychometric properties of the Conners scale:** The Conners test was standardized in the United States using a sample of 1,973 teachers of children aged 3–17 years. Responses use a four-level scale (0–3). The scale showed acceptable validity indicators and high reliability. Test–retest reliability over an interval of 6–8 weeks ranged from 0.47 to 0.88, and internal consistency ranged from 0.545 to 0.990. Conners stated that the scale is valid and useful for diagnosing attention-deficit/hyperactivity disorder and related disorders. (Conners, (1997)).

**7.2. Baddeley’s working memory tests:** This battery assesses two dimensions of working memory. It includes tests that measure the main components of working memory: the visuospatial sketchpad and the phonological loop. These were developed by Baddeley and Gathercole (1982) and Yuth et al. (1989), and adapted for the Algerian context by Qasimi Amal (2001). It also includes tests by Stegel R.S. and Ryan F.B. (1989), which were adapted by Muhammad Ali Kamel (2001). These tests include:

- **Visuospatial Sketchpad Test:**

- Test description: Designed by Baddeley and Gathercole (1982). It contains five sequences of grids, ranging from two to five grids. There are three trials for each sequence, for a total of 42 grids.

- Test administration: This test is administered under the following instructions:

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-Point to the square showing the third dot to form the line. Remember the position and color of the line, and then reproduce the pattern using the colored strips on the blank grid.

- **Materials:** We use grids measuring  $3 \times 3$  squares, one grid per page. Two dots are sufficient to define a single line. Each grid in the sequence uses a different color: red for the first grid, blue for the second, green for the third, purple for the fourth, and orange for the fifth. Colored strips are given to the child in no particular order; the number and colors of the strips match the number and colors of the lines the child must remember.
- **Administration:**
  - Begin the test with a practice consisting of a two-grid sequence presented by the examiner. Each grid contains two dots of the same color, and the child must point with a finger to the location of the third dot that would form the line.
  - At the start of the test, instruct the child to pay close attention to the color and position of the lines in the sequence and to keep them in mind. At the end of the sequence, give the child a third (blank) grid and the colored strips (unordered). The number and colors of the strips correspond to the lines shown in the sequence. The child must place the strips on the blank grid matching the correct colors and positions.
  - **Scoring:** The examiner marks based on color and position. The child receives one point for each line that is reproduced in the same color and position.
- **Phonological Loop Test — Sentences:**
  - **Test description:** Designed by Siegel, R. S., and Ryan, F. B. (1989), and administered by Siegler, A. (1998). The test contains five series of sentences, ranging from two to five sentences per sequence. There are three trials for each sequence, for a total of 42 sentences.
- **Administration:**
  - **Instruction:** ‘I will present a series of sentences. Each sentence has a missing word. You must find the missing word, say it out loud and remember it, so that you can repeat it after I have finished presenting the whole series.
  - **Materials:** Four sets of sentences totaling 42, composed of familiar, commonly used words.
  - **Procedure:** Begin with practicing a two-sentence sequence. Present the sentences one by one, allowing the child to say the final word of each sentence aloud. If they succeed, proceed to the next sequence in the same way. The student must remember the words they have spoken and be able to recall them at the end of each sequence.
  - **Scoring:** Award one point for each word that is correctly recalled and ordered.
  - **Phonological Loop Test – Words:**
    - **Test description:** Designed by Siegel, R. S., and Ryan, F. B. (1989), and administered by Siegler, R. A. (1998). The test comprises four sets of words, starting with sequences of two and progressing to sequences of five. Each set contains four words: three semantically related words and one ‘intruder’ word that is not semantically related to the other three. A total of 42 sets are presented.

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• **Administration:**

- **Instruction:** ‘I will show you a series of four words. Your task is to identify the intruder word — the one that is not related to the other three — and remember it. At the end of each series, recall the intruder words in order.’

- **Materials:** Common words that share a meaning, plus ‘intruder’ words that do not share the same meaning.

- **Procedure:** Begin with a two-group sequence with one trial for practice. Present each group of words and ask the child to identify the intruder word aloud (the word that has no semantic relation to the others) and remember it. The child must remember the intruder words and recall them in order at the end of each series.

- **Scoring:** Award one point for each intruder word that is correctly recalled and in the correct order.

- **Phonological Loop Test – Numbers:**

- **Test origin:** Used by Yuill et al. (1989). This test contains 42 number groups arranged in sequences of varying lengths, from two to five groups. There are three trials per sequence.

• **Administration:**

- **Instruction:** “I will present a series of number groups. You must say aloud the last number in each group and remember it so that, at the end of the series, you can recall all the last numbers in order.”

- **Materials:** Five sequences of number groups (digits 1–9), with each group consisting of three numbers.

- **Procedure:** Begin with a practice sequence of two groups. Present the sequence and ask the child to read the first group, remembering its last number. Then present the second group and ask the child to remember its last number. The child must retain both last numbers and recall them in order at the end of the sequence. If the child succeeds, proceed with the other sequences in the same way.

- **Scoring:** Award one point for each correctly recalled and ordered number.

• **Psychometric properties of the test:** To verify the test’s validity and reliability, it was administered to a sample of 90 pupils in Years 3 and 5 of primary school. The mean age of the sample was approximately 8.73 years (around eight to ten years old).

- **Test validity:**

- **Internal consistency validity:** The researcher calculated the correlation coefficient between each item and the total score of the relevant dimension. Item–total correlations for the first dimension (the verbal component) ranged from 0.73 to 0.88 ( $p < 0.01$ ). For the second dimension (the visuospatial sketchpad), item–total correlations ranged from 0.72 to 0.90 ( $p < 0.01$ ). For the third dimension (central executive), they ranged from 0.53 to 0.83 ( $p < 0.01$ ). For the final dimension (event source), they ranged from 0.82 to 0.87 ( $p < 0.01$ ). Correlations among the dimensions and with the whole scale ranged from 0.67 to 0.94, all of which were significant at  $p < 0.01$ .

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**-Discriminant validity:** To compute discriminant validity, the researcher applied an independent-samples t-test to compare the high and low groups on each item of the scale. Statistical analysis revealed significant differences between the two groups for each item. The test also distinguished between the two groups overall in terms of working memory level, which provides further evidence of the test's validity.

**Table 02: Indicator of test validity.**

|             | Mean  | Standard deviation | Calculated t | Critical t (Table) | Significance level |
|-------------|-------|--------------------|--------------|--------------------|--------------------|
| Lower total | 12,91 | 3,63               | 21,36        | 2,68               | 0,01               |
| Upper total | 38,54 | 4,61               |              |                    |                    |

Table 02 shows that the calculated t-value is greater than the critical t-value, indicating statistical significance at the 0.01 level. This means the test demonstrates strong validity.

• **Test reliability:**

**-Cronbach's alpha:** The researcher calculated the reliability of each dimension and of the whole test using Cronbach's alpha. The overall reliability coefficient was 0.93. The dimension reliabilities were acceptable, ranging from 0.48 to 0.82.

**-Split-half reliability:** The split-half reliability coefficient was 0.85. After applying the Spearman–Brown correction, this increased to 0.92, confirming the test's suitability for measuring working memory. Corrected reliabilities for the dimensions ranged from 0.52 to 0.85.

➤ **Statistical methods used:** This study relied on percentages.

**- Presentation and analysis of study results:**

**A. Case presentations:**

**-Case 1:**

- Case details: Name: S.J.
- Age: 10 years
- Sex: Male
- Grade: Year 5 / Birth order: First.
- Family information:** Father's age: 42 / Father's occupation: Driver
- Mother's age: 36
- Mother's occupation: Homemaker
- **Consanguineous marriage:** No.
- **Living conditions:** Household type: Single-family
- Number of rooms: 5
- **Language spoken:** Arabic
- Number of siblings: 4.
- **Pregnancy conditions:** Wanted pregnancy: Yes
- Did the mother take medication during pregnancy? No
- Delivery: Normal.

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**- Postnatal:**

- Did the child suffer birth asphyxia? No
- Any sensory disorders: No
- Any parasitic diseases: No.
- Any traumatic brain injury: No.
- **Motor development:** Breastfeeding: Normal / Sitting: Normal
- **Walking:** Normal
- **Dominant hand:** Right.
- **Language development:** Babbling began at: 2.5 months / First word: 'Mama'.
- **Social and family development:** Family life: Typical
- **Separation from mother:** No
- Child's relationship with siblings: Typical
- Child's behavior: Very active.

**B. Case 2:**

- **Case details:** Name: T.Sh. / Age: 8 years / Sex: Female / School level: Third grade (primary) / Birth order: Fourth.
- **Family information:** Father's age: 46 / Father's occupation: Merchant / Mother's age: 36 / Mother's occupation: Teacher / Consanguineous marriage: No.
- **Living conditions:** Home: Ordinary / Number of rooms: 3 / Language spoken: Kabyle (Berber dialect) / Number of siblings: 5.
- **Pregnancy conditions:** Pregnancy wanted: Yes / Did the mother take medication during pregnancy: No / Delivery: Abnormal.
- **Postnatal:** Birth asphyxia: No / Sensory disorders: No / Parasitic diseases: No / Traumatic brain injury: No.
- **Motor development:** Breastfeeding normal: Yes / Sitting: Normal / Walking: Typical / Dominant hand: Right.
- **Language development:** Babbling began at: 3 months / First word: "Baba" (Dad).
- **Social and family development:** Family life: Typical / Separation from mother: No / Relationship with siblings: Typical / Child's behavior: Very active.

**C. Case 3:**

- **Case details:** Name: A-E. / Age: 10 years / Sex: Male / School level: Fifth year / Birth order: Second.
- **Family information:** Father's age: 52 / Father's occupation: Unemployed / Mother's age: 43 / Mother's occupation: Unemployed / Consanguineous marriage: No.
- **Living conditions:** Home: Family household / Number of rooms: 6 / Language spoken: Arabic.
- **Pregnancy conditions:** Pregnancy wanted: No / Did the mother take medication during pregnancy: Yes / Delivery: Normal.
- **Postnatal:** Birth asphyxia: No / Sensory disorders: No / Parasitic diseases: No / Traumatic brain injury: No.
- **Motor development:** Breastfeeding normal: Yes / Sitting: Typical / Walking: Normal / Dominant hand: Left.

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- Language development:** Babbling began at: 1.5 months / First word: “Baba” (Dad).
- **Social and family development:** Family life: Unusual / Separation from mother: No / Relationship with siblings: Typical / Child’s behavior: Very active.

**D. Case 4:**

- Case presentation:** Name: T.B. / Age: 10 years / Sex: Male / Educational level: Grade 5 (primary).
- Birth order among siblings:** second.
- Family information:** Father’s age: 41 years / Father’s occupation: Merchant. Mother’s age: 38 years / Mother’s occupation: Unemployed.
- **Consanguineous marriage:** No.
- Living conditions:** Number of rooms: 2 / **Language spoken at home:** Kabyle (Tamazight dialect) / Number of siblings: 3.
- Pregnancy conditions:** Pregnancy wanted: No / Did the mother take medication: Yes / Any emotional or psychological trauma during pregnancy: No / Delivery: Spontaneous (vaginal).
- Postnatal conditions:** Any perinatal asphyxia: No / Any sensory illnesses: No / Any parasitic illnesses: No / Any traumatic brain injury: No.
- **Motor development:** Breastfeeding: Normal / Sitting: Typical / Walking: Normal / Handedness: Right.
- **Language development:** Babbling onset: 3 months / First word: “Mama”.
- **Family and social development:** Family life: Typical
- **Any separation from mother:** No
- Child’s relationship with siblings: Good
- **Child’s behavior:** Very active.

**E. Case 5:**

- Case presentation: Name: A.G.
- Age: 8 years
- Sex: Male
- Educational level: Year 4.
- **Birth order among siblings:** fourth.
- **Family information:** Father’s age: 60 years / Father’s occupation: Unskilled - laborer. Mother’s age: 55 years. Mother’s occupation: Unemployed.
- **Consanguineous marriage:** No.
- **Living conditions:** Type of housing: Single-family dwelling
- Number of rooms: 5
- **Language spoken at home:** Arabic
- Number of siblings: 3.
- **Pregnancy conditions:** Wanted pregnancy: Yes
- Did the mother take medication? No
- Delivery: Spontaneous (vaginal).
- **Postnatal conditions:** Any perinatal asphyxia: No
- Any sensory illnesses: No.
- Any parasitic illnesses: No.

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- Any traumatic brain injury: No.
  - **Motor development:** Breastfeeding: Normal
  - Sitting: Typical
  - Walking: Normal
  - Handedness: Right.
  - **Language development:** Babbling onset: 2 months. First word: 'Mama'.
  - **Family and social development:** Family life: Typical
  - Any separation from mother: No
  - **Child's relationship with siblings:** Conflictual
  - Child's behavior: Very active.
- **Presentation and analysis of working memory test results:**
1. **Presentation and analysis of the Visuospatial Sketchpad test results:**

**Table 03: Results of the Visuospatial Sketchpad Test.**

| Cases  | Two-item series | Three-item series | Four-item series | Five-item series | Total | Percent age |
|--------|-----------------|-------------------|------------------|------------------|-------|-------------|
| Case 1 | 6               | 9                 | 6                | 11               | 32    | %76,19      |
| Case 2 | 6               | 8                 | 12               | 12               | 38    | %90,47      |
| Case 3 | 6               | 9                 | 12               | 15               | 42    | %100        |
| Case 4 | 6               | 8                 | 6                | 5                | 25    | %59,52      |
| Case 5 | 5               | 8                 | 6                | 5                | 24    | %57,14      |

As shown in Table 3, Case 1 obtained 32 out of 42 points (76.19%), Case 2 obtained 38 out of 42 points (90.47%), and Case 3 obtained 42 out of 42 points (100%). Case 4 scored 25 out of 42 (59.52%), while Case 5 scored 24 out of 42 (57.14%).

Qualitative analysis: Application of the Visuospatial Sketchpad Test indicates that most cases achieved high to above-average scores on this component, suggesting strong visuospatial working memory retrieval abilities.

2. **Presentation and analysis of the phonological loop — words test:**

**Table 4 : The results of the phonological loop (words) test.**

| Cases  | Two-word series | Three-word series | Four-word series | Five-word series | Total | Percentage |
|--------|-----------------|-------------------|------------------|------------------|-------|------------|
| Case 1 | 3               | 5                 | 4                | 5                | 17    | %40,47     |
| Case 2 | 2               | 3                 | 6                | 5                | 16    | %38,09     |
| Case 3 | 2               | 6                 | 7                | 7                | 22    | %52,38     |
| Case 4 | 3               | 6                 | 4                | 0                | 13    | %30,95     |
| Case 5 | 3               | 5                 | 4                | 0                | 12    | %28,57     |

As shown in Table 4, Case 1 obtained 17 out of 42 points (40.47%), Case 2 obtained 16 out of 42 points (38.09%), Case 3 obtained 22 out of 42 points (52.38%), Case 4 obtained 13 out of 42 points (30.95%), and Case 5 obtained 12 out of 42 points (28.57%).

|                                                                                                                            |                                   |                                                 |                       |
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### **-Qualitative analysis:**

- From the phonological loop (words) test, most participants could only recall the first item in each two-item sequence.

For the three-word sequences: Cases 1, 2, 4 and 5 successfully recalled words from the first and second sets, but not the third. Case 3 recalled the first word of the first set and two words from the third set.

- For the four-word sequences: Cases 1, 2, 4 and 5 recalled two words from the first set, one word from the second set and one word from the third set. Case 3 recalled three words from the first set, as well as two words from both the second and third sets. (Note: the original text incorrectly referred to ‘Case 2’ twice; the above table reflects the reported patterns.)

For the five-word sequences: Cases 1 and 2 recalled two words from the first and second sets, and one word from the third. Case 3 recalled four words from the first set, two from the second set and one from the third set. Cases 4 and 5 were unable to recall any words in the five-word sequences.

### **-Interpretation:**

All cases showed difficulties in the phonological loop (words) subtest. Performance declines as sequence length increases, with especially poor recall for longer sequences.

- Many participants displayed atypical or disruptive behaviors that produced noise and interference, and they experienced difficulties in social communication (i.e. weak social interaction skills).

## **3. Presentation and analysis of the phonological loop — sentences:**

**Table 5: Results of the Phonological Loop (Sentences) Test.**

| Cases  | Two-sentence series | Three-sentence series | Four-sentence series | Five-sentence series | Total | Percentage |
|--------|---------------------|-----------------------|----------------------|----------------------|-------|------------|
| Case 1 | 3                   | 6                     | 5                    | 7                    | 21    | %50        |
| Case 2 | 2                   | 3                     | 5                    | 3                    | 13    | %30,95     |
| Case 3 | 5                   | 5                     | 3                    | 4                    | 17    | %40,47     |
| Case 4 | 3                   | 4                     | 5                    | 5                    | 17    | %40,47     |
| Case 5 | 2                   | 5                     | 3                    | 4                    | 14    | %33,33     |

As can be seen from Table 5, Case 1 obtained 21 out of 42 points (50.00%), Case 2 obtained 13 out of 42 points (30.95%), Case 3 obtained 17 out of 42 points (40.47%), Case 4 obtained 17 out of 42 points (40.47%), and Case 5 obtained 14 out of 42 points (33.33%).

### **-Qualitative analysis:**

On the phonological loop (sentences) subtest, which required the completion of missing sentence elements and the retention and recall of these elements at the end of each series, Cases 1, 2 and 4 were initially successful in recalling the missing

|                                                                                                                            |                                   |                                                 |                       |
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elements. However, for series composed of four- and five-item groups, these cases succeeded with the first group but failed with subsequent ones.

Cases 2 and 5 only recalled the early (first) series and failed on later series.

Overall, these patterns indicate that all cases exhibited reduced recall ability on the Phonological Loop (Sentences) subtest, with performance declining as series length increased.

Additionally, most cases displayed non-goal-directed behaviors (e.g. deliberate destruction or scattering of objects, fighting with others) and had difficulty adhering to rules and schedules.

#### **4. Presentation and analysis of the phonological loop — digits:**

**Table 6: Results of the Phonological Loop (Digits) Test.**

| Cases  | Two-digit series | three-digit series | four-digit series | five-digit series | Total | Percentage |
|--------|------------------|--------------------|-------------------|-------------------|-------|------------|
| Case 1 | 6                | 4                  | 3                 | 0                 | 13    | %30,95     |
| Case 2 | 5                | 3                  | 1                 | 1                 | 10    | %23,80     |
| Case 3 | 6                | 4                  | 4                 | 3                 | 17    | %40,47     |
| Case 4 | 6                | 4                  | 3                 | 3                 | 16    | %38,09     |
| Case 5 | 6                | 3                  | 4                 | 0                 | 13    | %30,95     |

As shown in Table 6, Case 1 obtained 13 points out of 42 (30.95%), Case 2 obtained 10 points out of 42 (23.80%), Case 3 obtained 17 points out of 42 (40.47%), Case 4 obtained 16 points out of 42 (38.09%), and Case 5 obtained 13 points out of 42 (30.95%).

#### **-Qualitative analysis:**

In the two-digit sequences, Cases 1, 3, 4 and 5 recalled all digits across the groups, whereas Case 2 failed to recall the second digit in Group 3.

In the three-digit sequences, Cases 1, 3 and 4 recalled two digits in Group 1 and one digit in each of Groups 2 and 3. Cases 2 and 5 recalled two digits in Group 1 and one digit in Group 2, but failed in Group 3.

In the four-digit sequences, Cases 1 and 4 recalled two digits in Group 1, one digit in Group 2 and one digit in Group 3. Case 2 recalled one digit in Group 1 and failed to recall any digits in the remaining groups.

- In the five-digit sequences, Cases 1 and 5 were unable to recall any digits. Cases 3 and 4 recalled two digits in Group 1 and one in Group 3. Case 2 recalled one digit in Group 2 only.

#### **-Overall interpretation:**

All cases exhibited difficulty recalling digits, consequently demonstrating low performance on the phonological loop – digits subtest.

|                                                                                                                            |                                   |                                                 |                       |
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- Clinically relevant observations: most cases display immature or childlike behaviors, such as failure to complete tasks, abrupt transitions between activities without cause, jumping, climbing and destructive behaviors.

## **5. Presentation and analysis of the global working memory selection results:**

**Table 7: Overall results for the working memory battery.**

| Test                   | Visual-spatial sketchpad<br>(visual-spatial notebook) | Phonological loop |              |          | subtests |
|------------------------|-------------------------------------------------------|-------------------|--------------|----------|----------|
|                        |                                                       | sentences         | Digits words | subtests |          |
| <b>Results by case</b> |                                                       |                   |              |          |          |
| Case 1                 | %76,19                                                | %40,47            | %50          | %30,95   | %49,40   |
| Case 2                 | %90,47                                                | % 38,09           | %30,95       | %23,80   | %45,82   |
| Case 3                 | %100                                                  | %52, 38           | %40,47       | %40,47   | %58,33   |
| Case 4                 | %59,52                                                | %30,95            | %40,47       | % 38,09  | %42,25   |
| Case 5                 | %57,14                                                | %28,57            | %33,33       |          | %37,49   |

The percentages shown in the previous table range from 37.49% to 58.33%.

Qualitative analysis: Based on the working memory battery, the performance of most participants fell between the average and below-average ranges. Therefore, we conclude that all five cases exhibit working memory impairments.

## **9. Interpretation and discussion of the results:**

After collecting and analyzing field data, we found that pupils with attention-deficit/hyperactivity disorder (ADHD) do not appear to exhibit impairments in the visuospatial sketchpad. Scores on the visuospatial tasks were generally average to high. In contrast, most participants demonstrated difficulty retrieving verbal material (words, sentences and digits), indicating deficits in the phonological loop. Performance on phonological tasks ranged from average to below average. Consequently, the majority of cases obtained average to below-average scores across working memory components (visuospatial sketchpad and phonological loop), supporting the hypothesis that pupils with ADHD experience working memory deficits.

These findings are consistent with those of Mohamed Ali Kamel (2001), who reported statistically significant differences between pupils with attentional disorders and typically developing peers in verbal working memory measures. He concluded that attentional disorders negatively affect the working memory system. They also align with the findings of Marusiak and Janzen (2005), who examined the working memory capacities of pupils with ADHD and found that they performed markedly worse in working memory tasks, particularly spatial ones, than their typically developing peers did.

This study falls within research on working memory in pupils with attention-deficit/hyperactivity disorder (ADHD), a condition that is a major factor impeding a pupil's academic progress.

Scoring: Award one point for each word that is correctly recalled and ordered.

|                                                                                                                            |                                   |                                                 |                       |
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**- Phonological Loop Test – Words:**

Test description: Designed by Siegel, R. S., and Ryan, F. B. (1989), and administered by Siegler, R. A. (1998). The test comprises four sets of words, starting with sequences of two and progressing to sequences of five. Each set contains four words: three semantically related words and one ‘intruder’ word that is not semantically related to the other three. A total of 42 sets are presented.

**• Administration:**

Instruction: ‘I will show you a series of four words. Your task is to identify the intruder word — the one that is not related to the other three — and remember it. At the end of each series, recall the intruder words in order.’

Materials: Common words that share a meaning, plus ‘intruder’ words that do not share the same meaning.

- Procedure: Begin with a two-group sequence with one trial for practice. Present each group of words and ask the child to identify the intruder word aloud (the word that has no semantic relation to the others) and remember it. The child must remember the intruder words and recall them in order at the end of each series.

Scoring: Award one point for each intruder word that is correctly recalled and in the correct order.

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