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Research Article

A Neurocognitive Approach to Early Reading Intervention for Elementary School Children with Dyslexia

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Abstract
Early reading difficulties, particularly dyslexia, pose significant challenges for elementary school children, affecting academic achievement and long-term literacy development. Neurocognitive research suggests that deficits in phonological processing, working memory, and rapid automatized naming are core contributors to reading impairments. Understanding these underlying cognitive mechanisms is crucial for designing effective early reading interventions that target both skill acquisition and brain-based processing. This study aims to investigate the efficacy of a neurocognitive-based early reading intervention for children with dyslexia, focusing on improvements in reading fluency, decoding accuracy, and phonological awareness. A quasi-experimental design was employed with 60 elementary school participants diagnosed with dyslexia, divided into intervention and control groups. Standardized neurocognitive assessments and reading tests were administered pre- and post-intervention. Results indicated that children receiving the neurocognitive intervention demonstrated significant gains in decoding accuracy, reading fluency, and phonological awareness compared to the control group. The study concludes that interventions informed by neurocognitive principles can effectively enhance reading outcomes for children with dyslexia, providing both practical and theoretical insights into tailored literacy instruction.

Keywords: Early Reading, Elementary Education, Phonological Processing

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INTRODUCTION

Reading is a fundamental skill that serves as the foundation for academic learning and cognitive development in children. Early literacy acquisition supports not only reading proficiency but also critical thinking, communication skills, and overall educational success (Peng et al., 2025; Saunders et al., 2024). Dyslexia, a neurodevelopmental disorder characterized by difficulties in accurate and fluent word recognition, phonological processing deficits, and spelling challenges, affects a significant proportion of elementary school children worldwide. Children with dyslexia often experience frustration, reduced motivation, and lower self-esteem, which can lead to cumulative academic underachievement if not addressed with timely interventions. Understanding the neurocognitive underpinnings of dyslexia is therefore essential to inform evidence-based approaches to early reading intervention. Neurocognitive research has highlighted specific cognitive mechanisms that contribute to reading development, including phonological awareness, working memory, and rapid automatized naming (Kuo et al., 2024; Visapää et al., 2023). These executive and language-related processes interact to support decoding, word recognition, and reading comprehension. Dyslexic children frequently exhibit impairments in one or more of these neurocognitive domains, which hinder their ability to acquire reading fluency despite normal intelligence and adequate educational exposure. Investigating the role of neurocognitive processes in early reading provides a framework for designing interventions that target the root causes of reading difficulties rather than merely compensating for surface-level deficits.

Early intervention is widely recognized as a critical factor in mitigating the long-term effects of dyslexia. Programs that integrate cognitive neuroscience findings with instructional practice can enhance phonological processing, improve working memory capacity, and facilitate strategy use during reading. Evidence suggests that timely, neurocognitively informed interventions are more effective than generic remedial instruction because they address underlying cognitive mechanisms that impede reading acquisition. This research situates itself within the intersection of educational psychology, cognitive neuroscience, and literacy instruction, emphasizing the necessity of neurocognitive approaches for children with dyslexia (Kuo et al., 2024; Visapää et al., 2023). Children with dyslexia face persistent difficulties in early reading acquisition, which negatively affect their academic performance and cognitive development. Despite exposure to standard literacy curricula, many dyslexic learners fail to achieve age-appropriate reading fluency and comprehension. This failure often results in a widening achievement gap between dyslexic and non-dyslexic peers, reinforcing the importance of identifying effective, targeted interventions that can address core cognitive deficits. Without systematic support, these children are at risk of long-term educational disadvantages. Traditional reading interventions frequently emphasize repetition, phonics drills, or general skill-building activities without addressing the underlying neurocognitive deficits that contribute to dyslexia. While such programs can provide incremental improvements, they often fail to produce durable gains in reading fluency or comprehension. Children continue to struggle with decoding, word recognition, and the cognitive load associated with integrating phonological, orthographic, and semantic information (Marx et al., 2025; Zhuang et al., 2025). The absence of interventions grounded in neurocognitive theory highlights a critical gap in early literacy support.

Variability in cognitive profiles among dyslexic children further complicates intervention strategies. Some children exhibit pronounced phonological deficits, while others display limitations in working memory or processing speed. These differences suggest that a one-size-fits-all approach to reading remediation is insufficient. Understanding the specific neurocognitive mechanisms that contribute to individual reading difficulties is necessary for developing personalized, effective intervention programs that can enhance early literacy outcomes for children with dyslexia (Visapää et al., 2023; Zhuang et al., 2025). The primary objective of this study is to evaluate the effectiveness of a neurocognitive-based early reading intervention in improving literacy outcomes for elementary school children with dyslexia. Specific objectives include enhancing decoding accuracy, reading fluency, and phonological awareness through targeted exercises that engage core cognitive processes associated with reading. The study seeks to establish empirical evidence linking neurocognitive interventions with measurable improvements in early literacy performance. Another objective is to investigate the differential contributions of specific neurocognitive components, such as phonological processing, working memory, and rapid automatized naming, to reading development in children with dyslexia. By examining the cognitive mechanisms underlying intervention outcomes, this research aims to clarify how targeted neurocognitive training facilitates reading acquisition and supports sustained literacy gains.

The study also aims to inform educational practice and policy by demonstrating the value of integrating cognitive neuroscience insights into early literacy instruction. Results are expected to provide actionable recommendations for teachers, curriculum designers, and special education practitioners, highlighting strategies to optimize reading development and mitigate the long-term academic challenges faced by dyslexic learners. Existing literature has established that dyslexia involves deficits in phonological processing, working memory, and rapid naming, but research examining interventions that explicitly target these neurocognitive domains remains limited. Most intervention studies focus on general literacy strategies or phonics-based instruction without incorporating the latest findings from cognitive neuroscience (Marx et al., 2025; Paula et al., 2023). This gap restricts the ability to develop evidence-based programs that address the root cognitive causes of dyslexia. Many previous studies report improvements in reading outcomes but fail to clarify which neurocognitive processes are driving these gains. The absence of detailed assessment and intervention targeting specific cognitive mechanisms limits the precision and generalizability of prior findings. A systematic investigation that links neurocognitive interventions to measurable changes in executive and language-related functions is therefore warranted. Cultural and contextual factors also contribute to the research gap. Variations in early literacy curricula, educational practices, and classroom environments may influence the effectiveness of interventions (Share, 2025; Zheng et al., 2025). Few studies have examined neurocognitive approaches within diverse educational contexts, leaving questions about the transferability of existing findings. Addressing these gaps can advance theoretical understanding and improve practical outcomes for children with dyslexia globally.

This study introduces a neurocognitive approach that integrates cognitive neuroscience principles with early reading intervention for children with dyslexia. Unlike traditional literacy programs, the intervention specifically targets deficits in phonological processing, working memory, and rapid naming, offering a theoretically grounded, evidence-based method to enhance reading fluency and accuracy (Bhalloo et al., 2025b, 2025a). This approach

contributes a novel framework for linking cognitive mechanisms to educational outcomes. The research provides methodological innovation by combining standardized neurocognitive assessments, targeted intervention exercises, and pre-post evaluation of reading outcomes. This comprehensive approach enables the identification of which executive and language-related cognitive processes are most responsive to intervention, providing insights that extend beyond surface-level literacy gains. The study's methodology can serve as a model for future interdisciplinary research in neurocognitive literacy intervention. Justification for this research lies in its potential to inform early education practice and policy (Daffern, 2024; Okechukwu et al., 2023). By demonstrating the efficacy of neurocognitive-based interventions, the study provides practical guidance for teachers and practitioners seeking to support children with dyslexia. Additionally, it contributes theoretically to the understanding of how cognitive mechanisms influence literacy acquisition, bridging cognitive psychology, neuroscience, and educational research in a manner that enhances both scientific knowledge and educational practice.

RESEARCH METHOD

The study employed a quasi-experimental research design to investigate the effectiveness of a neurocognitive-based early reading intervention for elementary school children with dyslexia. This design was chosen to allow for comparison between an intervention group and a control group while maintaining ecological validity within the school setting (Okechukwu et al., 2023; Wang & Booth, 2024). The research focused on assessing changes in reading fluency, decoding accuracy, and phonological awareness, enabling an evaluation of the direct impact of the neurocognitive intervention on literacy outcomes. Pre- and post-intervention assessments provided empirical evidence to determine the efficacy of targeted cognitive-based instructional strategies. The population consisted of elementary school children aged 6 to 9 years who were formally diagnosed with dyslexia according to standardized educational and clinical criteria. Participants were recruited from multiple urban and suburban schools to ensure demographic diversity (Chalikia et al., 2025; Yamashita et al., 2023). Purposive sampling was applied to select 60 participants, divided equally into intervention and control groups. Inclusion criteria required normal intellectual functioning, regular school attendance, and parental consent. Stratification by age and gender was conducted to control for potential confounding variables, providing a representative sample of early learners with dyslexia.

Instruments included standardized neurocognitive assessments and early reading measures (Couvignou et al., 2024; Uno et al., 2025). Executive functions were measured using tasks assessing working memory, phonological processing, and rapid automatized naming. Reading performance was evaluated with tests covering decoding, word recognition, and fluency, adapted for age-appropriateness and validated for the target population. The instruments demonstrated high reliability and validity, ensuring consistent and accurate measurement of both cognitive and literacy outcomes. Data collection procedures involved individual assessment sessions conducted in quiet, distraction-free environments within the participants' schools. Children completed executive function tasks followed by reading assessments, with trained researchers administering all measures. The intervention consisted of structured sessions incorporating phonological exercises, memory strategies, and guided reading tasks designed to engage specific neurocognitive processes. Ethical considerations,

including informed parental consent, child assent, confidentiality, and adherence to educational standards, were strictly observed (Milligan & Schotter, 2024; Parris et al., 2023). Data analysis involved descriptive statistics, paired t-tests, and repeated measures ANOVA to evaluate pre- and post-intervention performance and determine the effectiveness of the neurocognitive approach.

RESULTS AND DISCUSSION

Descriptive statistics were calculated to summarize participants' performance on executive function measures and early reading assessments. Table 1 presents mean scores, standard deviations, and ranges for working memory, phonological processing, rapid automatized naming, and reading fluency. The intervention group exhibited mean working memory scores of 22.4 (SD = 3.1), phonological processing scores of 24.1 (SD = 2.9), rapid naming scores of 18.7 (SD = 3.3), and reading fluency scores of 45.8 (SD = 6.2). The control group demonstrated lower mean scores: working memory 18.9 (SD = 3.4), phonological processing 20.7 (SD = 3.1), rapid naming 15.3 (SD = 3.5), and reading fluency 38.6 (SD = 6.8). Distributions were approximately normal across all variables, indicating suitability for parametric analyses. Data variability was moderate, reflecting individual differences in neurocognitive profiles and reading abilities among participants. The descriptive results provide an overview of baseline cognitive and literacy performance, demonstrating higher initial executive function and reading scores in the intervention group relative to the control group.

Table 1. Descriptive Statistics of Executive Functions and Reading Performance

Variable	**Intervention Mean (SD)**	**Control Mean (SD)**
Working Memory	22.4 (3.1)	18.9 (3.4)
Phonological Processing	24.1 (2.9)	20.7 (3.1)
Rapid Automatized Naming	18.7 (3.3)	15.3 (3.5)
Reading Fluency	45.8 (6.2)	38.6 (6.8)

Intervention group participants demonstrated marked improvement in reading fluency and decoding accuracy after the neurocognitive-based program. Gains were most pronounced in phonological processing tasks, indicating that targeted exercises effectively strengthened the ability to manipulate sounds and recognize word patterns. Working memory enhancement contributed to improved retention of letter-sound correspondences and multi-step decoding tasks. Improvement in rapid automatized naming reflected enhanced speed in word retrieval and processing efficiency. Control group participants exhibited smaller gains, primarily due to routine literacy instruction without cognitive targeting. The contrast highlights the effectiveness of interventions designed to engage underlying neurocognitive mechanisms in promoting reading proficiency. Pre- and post-intervention measures indicated substantial differences between the intervention and control groups. The intervention group improved an average of 7.2 points in reading fluency, 4.0 points in working memory, 3.8 points in phonological processing, and 3.4 points in rapid naming. Control group gains were smaller: 2.5 points in reading fluency, 1.3 points in working memory, 1.1 points in phonological processing, and 0.9 points in rapid naming. These differences suggest that neurocognitive-targeted activities produced measurable improvements in literacy and executive function

domains. Descriptive data also revealed individual variation within groups. Some intervention participants showed exceptional gains in phonological processing, while others exhibited higher improvements in working memory and rapid naming. This pattern reflects diverse cognitive profiles among children with dyslexia, emphasizing the importance of individualized intervention strategies to maximize reading outcomes.

Paired t-tests revealed statistically significant pre- to post-intervention improvements in the intervention group for reading fluency ($t = 7.21$, $p < 0.001$), working memory ($t = 5.34$, $p < 0.001$), phonological processing ($t = 5.67$, $p < 0.001$), and rapid automatized naming ($t = 4.89$, $p < 0.001$). The control group exhibited smaller and mostly non-significant changes across the same measures. Repeated measures ANOVA indicated a significant interaction between group and time ($F = 16.78$, $p < 0.001$), confirming that the intervention was responsible for differential improvement in the executive function and reading measures. Effect sizes were large for reading fluency ($\eta^2 = 0.38$) and phonological processing ($\eta^2 = 0.34$), moderate for working memory ($\eta^2 = 0.28$), and rapid naming ($\eta^2 = 0.26$), demonstrating substantial intervention impact. Correlational analyses showed strong positive relationships between executive functions and reading outcomes. Working memory correlated with reading fluency ($r = 0.62$, $p < 0.001$), phonological processing with decoding accuracy ($r = 0.59$, $p < 0.001$), and rapid naming with word recognition speed ($r = 0.54$, $p < 0.01$). These results suggest that improvement in neurocognitive capacities directly supports gains in literacy performance. The interaction among executive function components also influenced reading achievement. Children with balanced enhancement in working memory, phonological processing, and rapid naming displayed the highest reading fluency scores. Imbalanced improvements, such as gains in phonological processing without corresponding working memory improvement, produced moderate literacy gains, highlighting the synergistic effect of multiple cognitive domains.

A case study of an 8-year-old participant illustrates the impact of neurocognitive intervention. Baseline assessments showed deficits in working memory (score = 17), phonological processing (score = 18), and reading fluency (score = 36). Following the 12-week intervention, scores increased to 23 in working memory, 25 in phonological processing, and 48 in reading fluency. Observations indicated improved task engagement, reduced errors, and faster decoding. The case demonstrates that targeted neurocognitive exercises can produce significant individual gains. The participant's progress exemplifies the efficacy of interventions designed to strengthen underlying cognitive mechanisms rather than relying solely on traditional literacy practice. Case observations suggest that improvements in executive functions facilitated enhanced reading strategies. Strengthened working memory allowed retention of multi-step decoding sequences, while phonological processing exercises improved sound-letter mapping and word recognition. Rapid naming practice enhanced processing speed, reducing reading hesitation. These improvements illustrate that executive function development directly translates into practical literacy gains. The results provide evidence for the causal link between neurocognitive enhancement and reading proficiency in children with dyslexia, supporting the theoretical rationale of the intervention.

Overall, results confirm that neurocognitive-based interventions significantly improve reading outcomes for children with dyslexia. Gains in working memory, phonological processing, and rapid naming translated into measurable improvements in fluency, decoding accuracy, and reading comprehension. Findings highlight the practical importance of integrating cognitive neuroscience principles into early literacy instruction. Neurocognitive-

targeted strategies produce more substantial and sustainable improvements than conventional methods, suggesting a promising direction for research-informed educational practice (Couvignou et al., 2024; Parris et al., 2023). The study demonstrated that a neurocognitive-based early reading intervention significantly improved reading outcomes for elementary school children with dyslexia. Participants in the intervention group exhibited marked gains in reading fluency, decoding accuracy, phonological processing, and rapid automatized naming compared to the control group. Improvements were particularly notable in tasks requiring manipulation of phonemes and retention of multi-step decoding sequences, reflecting the efficacy of targeted cognitive exercises. Quantitative analyses indicated that executive function components, including working memory, phonological processing, and rapid naming, collectively accounted for a substantial proportion of variance in reading performance (Blockmans et al., 2024; Rane et al., 2025). Effect sizes were large for reading fluency and phonological processing, highlighting the robust impact of the intervention. Observational data supported these findings, showing enhanced engagement, reduced errors, and faster word recognition among participants.

The results confirmed that neurocognitive mechanisms are integral to early reading development in children with dyslexia. Intervention participants demonstrated a synergistic effect of strengthened executive functions on literacy outcomes, suggesting that improvements in cognitive capacities translate directly into practical reading skills. The study also highlighted individual differences in response to intervention. Children with balanced gains across working memory, phonological processing, and rapid naming achieved the highest literacy outcomes, whereas those with uneven improvements demonstrated moderate progress (Sigmund et al., 2024; Tucker & Hélène Deacon, 2025). This emphasizes the importance of multi-component neurocognitive training in addressing diverse dyslexic profiles. Findings are consistent with prior research indicating that phonological processing and working memory are critical predictors of reading success. Studies by (Bhalloo & Molnar, 2025; Modlin, 2025) similarly identified these cognitive mechanisms as central to dyslexia remediation. The present study extends these findings by demonstrating that rapid automatized naming also contributes meaningfully to reading fluency, underscoring the multi-faceted nature of neurocognitive deficits in dyslexia. Differences emerged when comparing effect sizes with previous interventions focusing solely on phonics or traditional literacy methods. Earlier studies reported incremental gains in reading accuracy but limited improvement in fluency or processing speed. The integration of neurocognitive principles in the current intervention produced broader and more pronounced improvements, highlighting the advantage of addressing underlying cognitive mechanisms rather than surface-level skills alone.

Cross-study comparisons reveal that interventions combining executive function training with literacy instruction consistently outperform single-component approaches. The current findings support a growing consensus in educational neuroscience that cognitive-based interventions can accelerate literacy development by enhancing underlying neurocognitive capacities (Bhalloo & Molnar, 2025; Dalboni da Rocha et al., 2024). The study contributes to bridging gaps between theory and practice by demonstrating that neurocognitive improvements are directly associated with measurable literacy gains. This alignment strengthens the theoretical foundation of neurocognitive intervention and provides empirical support for integrating cognitive neuroscience insights into early reading programs. The findings signify that early reading difficulties in children with dyslexia are closely tied to neurocognitive

deficits, particularly in phonological processing, working memory, and rapid naming. Improvement in these domains through targeted intervention reflects the brain's capacity for plasticity and adaptation, even in early elementary school years. Observed gains indicate that executive function development is not merely correlated with literacy outcomes but causally contributes to reading acquisition. Children with enhanced cognitive capacities demonstrated improved error monitoring, strategy use, and task engagement, which are essential for mastering complex literacy tasks.

The results also suggest that conventional reading interventions may overlook critical neurocognitive factors, limiting their effectiveness for children with dyslexia. Incorporating cognitive-based exercises can address foundational deficits, providing more comprehensive and sustainable improvements. Reflections from this study emphasize the value of personalized interventions that consider individual neurocognitive profiles. Tailoring instruction to specific deficits allows educators to maximize reading outcomes and address variability among dyslexic learners effectively (Klimovich-Gray et al., 2023; Lin & Zhang, 2025). The study has significant implications for early education practice, indicating that integrating neurocognitive principles into reading interventions can substantially enhance literacy outcomes for children with dyslexia. Educators may design curricula that incorporate phonological exercises, working memory activities, and rapid naming tasks to target the underlying cognitive mechanisms. Curriculum developers and policy makers can utilize these findings to implement structured, evidence-based interventions that go beyond traditional literacy instruction. Early identification and support for children with dyslexia can reduce long-term academic difficulties and improve overall educational attainment. Teacher training programs can integrate knowledge of neurocognitive processes, enabling practitioners to recognize executive function deficits and implement targeted strategies effectively. This can enhance classroom practices and foster greater student engagement and motivation. The results also suggest that intervention timing is crucial. Implementing neurocognitive-based reading support in early elementary grades maximizes the potential for cognitive and literacy development, preventing the consolidation of reading difficulties and promoting long-term academic success.

The effectiveness of the intervention reflects the central role of neurocognitive mechanisms in reading acquisition. Working memory supports retention and manipulation of phonemes and word structures, phonological processing facilitates decoding and word recognition, and rapid naming improves processing speed and reading fluency. Neuroplasticity in the developing brain allows targeted exercises to strengthen these cognitive processes (Klimovich-Gray et al., 2023; Navarrete-Arroyo et al., 2024). Consistent practice in controlled, supportive environments enhances neural connectivity, enabling children to apply improved executive function skills to reading tasks effectively. Structured, multi-component interventions address multiple deficits simultaneously, producing cumulative gains. Improvements in one cognitive domain, such as working memory, support performance in other domains, creating a synergistic effect that enhances overall literacy. Contextual factors, including individualized instruction, low student-teacher ratios, and immediate feedback during intervention sessions, further contributed to the observed outcomes. The combination of cognitive targeting and supportive learning conditions maximized the intervention's effectiveness.

Future research should explore longitudinal effects of neurocognitive interventions to determine whether early gains in reading fluency and executive functions are sustained over

time. Tracking academic progress can inform strategies for maintaining improvements and adapting programs for different developmental stages (Cantiani et al., 2023; Shilbi et al., 2024). Experimental studies could investigate the relative contributions of each executive function component to literacy outcomes, providing more precise guidance for intervention design. Comparative studies with larger and more diverse populations would enhance generalizability. Integration of digital technologies and adaptive learning tools may provide scalable solutions for delivering neurocognitive-based interventions. Gamified exercises targeting working memory, phonological processing, and rapid naming could engage learners while promoting cognitive development. Collaboration between cognitive psychologists, educators, and neuroscientists can further refine intervention protocols, ensuring that evidence-based practices are implemented effectively in real-world classroom settings. These efforts may establish standardized guidelines for early reading intervention for children with dyslexia globally.

CONCLUSION

The most significant finding of this study is that a neurocognitive-based early reading intervention effectively enhances reading fluency, decoding accuracy, and phonological processing in elementary school children with dyslexia. Working memory, phonological processing, and rapid automatized naming contributed uniquely and synergistically to literacy improvements, with the most pronounced gains observed in tasks involving phoneme manipulation and multi-step decoding. This evidence highlights that targeted interventions addressing underlying cognitive mechanisms produce more substantial and sustainable outcomes compared to traditional literacy approaches. The added value of this research lies in both conceptual and methodological contributions. Conceptually, the study integrates cognitive neuroscience principles with early literacy instruction, demonstrating how specific neurocognitive mechanisms directly influence reading acquisition. Methodologically, the combination of standardized neurocognitive assessments, pre- and post-intervention comparisons, and observational case analysis provides a comprehensive framework for evaluating intervention efficacy. These dual contributions offer a model for future interdisciplinary studies that bridge theory and practice in educational neuroscience and special education. Limitations of the study include a relatively small sample size and the quasi-experimental design, which may limit generalizability and causal inference. The sample was restricted to children within specific urban and suburban school settings, and long-term retention of reading gains was not assessed. Future research should employ longitudinal designs with larger and more diverse populations, examine sustained effects of intervention, and explore the integration of digital adaptive tools to enhance scalability. Investigating the influence of socio-emotional and classroom environmental factors may also provide a more holistic understanding of early reading intervention efficacy for children with dyslexia.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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