

Review of the Research Literature on Dyscalculia: from Genetic Genealogy to Adaptive Teaching Tools

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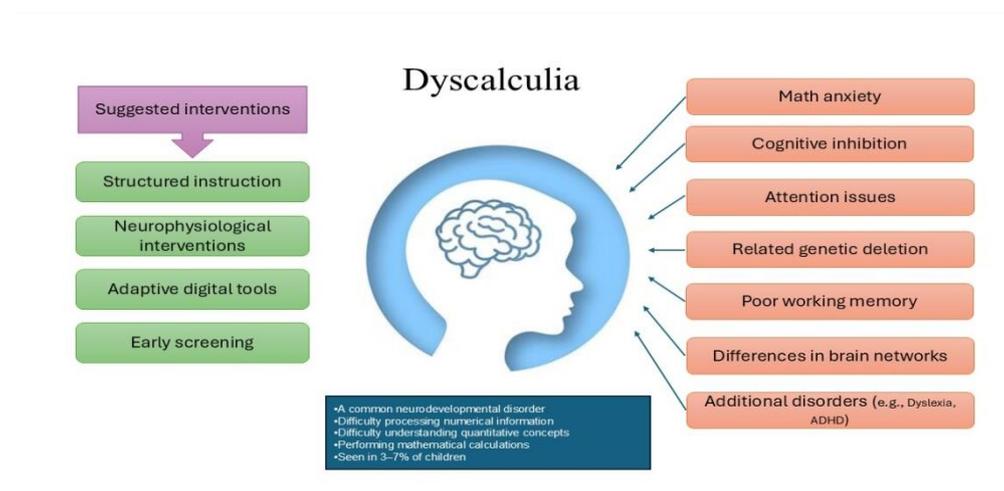
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ABSTRACT

Dyscalculia is a common neurodevelopmental disorder characterized by difficulties in processing numerical information, understanding quantitative concepts, and performing simple mathematical calculations, and is seen in approximately 3 to 7 percent of children. This article reviews 61 studies between 2006 and 2025 to analyse the strategies and challenges of cognitive, neurological, and technological interventions. The results show that dyscalculia is a heterogeneous disorder and is associated with problems such as poor working memory, attention, cognitive inhibition, and math anxiety. Brain imaging findings such as fMRI show reduced activity in areas related to number perception, such as the interparietal sulcus and angular gyrus. Differences in the brain networks of children with dyscalculia can also help identify specific cognitive profiles. Four areas of intervention are proposed, including structured instruction, adaptive digital tools, early screening, and neurophysiological interventions (such as brain stimulation). Tools such as Calcularis and EDSense are effective in improving numerical skills and reducing anxiety. However, children with co-occurring disorders such as dyslexia or ADHD respond less well to interventions. Genetic studies also suggest genetic overlap between these disorders and deletions of genes such as 15q11.2. Finally, the need to design multi-layered, personalized interventions and use new technologies is emphasized to map out a more effective path to identifying and treating dyscalculia.

Keywords: Dyscalculia development; Dyscalculia treatment; technological intervention; Intervention strategies; ADHD; Genetic; AI; Machine learning.

Graphical abstract



INTRODUCTION

Dyscalculia, one of the specific learning disabilities, is a neurodevelopmental disorder that causes persistent difficulties in understanding and using numerical concepts and mathematical skills [1]. The prevalence of this disorder is estimated to be between 3% and 7%, and these effects may persist into adulthood [2]. Dyscalculia, in addition to affecting academic performance in pupils have significant consequences such as math anxiety, reduced self-confidence, and limitations in career and social choices [3].

Considering the phenotypic and cognitive complexities in dyscalculia, educational and therapeutic interventions should be designed in a targeted, personalized, and multidimensional manner [4]. The studies have shown that students with dyscalculia experience difficulties in understanding numerical symbols and show deficits in basic processes such as working memory, attentional processing, and spatial representation of numbers [5,6]. The use of digital tools is an effective treatment strategy for dyscalculia. Specifically, educational software such as *Calcularis* and games like *The Number Race* have been shown to improve numerical representation and calculation accuracy within a short period of time [2,7]. Dynamic Bayesian networks may facilitate both detection and learning in children with dyscalculia [9]. These tools are based on step-by-step exercises and immediate feedback to reinforce learning [8]. For instance, the *EDSense* platform adapts the learning path based on the child's real-time responses and adjusts task difficulty dynamically. Such systems can increase motivation and accuracy simultaneously.

In parallel, screening and diagnostic tools play an important role in early intervention. Research has shown that computer-based tests can accurately identify the risk of dyscalculia in children before they develop serious academic problems [10]. In addition to digital tools, structured cognitive interventions remain among the most fundamental approaches. Targeted exercises to strengthen working memory, number recognition, and verbal problem-solving have produced significant improvements in controlled studies, although responses are typically weaker in children with combined disorders (MD+RD) [4].

In the field of neurocognitive studies, findings suggest that dyscalculia is associated with distinct brain activity patterns, particularly in the intraparietal sulcus (IPS), angular gyrus, and frontal lobe [12,13]. Beyond this, interventions based on social robots and virtual reality have received attention. These tools may enhance not only numerical learning but also executive skills, self-regulation, and social interaction [14]. Nevertheless, implementing these technologies in public classrooms still faces challenges such as cost, staff training, and accessibility.

Another important focus is the investigation of cognitive subtypes in dyscalculia. Studies show that dyscalculia is a heterogeneous disorder with at least two distinct subtypes: one with a pure deficit in number and the other with a combined deficit with attentional impairment [5]. The 15q11.2 gene deletion has been identified as a genetic marker for dyslexia and dyscalculia [15]. Genetic structural models suggest that dyslexia and ADHD form a genetic cluster independently of other psychiatric disorders [16]. These data provide the basis for combined genetic-behavioural studies to design preventive interventions.

METHODS

The Methods section followed the Cochrane guideline, and it is presented in four sections: Inclusion and exclusion criteria, Data extraction, and study variables.

Study inclusion and exclusion criteria

In the present review, the inclusion and exclusion criteria for studies were defined in a way that maintained the comprehensiveness and accuracy of the analysis. Accordingly, only studies that addressed dyscalculia in an experimental, clinical, or systematic review manner, whose target population included children or adolescents aged 5 to 18 years, examined interventions such as cognitive training, digital tools, brain stimulation, or new technological methods, and were published between 2006 and 2025 were included. In addition, full access to the text of the article and the presence of an English abstract were other inclusion criteria. In contrast, studies that were conducted only on adults, or were theoretical and lacked empirical data, or focused outside of dyscalculia

(e.g., numerical disorders in the general context or in animals) were excluded from the analysis. Also, studies with unclear methodology, poor reporting, or combined interventions without effect separation were not included in the final analysis. This screening approach enabled a precise and targeted selection of scientific literature and ensured the consistency of the extracted results.

Characteristics of the reviewed studies

The studies reviewed in this article included a diverse set of quantitative and qualitative studies published between 2006 and 2025. Most of these studies (over 70%) were experimental or quasi-experimental in design and used methods such as brain imaging (fMRI, MRI, EEG), cognitive tests, and standardized screening tools. The main countries producing these studies included the United States, Germany, Switzerland, Canada, Iran, and the United Kingdom, reflecting a high concentration of research in leading academic communities. Sample sizes in most studies ranged from 20 to 100 children, and some included comparison groups, including normal children, dyslexics, or ADHD. The assessment tools used included a range of numerical tests, working memory, math anxiety, and measures of brain function. Also, more than a third of the studies analysed the impact of specific interventions such as educational software, brain stimulation, and adaptive learning systems. This diversity of methodology and content has allowed the present article to provide a comprehensive picture of the current scientific state of dyscalculia and provide a basis for targeted intervention recommendations.

Search strategy and screening

A comprehensive and systematically structured literature search was conducted in January 2025 across four major electronic databases: PubMed, Scopus, Web of Science, and Google Scholar. The search strategy was carefully developed to identify studies addressing dyscalculia and related learning disorders, with a particular focus on diagnosis, early detection, neurobiological correlates, and emerging technology-based approaches. To ensure both breadth and precision, relevant keywords were combined using Boolean operators. The search string incorporated terms related to the disorder (“Dyscalculia” OR “Learning Disorder” OR Treatment OR Diagnosis OR “Early Detection”), the target population (preschool OR Genetics OR paediatric OR children OR childhood OR child), neurobiological and imaging dimensions (Connectivity OR Neuroimaging OR fMRI OR “Functional magnetic resonance imaging”), and innovative analytical or therapeutic modalities (New technology OR AI OR “Machine learning” OR “Digital treatment”). Minor adaptations were applied where necessary to align with the indexing systems and technical specifications of each database.

All retrieved records were compiled, and duplicate entries were systematically removed prior to screening. The remaining studies were then subjected to a structured selection process. Screening was conducted independently by three reviewers. In the initial stage, titles and abstracts were assessed independently by two reviewers according to predefined eligibility criteria. Any discrepancies concerning study inclusion or exclusion were resolved through discussion, and when consensus was not immediately achieved, the third reviewer participated to reach a final decision. This multi-reviewer procedure was implemented to enhance methodological rigor, ensure consistency in study selection, and minimize potential selection bias.

Data extraction and study variables

Data extraction from the screened articles was conducted by 1 author using an Excel file shared on Google Drive. General data, such as the country of study, study design, aim of study, and specific data including case and control population characteristics, type of equipment used, type of fMRI task, and extra tests, were included in the extracted data for each article. The extracted data was reviewed and revised by the second author.

Risk of bias assessment

The methodological quality of the included studies was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Case–Control Studies. All 61 eligible articles were systematically assessed in accordance with the standardized criteria outlined in this instrument.

The appraisal covered key methodological domains relevant to case–control designs. The first domain examined the comparability of case and control groups, including the appropriateness of case definitions, the consistency of participant selection procedures, and the adequacy of matching between groups. Particular attention was paid to whether cases and controls were drawn from comparable populations and whether explicit and valid criteria were used to identify each group. The second domain addressed the identification of potential confounding factors and the implementation of strategies to manage them, such as matching procedures or statistical adjustments. The subsequent domain evaluated the validity, reliability, and standardization of exposure and outcome measurements across both groups to ensure methodological consistency. Finally, the appropriateness of the statistical analyses in relation to the study design and research objectives was assessed.

Each item within the checklist was rated as “Yes,” “No,” “Unclear,” or “Not Applicable,” in line with JBI guidance. A detailed summary of the risk-of-bias assessment is presented in Table 2.

The search strategy applied to identify eligible studies combined terms related to dyscalculia and learning disorders (“Dyscalculia” OR “Learning Disorder” OR Treatment OR Diagnosis OR “Early Detection”), target populations (preschool OR Genetics OR paediatric OR children OR childhood OR child), neurobiological dimensions (Connectivity OR Neuroimaging OR fMRI OR “Functional magnetic resonance imaging”), and emerging technological approaches (New technology OR AI OR “Machine learning” OR “Digital treatment”), using Boolean operators to ensure comprehensive retrieval of relevant literature.

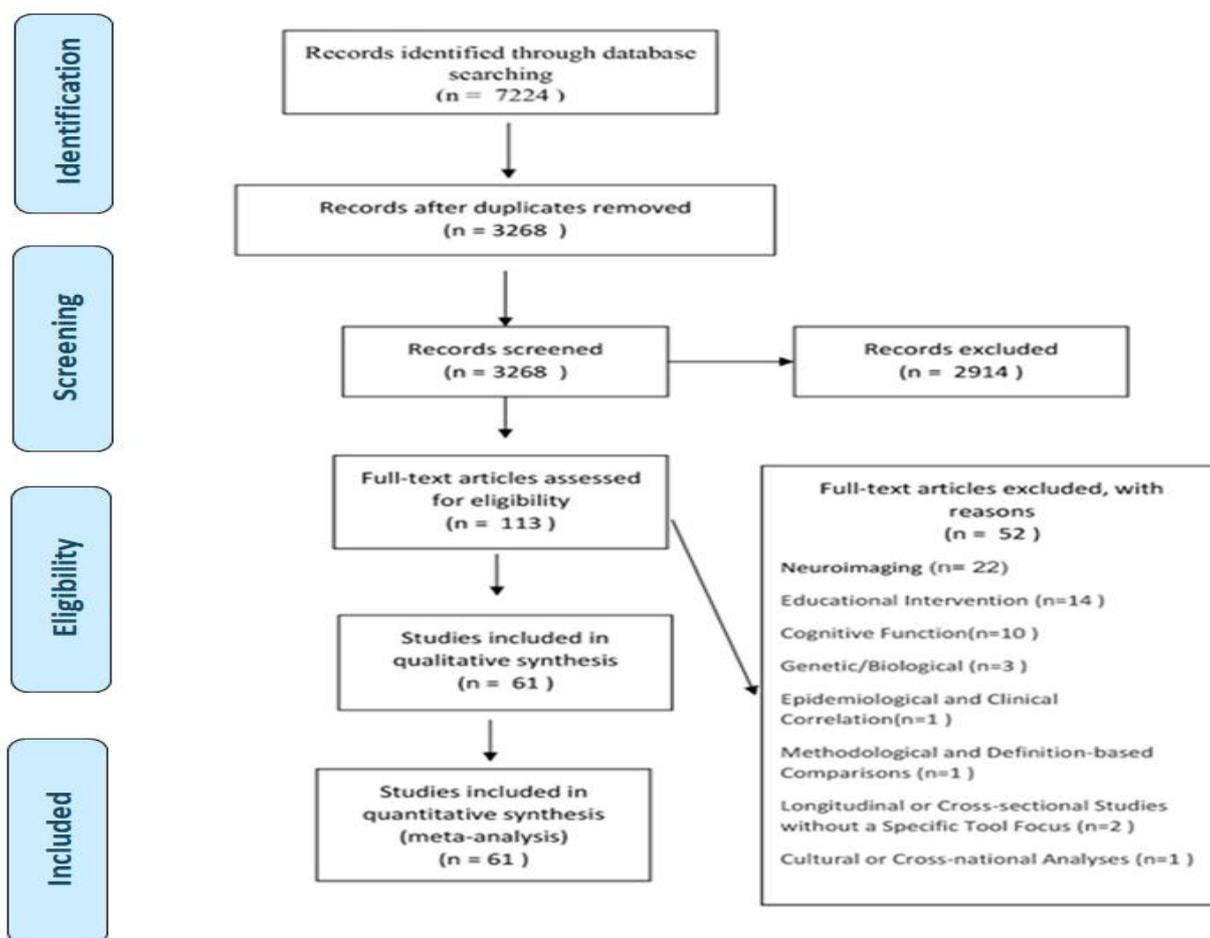


Fig. 1: PRISMA Diagram of inclusion and exclusion and screening

RESULTS

The results obtained from the analysis of the articles reviewed in this study, published between 2006 and 2025, led to the identification of four key areas that play a critical role in understanding and treating dyscalculia, the detailed information about these articles is listed in Table No. 1. Also, a more detailed description of the steps taken by the PRISMA chart is shown in Fig. 1.

Traditional structured and cognitive interventions

Several studies have shown that traditional numerical exercises, such as number combination exercises, word problems, and the four basic arithmetic operations, have been effective in improving the performance of children with dyscalculia [4,17]. These exercises, with a regular structure and short, consecutive sessions, have improved accuracy, processing speed, and number comprehension.

However, the response to interventions has been generally weaker in children with mixed reading-mathematics disorder (MDRD). In these cases, there is a need to design interventions with a dual structure to cover both language and mathematics domains [18].

Digital tools and new educational technologies

Software such as circularise and The Number Race are among the digital tools that have been successfully used to improve number representation and reduce number [2,7]. These programs use adaptive algorithms to adjust the level of difficulty based on the child's performance and provide immediate feedback.

New systems such as ED Sense have been developed based on dynamic Bayesian networks and can personalize the learning path for each child in real time [9]. In studies, these tools have improved calculation accuracy, concentration, and reduced math anxiety.

Social robots such as Nao and Kaspar have also been used to improve educational interactions and have been able to strengthen numerical and self-regulation skills in affected children [14,17].

Screening and diagnostic tools

Digital tests such as the SCLST have played an effective role in identifying children at risk for dyscalculia. A study of over 200 children showed that this tool had a sensitivity of 97.4% and a specificity of 76.9% in identifying dyscalculia these tools can be used in schools and even at home and can facilitate early interventions [10].

Neurophysiological Interventions and Brain Imaging

FMRI and MRI studies have shown that many children with dyscalculia have reduced activity in areas such as the interparietal sulcus (IPS), angular gyrus, and prefrontal [12,13]. Some of these children also have functional hyperconnectivity patterns in brain areas unrelated to numerical computation, which is considered a compensatory mechanism [19].

Cognitive Diversity and Phenotypic Classification

Studies showed that dyscalculia is a heterogeneous disorder and has at least two distinct subgroups: a group with pure numerical impairment and a group with a combined deficit with ADHD or attention problems. These differences are also seen in response to treatment and cognitive performance [5].

Also, examination of cognitive functions such as numerical working memory, response inhibition, mental rotation and visual-spatial coordination has shown that these factors play a key role in the occurrence and severity of dyscalculia [20,21]

Emotional factors and mathematical anxiety

Children with high numerical anxiety showed poorer performance in arithmetic tasks. Studies showed that activation of emotional systems such as the amygdala reduces access to cognitive resources in the prefrontal cortex and, as a result, numerical skills are impaired [22,23].

Hyperactivation of the HPA axis in response to academic stress was also associated with reduced numerical performance and increased math anxiety. Interventions that focused on reducing anxiety and increasing self-efficacy resulted in significant improvements in math performance.

Genetic evidence

Genetic studies have shown that dyscalculia shares genetic overlap with other disorders such as dyslexia and ADHD. Deletions of regions such as 15q11.2 have been identified as a risk factor for the combined occurrence of dyscalculia and dyslexia [15].

Structural genetic models such as Genomic SEM have also shown that dyscalculia, dyslexia, and ADHD are likely to be located in a genetic cluster independent of other psychiatric disorders [16].

Table 1: Summary of studies conducted

Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
Theoretical review (neuroscience + education)	None (literature-based)	Not applicable	Neurocognitive models of dyscalculia, imaging data, finger-based learning research	Supports neurofunctional link between finger use and number processing; finger gnosis linked to better arithmetic in children	Advocates for educational use of neuroscience; finger-based strategies aid math learning; calls for child-specific, multi-deficit models over adult-based single-deficit frameworks	[1]
Descriptive bibliographic review	Not applicable (literature-based)	No direct intervention; discussed early pedagogical interventions and strategies	Causes and manifestations of dyscalculia; strategies for classroom support and diagnosis	Early diagnosis, family involvement, and use of educational tools enhance outcomes; typical dyscalculia traits categorized (e.g., symbol confusion, sequential errors)	Dyscalculia is a neurodevelopmental condition requiring collaborative and early pedagogical intervention. Teaching strategies must align with individual learning styles and promote meaningful mathematical understanding.	[2]
Bibliometric analysis	9,166 publications from 2000–2021 (no human participants)	None (descriptive statistical mapping)	Article count, citations, h-index, keywords, countries, journals, and institutions	USA, UK, and Germany were most productive; top keywords: phonological awareness, intervention, EEG, dyscalculia, fMR	Dyslexia research is growing, focuses on phonology, literacy, and neuroscience; future hotspots include bilingualism and executive function	[3]
Synthesis of 3	~422 students	Math tutoring (30–	Performance in number	Students with MD+RD showed	MD+RD is a distinct LD subtype; requires	[4]

randomized controlled trials	(grades 3–5); subgroups: RD, MD, MD+RD	45 min/session, 3–4 times/week, over 12–20 weeks)	combinations and word problems	lower gains, especially in word problems; unique cognitive profiles (e.g., RAN, concept formation)	differentiated intervention targeting both phonological and conceptual weaknesses	
Cross-sectional; data-driven mixture model analysis	174 children with dyscalculia (Subsample 1: M=9.28 yrs, n=71; Subsample 2: M=8.94 yrs, n=103)	No intervention; cognitive assessments only	Intelligence, working memory, reading fluency, attention, basic and complex math skills	Identified two subtypes: slightly vs. strongly impaired. Biggest differences were in math skills and attention; minimal in IQ and working memory	Subtypes vary mainly by math ability and attention profile; supports individualized intervention strategies	[5]
comparative behavioral study using ANT-I	28 university students 14 with developmental	No intervention; ANT-I test administered in one session	Attention Network Test-Interactions (ANT-I): alerting, orienting, executive control	DD group showed larger alerting and congruity effects; slower in non-cued trials.	Even in “pure” dyscalculia, deficits in alerting and executive attention networks exist	[6]
Pilot intervention study	32 children with math learning difficulties; age not precisely stated	Calcularis program, 6–12 weeks, 20 min/day, 5 days/week	Neuropsychological tests on number representation and arithmetic	Significant improvements in number representation and arithmetic; high engagement reported.	Adaptive, multimodal computer-based programs like Calcularis are effective for supporting numerical cognition	[7]
Narrative review	Various studies reviewed; age range mostly children aged 6–16	Reviewed multiple interventions including games, VR, AI tools, mobile apps; durations vary by study(2–12 weeks)	Performance in math concepts: number sense, arithmetic, motivation, engagement	Interactive tech (e.g. The Number Race, Calcularis, Active Math, VR apps) improved math performance and motivation in students with dyscalculia.	Technology-supported interventions are promising for personalized dyscalculia support; multi-modal tools (VR, AI, mobile) increase accessibility and effectiveness	[8]
Pre-post empirical study	158 children, aged 6–10 years	Adaptive digital intervention (EDSense); duration not specified, tested with	Smartick Dyscalculia Assessment Tool; numerical cognition skills	Significant improvements in arithmetic performance post-intervention	Gamified adaptive tools like EDSense support personalized interventions; DBNs enhance diagnosis and feedback	[9]

		pre/post design				
Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
Diagnostic validation study	207 children with ADHD, RD, or MD (matched 1:1 with controls); school-age (exact age not specified)	No intervention; computerized screening assessment	SCLST (subtests for attention, reading, math); CAT, CLT-R, CLT-M tools	SCLST showed high sensitivity/specificity for MD (97.4%/76.9%), RD (81.1%/85.6%), ADHD (84.6%/88.5%).	SCLST is an effective tool for early detection of learning disabilities including dyscalculia in schools and homes	[10]
fMRI single-case comparison study using self-paced task design and multivariate methods (SVM, clustering)	32 children: 16 with DD (7 girls, 9 boys) and 16 controls (8 girls, 8 boys); mean age \approx 8.2 years	No intervention; two fMRI tasks (comparison & calculation) repeated in one session	Brain activation patterns during non-symbolic comparison and calculation tasks; reaction time and accuracy; ICC-based reliability measures	DD children showed heterogeneous activation patterns; lower activity in visual cortex, more in higher visual/frontal regions; ROI-based SVM achieved up to 87.5% classification accuracy.	DD is neurofunctionally heterogeneous; reliable individual fMRI data can distinguish DD from TD in many cases; multivariate analysis shows promise for clinical use	[11]
MRI-based group comparison study using verbal/numerical localizers	40 children (20 MD, 20 TD); ages 8–14 (mean \approx 11.5)	No intervention; participants completed fMRI multiplication tasks with problem-size manipulation	Brain activation (fMRI) in numerical (IPS/SPL) and verbal (IFG, STG/MTG) regions; accuracy and RTs	MD children showed reduced activation in both verbal and numerical regions. TD children showed stronger activation in verbal areas for small problems.	MD children fail to engage both numerical and verbal regions during multiplication; impairments in IPS may hinder formation of verbal memory for math facts.	[12]
Literature review (narrative survey)	Review of 80+ studies across five disability categories (age range varies, 0–18)	Various AI/robotics systems (e.g. exoskeletons, NAO, Pepper); duration varies widely	Motor function, emotion regulation, math performance, communication, accessibility	Technologies improved learning, motor skills, and social interaction across disabilities; gaps in personalization and accessibility remain	AI-powered tools (e.g., for dyscalculia, CP, ASD) show promise; need for user-centered, inclusive, and ethical designs	[13]
Case-control study with neuropsych	71 deletion carriers and 643 controls; Age 18–65	None; observational study	Cognitive tests (IQ, working memory, Stroop, etc.),	Deletion carriers had impairments in reading/math, reduced left fusiform gyrus	15q11.2 deletion impacts both cognitive abilities and brain	[14]

h testing + MRI/fMRI	(Icelandic population sample)		fMRI tasks (reading, multiplication), structural MRI	volume, altered activity in angular/fusiform gyri during tasks.	structure/function related to dyslexia and dyscalculia; highest risk for comorbid form	
Genomic structural equation modeling (Genomic SEM) using GWAS meta-analysis	Combined GWAS data: 453,408 cases and 2,374,026 controls	No intervention; genetic analysis only	Genetic correlations, factor analysis of psychiatric and developmental traits	Identified 5 genetic latent factors; dyslexia clustered closely with ADHD under the “attention and learning difficulties” factor (F5); 49 shared genetic loci found.	Dyslexia and ADHD share genetic architecture distinct from autism; strong pleiotropy exists; future studies should include dyscalculia	[15]
Scoping review (PRISMA-guided)	19 studies reviewed; participants aged 0–8 years (some up to 12 years); most with autism diagnosis	Various RAT programs using humanoid and non-humanoid robots (e.g., NAO, Jibo, Probe); durations ranged from 15 minutes to 20 sessions over weeks	Measures of social skills (e.g., eye contact, communication), emotional understanding, problem-solving, imitation, self-initiation	Robot-assisted interventions improved social interaction, emotion recognition, and engagement in most studies; more effective in clinical settings than real-life settings.	RAT can improve SEL in autistic children, but more classroom/community-based research is needed; interventions must be personalized and blended with human interaction	[16]
Mixed-method cross-sectional + neuroanatomical model mapping	360 individuals (RD, MD, MDRD groups); mean age ≈ 25.8 years	No intervention; standardized psychoeducational tests + literature review	Tests on reading, math, phonological memory, semantic memory, working memory	Comorbid group (MDRD) showed unique deficits in working and semantic memory; additive impairments from both RD and MD.	Comorbid RD+MD involves both domain-general and domain-specific impairments; mapped to left angular gyrus dysfunction	[17]
fMRI-based pre/post interventional study	31 children (15 with DD, 16 TD); mean age: 9.5 years	5-week number line training, 15 min/day, 5 days/week	fMRI connectivity, number processing tasks (ZAREKI-R), number line accuracy, arithmetic	Pre-training: DD group had hyperconnectivity; Post-training: normalized functional connectivity, improved math performance.	Intensive number line training normalizes abnormal functional connectivity in DD and improves numerical skills	[18]

Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
Literature review and synthesis of cross-sectional population data	Multiple population samples cited (e.g., 3029 Israeli children aged ~11)	No direct intervention; analysis of prior studies and clinical profiles	Comorbidity rates with ADHD, CBCL scores, WISC sequential subtests, arithmetic errors	Strong link between attention deficits and procedural/memory-based arithmetic errors; ADHD symptoms common in dyscalculia cases	Attention deficits—especially in executive function and working memory—play a significant role in many dyscalculia cases; early identification and targeted support essential	[19]
Experimental group comparison using four NLE tasks (verbal and number-to-position, 0–100 and 0–1000)	52 children (32 at dyscalculia risk, 20 typically developing); mean age = 9.88 years	No intervention; each child performed 4 tasks with 26 trials each	Estimation error (verbal and spatial) on number lines (0–100 and 0–1000), by group and by number	Significant group differences in EE, especially for 0–1000 verbal and number-to-position tasks; DR group showed more under- and overestimation; high within-group variability in DR.	Group differences in NLE are influenced by number range and task type; individual-level data show high heterogeneity in DR population; standard group-level analysis may obscure important individual patterns	[20]
Resting-state fMRI group comparison	44 girls with Turner Syndrome (13 with DD); 14 controls (mean age ~13–14)	No intervention	Resting-state FC (ReHo, ALFF, DC, fALFF); math tests	TS+DD group had decreased FC between PFC and occipital cortex vs TS–DD and controls.	DD in Turner Syndrome is linked more to prefrontal (executive) deficits than to visuospatial dysfunction alone	[21]
Predictive cross-sectional study	102 6th-grade Hungarian students (mean age: 12.3 yrs)	No intervention	WISC-IV IQ, DPV (dyscalculia screener), MARS (math anxiety), SES, school math grades	IQ predicted 52% of variance in grades; full model (IQ, math ability, SES, anxiety) predicted 56%; anxiety added small unique variance	Psychometric intelligence is strongest predictor of math performance; anxiety and SES have minor added effects	[22]
Pilot case study	40 children (20 with dyslexia, 20 with dyscalculia); mean ages:	No intervention; two 45-minute assessment sessions	Semantic Updating Test (PASE), Modified PASE, EDICOLE, Mathematical	Dyslexia group struggled more with verbal and language-based tasks; Dyscalculia group performed worse in integration and math-	Dyslexia and dyscalculia involve distinct working memory patterns; WM performance predicts reading comprehension;	[23]

	8.9 and 8.43 years		Reading Comprehension Test (RCTMC)	text reading comprehension; significant differences in MRC, TR, VA, and RC ($p < 0.01$).	supports tailored WM-based interventions	
Clinical practice guideline; systematic review and meta-analysis	Literature-based (no primary sample); derived from multiple studies	Disorder-specific math interventions, delivered individually by trained professionals; at least 45 minutes	Mathematical performance, comorbid symptoms (e.g., ADHD, dyslexia, anxiety), effect sizes from intervention trials	Mean effect size of 0.52 across all interventions; early, individualized interventions were most effective	Diagnosis should be based on psychometrics, clinical, and psychosocial evaluation; early, tailored interventions yield the best outcomes; comorbidities must be addressed	[24]
Open-trial pilot study	9 children with math learning difficulties, aged 7–9	The Number Race game, 30 min/day, 4 days/week, for 5 weeks	Tasks: counting, transcoding, base-10, enumeration, addition, subtraction, number comparison	Improved subitizing, numerical comparison, subtraction (23% gain); no change in addition or base-10.	Suggests effectiveness for early remediation in core number sense; needs larger controlled studies	[25]
Cross-sectional diagnostic accuracy study	18,405 students, aged 9–15, Grades 3–9	None; school-based digital screener (FUNA-DB)	Number processing (comparison, matching); arithmetic fluency	Number processing skills effectively identified MLD (cut-off $< 5%$); more accurate than for LA (cut-off $< 25%$).	Both number processing and arithmetic fluency should be assessed for accurate MLD screening	[26]
ERP experimental study	44 children, aged 9–11 (22 with dyscalculia, 22 controls)	No intervention; EEG recording during the addition verification task	ERP markers: N400 and LPC; accuracy and reaction time	DYS group lacked N400 effect, but showed LPC; subgroups emerged based on working memory (WM) capacity.	Dyscalculia is heterogeneous; WM deficits explain differences in brain activity and arithmetic processing	[27]
fMRI-based event-related design using both univariate and multivariate	34 children (17 DD, 17 TD), ages 7–9 (2nd–3rd grade), matched for IQ and reading ability	No intervention; participants performed simple and complex addition during a ~6.5-minute fMRI scan	Brain activation in IPS, PFC, visual areas (fMRI), behavioral performance (accuracy and RT), and representation	Children with DD showed reduced activation in IPS, PFC, and visual areas during complex problems and failed to differentiate between problem types in activation patterns.	DD is characterized by impaired neural modulation and indistinct stimulus representations in brain areas related to arithmetic; IPS dysfunction is central to these deficits	[28]

Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
Neural simulation model using spiking neural networks; no human participants	Simulated learning model (not based on a human sample)	Modeled parallel cortical and basal ganglia networks; practice-based simulation using “Slow-Net” and “Fast-Net”	Reaction time, accuracy, transition from counting to recall strategies, internal error signal learning	The Fast-Net gradually replaces Slow-Net via learned digit associations; improves speed and accuracy of addition;.	Provides a biologically plausible mechanism for mathematical skill acquisition; explains difficulty in recall transition as seen in dyscalculia	[29]
Experimental (pre-post test with control group)	26 children (7–10 years old) selected from 300 screened	18 educational math games in virtual environment; ~3–4 weeks	Scholastic Performance Test (SPT): arithmetic subtest	Significant improvement in math skills in experimental group ($p \leq 0.05$); no improvement in control group.	Virtual environments using gamified learning enhance motivation and math learning in dyscalculic children	[30]
Randomized controlled trial	67 children (mean age: 8.96 years, grades 2–5)	Calcularis 2.0 training, 42 × 20-minute sessions over 13 weeks	Arithmetic performance, number line estimation, and math anxiety	The Calcularis group outperformed the control in arithmetic and spatial number representation; benefits stable after 3 months.	Computer-based adaptive training is effective, especially for low math-anxiety children without comorbid reading/spelling issues	[31]
Open-label clinical study	40 children: 25 with RD (mean age ≈ 8.1), 15 with MD (mean age ≈ 9.3)	RD: 50 min × 2/week, avg. 22.5 months; MD: 50 min × 1–2/week, avg. 18 months	CLT-R and CLT-M (Reading and Math); K-WISC-IV; CAT for attention	Significant improvement in phonological awareness, word reading fluency, number sense, arithmetic fluency, and estimation accuracy.	Structured interventions targeting phonology and number sense significantly improve academic skills in RD and MD	[32]
fMRI group comparison and regression analysis with	Study 1: 66 children/adolescents aged 6–16; Study 2: 23 MD, 18 TD; IQ ≥ 85	No intervention; visual motion task during ~4.5	Brain activity (V5/MT), Woodcock-Johnson math tests (Calculation, Fluency),	No relationship between math performance and V5/MT activity; no group differences between MD and TD	Dorsal stream activity (V5/MT) during visual motion perception is not related to math ability or it	[33]

Bayesian inference		min fMRI session	reading, and ADHD scores as covariates	in V5/MT or other regions.	contradicts the dorsal stream vulnerability hypothesis	
Resting-state fMRI group comparison using functional connectivity multivariate pattern analysis (fc-MVPA)	42 children (19 with DD, 23 typically developing); mean age \approx 8 years	No intervention; 10-minute resting-state fMRI scan	Functional connectivity between brain regions (DMN, SMN), neuropsychological tests (di-CALC, WISC-IV, PROLEC-R), IQ, reading, and working memory	DD children showed decreased connectivity between the middle temporal gyrus (MTG) and the default mode network (DMN), and increased connectivity with the sensorimotor network (SMN); lower IPS-insula connectivity was also found.	DD is associated with altered resting-state connectivity, especially between DMN and SMN regions. These abnormalities suggest disrupted network coordination in numerical development	[34]
MRI-based group comparison (pre-registered univariate & Bayesian analysis)	68 children (30 with DD, 38 typically achieving), ages 8–10	No intervention; 3 fMRI tasks (arithmetic, number matching, VSWM)	Brain activation patterns; task accuracy and response time; TEMA scores	DD children were less accurate in arithmetic and number tasks but showed no significant differences in brain activation across tasks; Bayesian analysis supported the null hypothesis.	DD may not be explained by consistent univariate brain differences; calls for multivariate/network-based neuroimaging approaches	[35]
Experimental affective priming task	23 children (12 DD, 11 controls); ages 7–13	No intervention; word–arithmetic priming task	Reaction time and accuracy in arithmetic based on affective and math-related primes	Children with DD responded faster after negative and math-related primes; the opposite effect in controls.	Arithmetic-affective priming shows math is emotionally negative for DD; useful for implicit assessment of math anxiety	[36]
Case-control study using NADL battery	26 adults with DD (mean age \approx 25), 26 controls	No intervention; assessment only	NADL subtests: formal math, informal tasks (e.g., time estimation, money, daily number use)	Adults with DD scored significantly lower in formal and informal math tasks, especially time/measure/money;	Dyscalculia persists into adulthood, impacting daily life activities; highlights the need for adult-appropriate interventions	[37]
Selective interdisciplinary review	Based on existing diagnostic/treatment literature; no new sample	Pedagogical-therapeutic interventions ; duration not specified	Neuropsychic evaluations, math testing (ZAREKI, TEDI-MATH), and comorbidity with	Early diagnosis improves outcome; comorbidity is high; WM and visuospatial deficits are common	Emphasizes early neuropsychological assessment; individual profiles are essential for planning effective treatment	[38]

Study Design	Sample Size & Age Means	Intervention and Duration	ADHD/dyslexia Outcome Measures	Results	General Conclusions	Ref.
Qualitative scoping study (semi-structured interviews)	10 postgraduate medical educators (Wales, UK); adult population	No intervention; interpretivist interviews	Thematic analysis of educator awareness, attitudes, and perceived support challenges	Most educators are unaware of dyscalculia; rely on experience with dyslexia, concerns over patient safety, and support gaps.	PGME lacks structured awareness or guidance for dyscalculia; educators need training and institutional support frameworks	[39]
Cross-sectional comparative study	2282 children with epilepsy, 2371 controls (mean age ~9.2 vs 10.2)	No intervention; screening with arithmetic and reading fluency	Prevalence of DD, dyslexia, and comorbidity under -1 SD and -1.5 SD cutoffs	Children with epilepsy had significantly higher rates of DD and comorbidity than controls; patterns varied by gender and condition.	Idiopathic epilepsy is a major risk factor for LDs, especially DD; it emphasizes the need for targeted interventions	[40]
Neuroimaging study (3 sub-studies: cross-sectional and longitudinal MRI)	88 children (44 DD, 42 TD); ages 7.8–16.5	No intervention; MRI + numerical testing (ZAREKI-R, BASIS-Math)	Sulcal pattern of IPS & PoCS; arithmetic, symbolic & non-symbolic comparison	Left IPS sulcal sectioning was related to better arithmetic; the DD group had more double-horizontal and non-sectioned IPS	Sulcal morphology of left IPS may be an innate marker of arithmetic ability; neurodevelopmental structure influences numeracy	[41]
Genetic case series using Next-Generation Sequencing (NGS)	21 individuals with SLD in 9 families (mean age ~13.4 yrs)	None; genetic screening only	NPs in 15 candidate genes (e.g., DCDC2, KIAA0319, ROBO1)	8/9 families had SNPs in genes like DGKI, DIP2A, KIAA0319; no conclusive causality but inherited variants linked to language issues	Evidence of heritable genetic variants in SLD; findings support gene-environment interactions in dyscalculia and related disorders	[42]
Structural equation modeling, cross-sectional	234 first-grade children, mean age 6.5 years	No intervention; cognitive assessments only	Word reading, math computation, phonological processing, rapid naming, working memory, reasoning	Core (e.g., verbal counting) and domain-general (e.g., WM) skills predicted shared variance in both word reading and math computation.	Targeting shared cognitive processes can improve both reading and math simultaneously.	[43]

Experimental comparison, physiological stress measurement	83 Grade 1 children (39 MD, 44 typically achieving)	No intervention; salivary cortisol measured before/after tasks	Working memory, processing speed, math tasks, cortisol (stress)	High stress reactivity linked to lower WM and math performance; MD group especially affected	Reducing stress may improve WM and math performance in young children with MD.	[44]
Experimental comparison, physiological stress measurement	83 Grade 1 children (39 MD, 44 typically achieving)	No intervention; salivary cortisol measured before/after tasks	Working memory, processing speed, math tasks, cortisol (stress)	High stress reactivity linked to lower WM and math performance; MD group especially affected.	Reducing stress may improve WM and math performance in young children with MD.	[45]
Cross-sectional comparison (LA vs LD, IQ-discrepant vs LA-only)	813 third-grade students, mean age \approx 8.5	No intervention; achievement and cognitive testing	Math and reading achievement, cognitive skills (e.g., WM, attention)	Arithmetic fluency distinguished LD from non-LD; IQ-discrepant group showed better word problem solving.	LD definitions matter; cognitive profiles vary based on classification method.	[46]
Experimental affective priming study	172 children (76 DD, 96 controls); mean age \approx 8.6 years	No intervention; affective priming task + math anxiety interview	<i>Accuracy and reaction time on arithmetic after positive/negative/math primes; math anxiety intensity (MAI)</i>	<i>No consistent negative math priming effect found; DD group showed higher anxiety and lower performance</i>	Symbolic processing crucial in DD	[47]
Cross-national comparison	N=196; Age 8-9	None	<i>Symbolic/no symbolic number processing</i>	<i>DD showed persistent symbolic processing deficits</i>	Sex modulates DD neural signature	[48]
fMRI gender comparison	N=24; Ages 9-11	None	Mental rotation + math tasks	Gender differences in activation pattern.	Developmental GS may underlie DD	[49]
Neurodevelopmental case analysis	N=51; Ages 7-10	Neurological and behavioral exams	DD diagnosis + GS symptoms	High overlap with Gerstmann symptoms	Findings indicate that developmental dyscalculia is linked to impaired parietal mechanisms of magnitude processing, particularly in the right IPS; this may	[50]

Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
fMRI-based group comparison study	16 right-handed children (8 with pure DD, 8 typically developing), matched by age (~8–10 years)	No intervention; numerosity comparison task during fMRI	Brain activation (especially in IPS), response accuracy and reaction time under varying numerical distances	Children with DD showed reduced activation in the right intraparietal sulcus (IPS) compared to controls, especially under high task demand (small distance)	Arithmetic deficits in DD are linked to aberrant task-specific brain modulation and widespread IPS hyper-connectivity rather than simple under activation; subtraction especially reveals these deficits	[51]
fMRI group comparison study using block design and generalized psychophysiological interaction (gPPI)	36 children total (16 with DD, 20 TD), aged 7–9 years (mean ≈ 8.4)	No intervention; fMRI during addition and subtraction tasks	Brain activation (especially IPS, fusiform, PFC), behavioral performance (accuracy, RT), IPS connectivity (gPPI)	DD group showed greater IPS activation during subtraction, hyper-connectivity of IPS with both task-positive and task-negative networks, and operation-specific impairments.	DD is characterized by impaired neural modulation and indistinct stimulus representations in brain areas related to arithmetic; IPS dysfunction is central to these deficits	[52]
fMRI-based event-related design using both univariate and multivariate analyses (RSA)	34 children (17 DD, 17 TD), ages 7–9 (2nd–3rd grade), matched for IQ and reading ability	No intervention; participants performed simple and complex addition during a ~6.5-minute fMRI scan	Brain activation in IPS, PFC, visual areas (fMRI), behavioral performance (accuracy and RT), and representational similarity (RSA)	Children with DD showed reduced activation in IPS, PFC, and visual areas during complex problems and failed to differentiate between problem types	DD reflects impaired number-specific executive function, not general EF or ANS acuity; such EF also predicts math performance across the full achievement range	[53]
longitudinal group comparison and regression study using	448 children (ages 4–13); achievement tracked across 6 years	No intervention; assessments at multiple time points including 6th grade	Accuracy on congruent/incongruent no symbolic comparison trials; reading; EF (Corsi,	Only incongruent trial accuracy predicted math achievement; DD group had deficits on incongruent but not congruent trials even after controlling for	Transitive reasoning is impaired in MLD at both behavioral and neural levels; IPS dysfunction extends to non-	[54]

behavioral tasks		number tasks and EF tests	Hearts & Flowers); math achievement (WJ-III, KeyMath-3)	domain-general EF and reading.	numerical processes like reasoning	
MRI group comparison with story-based reasoning tasks (transitive vs non-transitive)	34 children (18 TD, 16 MLD); ages 8–12 years	No intervention; 4 self-paced fMRI story tasks (~12 scenarios each)	Behavioral accuracy (reasoning & memory questions), IPS activation during fMRI	TD children had greater IPS activation and higher reasoning accuracy; MLD children showed no reliable IPS activity for transitive Reasoning.	DD is best explained by visuo-spatial WM and inhibition deficits, not magnitude representation; these deficits are functionally and diagnostically significant	[55]
Behavioral comparison study testing five cognitive theories (MR, WM, inhibition, attention,	1004 children screened; 12 DD vs 12 matched controls in experimental phase (mean age ~9.1)	No intervention; 16 tasks over 7–8 hours	STM/WM (verbal & visuo-spatial), inhibition (Stroop, Stop-signal), spatial tasks, magnitude comparison	DD group showed robust deficits in visuo-spatial WM and inhibition, but no significant difference in symbolic/non-symbolic magnitude tasks.	DD is associated with abnormal gray matter network structure for number processing and memory	[56]
Structural MRI (VBM-based) cross-sectional study	37 children (19 DD, 18 TD); mean age ≈ 11.5 years	No intervention	Structural covariance (GM volume correlations), arithmetic tasks	DD group had higher structural covariance between IPS, hippocampus, and frontal/temporal regions.	Single-case fMRI with reliability measures can distinguish DD; DD involves diverse, individualized brain activation profiles	[57]
MRI single-case + group comparison study	16 children with DD, 16 TD controls (ages ~7–10, mean ~8.2 years)	No intervention; self-paced fMRI during non-symbolic number tasks	Voxel wise BOLD contrast activation; SVM classification; test–retest reliability	DD group showed heterogeneous brain activation, mainly in visual areas; some children compensated via fronto-parietal activation.	Math learning is dynamic and trainable	[58]
Computational model and fMRI	N=40; Age 7–9	Math learning over time	Brain maturation, accuracy, RT	Practice enhanced neural efficiency in math network	PMD is predictable from early SES, cognitive, language, behavioral factors; early preschool and education interventions can reduce risk but need	[59]

Study Design	Sample Size & Age Means	Intervention and Duration	Outcome Measures	Results	General Conclusions	Ref.
Longitudinal educational study	N=7,500; Grades 1–3	Tracking risk over time	Persistent mathematics difficulty (bottom 25% on math tests at multiple time points), SES, vocabulary, reading difficulty, behavior, IEP/retention, preschool access	Low SES, cognitive/vocabulary delays, RD, inattention, disabilities, and grade retention all increased risk of PMD; preschool center care reduced early PMD but not later.	Dyscalculia stems from impaired numerosity representation in the parietal lobe (IPS); targeted early interventions and adaptive technology can improve foundational math skills	[60]
Narrative literature review and theoretical model development	Not empirical; synthesis from multiple studies involving children and adults	Discusses multiple interventions including Number Race and Graphogame -Maths; typical duration 3 weeks	Numerosity processing, symbolic number mapping, IPS activity, gray matter density, behavioral math performance	Identifies a core deficit in numerosity processing and reduced IPS function/structure in dyscalculia; adaptive games improve number comparison but not generalized arithmetic	Dyscalculia stems from impaired numerosity representation in the parietal lobe (IPS); targeted early interventions and adaptive technology can improve foundational math skills	[61]

Table 2: Risk of Bias Assessment

Study	Comparability of groups	Appropriate matching of cases and controls	same criteria for cases and controls	Standard, valid and reliable measurement of exposure	Exposure measurement in the same way for cases and controls	Identification of confounding factors	Strategies to deal with confounding factors	Standard, valid and reliable assessment of outcomes	Meaningfulness of length of exposure period of interest	Appropriateness of statistical analysis
[1]	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes	No	Yes
[2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
[3]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
[4]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[5]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
[6]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[7]	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes
[8]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes

[9]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
[10]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[11]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
[12]	Yes	No	Yes							
[13]	Yes	No	Yes							
[14]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[15]	Yes	No	Yes							
[16]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[17]	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes
[18]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes
[19]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
[20]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[21]	Yes	No	Yes							
[22]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[23]	Yes	No	Yes							
[24]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[25]	Yes	No	Yes							
[26]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[27]	Yes	No	Yes							
[28]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[29]	Yes	No	Yes							
[30]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[31]	Yes	No	Yes							
[32]	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes
[33]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes
[34]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
[35]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[36]	Yes	No	Yes							
[37]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[38]	Yes	No	Yes							
[39]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[40]	Yes	No	Yes							
[41]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[42]	Yes	No	Yes							

[43]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[44]	Yes	No	Yes							
[45]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[46]	Yes	No	Yes							
[47]	Yes	Yes	No	No	Yes	Yes	No	Yes	No	Yes
[48]	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes
[49]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes
[50]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[51]	Yes	No	Yes							
[52]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[53]	Yes	No	Yes							
[54]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[55]	Yes	No	Yes							
[56]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[57]	Yes	No	Yes							
[58]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes
[59]	Yes	No	Yes							
[60]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
[61]	Yes	No	Yes							

DISCUSSION

Based on the reviewed studies, it can be stated that various factors play a role in the emergence of dyscalculia , and these various dimensions, which include the biological, cognitive, emotional, and social fields. In the past, although dyscalculia was considered only as a disorder in the learning of mathematics, recent studies show that dyscalculia can be considered a complex neurodevelopmental condition. Symptoms of this disorder include difficulties in the ability of number representation, working-memory limitation, and the inability to inhibit responses and maintain sustained attention. If this disorder is accompanied by other cognitive disorders such as ADHD, diagnosis and interventions become more complex and require more detailed examination. Given this diversity, the spectrum of educational and therapeutic interventions should be designed and personalized according to the characteristics of each child. Brain imaging studies, conducted through fMRI and MRI, have identified key brain regions in numerical processing, including the interparietal sulcus, angular gyrus, and prefrontal cortex in children with dyscalculia, which often show reduced activation. Other evidence from these studies suggests that compensatory activity occurs in other brain networks, which may indicate the brain's attempt to compensate for the deficits and executive dysfunctions in the main networks related to numerical processing in people with this disorder. Among the most important results obtained from recent research is that targeted training can change brain activity patterns, which confirms the vital role of neuroplasticity in the design of interventions.

The impact of emotional factors on cognitive performance has been an important aspect of early studies of dyscalculia, and has received little attention. But new research has shown that math anxiety can impair working memory performance and affect children's problem-solving ability, leading to executive decline. Brain imaging studies have also shown that the amygdala and HPA axis are activated during numerical stress, suppressing prefrontal cortex function. These findings suggest that interventions that focus only on math education will not

be effective without addressing anxiety. Therefore, multidimensional approaches that also focus on reducing anxiety and increasing self-efficacy are recommended and emphasized.

New technologies in the field of education have made significant progress in recent years and have introduced new tools to help those with developmental disorders, including dyscalculia. These tools affect increasing accuracy and reducing anxiety, and increase motivation for learning in sufferers. To improve the performance of these children, other interventions using direct current brain stimulation or random noise (rTMS) have been designed to improve the performance of the brain's numerical networks, working memory, and processing speed. Although the initial results have been promising, there is still insufficient evidence for their long-term effectiveness, and further studies are needed.

Tools such as the SCLST, a computer-based test, that has high accuracy and sensitivity, play an effective role in the early detection of this disorder in children, by following up with therapeutic interventions, and prevent the negative effects of dyscalculia in the future. A combined cognitive-neuropsychological assessment helps teachers and psychologists to both identify the presence of the disorder and also be able to assess its type and severity.

Evidence shows that dyscalculia shares genetic risk with other disorders such as dyslexia and ADHD. Despite recent advances in technology and the creation of platforms and software that can have beneficial effects in diagnosing, reducing symptoms, and improving this disorder, the use of these modern methods is accompanied by challenges, including high costs and the lack of sufficient financial resources and specialized personnel, especially in developing countries.

The use of digital tools and new technologies to help students with dyscalculia will be truly effective when teachers also make effective changes in their teaching methods. In line with new technologies, because using technology without a designing specific educational framework only increases the workloads of exercises in class while the main problems of the student, such as the ability to understand numbers or the use of working memory and focused attention, still may remain unresolved.

To achieve this important aim, the teacher must specify which skill exactly is going to be strengthened by each digital activity (such as understanding the place value of numbers, etc.) and, by asking students short questions after the training, ensure that learning is achieved. Many recent studies emphasize that the best method is providing a set of combined-stage training; before working with the tool, it might be useful to train in a clear and step-by-step method, then new tools are used for targeted practice and feedback, and finally, with classroom activities or supplementary exercises, learning occurs. Also, by considering the disabilities caused by this disorder, the teacher should break down tasks into smaller, more manageable parts, and avoid the technology causing mental clutter and added pressure itself; for instance, by shortening steps, simplifying instructions, and choosing exercises that actually increase the ability of number understanding. Furthermore, digital tools' feedback from students is measurable data, and teachers must be able to interpret this data correctly, such as error patterns, response times, or difficulty levels. Because they can decide whether a student needs to be taught a concept again or if the solution, they are using to a problem should be modified by interpreting results, which means that technology is being used effectively in education. In addition, the issue of math anxiety is also prominent in many recent articles. Despite the presence of appropriate digital tools, if the teacher manages the classroom environment in such a way that making mistakes is not natural and causes stress for students, and feedback is not progress-oriented, students, due to anxiety, may still distance themselves from learning math. Therefore, if the transition from traditional methods to technology is to really happen, both teacher empowerment must be planned, and tools must be selected in accordance with the actual conditions of the school; the use of technology will remain just an attractive idea and will not create a lasting effect.

CONCLUSION

Using intelligent algorithms and real-time feedback may have been able to increase motivation for learning in children with dyscalculia. This evidence emphasizes the need to identify different phenotypes of dyscalculia and design interventions tailored to them, and shows that no single intervention is effective for all affected children.

Success in improving the performance of these children's lives is achieved when the educational system, researchers, psychologists, neurologists, and parents collaborate.

Declaration of competing interest

The authors disclose the following financial interests and/or personal relationships that could be perceived as potential conflicts of interest.

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