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Study of working memory and its relationship to academic and motor performance in secondary school students: A case study in the Sidi Slimane delegation, Morocco

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Abstract

OBJECTIVES: Neurocognitive functions play a key role in the learning process. The objective of this study is therefore to assess memory skills and their relationship with academic and motor performance in secondary school students. (Delegation: Sidi Slimane, Morocco).
METHOD: Using a sample of 384 students aged between 12 and 19, working memory was assessed using the RCF-A test (ELIAN-ANOTO digital). In addition, academic performance was studied in this study using the overall average obtained during the 2021-2022 school year. Motor performance is represented in this study by the final grade in physical education and sports obtained in the second semester of the same school year.
RESULTS: The results showed an overall test score of 38.97 ± 11.553, with a significant difference between the two sexes (U = 21555.0; W = 40276.0; $p = 0.004$) in favor of boys or girls, and that RCF-A (working memory) test scores increase with school level and age. The study also showed that the difference between the groups studied in terms of working memory is significant (U = 23232.500; W = 41760.500; $p = 0.000$). In addition, this study found a significant positive correlation between working memory and motor performance ($r = 0.122$; $p < 0.05$). However, no significant correlation was observed between working memory and academic performance ($r = 0.051$; $p > 0.05$).
CONCLUSION: This study highlights the importance of working memory in motor performance and emphasizes the need to take neurocognitive functions into account in the field of education.

Introduction

Students' academic performance depends largely on their cognitive abilities, which determine their capacity to acquire, organize, and reproduce disciplinary knowledge. Among these abilities, reading plays a central role, as it is the main vector for acquiring knowledge and developing higher cognitive skills (Aziz & Rawian 2022). Several recent studies show that cognitive functions are significant predictors of academic performance, particularly in reading and mathematics. For example, a meta-analysis by Spiegel *et al.* (2021) highlights that working memory, inhibition, and cognitive flexibility are strongly linked to the academic skills of primary school students. In addition, training programs targeting working memory improve academic performance in several subjects (Mahdavi *et al.* 2025). Sustained attention is also an essential factor, as it is associated with standardized test scores and overall school assessments (Gallen *et al.* 2023). Finally, executive functions support self-regulated learning: students who are able to plan, monitor, and adjust their study strategies achieve better results (Dignath & Büttner 2008).

Working memory plays a central role among cognitive functions, as it supports the simultaneous processing and integration of information necessary for complex learning. A high working memory capacity promotes planning, problem solving, and learning new knowledge (Cowan 2017). Empirical research has shown that interindividual variations in working memory account for a significant portion of differences in academic achievement, particularly in the areas of reading and mathematics (Alloway & Alloway 2010). Working memory was initially conceptualized by Miller, Galanter, and Pribram (1960) as an organized system for processing information necessary for planning and executing actions. Baddeley and Hitch (2019) proposed a multi-component model comprising a limited-capacity system capable of simultaneously maintaining and processing temporary information. Baddeley (1986) expanded on this model with the introduction of the central executive, responsible for actively manipulating information (updating, inhibiting, and switching between tasks). Functionally, working memory is the cognitive space where temporary storage and processing of information occur during mental activities (Fuster 2022).

More specifically, working memory is defined as the ability to store, manipulate, and process information during complex cognitive tasks, with a limited capacity for the number of items that can be held simultaneously (Rhodes *et al.* 2019). This limitation explains its decisive role in intellectual functioning and academic learning (Cornoldi & Giofrè 2014). In the educational context, working memory is a robust predictor of academic success, as it influences the ability to follow complex instructions, solve problems, and acquire new skills (Ahmed *et al.* 2022). It also plays a role in the development of motor skills, where the planning and coordination of actions depend on the manipulation of information in memory (Chevalère *et al.* 2023).

In Morocco, neuropsychological research applied to the school environment remains limited. In this context, the present study aims to assess memory skills in secondary school students and analyze the link between working memory, academic performance, and motor skills in order to extend our understanding of the cognitive mechanisms involved in learning and to identify factors for optimizing teaching practices in the national education system.

Material and methods

<u>*Location and duration of the study*</u>

The study was conducted between March and May 2022 in two schools: Sidi Yahia du Gharb high school (semi-urban area) and Kceibya high school (rural area), located in the Sidi Slimane province, Rabat-Salé-Kénitra region, in northwestern Morocco.

The rural areas, in this study, are characterized by a disadvantaged socioeconomic environment and limited access to extracurricular and leisure activities.

- **Selection criteria:**
  In order to establish a representative sample, inclusion and exclusion criteria were defined.

- **Inclusion criteria:**
  - Age between 12 and 19 years old.
  - Registration in a public secondary school; Enrollment in all subjects of the secondary school curriculum.

- **Exclusion criteria:**
  - Uncorrected visual impairments.
  - Neurological history (stroke, head trauma, etc.).
  - Medication that may cause attention disorders and/or drowsiness.
  - Severe depression or unstable psychiatric disorders.

- **Ethical considerations:**

Every precaution was taken to ensure the privacy and confidentiality of students' data. The study was conducted in accordance with the ethical principles established by the Declaration of Helsinki, as last revised in 2013 (World Medical Association 2013).

Authorization to conduct the survey was obtained from the provincial delegation of the Ministry of National Education in the province of Sidi Slimane. The directors of the schools concerned were informed of this authorization. In addition, informed consent was obtained from legal guardians, who were informed that the data collected would be anonymous and confidential.

Tab. 1. Distribution of the sample by gender, age, grade level, and living environment

		Frequency	Percentage %
Sex	Female	191	49.7
	Male	193	50.3
Age	12 years	31	8.1
	13 years	73	19.0
	14 years	54	14.1
	15 years	47	12.2
	16 years	50	13.0
	17 years	74	19.3
	18 years	42	10.9
	19 years	13	3.4
School level	1 AC	64	16,7
	2 AC	64	16,7
	3 AC	64	16,7
	Common core	64	16,7
	1st Bac	64	16,7
	2nd Bac	64	16,7
Area	Urbain	192	50
	Rural	192	50

Sample and type of study

This is an exploratory descriptive study conducted on a sample of secondary school students. Participants were randomly selected with good physical fitness, enabling them to participate in regular sports activities.

The total sample consisted of 384 students, divided as follows: 193 boys (mean age = 15.34 ± 2.03 years) and 191 girls (mean age = 15.10 ± 1.98 years). All participants gave their consent to take part in this research

Tools used:

Elian Test

The assessment of neurocognitive processes, particularly working memory, was carried out using the computerized version of the Rey Complex Figure Test (RCF-A). (Osterrieth 1945). This complex two-dimensional figure comprises 18 geometric elements (crosses, squares, triangles, circles) arranged around a central rectangle. It allows for the assessment of several cognitive functions: visual perception, visuospatial organization, working memory, attention, and inhibition (Vannetzel 2010).

We used the digital version of the test, which involves the use of:

- The digital version used is based on the following elements:
- An Anoto DP-201 digital pen.
- Raster paper with a normal appearance that does not interfere with the scripter; the raster consists of a myriad of dots juxtaposed together.
- ELIAN (Expert Line Information Analyzer) software, developed by Seldage (www.eliansoftware.com), which allows the data recorded by the pen to be viewed and analyzed.
- Experimental approach:

The RCF-A test is conducted in two phases:

- **Copying phase:** the model is presented horizontally to the participant, who must reproduce it faithfully.
- **Reproduction phase:** the participant must reproduce the figure from memory, without a model.

According to Wallon and Mesmin (2009) and Alice (2012) there is a delay of less than three minutes between the two phases.

Among the two types of scoring proposed by Rey (1959) (numerical and typological), only numerical scoring was used for this study, thus enabling the calculation of an overall score.

Academic performance

Academic performance was assessed based on each student's overall annual average for the 2021-2022 school year. This average was calculated based on the results obtained in all subjects in the secondary school curriculum.

Motor skills

Motor skills were measured based on the final physical education and sports (EPS) grade obtained in the second semester of the 2021-2022 school year, in accor-

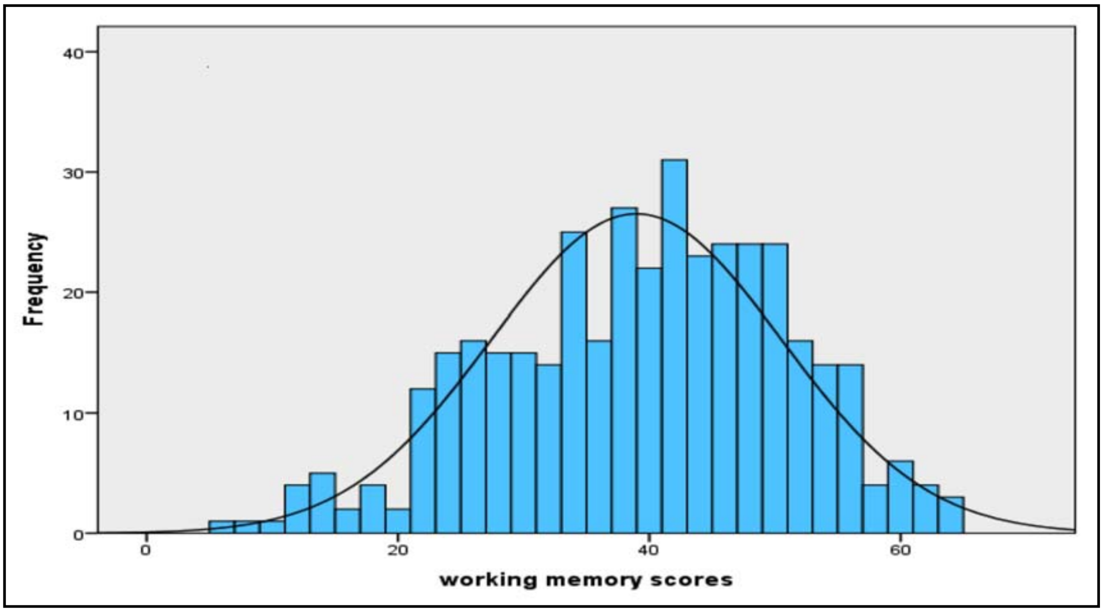

Fig. 1. Distribution of the study sample according to working memory scores

dance with the Pedagogical Guidelines for Secondary School EPS Programs (OP 2007–2009).

Statistical analysis
All data collected was processed using specific statistical software. The statistical analysis of the data is based on two axes.

- **Descriptive statistical analysis:** presentation of the sample in the form of means ± standard deviation and percentages.
- **Inferential statistical analysis:** Comparison of means between different groups (according to gender, age, and grade level) using appropriate statistical tests:
  - **Parametric tests:** Student's t-test, ANOVA.
  - **Nonparametric tests** if normal conditions are not met.
  - **Bivariate** correlation between working memory and academic and motor performance.

The statistical significance threshold was set at $p < 0.05$.

Results

Sample studied
The distribution of our sample by gender, age, level of education, and living environment. In terms of gender, 191 girls make up 49.7% of the population, aged between 12 and 19, across six secondary school levels (1st, 2nd, and 3rd year of middle school, Common core, 1st year of high school, and 2nd year of high school) represented by 64 students for each grade level, and in each living environment represented by 192 students. The sample is distributed as follows (Table 1):

Study of the meniscus profile
a) Overall results of working memory test scores
The study of working memory in the sample showed an overall test score average of 38.97 with a standard devia-

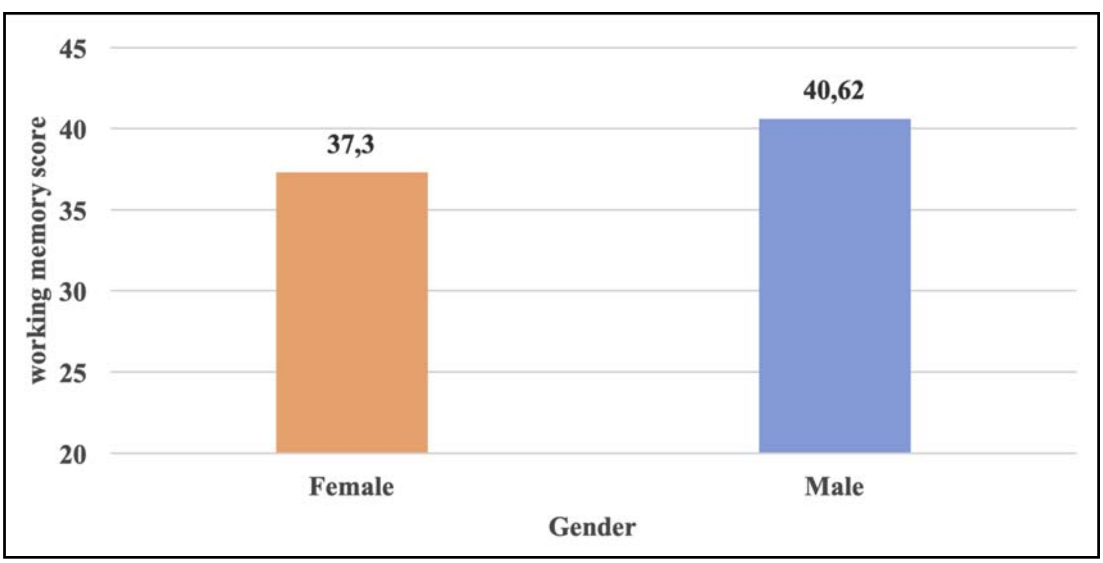

Fig. 2. Distribution of working memory scores according to student gender.

Tab. 2. Descriptive table of ELIAN working memory test scores by age

	12 years	13 years	14 years	15 years	16 years	17 years	18 years	19 years
Frequency	31	73	54	47	50	74	42	13
Average	37,06	37,44	39,04	35,38	40,06	43,18	39,02	36,46
Standard deviation	11,171	11,643	10,849	10,045	14,413	10,099	11,399	10,990
Minimum	9	12	11	14	8	22	6	22
Maximum	56	64	63	57	61	63	61	51

Tab. 3. Descriptive table of ELIAN working memory test scores by school level

	1AC	2AC	3AC	C.C	1st Bac	2nd Bac
Frequency	64	64	64	64	64	64
Average	35,31	39,25	38,56	40,23	39,48	40,97
Standard deviation	12,945	10,150	12,172	11,519	10,814	11,103
Minimum	8	16	14	13	18	6
Maximum	61	59	64	63	59	61

tion of 11.55, a maximum score of 64, and a minimum score of 6. The distribution of the sample according to working memory scores is shown in Figure 1.

b) Distribution of working memory test results according to gender

The distribution of average working memory scores by gender (Figure 2) shows that boys' scores are higher (40.62 ± 11.391) than girls' scores (37.30 ± 11.505).

For girls, the highest working memory score is 63, and the lowest score is 6.

For boys, the highest working memory score is 64, and the lowest score is 8.

Statistical analysis using the Mann-Whitney U test shows a significant difference between the two genders (U = 21555.0; W = 40276.0; $p = 0.004$). This means that gender affects working memory.

c) Distribution of working memory test results according to age

The highest average working memory score, for 17-year-olds, is 43.18 ± 10.09. It is still significant, at 40.06 ± 14.41 for 16-year-olds. The lowest score is recorded among 19-year-old students, at 36.46 ± 10.99. (Table 2).

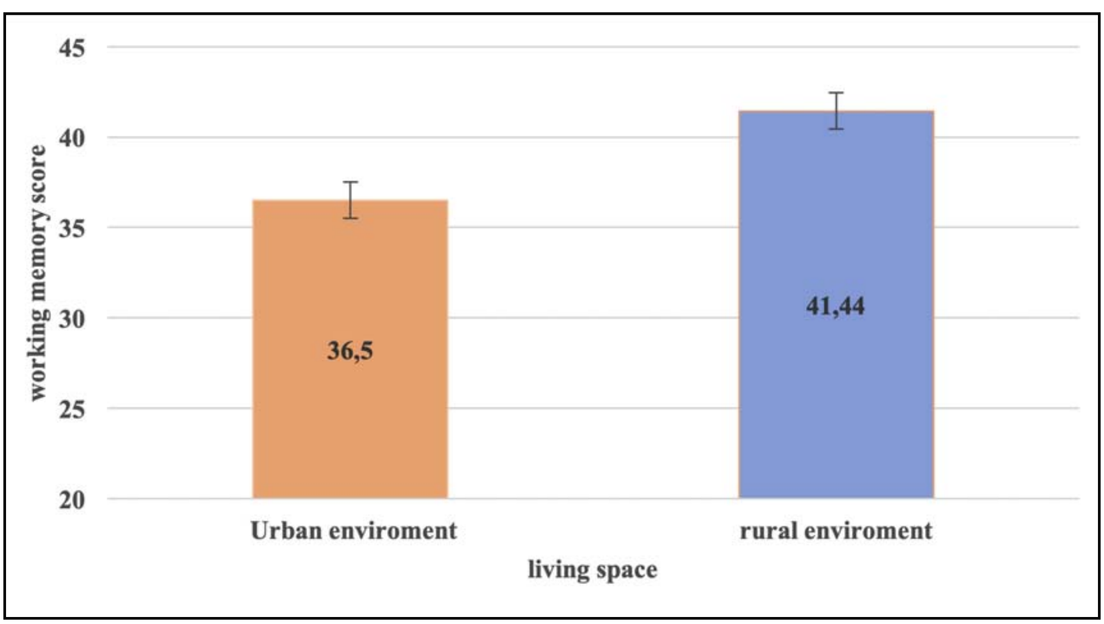

Fig. 3. Répartition des scores de la mémoire de travail selon le milieu de vie des élèves.

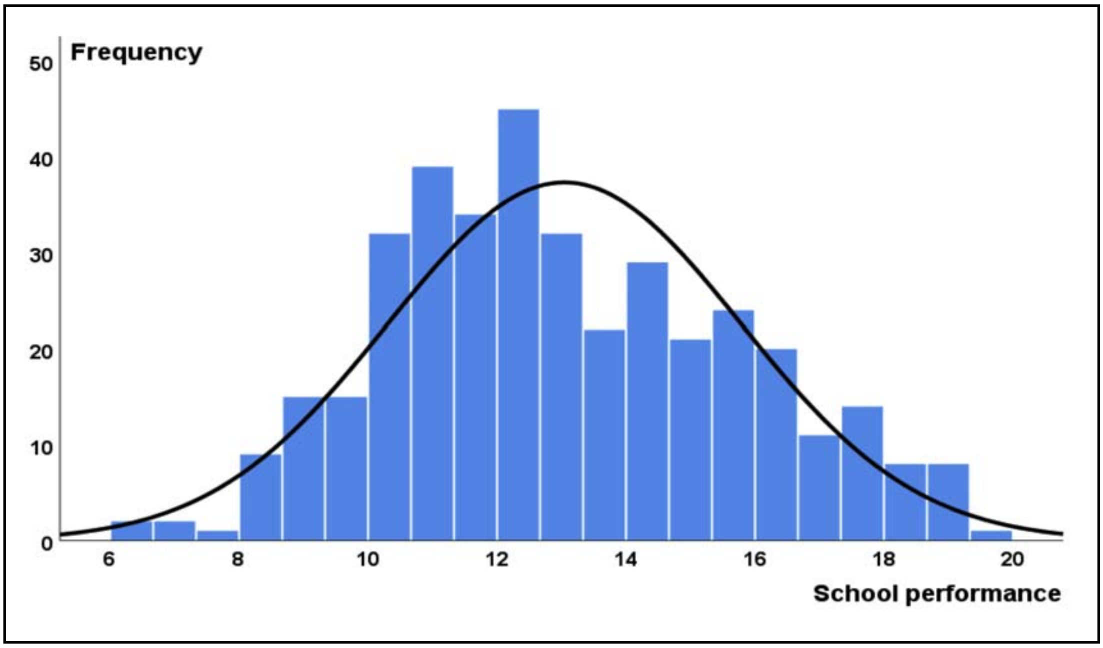

Fig. 4. Distribution of the sample according to academic performance

In general, average working memory scores increase gradually with age, but at age 15 and after age 17, a slight decline is observed among the students surveyed.

The statistical analysis using the Kruskal-Wallis test shows a significant difference between the different age groups (H = 20.291; ddl = 7; p = 0.005). It appears that working memory depends on the age of the students.

d) Distribution of perception test results according to school level

The highest average working memory score was recorded among students in their second year of high school (40.97 ± 11.103), and the lowest score was among students in their first year of middle school (35.31 ± 12.945) (Table 3).

Statistical analysis using the Kruskal-Wallis test revealed no significant differences between the means for the different school levels (H = 7.900; ddl = 5; p = 0.162). This means that school level has no effect on working memory.

e) Distribution of working memory results according to living environment

The distribution of average working memory scores according to environment (Figure 5) shows that students from rural areas (41.44 ± 11.830) score higher on average than students from urban areas (36.50 ± 10.745).

Statistical analysis using the Mann-Whitney U test shows a highly significant difference between the scores of students from urban areas and those from rural areas (U = 23232.500; W = 41760.500; p = 0.000). This means that the living environment has an effect on working memory.

Relationship between memory and solar and motor performance

a) Overall results for academic and motor performance

a1) Overall results for academic performance

The results show that the academic performance of the sample studied is characterized by an overall average of 13.04 out of 20, with a standard deviation of 2.73. This average is considered fairly good, with scores ranging from 6.00 to 19.35. This suggests that the students in the sample generally have satisfactory academic results (Figure 4).

a2) Overall motor performance results

The results of the motor performance study reveal an overall average of 15.91 out of 20, with a standard deviation of 1.80. This average is considered good, with scores ranging from 8.69 to 19.67. This indicates that the students in the sample generally have satisfactory results in terms of motor performance (Figure 5).

b) Correlation between working memory and academic and motor performance

We performed correlation analyses between the different scales used in this study. The results presented in Table 4 show that:

- There is a significant correlation between working memory and motor performance (r = 0.122; $p < 0.05$).
- However, there is no significant correlation between working memory and academic performance (r = 0.051; $p > 0.05$).

Furthermore, multiple linear regression (stepwise method), with academic and motor performance results as dependent variables and working memory

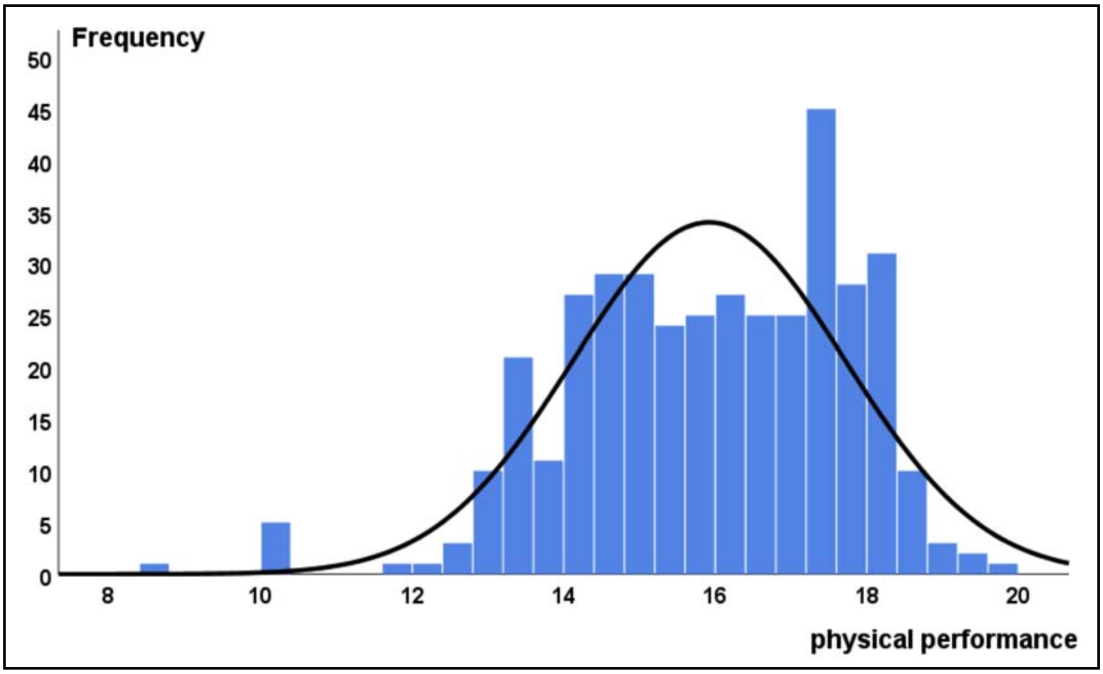

Fig. 5. Distribution of the sample according to motor performance

as an explanatory variable, retained only motor performance and working memory.

Indeed, the standardized coefficient for the latter, which is 1.22, proved to be statistically significant (t = 2.05, $p = 0.016$), while that of working memory had no significant effect on the variation in academic results (t = 1.01, $p = 0.316$).

Consequently, the linear regression model is as follows:

$$MP=1,22\ WM+ 15,17$$

The model is statistically valid and correctly expresses the data (F = 18.58, $p = 0.016$).

Discussion

This study focuses on adolescents attending school in urban and rural areas of the Sidi Slimane province, Rabat-Salé-Kénitra region. The main objective is to examine the memory profile and its relationship with academic and motor performance in this population. Memory assessment, conducted using the ELIAN test, revealed that adolescents in Sidi Slimane have an average working memory score of 38.97 ± 11.55 (≈61% of the maximum score), with a high degree of dispersion. These results are comparable to those reported by Eloirdi *et al.* (2018) in Moroccan high school students (40.79 ± 12.23) The high variability suggests the existence of a subgroup of students with difficulties, already documented in Morocco, where 21% of high school students have memory deficits associated with poor academic performance (Eloirdi *et al.* 2019), highlighting the role of socioeconomic and educational context in cognitive development (Ahami *et al.* 2017). Given that working memory is linked to academic achievement and motor skills (Alloway & Alloway 2010; Diamond 2013), these results highlight the need to develop cognitive stimulation programs and establish appropriate Moroccan standards to support the memory development of adolescents.

The results highlight a significant difference in average working memory scores according to gender, with boys achieving higher average scores (40.62 ± 11.39) than girls (37.30 ± 11.51). These data are consistent with international observations, which report faster reaction times in boys and greater accuracy in girls (González *et al.* 2023). They are also confirmed in Morocco by Eloirdi *et al.* (2019), who report marked

Tab. 4. Correlations between working memory and academic and motor performance

Correlations				
			Motor performance	**School performance**
Rho of Spearman	working memory	Correlation coefficient	,122*	0,051
		Sig. (two-tailed)	,016	,316
		N	384	384

*. The correlation is significant at the 0.05 level (two-tailed).

gender differences in verbal and spatial working memory in adolescents. The superiority of male scores observed here is also consistent with other studies (Esposito & Giofrè 2025). The differences observed according to educational level and age confirm the well-known positive link between working memory capacity, age, and educational level (Archer *et al.* 2018; Tikhomirova *et al.* 2020). The Kruskal-Wallis test showed a significant difference between the different ages (H = 20.291; ddl = 7; $p = 0.005$), confirming that working memory develops throughout childhood and adolescence. This development reflects neural maturation and exposure to complex cognitive challenges at school (Takeuchi *et al.* 2010; Cowan 2017). Analysis of school grades shows that average working memory scores generally increase with academic progress, consistent with the findings of Dubuc *et al.* (2020) and Titz and Karbach (2014), who emphasize that neurological growth and engagement in complex school tasks contribute to improved working memory abilities.

Our study reveals that students from rural areas achieve significantly higher working memory scores than their urban counterparts. This observation contradicts the idea that urban environments are universally beneficial for cognitive development (Scott *et al.* 2023). The rural environment may promote better sustained attention and concentration due to less exposure to multitasking and distracting stimuli (Stevenson *et al.* 2019). These findings highlight the importance of considering local cultural and environmental contexts in neuropsychological research (Dutt *et al.* 2022). Significantly, working memory is positively correlated with motor performance ($r = 0.122$; $p < 0.05$), confirming the role of executive functions in the execution of complex movements (Feigenbaum 2017; Shi *et al.* 2024). In the Moroccan context, the work of Ahami and Eloirdi (2019) shows that visuospatial working memory significantly influences motor performance. Motivation and self-esteem in physical education also interact with cognitive abilities to improve motor learning (Eloirdi *et al.* 2017). These results confirm that cognition and motor skills are interconnected and support contemporary models that consider these dimensions as an integrated system (Lambert *et al.* 2024). Thus, working memory appears to be a key determinant of motor performance. Models of working memory, information processing, and attentional resources (Wickens 2008; Baddeley 2012) suggest that educational and sports practices should simultaneously engage cognitive, motor, and motivational dimensions to promote the overall development of adolescents.

Our results indicate no significant correlation between working memory and overall academic performance ($r = 0.051$; $p > 0.05$), which is consistent with certain international studies reporting weak or inconsistent links (Dubuc *et al.* 2020; Amzil 2022). This lack of a direct relationship can be explained by the heterogeneity of the memory components assessed (phonological, visuospatial, executive) and by contextual factors such as language of instruction, family support, and teaching quality (Andersson 2008). These results suggest that working memory plays a more important role in the acquisition of fundamental cognitive skills such as reading and arithmetic than in the assessment of overall academic results, a trend that has been reported in previous research showing close links between working memory and learning outcomes (Alloway & Alloway, 2010). This highlights the need for more refined and longitudinal methodological approaches to better understand its role in academic achievement, particularly in the Moroccan educational context.

Conclusion

This study conducted among adolescents in Sidi Slimane province, shows that while working memory performance is generally in line with international standards, significant variability reveals the existence of a subgroup of students with difficulties who require specific support. Working memory thus appears to be a major determinant of cognitive and motor development, but its influence is modulated by educational and environmental factors such as age, school level, and living space.

Our results show that, although gender has a limited effect, living environment and academic progress are significant variables, with students from rural areas performing better than their urban peers. Working memory does not directly explain academic success in Morocco, due to contextual factors and variability in assessments.

These results enrich contemporary models that consider cognition and motor skills as integrated systems and pave the way for differentiated educational and sports practices that are tailored to the specific needs of students and promote optimal overall development.

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