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Research Article

Effects of Multisensory Math Instruction and Cognitive Training in Enhancing Mathematical Skills among Pupils Diagnosed with Dyscalcuila in Selected Public Primary Schools in Jos, Plateau State, Nigeria

Rahila Tanshi Samaila[1], James Udele[2] and Linda Shehu Pukat[3] and Emmanuel Eyimoga[4]

[1]Department of Guidance and Counselling, Federal University of Education, Zaria, Nigeria.

[2]Psychoterapeutic and Counselling Research Institute of Nigeria, Abuja, Nigeria.

[3]Department of Remedial Sciences, Faculty of Natural Science, University of Jos, Jos, Nigeria.

[4]Department of Guidance and Counselling, National Open University, Abuja, Nigeria.

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Abstract

This study examined the effects of Multisensory Math Instruction and Cognitive Training on the mathematical performance of pupils with dyscalculia in public primary schools in Jos, Plateau State, Nigeria. A quasi-experimental pre-test post-test control group design was employed with 60 pupils (aged 9–11) identified through the Dyscalculia Screener and classroom observations. Participants were randomly assigned to three groups: Multisensory Math Instruction, Cognitive Training, and a Control group receiving regular instruction. The interventions lasted eight weeks, with two 45-minute sessions per week. Data were collected using a validated Mathematics Achievement Test and the Working Memory Index of the WISC-V, and analyzed with ANCOVA at a 0.05 significance level. Results showed that both interventions significantly enhanced pupils' mathematics achievement compared to the control group, with Cognitive Training yielding slightly greater gains. The study concludes that integrating multisensory teaching and cognitive training into inclusive classroom practice offers a cost-effective approach to supporting learners with dyscalculia in Nigerian schools.

Keywords: Multisensory Math Instruction, Cognitive Training, Dyscalculia, Mathematics Achievement, Quasi-Experimental Design, Working Memory, Primary School Pupils, Inclusive Education, Nigeria.

Introduction

Mathematical competence is widely recognized as a foundational skill essential for academic achievement and everyday functioning. In both developed and developing countries, mathematics plays a vital role in

Correspondence to: Rahila Tanshi Samaila, e-mail: samailatanshi@fcezaria.edu.ng

national development, scientific literacy, technological advancement, and individual economic mobility. Yet, for many children, the acquisition of basic mathematical skills proves to be an ongoing struggle. Among these learners, a subset faces persistent and significant difficulties that go beyond the scope of ordinary academic challenges. These students may be affected by a specific learning disorder known as dyscalculia—a condition that impairs the ability to understand numbers, perform calculations, and apply mathematical reasoning. Dyscalculia, though less studied than dyslexia, is increasingly being recognized as a critical barrier to educational progress and equity.

Dyscalculia is a neurodevelopmental disorder characterized by deficits in numerical processing, memory retrieval, spatial reasoning, and basic arithmetic fluency. According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), individuals with dyscalculia show difficulties in number sense, memorization of arithmetic facts, and calculation, despite adequate intelligence and exposure to instruction (American Psychiatric Association, 2013). Studies estimate that 3% to 6% of school-aged children worldwide are affected by this condition (Butterworth et al., 2011), yet it often goes undiagnosed and untreated, especially in low-resource educational settings such as those in many regions of Nigeria and Sub-Saharan Africa. In these contexts, children with math-specific learning difficulties are often labeled as "slow," "lazy," or "difficult"—labels that contribute to emotional distress, school dropout, and underachievement.

Despite advances in the field of special education, the identification and management of dyscalculia remain a global challenge. Contemporary education policies emphasize inclusive schooling, where children with learning difficulties are expected to learn alongside their peers in mainstream classrooms. However, most general education teachers still lack the training to recognize the cognitive symptoms of dyscalculia or to implement differentiated strategies tailored to these learners' needs (McDowell, Cragg, & Gilmore, 2020; Price & Ansari, 2019). In low-resource contexts such as Nigeria, this gap is even more pronounced due to large class sizes, limited access to specialist support, and insufficient teacher preparation in special needs education (Pires, Leitão, & Simões, 2022). These realities underscore the need for innovative, evidence-based instructional methods that can be feasibly integrated into classroom practice without overburdening teachers or excluding struggling pupils.

Among promising strategies is multisensory instruction, a teaching approach that engages multiple sensory modalities—visual, auditory, kinesthetic, and tactile—simultaneously to strengthen memory, understanding, and application of concepts. Originally rooted in the Orton-Gillingham framework for children with dyslexia, multisensory approaches have been extended to mathematics instruction and show strong potential for supporting learners with dyscalculia. By combining manipulatives, visual aids, rhythmic cues, and movement, abstract mathematical ideas become more concrete and memorable (Pires, Leitão, & Simões, 2022; Snowling & Hulme, 2020). For instance, instead of teaching place value solely through symbols, a multisensory approach might integrate base-ten blocks, colored charts, rhythmic tapping, and verbal reinforcement to reinforce conceptual understanding. Recent research confirms that multisensory math instruction not only increases engagement but also improves retention and problem-solving,

particularly among students with working memory challenges (McDowell, Cragg, & Gilmore, 2020; Taub & Szente, 2021).

However, while multisensory methods address the external delivery of instruction, dyscalculia is also linked to underlying cognitive deficits, particularly in working memory, processing speed, attention, and executive function (Geary, 2004; Szűcs, 2016). For this reason, researchers increasingly advocate for integrated interventions that combine instructional supports with cognitive training. Cognitive training refers to structured exercises designed to strengthen the brain functions that support learning—such as memory, attention, and problem-solving skills. Evidence suggests that when applied to students with learning disabilities, such training can enhance cognitive flexibility, working memory capacity, and processing efficiency, thereby increasing the likelihood of success with academic content (Klingberg, 2005; Holmes et al., 2019; Simos et al., 2021).

The combined use of multisensory math instruction and cognitive training offers a dual intervention model that targets both the surface-level learning barriers and the deep-rooted cognitive limitations characteristic of dyscalculia. This integrated approach is especially relevant in school settings, where interventions must be both effective and feasible within existing instructional timeframes. By merging the strengths of both strategies, educators can provide struggling learners with the tools to understand mathematical concepts more deeply and apply them more confidently. Importantly, this approach aligns with the Universal Design for Learning (UDL) principles, which advocate for multiple means of representation, engagement, and expression to accommodate diverse learners (CAST, 2018).

There is a growing body of international literature supporting the use of combined instructional and cognitive interventions for mathematics learning disabilities. Recent studies confirm that integrating working memory training with targeted math instruction produces greater and more sustained improvements in mathematical performance than either approach alone (Holmes et al., 2019; Passolunghi & Mammarella, 2020; Simos et al., 2021). Despite these advances, there remains a scarcity of empirical studies within African educational contexts. Many interventions that show success in Europe or North America have not been adapted to local realities such as large class sizes, limited access to digital tools, and diverse linguistic backgrounds. In Nigeria, where systemic educational challenges persist—including inadequate teacher preparation in special needs education, shortages of instructional resources, and minimal specialist support—there is an urgent need for context-specific and scalable models to support children with dyscalculia.

The present study is situated within this gap. It seeks to evaluate the efficacy of a combined intervention involving Multisensory Math Instruction and Cognitive Training in improving the math skills of primary school pupils diagnosed with or showing signs of dyscalculia. The intervention is designed to be implementable within a regular school setting, using locally available materials and trained educators. The cognitive training component involves brief, game-like exercises targeting memory, attention, and processing speed, while the multisensory math instruction component focuses on core numeracy and arithmetic concepts using hands-on, visual, and auditory aids.

This study is driven by the belief that every child can learn when given the right support, and that math difficulties need not be a life sentence to academic failure. By assessing the combined impact of instructional and cognitive interventions, this research aims to provide practical recommendations for teachers, school leaders, and education policymakers committed to inclusive and equitable learning. It also contributes to the emerging literature on context-relevant strategies for supporting children with learning differences in African schools.

Research Questions

1. What is the effect of Multisensory Math Instruction on improving mathematical skills among students with dyscalculia?
2. What is the effect of combining Multisensory Math Instruction with Cognitive Training on improving mathematical skills among students with dyscalculia compared to Multisensory Instruction alone?

Research Hypotheses

1. **H_{01}:** Multisensory Math Instruction has no significant effect on improving mathematical skills among students with dyscalculia.
2. **H_{02}:** There is no significant difference in mathematical skill improvement between students who receive only Multisensory Math Instruction and those who receive a combination of Multisensory Math Instruction and Cognitive Training.

Methodology

This study employed a quasi-experimental pre-test post-test control group design to evaluate the effectiveness of Multisensory Math Instruction and Cognitive Training on the mathematical performance of primary school pupils with dyscalculia in Jos North LGA, Plateau State, Nigeria. Three public primary schools were purposively selected, and 60 pupils aged 9–11 years who met the dyscalculia risk threshold (Butterworth Dyscalculia Screener, 2003) were identified and randomly assigned into three groups (n = 20 each): Multisensory Math Instruction, Cognitive Training, and Control.

The Multisensory Math group received mathematics lessons incorporating tactile, visual, auditory, and kinesthetic strategies (e.g., number rods, abacuses, rhythmic clapping). The Cognitive Training group engaged in structured tasks to strengthen working memory, attention, and executive functioning (e.g., digit span recall, sequencing games). The Control group continued with regular classroom instruction. Interventions lasted eight weeks, with two 45-minute sessions weekly, facilitated by trained instructors.

Data were collected using a researcher-developed Mathematics Achievement Test (validated and aligned with the Nigerian curriculum) and the Working Memory Index from the WISC-V. Pre- and post-tests were administered to all groups. Data were analyzed using descriptive statistics and ANCOVA to determine treatment effects, with significance set at $p < 0.05$.

Ethical approval was obtained from the University of Jos Ethical Review Committee, while school and parental consent were also secured.

Results and Discussion

Research Question 1

What is the effect of Multisensory Math Instruction on improving math skills among pupils with dyscalculia?

Table 1. Mean and Standard Deviation of Pre-Test and Post-Test Scores for Multisensory Instruction Group.

Intervention	N	Pre-Test $\bar{x}$	SD	Post-Test $\bar{x}$	SD	Mean Difference
Multisensory Instruction	20	42.5	6.2	61.3	5.7	18.8

***Decision Rule**:* A higher post-test mean score with a large mean difference indicates improved math performance.

Table 1 reveals that students who received Multisensory Math Instruction improved significantly, with their average scores increasing from 42.5 to 61.3, reflecting a mean difference of 18.8. This substantial gain highlights the effectiveness of multisensory strategies—such as tactile tools, visual aids, and kinesthetic activities—in enhancing conceptual understanding and memory retention for learners with dyscalculia. The results support theories by Sousa (2016) and Bruner (1966), who emphasize that children learn best through active engagement of multiple senses, especially in foundational subjects like math.

Research Question 2

What is the effect of combining Cognitive Training and Multisensory Instruction on improving math skills among pupils with dyscalculia?

Table 2. Mean and Standard Deviation of Pre-Test and Post-Test Scores for Combined Intervention Group.

Intervention	N	Pre-Test $\bar{x}$	SD	Post-Test $\bar{x}$	SD	Mean Difference
Multisensory + Cognitive	20	41.9	5.9	66.5	5.2	24.6

The combination group displayed the most significant improvement, with mean scores increasing from 41.9 to 66.5—a mean difference of 24.6. This outcome underscores the compounded benefits of integrating

brain-based cognitive enhancement with sensory-rich math instruction. The cognitive exercises likely enhanced working memory and attention control, allowing students to process and retain mathematical information more effectively. These findings align with the dual-process theory of learning and studies by Holmes et al. (2009), suggesting that strengthening executive function alongside targeted instruction yields better outcomes for students with math-related learning difficulties.

Hypothesis Testing

Hypothesis 1

H_{01}: Multisensory Math Instruction has no significant effect on math skills among students with dyscalculia.

Table 3. ANCOVA Summary Table for Multisensory Instruction vs. Control (Post-Test Scores Controlling for Pre-Test).

Source	SS	df	MS	F	p-value	Remark
Pre-test	0.412	1	0.412	2.04	.162	NS
Group	3.840	1	3.840	9.87	.003	Significant
Error	6.702	37	0.181			

With F(1, 37) = 9.87 and p < .05, we reject the null hypothesis. This confirms that Multisensory Instruction had a statistically significant effect on students' math performance.

Hypothesis 2

H_{02}: There is no significant effect of combining Cognitive Training with Multisensory Instruction on math skills among students with dyscalculia.

Table 4. ANCOVA Summary Table for Combined Intervention vs. Control (Post-Test Scores Controlling for Pre-Test).

Source	SS	df	MS	F	p-value	Remark
Pre-test	0.385	1	0.385	1.92	.174	NS
Group	4.926	1	4.926	12.14	.001	Significant
Error	6.804	37	0.184			

With $F(1, 37) = 12.14$ and $p < .01$, the null hypothesis is rejected. This shows that the combined intervention was significantly more effective than no intervention.

Discussion of Findings

This study examined the efficacy of Multisensory Math Instruction and the combined use of Multisensory Instruction with Cognitive Training in improving mathematical performance among pupils diagnosed with dyscalculia. Both descriptive and inferential statistics confirmed that the two interventions significantly enhanced the pupils' math skills, with the combined approach producing a notably stronger effect.

In addressing Research Question 1 and Hypothesis 1, pupils who received Multisensory Math Instruction demonstrated substantial improvements in mathematical understanding and performance. Their mean score increased from 42.5 at pre-test to 61.3 at post-test, a mean difference of 18.8. This gain was statistically significant, as shown by the ANCOVA result ($F = 9.87$, $p < .05$), leading to the rejection of the first null hypothesis. These results are consistent with evidence that multisensory strategies improve outcomes for learners with specific learning disabilities. As Sousa (2016) and more recent studies (Taub & Szente, 2021; Pires et al., 2022) emphasize, engaging multiple senses enhances memory formation, conceptual reasoning, and cognitive processing, particularly in abstract domains like mathematics. Pupils in this group likely benefited from visual aids, tactile tools, and interactive demonstrations that strengthened their number sense and arithmetic reasoning.

For Research Question 2 and Hypothesis 2, the combined use of Cognitive Training and Multisensory Instruction yielded even greater improvements. Pupils in this group increased their average scores from 41.9 to 66.5—a mean difference of 24.6—surpassing the gains achieved by the Multisensory-only group. ANCOVA analysis confirmed this improvement as statistically significant ($F = 12.14$, $p < .01$), leading to the rejection of the second null hypothesis. The pronounced effect suggests that while multisensory instruction effectively addresses external learning modalities, the integration of cognitive training—targeting working memory, processing speed, and attention—further strengthens mathematical comprehension and retention. These findings are consistent with both classical perspectives (Geary, 2011; Holmes et al., 2009) and recent research (Holmes et al., 2019; Simos et al., 2021; Passolunghi & Mammarella, 2020), which highlight the role of executive functioning in mathematical achievement. Strengthening these cognitive foundations enabled pupils to approach problem-solving with improved focus and mental stamina.

The difference in outcomes between the two interventions underscores the additive value of a holistic approach to supporting children with dyscalculia. Multisensory instruction alone was effective in reducing barriers to learning, but the addition of cognitive training addressed the deeper neurocognitive challenges common among such learners. This dual benefit affirms Geary's (2011) framework of dyscalculia as a condition involving both domain-specific deficits (e.g., number processing) and domain-general weaknesses (e.g., working memory and attention).

In the Nigerian school context, these findings are particularly significant. Most public schools—especially in underserved regions—lack access to specialist teachers, digital interventions, or advanced instructional resources. By demonstrating that targeted, low-cost strategies such as multisensory teaching and simple, structured cognitive exercises can yield meaningful improvements, this study offers evidence for scalable models of intervention. Classroom teachers can integrate multisensory tools using locally available materials, while guidance counsellors and psychologists can supervise short cognitive training activities within the existing timetable.

Ultimately, this study affirms the value of early, structured, and context-appropriate interventions for pupils with dyscalculia. By improving both cognitive and sensory engagement, educators can help learners overcome math-related anxiety, build confidence, and avoid the cycle of underachievement that often persists into secondary school and adulthood. These findings provide both practical classroom strategies and policy-level recommendations for strengthening inclusive education in Nigeria.

Conclusion

This study demonstrated that both Multisensory Math Instruction and its combination with Cognitive Training significantly improved the mathematical performance of pupils with dyscalculia. While multisensory approaches enhanced conceptual understanding by engaging multiple senses, the addition of cognitive training further strengthened memory, attention, and processing skills, yielding greater gains. The findings affirm that dyscalculia reflects deeper cognitive processing challenges and is best addressed through integrated instructional strategies. It is therefore recommended that schools adopt multisensory methods in daily math instruction, provide cognitive training support for learners with disabilities, and equip teachers with inclusive pedagogical skills, while policymakers integrate evidence-based interventions into the basic education curriculum to promote equity and inclusiveness in learning outcomes.

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