

Dyscalculia and working memory deficits in Moroccan children



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Background: Dyscalculia, a specific learning disorder, impairs number comprehension and arithmetic skills and is often associated with working memory deficits. However, this relationship remains understudied in Morocco because of diagnostic and linguistic challenges.

Aim: This study aimed to examine how dyscalculia specifically affects different components of working memory – verbal, visuospatial, and executive – among Moroccan primary school children.

Setting: Public primary schools in Morocco.

Methods: A cross-sectional design was employed with 64 fourth-year pupils (32 diagnosed with dyscalculia and 32 typically developing controls), randomly selected from Moroccan schools. Dyscalculia was confirmed using standardised diagnostic tools, and working memory was assessed with validated subtests adapted for Moroccan children.

Results: The dyscalculia group (DD) demonstrated significantly lower performance across all working memory components compared to typically developing peers ($p < 0.001$), with marked deficits in verbal updating ($r = 0.75$) and visuospatial capacity ($r = 0.70$).

Conclusion: Findings confirm that dyscalculia is associated with pronounced working memory impairments, particularly in verbal and visuospatial domains, consistent with theoretical models of cognitive deficits in developmental dyscalculia.

Contribution: This pioneering Moroccan study extends international evidence by demonstrating similar cognitive patterns in an underrepresented cultural context and underscores the need for culturally adapted interventions to strengthen phonological and visuospatial skills, while acknowledging limitations linked to the small sample size.

Keywords: dyscalculia; working memory; verbal memory; visuospatial memory; executive function; Moroccan children; arithmetic skills; educational interventions.

Introduction

Dyscalculia is a specific learning disorder classified among neurodevelopmental disorders, characterised by significant difficulties in understanding and processing numerical concepts, adversely affecting academic performance and daily skills of affected children (Salisa & Meiliasari 2023). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), dyscalculia is diagnosed as a disorder impairing the ability to comprehend numbers and arithmetic operations, even in the absence of general intellectual deficits (American Psychiatric Association 2013; Mazeau, Pouhet & Ploix Maes 2021). Prevalence estimates suggest dyscalculia affects 3% – 6% of children, comparable to disorders like dyslexia and attention deficit hyperactivity disorder (ADHD), which are often comorbid, complicating cognitive profiles (Guedes, Blanco & Neto 2019; Habib 2018; Santos et al. 2022; Shalev et al. 2000). While traditional definitions focus on mathematical difficulties, recent research highlights deficits in neurodevelopmental cognitive functions, particularly working memory, which is central to this study (Zygouris et al. 2017). In Morocco and other culturally and linguistically diverse contexts, where systematic neuropsychological studies remain scarce, exploring this relationship is crucial for developing effective, contextually appropriate educational interventions.

The structure and function of working memory

The working memory model by Baddeley (2000) provides a robust theoretical framework for understanding cognitive processes in mathematical learning. It comprises three primary components: the phonological loop, which manages verbal information storage and processing;

the visuospatial sketchpad, which handles visual and spatial data; and the central executive, which coordinates these activities and controls attention. Importantly, the central executive is conceptualised as domain-general, meaning it operates across different types of information (verbal, visuospatial, semantic), unlike the storage systems which are modality-specific. However, this distinction between domain-general and domain-specific processing is debated in culturally and linguistically diverse samples (Cockcroft 2022), particularly in non-Western contexts. In addition, Baddeley's model includes the episodic buffer, a fourth component that integrates information from multiple domains and supports memory strategies such as chunking (Baddeley 2007). The episodic buffer has received less empirical attention because of ongoing theoretical debates about its precise role and the absence of standardised tests specifically measuring it; therefore, it was not included in the present study's assessment battery.

These working memory components support various mathematical tasks, including acquiring basic arithmetic skills (Lemaire 1996), number comprehension (Traverso et al. 2021), retrieving arithmetic facts (LeFevre et al. 2013), and problem-solving (Kaskens et al. 2022). Research indicates that children with dyscalculia exhibit marked deficits in working memory, particularly in the visuospatial sketchpad and central executive. For instance, Mammarella et al. (2017) and Menon (2016) found that children with dyscalculia struggle with tasks requiring spatial information processing, such as block recall tests. In addition, Andersson and Lyxell (2007) suggest that central executive deficits impair simultaneous processing and storage of numerical information, exacerbating arithmetic difficulties. However, Attout and Majerus (2015) propose that deficits may be more related to sequential information processing, raising questions about the specificity of these impairments in dyscalculia.

Working memory deficits in dyscalculia: Evidence from diverse contexts

Further studies reinforce these findings while highlighting important nuances. Friso-van den Bos et al. (2013), in a meta-analysis, demonstrate that all working memory components are linked to mathematical performance, with a stronger association for verbal updating. Similarly, DeStefano and LeFevre (2004) confirm that mental arithmetic relies on the integration of all working memory components. Clearman, Klinger and Szűts (2017) show higher interference between arithmetic tasks and visuospatial working memory compared to the phonological loop, underscoring the visuospatial sketchpad's particular role in dyscalculia. Importantly, Layes (2022) notes that Arabic-speaking children with dyscalculia exhibit deficits in both verbal and visuospatial memory, particularly when comorbid with dyslexia, highlighting cognitive interactions between disorders relevant to Arabic-speaking populations. However, Schuchardt, Maehler and Hasselhorn (2008) suggest dyscalculia is more associated with the visuospatial sketchpad, while dyslexia is linked to

the phonological loop, indicating distinct cognitive profiles. These discrepancies raise questions about the specificity of working memory deficits in dyscalculia, and importantly, underscore the need to investigate these patterns in culturally and linguistically diverse contexts.

Most existing studies on working memory and dyscalculia have been conducted in western, educated, industrialised, rich, and democratic (WEIRD) contexts, predominantly with monolingual children from high socioeconomic backgrounds. These studies provide robust evidence of working memory's role in dyscalculia but face significant limitations because of methodological differences and varying definitions of dyscalculia. For example, while Layes (2022) focuses on Arabic speakers and is relevant to Morocco, this study does not account for linguistic diversity such as Tamazight (also known as Amazigh), an official language in Morocco that may differentially affect phonological loop performance. Recent research from South African contexts – which share similarities with Morocco in terms of multilingualism, lower socioeconomic circumstances and linguistic diversity – provides valuable insights. Cockcroft and Milligan (2019) found that the structure of working memory in atypical development differed significantly from typically developing children, with human immunodeficiency virus (HIV)-affected children showing undifferentiated working memory structures. This suggests that contextual and developmental factors substantially influence how working memory components are organised and function. Furthermore, Cockcroft (2022) critically examines whether dominant working memory models developed in WEIRD samples are adequately applicable to non-WEIRD populations, arguing that the presumed domain-general nature of the central executive may vary across cultural and linguistic contexts.

The Moroccan context: Addressing a critical research gap

In Morocco, examining the relationship between working memory and dyscalculia is critical because of limited local research and specific contextual challenges. Moroccan children face unique linguistic and socioeconomic circumstances that may jointly influence working memory functioning. The educational system is multilingual (Standard Arabic, Moroccan Darija, Tamazight and often French), and the phonological properties of these languages differ substantially; for instance, Arabic is a consonantal script, while Tamazight has distinct phonological structures that place different demands on phonological encoding and processing. The confluence of multilingual education and code-switching increases reliance on central executive resources, potentially affecting the typical organisation and efficiency of working memory. In addition, low awareness of dyscalculia often leads to misinterpretation as a lack of effort or intelligence, hindering early interventions. Furthermore, most standardised working memory and mathematical assessments have been developed and validated in Western samples and may not be culturally or linguistically appropriate for Moroccan children, compounding diagnostic and intervention challenges in this context.

Studies such as Gupta and Sharma (2017) offer promising insights, demonstrating that cognitive strategy training can enhance mathematical performance by reducing working memory load, suggesting that targeted interventions tailored to specific populations and contexts can be effective. This study hypothesises that Moroccan children with dyscalculia will exhibit deficits in working memory components, particularly the visuospatial sketchpad and central executive, and that these deficits may manifest differently because of cultural and linguistic factors. By examining this relationship in a Moroccan sample of urban, middle-socioeconomic status children from multiple cities, the study aims to extend international evidence of dyscalculia's neurocognitive correlates to an underrepresented context, while accounting for the linguistic diversity (Moroccan Darija, Tamazight) and educational practices unique to Morocco. This will provide empirical evidence to support the development of culturally and linguistically adapted assessment approaches and interventions, advancing both scientific understanding and practical support for children with dyscalculia in non-WEIRD contexts.

Research methods and design

Study design

This study adopted a cross-sectional design comparing working memory functions between children with dyscalculia and typically developing controls. Participants were selected based on specific inclusion and exclusion criteria, with working memory assessed using four validated subtests.

Participants

Sample characteristics

The sample comprised 64 fourth-year primary pupils, aged 9.0–11.0 years, divided into two groups: children with dyscalculia group (DD, $n = 32$) and typically developing children (TD group, $n = 32$). The DD group consisted of 14 males and 18 females ($Age = 9.58$ years, standard deviation [SD] = 0.50, range = 9.00–11.00 years; 43.75% male). The TD group comprised 16 males and 16 females ($Age = 9.55$ years, range = 9.0–10.5 years; 50% male). The two groups did not differ significantly in age ($t(62) = 0.30$, $p = 0.76$) or gender distribution ($\chi^2 = 0.50$, $p = 0.48$), ensuring comparability on these demographic variables. While gender matching was not an initial selection criterion, the groups showed similar gender distributions. This is not considered problematic given the absence of consistent evidence for significant gender differences in the prevalence or cognitive profile of developmental dyscalculia (Devine et al. 2013; Shalev et al. 2000).

Dyscalculia group selection

The DD group was recruited from a learning disabilities association located within a public school in Morocco through a multi-stage process. Initially, 64 children who had been previously diagnosed with developmental dyscalculia by school psychologists were identified based on persistent

difficulties in numerical and arithmetic tasks. Exclusion criteria included intellectual disability (Raven's Coloured Progressive Matrices [RCPM] < 10th percentile), comorbid learning disorders (particularly dyslexia), neurological or sensory impairments, and lack of parental consent. Following application of these criteria, 14 children were excluded (8 because of low cognitive ability on the RCPM, 4 because of suspected comorbid dyslexia, and 2 because of lack of parental consent), resulting in 50 eligible children with dyscalculia. From this pool, 32 participants were randomly selected to form the final DD group. All children in the final DD group scored within or above the average range on the RCPM, ensuring that observed mathematical difficulties were attributable to dyscalculia rather than general intellectual deficits.

Typically developing group selection

The TD group was recruited from public schools to ensure comparability in educational environment, linguistic context and socioeconomic background. To ensure that the TD group did not include children with undiagnosed dyscalculia, all potential TD participants were screened using the Custom Dyscalculia Test (see Instruments section). Only children who scored above the established cut-off (> 55 , indicating typical mathematical performance) and who met the following inclusion criteria were eligible: (1) age between 9 and 11 years; (2) enrolment in fourth-year primary for the first time; (3) no history of diagnosed learning, neurological or psychiatric disorders; (4) normal or corrected-to-normal vision and hearing; and (5) parental consent. From a larger pool of eligible children, 32 participants were randomly selected and individually matched to the DD group on age (within 6 months) and gender.

Instruments

Dyscalculia diagnosis: Two tools were used to diagnose and confirm dyscalculia:

Raven's coloured progressive matrices: The RCPM (Raven, Court & Raven 1998) assessed non-verbal fluid intelligence to screen for intellectual disability that might confound dyscalculia diagnosis. This culturally reduced test measures the ability to perceive relationships and reason by analogy, independent of language. Performance below the 10th percentile was used as an exclusion criterion to ensure arithmetic difficulties were not attributable to general intellectual deficits. The RCPM has demonstrated good psychometric properties across diverse cultural contexts (Raven 2000).

Custom dyscalculia test: The Custom Dyscalculia Test was developed to assess arithmetic competence aligned with DSM-5 diagnostic criteria (American Psychiatric Association 2013) for Specific Learning Disorder with Impairment in Mathematics, evaluating core deficits including impaired number sense, calculation accuracy and mathematical reasoning. The test assesses nine arithmetic domains: calculation without counting, counting dots, reverse oral

counting, quantity and number comparison, visual quantity estimation, number reading, number conversion between symbolic systems, positioning numbers on a number line, arithmetic operations and mathematical problem-solving.

The test draws on established theoretical models including McCloskey, Caramazza and Basili's (1985) arithmetic model, Dehaene's (1992) triple-code model, Butterworth's (2005, 2010) primary dyscalculia model and Von Aster and Shalev's (2007) developmental numerical cognition model. It also incorporates insights from systematic reviews (Lafay, Saint-Pierre & Macoir 2014; Marcon & Lafay 2019), Algerian adaptations (Lahmer 2021; Lahmer & Mecherbet 2017) and diagnostic batteries including Zareki-R (Dellatolas & Von Aster 2006), Numerical (Gaillard 2000) and UDN II (Utilisation du Nombre II [Use of Number II]) (Meljac & Lemmel 1999), while aligning with Morocco's Ministry of National Education curriculum (2021).

The test underwent expert validation, pilot testing and psychometric evaluation with 128 typically developing children and 32 children with dyscalculia. Test-retest reliability was $r = 0.88$, internal consistency $\alpha = 0.76$ – 0.79 and split-half reliability $\rho = 0.84$. Exploratory factor analysis (Kaiser-Meyer-Olkin [KMO] = 0.78) confirmed construct validity. Receiver operating characteristic (ROC) curve analysis yielded area under the curve (AUC) = 0.927 (95% confidence interval [CI]: 0.881–0.973) with optimal cut-off ≤ 55 (Sensitivity = 87.5%; Specificity = 83.6%).

Working memory assessment: Four standardised subtests assessed Baddeley's (2000) working memory components. These subtests were adapted from the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler 2003) and validated for Moroccan children (Er-Rafiqi 2020; Er-Rafiqi et al. 2017, 2022).

Digit span forward (Wechsler 2003; adapted by Er-Rafiqi et al. 2017): This subtest measures phonological loop capacity, the verbal short-term storage component. Participants recall sequences of digits of increasing length in the same order. The test discontinues after two consecutive failures.

Digit span backward (Wechsler 2003; adapted by Er-Rafiqi et al. 2017): This subtest measures verbal working memory, requiring temporary storage (phonological loop) and active manipulation through mental reversal (central executive). Participants recall digit sequences in reverse order, tapping both storage and updating functions through the domain-general central executive (Baddeley 2000). The test discontinues after two consecutive failures.

Corsi block-tapping forward (adapted by Er-Rafiqi et al. 2017): This subtest measures visuospatial sketchpad capacity. The examiner taps a sequence of blocks, and participants reproduce the sequence in the same order. The test discontinues after two consecutive failures.

Corsi block-tapping backward (adapted by Er-Rafiqi et al. 2017): This subtest measures visuospatial working memory, requiring temporary storage (visuospatial sketchpad) and active manipulation through mental reversal (central executive). Participants reproduce tapped sequences in reverse order, tapping both storage and updating functions through the domain-general central executive (Baddeley 2000). The test discontinues after two consecutive failures.

Procedures

Assessments were conducted individually in quiet school rooms by trained researchers fluent in Moroccan Arabic (Darija). For the DD group, dyscalculia was confirmed using the RCPM and Custom Dyscalculia Test, followed by working memory tests in fixed order (Digit Span Forward, Digit Span Backward, Corsi Block Forward, Corsi Block Backward) in a single 45 min – 60 min session. For the TD group, the Custom Dyscalculia Test screened for undiagnosed dyscalculia before administering the working memory battery. All tests followed standardised protocols adapted for Moroccan children, with culturally adapted instructions.

Data analysis

Data were processed using Statistical Package for the Social Sciences (IBM SPSS Statistics, version 27; IBM Corporation, Armonk, New York, United States) (version 27). The Shapiro-Wilk test revealed significant deviations from normality in both groups across most working memory subtests (all $p < 0.05$), particularly in the DD. Consequently, non-parametric analyses were deemed most appropriate.

Statistical procedures

Mann-Whitney U tests were conducted to compare groups on each working memory subtest. This non-parametric test was chosen because it does not assume normal distribution and is robust to violations of normality. To control for Type I error inflation because of multiple comparisons (four tests), a Bonferroni correction was applied, adjusting the significance threshold to $\alpha = 0.0125$ ($0.05/4$).

Effect sizes were calculated using $r = |Z|/\sqrt{N}$, where Z is the standardised test statistic and $N = 64$. Effect sizes were interpreted according to Cohen's (1988) conventions: $r \geq 0.10$ (small), $r \geq 0.30$ (medium), and $r \geq 0.50$ (large).

Power analysis

To ensure adequate statistical power, a post hoc power analysis was conducted using G*Power 3.1 (Faul et al. 2007). Considering a two-tailed Mann-Whitney U test, $\alpha = 0.05$ (before Bonferroni correction), and a large effect size ($d = 0.80$) consistent with previous dyscalculia research (e.g. Szűcs et al. 2013), the achieved power ($1-\beta$) was 0.87. This indicates sufficient power to detect large group differences, even within the constraints of recruiting a well-diagnosed clinical population. Similar sample sizes have been reported

in prior dyscalculia research because of the rarity of rigorously diagnosed cases (e.g. Passolunghi & Mammarella 2012; Schuchardt et al. 2008).

Ethical considerations

Ethical approval to conduct this study was obtained from the Kingdom of Morocco, Ministry of National Education, Preschool and Sports Educational Affairs Department and Sidi Mohamed Ben Abdellah University, Faculty of Arts and Humanities and was received on 1 February 2023. The ethical approval number is 19/21. This study was reviewed and approved by the Applied Psychology, Languages, and Philosophy Laboratory, Fez, Morocco, and received formal authorisation from the participating educational institutions and the Moroccan Association of Dyslexia. Informed written consent was obtained from the legal guardians of all participating children. All ethical principles related to educational and psychological research, including confidentiality, privacy and voluntary participation, were strictly observed. The study was approved by the institutional ethics committee in accordance with the Declaration of Helsinki.

Results

Descriptive statistics

Descriptive statistics for all working memory measures by group are presented in Table 1. The typically developing group (TD) consistently outperformed the DD across all four working memory subtests, with differences evident in both means and medians.

Group comparisons

Mann-Whitney *U* tests were conducted to compare the two groups on each working memory subtest. Results are presented in Table 2 and illustrated in Figure 1.

The DD performed significantly worse than the TD across all four working memory measures (all $p < 0.001$), with all comparisons remaining significant after Bonferroni correction. Effect sizes ranged from medium to large, indicating substantial working memory impairments in children with dyscalculia.

TABLE 1: Descriptive statistics for working memory measures by group.

Measure	Group	<i>M</i>	<i>SD</i>	<i>Mdn</i>	Range
Digit span forward (Phonological loop)	DD	4.97	1.23	5.00	3–7
	TD	7.09	1.57	7.00	4–10
Digit span backward (Verbal updating)	DD	3.25	1.08	3.00	2–6
	TD	5.75	1.22	6.00	4–8
Corsi block forward (Visuospatial sketchpad)	DD	5.44	1.37	6.00	3–8
	TD	8.06	1.48	8.00	4–11
Corsi block backward (Visuospatial updating)	DD	4.34	1.66	4.00	2–8
	TD	5.97	1.26	6.00	4–8

Note: Parenthetical labels indicate the working memory component assessed by each measure according to Baddeley's (2000) model.

DD, Dyscalculia Group ($n = 32$); TD, Typically Developing Group ($n = 32$); *M*, mean; *SD*, standard deviation; *Mdn*, median.

Verbal Working Memory: The largest group differences were observed in verbal working memory tasks. For Digit Span Backward (verbal updating), the DD showed marked deficits ($U = 70.5$, $Z = -6.032$, $p < 0.001$, $r = 0.75$), representing a large effect size. This suggests substantial difficulties in the simultaneous storage and manipulation of verbal information, implicating both the phonological loop and central executive components of working memory. For Digit Span Forward (phonological loop capacity), the DD also demonstrated significant impairments ($U = 159.0$, $Z = -4.839$, $p < 0.001$, $r = 0.60$), indicating deficits in the temporary storage of verbal information.

Visuospatial Working Memory: Substantial deficits were also evident in visuospatial working memory. For Corsi Block Forward (visuospatial sketchpad capacity), the DD showed large impairments ($U = 103.5$, $Z = -5.591$, $p < 0.001$, $r = 0.70$), reflecting difficulties in the temporary storage of visuospatial information. For Corsi Block Backward (visuospatial updating), the DD demonstrated medium to large deficits ($U = 236.5$, $Z = -3.793$, $p < 0.001$, $r = 0.47$), indicating difficulties in the simultaneous storage and manipulation of visuospatial information.

The negative *Z*-values across all comparisons confirm that the DD consistently obtained lower scores than the TD, supporting the hypothesis that children with dyscalculia exhibit pervasive deficits across multiple components of working memory.

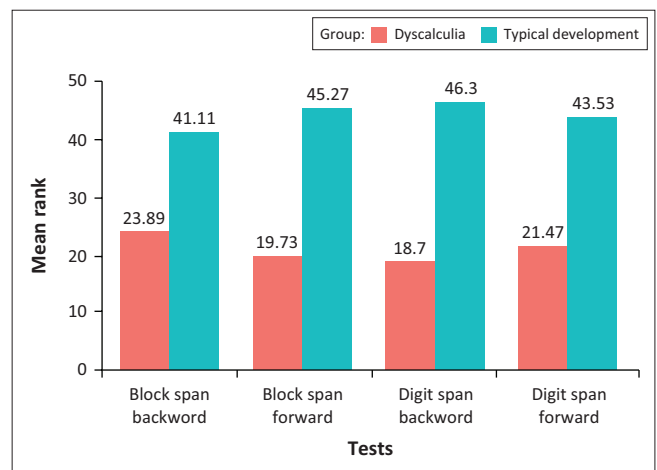


FIGURE 1: Comparison of mean rank scores between participants with dyscalculia and typically developing controls across four working memory span tasks.

TABLE 2: Comparison of working memory performance between dyscalculia and typically developing groups.

Subtest	<i>U</i>	<i>Z</i>	<i>p</i>	<i>r</i>
Digit span forward	159.0	-4.839	< 0.001	0.60
Digit span backward	70.5	-6.032	< 0.001	0.75
Corsi block forward	103.5	-5.591	< 0.001	0.70
Corsi block backward	236.5	-3.793	< 0.001	0.47

Note: All results remained statistically significant after Bonferroni correction (adjusted $\alpha = 0.0125$). *U*, Mann-Whitney *U* statistic; *Z*, standardised test statistic; *p*, two-tailed significance level; *r*, effect size.

Discussion

The primary objective of this study was to investigate the impact of dyscalculia on verbal and visuospatial working memory among Moroccan children. The findings revealed significant deficits in all working memory components among children with dyscalculia compared to their typically developing peers, providing valuable insights into the cognitive challenges associated with this neurodevelopmental disorder in a Moroccan context. This section discusses these findings in relation to existing literature, highlights their practical implications and addresses the study's strengths, limitations and recommendations for future research.

Children with dyscalculia exhibited notable deficits across all working memory components. The pronounced deficits in verbal updating ($r = 0.75$) and visuospatial capacity ($r = 0.70$) suggest that these components are particularly sensitive to dyscalculia-related impairments. These findings align with Baddeley's (2000) working memory model and support previous research by Andersson and Lyxell (2007), who reported similar deficits in the phonological loop and central executive, and Mammarella et al. (2017) and Menon (2016), who confirmed that visuospatial sketchpad deficits are a hallmark of dyscalculia, particularly in spatial processing tasks.

However, Attout and Majerus (2015) suggest that deficits may be more closely tied to sequential processing rather than storage alone, indicating that the observed impairments may encompass both storage and processing capacities. In the Moroccan context, Layes (2022) found that Arabic-speaking children with dyscalculia exhibit deficits in both verbal and visuospatial memory, particularly when dyslexia is comorbid, highlighting the interaction between cognitive domains. These findings underscore the complexity of working memory deficits in dyscalculia and the importance of examining these patterns in culturally and linguistically diverse contexts, where models developed in Western samples may not fully capture the structure and function of working memory (Cockcroft 2022).

The study's results align with established theoretical frameworks, particularly Dehaene's (1992, 2003) triple-code model of numerical cognition and mathematical reasoning, which links verbal and visuospatial representation difficulties to arithmetic challenges. The large effect sizes in Digit Span Backward and Corsi Block Forward indicate that verbal updating and visuospatial capacity are critical areas of impairment, consistent with Friso-van den Bos et al.'s (2013) meta-analysis. The medium to large effect in Corsi Block Backward ($r = 0.47$) suggests that visuospatial updating, while significantly impaired, may show a somewhat smaller effect, possibly because of increased task complexity or differential reliance on central executive resources (Menon 2016). However, the current findings demonstrate substantial impairments in both verbal and visuospatial working memory in children with dyscalculia, suggesting that the

cognitive profile of dyscalculia may be more heterogeneous than previously thought, particularly in multilingual contexts like Morocco where phonological processing demands are more complex.

In Morocco, where research on dyscalculia is limited, these findings are significant. The study extends international evidence on dyscalculia to an underrepresented context, demonstrating that working memory deficits observed in Western samples are also evident in Moroccan children. The impact of linguistic diversity on phonological loop performance may complicate diagnosis and intervention, as children must navigate multiple phonological systems with distinct orthographic and phonological properties. This multilingual context places additional demands on central executive resources, which may exacerbate working memory deficits in children with dyscalculia (Cockcroft 2022). Low awareness of dyscalculia often leads to its misinterpretation as a lack of effort or intelligence, hindering early identification and support. Gupta and Sharma (2017) suggest that cognitive strategy training can reduce working memory load and enhance mathematical performance, offering a promising approach for Moroccan educators. The development of Arabic-language educational materials aligned with the Moroccan curriculum, as recommended by Layes (2022), could address these challenges and improve outcomes for children with dyscalculia.

This research underscores the need for tailored educational interventions in Morocco to support children with dyscalculia. Phonological exercises to strengthen verbal memory, as suggested by Swanson and Sachse-Lee (2001), and visuospatial activities to enhance number representation, as proposed by Gupta and Sharma (2017), could be integrated into school curricula. Psychologists and educators should prioritise developing culturally and linguistically adapted assessment tools to identify working memory deficits accurately, as most standardised assessments have been developed and validated in Western samples and may not be appropriate for Moroccan children (Cockcroft 2022). These tools could facilitate early diagnosis and intervention, addressing the unique challenges posed by Morocco's multilingual educational system. In addition, teacher training programmes should emphasise recognising the signs of dyscalculia and distinguishing it from general low achievement or lack of motivation, which would enable earlier referral and support.

Strengths and limitations

This study provides a pioneering exploration of dyscalculia in Morocco using validated, culturally adapted tools (Er-Rafiqi et al. 2017, 2022) and rigorous diagnostic procedures, including RCPM and a custom dyscalculia test. The comprehensive assessment of multiple working memory components provides a nuanced understanding of cognitive deficits, extending beyond single-component assessments.

However, several limitations warrant acknowledgment. The sample size ($n = 32$ per group) is relatively small, which limits statistical power for detecting smaller effects and restricts generalisability. This limitation is partly attributable to diagnostic challenges in Morocco, where culturally adapted tools and trained specialists are scarce. However, the large effect sizes observed across all working memory measures suggest that the sample was adequate for detecting the substantial group differences evident in this study. The study's focus on working memory excludes other executive functions such as inhibition or cognitive flexibility, limiting understanding of broader cognitive interactions. While general intelligence was controlled using RCPM, this measure provides only a broad estimate of non-verbal reasoning and may not capture all relevant cognitive abilities that could influence working memory performance. Finally, the cross-sectional design precludes causal inferences about the relationship between working memory deficits and dyscalculia; longitudinal studies are needed to examine how working memory difficulties emerge and evolve over time in children with dyscalculia.

Recommendations for future research

Future research should involve larger, regionally diverse Moroccan samples to enhance generalisability. Longitudinal studies examining the developmental trajectory of working memory deficits in dyscalculia and the long-term impact of working memory interventions on academic outcomes are strongly recommended. Functional neuroimaging could explore the neural bases of working memory deficits in Moroccan children compared to Western samples. The development of locally adapted assessment and intervention tools tailored to Morocco's linguistic and cultural context is crucial and should be a priority for researchers and educational policymakers. Educators and policymakers should invest in teacher training programmes to raise awareness of dyscalculia, improve diagnostic accuracy, and implement evidence-based, culturally sensitive teaching strategies.

Conclusion

This study provides critical insights into the impact of dyscalculia on working memory among Moroccan children, confirming significant deficits in verbal and visuospatial components consistent with theoretical models (Baddeley 2000; Dehaene 1992). By demonstrating that working memory deficits characteristic of dyscalculia are evident in a non-Western, multilingual context, the findings highlight the need for culturally sensitive interventions and assessment tools to support affected children. This research marks a foundational step towards understanding dyscalculia in Morocco, paving the way for improved educational and psychological support to enable children with dyscalculia to thrive academically.

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Competing interests

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CRedit authorship contribution

Salahddine Zerouali: Conceptualisation, Data curation, Formal analysis, Methodology, Writing-original draft. Hamid Kaddouri: Methodology, Writing-review & editing. Abdelouahed El-kamia: Data curation, Funding acquisition. Smail Alaoui: Visualisation, Supervision. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are openly available from the corresponding author, Salahddine Zerouali, upon reasonable request.

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