Research Paper

Assessing Visual Perception and Working Memory Using Digital Pen in Moroccan Students With Learning Difficulties

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ABSTRACT

Objectives: This study investigates the relationship between visual perception, working memory, and academic performance among middle school students with learning difficulties in the Middle Atlas region of Morocco. Specifically, it examines how these cognitive factors impact academic performance and highlights the importance of neurocognitive evaluation.

Methods: This study employed the Anoto DP-201 pen, a computerized tool used in neuropsychology, to assess visual perception and working memory. The research involved a sample of middle school students with learning difficulties and a control group. The ROCF-A test-copying phase was utilized to measure accuracy scores in visual perception tasks.

Results: The learning-disabled group had a lower mean accuracy score (59.98±11.34) than the control group (66.68±3.72). Statistical analysis using an independent sample t-test indicated a statistically significant difference between the two groups (t=4.44, P<0.000), highlighting the disparity in accuracy scores in the Rey-Osterrieth complex figure (ROCF-A) test-copying phase copying phase.

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Discussion: The findings suggest the critical role of neurocognitive evaluation in identifying students with deficits in visual perception and working memory. This study emphasizes the need for a multidisciplinary diagnostic approach to effectively manage and remediate cognitive challenges in learners with learning difficulties. Using the Anoto DP-201 pen provides valuable insights into the neurocognitive profiles of students and supports targeted interventions to enhance academic performance.

Highlights

● This study examines the relationship between visual perception, working memory and academic performance in middle school students with learning difficulties in the Middle Atlas region of Morocco using the Anoto DP-201 digital pen.

● Students with learning difficulties scored lower in accuracy and made more errors in visual perception and memory tasks.

● Rural students and those who repeated grades performed worse in these tasks.

● The control group demonstrated more organized task strategies, whereas students with learning difficulties showed less structured approaches.

● Poor performance on visual perception and memory tasks was strongly associated with lower academic achievement.

Plain Language Summary

This study explores how visual perception (the ability to interpret and make sense of what we see) and working memory (the capacity to retain and use information) influence school performance. The focus of the study was on middle-school students with learning disabilities in the Middle Atlas region of Morocco. We used the Anoto DP-201 digital pen, a specialized tool for detailed data collection to assess their visual perception and memory. Accordingly, students with learning difficulties performed significantly worse on a drawing test compared to their peers without learning challenges. These differences were statistically significant, suggesting that they stem from specific cognitive difficulties rather than random variation. The results highlight the importance of comprehensive assessments and a multidisciplinary approach to diagnosing and supporting students with challenges in visual perception and working memory. Early identification of these issues can enable targeted interventions, improving learning outcomes and academic performance.

Introduction

Visual perception and work memory are foundational cognitive functions that play a central role in daily activities. Visual perception is a neuropsychological process involving the interpretation and integration of sensory information at the cortical level [1]. This complex process enables individuals to recognize and identify attributes of objects, such as shapes, colors, and spatial relationships [2, 3].

Research suggests that visual perception is not merely a passive reception of stimuli but actively shapes how individuals understand and interact with their surroundings. Perceptual skills, such as visual attention, discrimination and memory, are vital for effective learning and comprehension [1, 4].

Neurophysiological studies indicate heightened activity in brain regions, like the occipital cortex during visual tasks, underscoring the neural basis of visual information processing and retention [4-6].

Working memory, introduced by A. Baddeley and Hitch [7], is a complex cognitive system comprising multiple components that can be selectively influenced [8, 9]. Functional neuroimaging studies have revealed that fronto-parietal networks are activated during verbal and visuo-spatial working memory tasks [10]. Baddeley defines working memory as a system of limited capacity, which allows for the temporary storage and manipulation of information that is necessary for the performance of complex cognitive tasks, such as comprehension, learning, and reasoning [2].

The interplay between visual perception and memory is particularly noteworthy. Effective visual processing enhances memory retention while working memory influences how visual information is interpreted and utilized [5, 11]. Research shows that difficulties in visual perception often manifest as challenges in reading, copying, writing and math [12, 13]. Similarly, working memory abilities have been linked to various learning situations, such as vocabulary acquisition and mental arithmetic [10].

Despite the critical role of these cognitive functions in learning, relatively few studies have explored the correlations between visual perception, working memory and academic performance, particularly during adolescence. This gap is especially evident in the context of middle school students with learning difficulties. To address this, the current study examines the relationship between visual perception, working memory, and academic performance among middle school students in Morocco's Middle Atlas region who experience learning difficulties. Understanding these connections can provide valuable insights into cognitive processes underlying academic success and inform strategies to support students facing learning challenges.

Materials and Methods

Study design and setting

This study employed a cross-sectional design to investigate the relationship between visual perception, working memory, and academic performance among adolescents. The study involved 122 college students from three colleges located in the Province of Khenifra, situated in the Middle Atlas Mountains of Morocco. The participants had a MEAN±SD age of 14.1±1.4 years, ranging from a minimum age of 12 years to a maximum of 18 years.

Study procedure

Neuropsychological assessment tool

In this study, the Rey–Osterrieth complex figure test (ROCF), also known as ROCF-A (Figure 1), was employed. This neuropsychological test evaluates multiple cognitive functions, including visuospatial and visuoconstructive abilities, non-verbal and working memory, attention, and planning [14]. To assess visual perception and working memory, a numerical version of ROCF-A was used, comprising the following elements: Raster paper which is a surface with a pattern of small dots that appears as a simple grey background, minimizing distractions for the user; digital pen (Anoto DP-201 Pen) which is a precision tool equipped with an infrared laser camera, capable of accurately tracking movements on the raster paper (Figure 2); Elian software (Expert Line Information ANalyser) facilitates visualization and analysis of input data and provides near-instantaneous feedback, along with an easy-to-use Excel-compatible data table for statistical evaluation.

The combination of Elian software (Expert version), and the digital pen allows for the collection of highly precise, objective data, with an accuracy of 1/10 of a mm and 1/100 of 1 s. This setup ensures reliable measurement of visual perception and working memory performance.

Selection of study groups

To examine the relationship between visual perception, working memory, and academic performance among the adolescents in our sample, we recruited two distinct groups as shown in Figure 3.

Group 1 (learners with learning difficulties; n=59) was identified based on an in-depth review of the learners' academic records, their academic performance, and input from their teachers. Meanwhile, group 2 (control group; n=63) consisted of learners without learning difficulties, serving as a comparison group.

Procedure and scoring of the ROCF test

Passing the test

The test was administered in two stages. The copying stage: The model is placed horizontally in front of the participant, ensuring clear visibility. The participant is instructed to copy the figure as accurately as possible. Reproduction stage: After the model is removed, the participant is asked to reproduce the figure from memory.

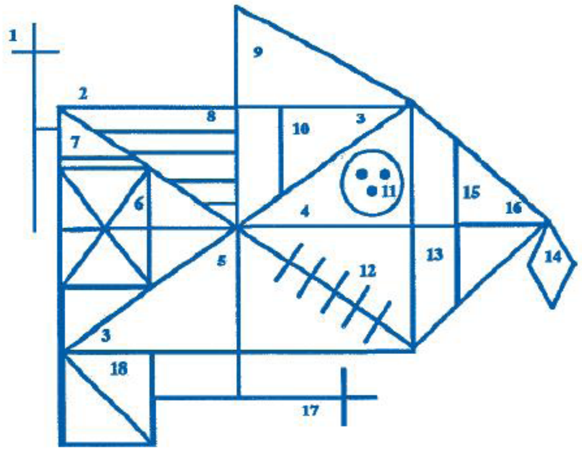

Figure 1. The ROCF-A test

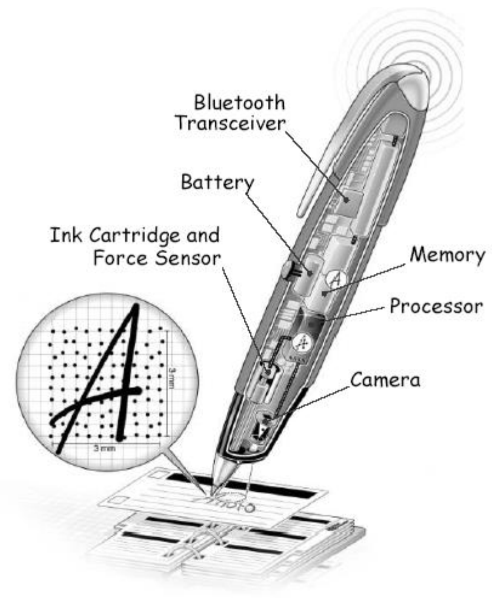

Figure 2. Digital pen anoto DP-201

Wallon and Mesmin recommend a waiting period of less than 3 min between these stages. The time allowed for each stage is unrestricted [14].

Scoring methods

André Rey developed two scoring approaches to evaluate participants' performance on the test.

Numerical scoring: The ROCF-A is divided into 18 elements (Figure 1) and each element is scored as follows:

1) Unrecognizable or absent (0 points); 2) Deformed or incomplete but recognizable and poorly placed (1 point); 3) Deformed or incomplete but recognizable and well placed, or correctly drawn but poorly placed (2 points); 4) Correctly drawn, well placed but imperfect (3 points); 5) Correctly drawn and well placed (4 points). The total score ranges from 0 to 72, with higher scores indicating better performance [14].

Type rating: The type rating method evaluates the strategy used by the participant to copy and reproduce the figure. The ELIAN software, with its " expert" version, analyzes the sequence of strokes to identify the organizational strategy employed. Wallon and Mesmin categorized seven organizational strategies.

Type I (construction of the framework): The participant begins by drawing the large central rectangle, which serves as a framework to group all other elements. This strategy is the most structured and advanced. Type II (details included in the framework): The participant starts

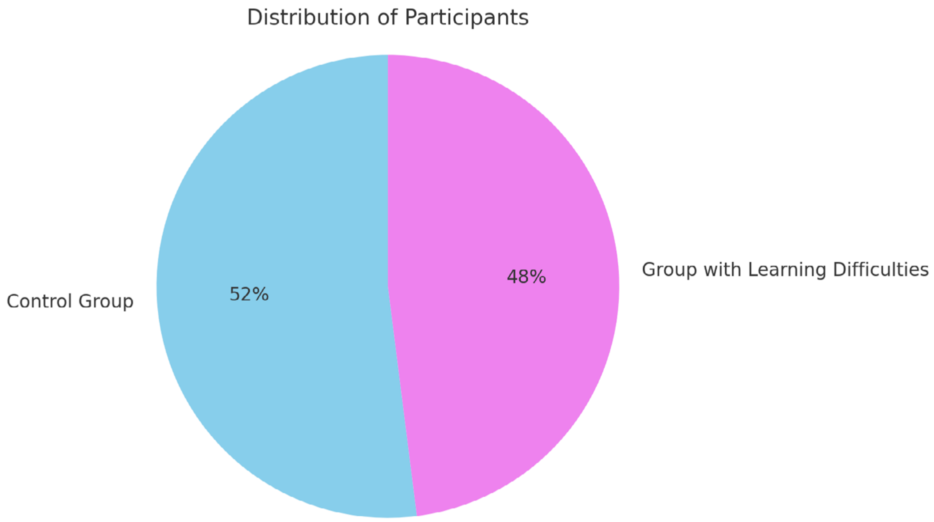

Figure 3. Distribution of learners by academic performance

Table 1. Socio-demographic and educational profile of the sample (n=122)

Variables		No. (%)	Chi-squared	P
Sex	Female	67(54.9)	1.181	>0.05
	Male	55(45.1)		
Geographic provenance	Urban	58(47)	0.295	>0.05
	Rural	64(53)		
Redoubling	No	38(31)	17.344	<0.001
	Yes	84(69)		
Age (y) (Mean±SD)		14.1±1.4		

Note: All estimates are described as the frequencies and proportions unless stated otherwise.

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with a detail (e.g. the upper left cross or a diagonal) and then completes the central rectangle, as in Type I. Type III (general outline): The participant reproduces the full outline of the figure, without differentiating the central rectangle. Interior details are added to this container. Type IV (juxtaposition of details): The participant reproduces the figure by adding details one by one, like assembling a puzzle, without a guiding framework. This approach often results in distortion. Type V (details on a confusing background): The participant produces a poorly organized graphic where the overall pattern unrecognizable, though some individual details are may be identifiable. Type VI (reduction to a familiar pattern): The participant simplifies the figure into a familiar shape (e.g. a house, boat, or fish) that vaguely resembles the original model. Type VII (scribble): The participant produces a scribble with no recognizable elements or structure. This dual-scoring method provides a comprehensive analysis of both the accuracy of the figure reproduction and the cognitive strategies used. It enables an in-depth understanding of participants' visuospatial organization, planning abilities, and memory processes.

Statistical analysis

The collected data were initially organized and filtered in Excel before being transferred to SPSS software, version 25 for statistical analysis. Both descriptive and inferential statistical methods were utilized in this study. Descriptive statistics, including measures such as median and Mean±SD, were used to summarize the central tendencies and variability within the data. For analytical purposes, the Pearson correlation, independent sample t-test and multiple linear regression were applied to explore relationships between variables. A P=0.05 was set as the threshold for statistical significance.

Results

Socio-demographic and educational profile of the sample

During the study period, 122 learners agreed to participate in this study with an average age of 14.1±1.4 years. Regarding gender, we noted a sex ratio of 1/2 with a non-significant differentiation between the two sexes (chi-squared=1.181 and P>0.05). For the environment, 53% of the participants were from rural areas while

Table 2. Comparison of accuracy scores and error-missions in the copying phase between the two groups (n=122)

Variables	Mean±SD Group With Learning Difficulties (n=59)	Mean±SD Group Without Learning Difficulties (n=63)	t	P
Accuracy score	59.98±11.34	66.68±3.72	4.44	<0.001
Errors and omissions	12.01±11.34	5.31±3.72	-4.44	<0.001

Note: P<0.05 are considered statistically significant.

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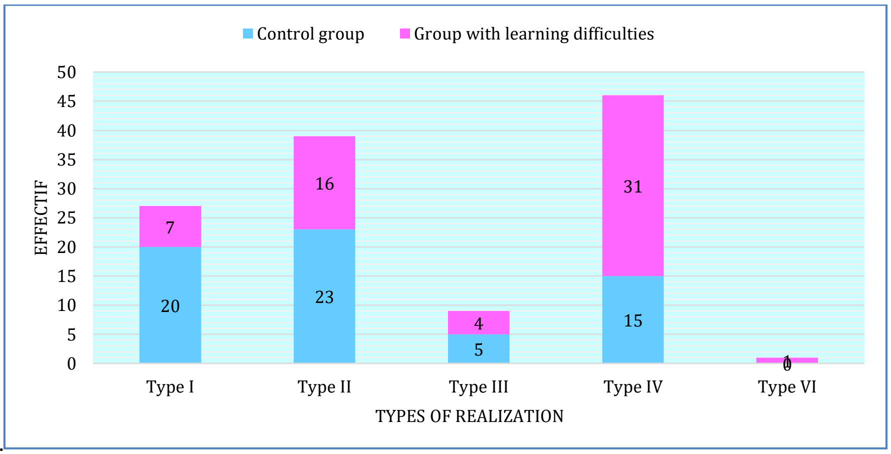

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Figure 4. Comparison of the type of achievement during the copying phase of FCR-A in the two groups of learners

47% of the participants were from urban areas with a non-significant difference between the two sexes (chi-squared=0.295 and P>0.05). For school repetition, 31% of the adolescents in our population have repeated at least one school year with an average of 1.2 years, while 69% of the participants have never repeated a year with a statistically significant difference between the two modalities (chi-squared=17.344 and P<0.001; Table 1).

Studying the relationship between visual perception, work memory, and academic performance

Visual perception and academic performance: the copying phase of the ROCF-A

The numerical quotation during the copy phase included comparison of the means of accuracy scores and errors-omissions in the copying phase of the Rey complex figure between learners in the learning-disabled group and the control group through independent sample t-tests of the results are shown in Table 2. According to the results of the copying phase of the ROCF-A, the group with learning difficulties had a low mean accuracy score of 59.98±11.34 compared to the control group without learning difficulties with the following mean: 66.68±3.72 and the independent sample t-test shows a statistically significant mean difference between the two groups regarding accuracy scores in the copying phase of the ROCF-A (t=4.44, P<0.001, Table 2). Similarly, the group with learning difficulties had a higher mean error/omission score of 12.01±11.34 compared to the control group without learning difficulties with the following mean: 5.31±3.72 and, the independent sample t-test showed a statistically significant difference between the two groups regarding accuracy scores in the copying phase of the Rey-Osterrieth complex figure test (ROCF-A) (t=-4.44, P<0.001, Table 2).

The quotation in types during the copying phase

The analysis of the type of achievement used by the learners in the two groups leads to the results presented in Figure 4.

Comparison of the type of achievement during the copying phase shows significant differences between learners in the two groups: 31.74% of learners in the control group achieved Type I (framework construction) compared to only 11.68% of learners with learning difficulties. Type II (details included in the framework) was completed by 38.98% of learners in the control group versus 27.11% of learners in the difficulty group. Type III (general outline) was completed by almost the same number of learners in both groups. For Type IV (the juxtaposition of details), 52.54% of the learners with difficulties performed this type of exercise compared to 25.42% of the learners in the control group. Type VI (reduction to a familiar pattern) was completed by only one learner with learning difficulties. In the same way, the chi-squared test allows us to verify the existence of a significant link between the different types during the copying phase of the ROCF-A and academic performance with a chi-squared value of 14.076 (P<0.05; Figure 4).

Investigating the relationship between visual perception and academic performance: The reproduction phase of the ROCF-A

The numerical quotation during the reproduction phase

Comparison of the means of the accuracy scores and the errors-omissions in the memory phase of the complex figure of Rey between the learners of the group in the difficulty of learning and the control group through

Table 4. Cronbach α index of the two dimensions

Dimension	Cronbach α
1	0.792
2	0.600
Mean	0.717

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Table 3. Comparison of accuracy scores and error-missions in the memory phase between the two groups (n=122)

Variables		Group	No.	Mean±SD	Student t-test	P*
Memory phase	Accuracy score	Control group	63	46.11±12.8917	5.01	<0.001
		The group with learning difficulties	59	33.79±14.20		
	Errors and omissions	Control group	63	25.88±12.89	-5.01	<0.001
		The group with learning difficulties	59	38.20±14.20		

*P<0.001 indicates difference statistically significant.

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independent sample t-test shows the results presented in Table 3.

Based on the results of the reproduction or memory phase of the ROCF-A, the learning-disabled group had a low mean accuracy score of 33.79±14.20 compared to the control group with a mean of 46.11±12.89 and the independent sample t-test shows a statistically significant difference between the two groups regarding accuracy scores in the copying phase of the ROCF-A (t=5.01, P<0.001). Similarly, the learning-disabled group had a higher mean error and omission score of 38.20±12.89 compared to the control group, which had fewer errors with a mean of 25.88±14.20 and the independent sample t-test shows a statistically significant difference between the two groups regarding accuracy scores in the memory phase of the ROCF-A (t=-5.01, P<0.001, Table 3).

The quotation in types during the reproduction phase

Analysis of the type of achievement used by learners in both groups yields the results shown in Figure 5.

Comparison of the type of achievement during the replication phase in memory shows significant differences between learners in the two groups: 19.04% of learners in the control group achieved type I (frame construction) compared to only 11.86% of learners with learning dif-

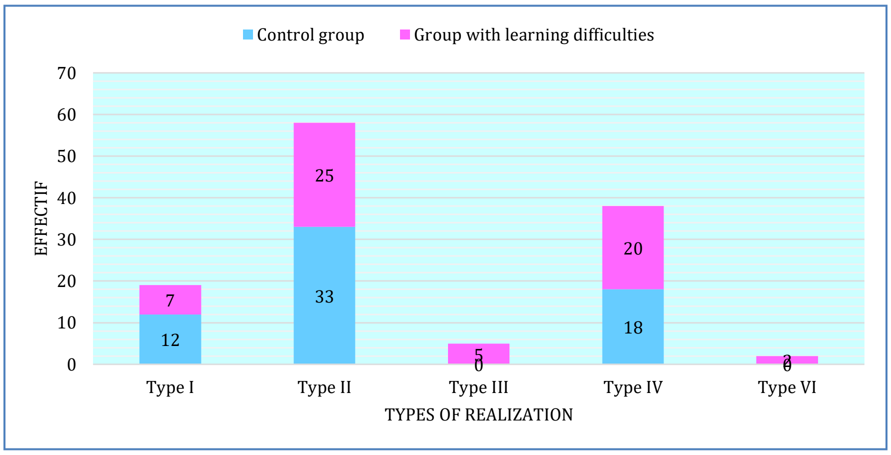

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Figure 5. Comparison of the type of achievement during the ROCF-A memory phase in the two groups of learners.

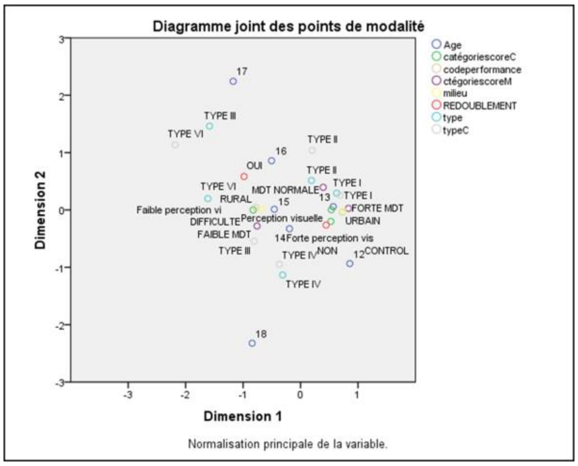

Figure 6. Projection of modalities of different variables by MCA

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ficulties. Type II (details included in the framework) was completed by 52.38% of learners in the control group versus 42.37% of learners in the difficulty group. Type III (general outline) was done only by learners with difficulties. For type IV (the juxtaposition of details), 33.89% of the learners with difficulties performed this type compared to 28.57% of the learners in the control group. Type VI (reduction to a familiar pattern), like type III, was completed by only two learners with learning difficulties. In the same way, the chi-squared test allows us to verify the existence of a significant link between the different types during the phase of reproduction in memory of the ROCF-A and school performance with a value of chi-squared=9.403 and $P<0.05$ (Figure 5).

The multiple correspondence analysis of the studied variables (age, environment, copy score, copy types, reproduction score, reproduction types, academic performance, repetition) showed a homogeneity between the modalities at the level of the two dimensions 1 and 2 with a Cronbach α of 0.79 and 0.60, respectively (Table 4).

The projection of these modalities in the space bounded by axes I and II, which alone absorb 72% of the total variation, defines two major groups (Figure 6).

The first group is characterized by the learners in the control group, aged between 12 and 15 years old living in an urban environment, not repeating a year, the best performers in copy (visual perception) and reproduction (working memory) accuracy scores, who carry out the most methodical execution schemes (type I and II).

The second group is categorically opposed to this first group. It is characterized by learners with learning difficulties with a high repetition rate, aged between 16 and 18 years old, living in rural areas, the least performing in terms of accuracy score in the copying phase (visual perception) and in the reproduction phase (working memory) who perform the least methodical execution patterns (type III and VI).

Discussion

The use of the numerical version of the complex figure of Rey -A (ROCF-A), during this study, aimed to highlight the relationship between two cognitive functions that are solicited by the two phases of the ROCF-A test: Visual perception and working memory on the one hand and academic performance on the other hand in a sample of college students. The results of this study showed that learners with learning difficulties recorded lower accuracy scores, committed more errors, had more omissions, and performed the least methodical patterns of execution compared to the control group and those in the copying and reproduction in memory phases of the ROCF-A test. These results make it possible to establish a link between learning difficulties and learners' performance in cognitive tasks involving visual perception and working memory. The conclusions of this study are in line with previous work on visual perception, a significant association between reading and visual discrimination has been described, a significant association with poor visual and motor integration (low visual-motor) has been observed in 22% of dysgraphia and dyscalculia learners and a correlation between written skills and visual-motor abilities has been reported [12]. The finding that children with learning difficulties in mathematics had significantly more visual perception problems compared to control children was consistent with some studies, but this contrasts with the findings of other authors in a more heterogeneous sample of participants between 6 and 19 years of age [13]. Other researchers [15] have linked math problems with visual perception problems and or motor skills as well as the integration of the two. According to other researchers visual processing of time was an important factor in several language skills such as spelling and word reading [16]. Other investigations have shown a strong association between reading and spelling performance and different categories of perception including visual perception [17]. Regarding working memory, learners with learning difficulties show poor performance in visuospatial MDT compared to learners in the control group. These findings are consistent with other research that has established the relationship between learners' performance on tasks that require visual working memory and their achievement in English, math, and science [18]. Other studies have shown specific associations between performance in visuospatial working memory tasks and low math achievement [19], and similarly investigations have found a positive correlation between learners' math and reading performance and working memory ability [20]. Researchers have suggested that the three components proposed by Baddeley may play a role in mental arithmetic [21]. Similarly, the involvement of working memory in a wide variety of complex cognitive activities, such as reasoning, comprehension and problem solving has been demonstrated by several studies making it a major determinant of academic success [5, 22-37].

Conclusion

This study emphasizes that learners with learning difficulties consistently exhibit poor performance on tasks requiring visual perception and working memory. These two cognitive functions play a critical role in a wide range of learning activities, including reading, writing, mathematics, and problem-solving. Impairments in these areas not only hinder academic achievement but can also impact self-esteem, motivation, and overall cognitive development.

Given the fundamental importance of visual perception and working memory in educational success, we underscore the necessity of comprehensive neurocognitive evaluations and multidisciplinary diagnostic approaches. Such assessments can help identify learners who exhibit deficits in these areas at an early stage, enabling timely and targeted interventions. A neurocognitive evaluation should include tests that assess not only visual perception and working memory but also related skills such as visual-motor integration, attention, and executive functioning.

Moreover, the integration of a multidisciplinary team comprising educators, psychologists, neuropsychologists, and speech or occupational therapists is vital to developing individualized support plans. These plans can include cognitive training, remediation programs and classroom accommodations tailored to the specific needs of learners. For instance, interventions such as visual-perceptual skill training, working memory enhancement exercises, and assistive technology tools can provide practical support for students struggling in these areas.

In addition to individualized interventions, broader systemic efforts are needed to address these challenges. Schools and educational institutions should prioritize teacher training to recognize signs of cognitive difficulties, implement evidence-based strategies for remediation, and foster an inclusive learning environment. Policymakers and educators must also ensure that resources and tools for neurocognitive assessment and support are accessible, particularly in underserved regions or populations where such difficulties may go unnoticed.

Future research should explore the effectiveness of various neurocognitive interventions and their long-term impact on learners' academic performance and overall development. Longitudinal studies with larger and more diverse samples could provide deeper insights into the complex relationships between cognitive functions and learning outcomes. Expanding this research would not only enhance our understanding of these deficits but also contribute to the development of innovative solutions to support learners with learning difficulties.

Identifying and addressing deficits in visual perception and working memory is crucial for enabling learners to reach their full academic potential. By adopting a proactive, multidisciplinary approach to assessment and intervention, educators and clinicians can help mitigate the challenges faced by these learners, fostering improved educational outcomes and long-term success.

Study limitations

This study faced several limitations that warrant consideration. First, the sample size of 122 participants, while adequate for initial analysis, may restrict the generalizability of the findings to a broader population. A larger sample size would enhance the statistical power and allow for more robust conclusions about the relationships between visual perception, working memory, and academic performance. Second, the division of participants into groups based on academic performance introduces potential biases. These biases may stem from unmeasured factors such as self-esteem, motivation, socio-economic background, and other psychosocial variables that were not controlled for in this study. Third, without matching participants on certain, it is difficult to determine the extent to which these factors influenced the observed outcomes. Finally, while the methods used, including the ROCF-A test and its digital adaptations, provide valuable insights, they do not account for potential cultural or contextual differences that may influence task performance. For example, students' familiarity with digital tools or specific test formats may vary, potentially affecting their results.

Future research should aim to address these limitations by employing a longitudinal design to track changes over time. Expanding the sample to include a more diverse population in terms of socioeconomic background, geographic location, and academic achievement would improve the generalizability of the findings. Moreover, controlling for psychosocial and contextual factors through matching or advanced statistical modeling could provide a clearer understanding of the direct and indirect relationships between visual perception, working memory and academic performance. Finally, exploring additional cognitive and environmental variables would offer a more comprehensive perspective on the complex interplay of factors influencing learning outcomes.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of the Sidi Mohamed Ben Abdallah University, Fez, Morocco (FLSH04/2024). This research was conducted with utmost commitment to ethical considerations, ensuring the voluntary collaboration of participants, upholding patients' right to self-determination and rigorously adhering to ethical guidelines regarding privacy, anonymity, and data confidentiality.

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Authors' contributions

Conceptualization: Mounir Bouzaboul; Methodology: Francesco Chirico, Zakaria Abidli, Driss Ait Ali, Murat Yildirim and Amelia Rizzo; Software: Zakaria Abidli, Younes Rami, Amèle El Achhab, Ziri Rabea and Łukasz Szarpak; Validation: Francesco Chirico, Amelia Rizzo, Livio Tarchi and Kavita Batra; Formal Analysis: Zakaria Abidli; Investigation: Zakaria Abidli, Mounir Bouzaboul and Abdeslam Amri; Resources: Amèle EL Achhab, Ziri Rabea; Data collection: Zakaria Abidli, Abdeslam Amri and Adil Hadri; Writing the original draft: Mounir Bouzaboul; Supervision: Francesco Chiricoand Amelia Rizzo; Project administration: Hicham Khabbache; Funding acquisition: Hicham Khabbache; Review and editing: All authors.

Conflict of interest

The authors declared no conflict of interest.

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