Mapping Cognitive Profiles in Dyslexia and Mathematical Disabilities: A Narrative Review of the Cattell-Horn-Carroll (CHC) Model (2015–2025)

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ABSTRACT

Dyslexia and mathematical disabilities (MD) are neurodevelopmental disorders that significantly impact academic achievement and require appropriate identification and intervention. This narrative review synthesizes empirical evidence on the application of the Cattell-Horn-Carroll (CHC) Model in mapping cognitive profiles of both conditions. A literature search was conducted across Scopus, Web of Science, PubMed, PsycINFO, and ERIC databases, focusing on publications from 2010-2025. Nine studies met the inclusion criteria and were analyzed thematically. The available evidence, while limited, suggests differentiable but overlapping patterns: dyslexia is consistently associated with deficits in Auditory Processing (Ga) and Short-Term Memory (Gsm), with relative preservation of Fluid Reasoning (Gf). MD, based on limited direct evidence, appears characterized by deficits in Executive Functions and Visual Processing (Gv), with Gsm emerging as a potential common vulnerability factor. However, contradictory findings exist (e.g., Gv deficits reported in some dyslexia studies), and the MD evidence rests primarily on one study. Critical limitations include a small evidence base with no intervention studies, measurement challenges in CHC subtests, poor ecological validity, and overrepresentation of WEIRD samples. The CHC framework provides a useful structure for understanding cognitive diversity in learning disorders, but the evidence base remains too limited to support strong claims. Rigorous longitudinal research, direct comparisons of both conditions, and intervention trials are urgently needed.

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1. INTRODUCTION

Dyslexia and mathematical disabilities (MD) or dyscalculia are prevalent neurodevelopmental disorders that have a significant impact on academic achievement, psychosocial well-being, and an individual's future prospects [1], [2]. In the 21st-century educational landscape, which emphasizes literacy and numeracy as basic competencies, failure to identify and address these two conditions appropriately can exacerbate educational inequality [3], [4]. However, conventional diagnostic practices such as the discrepancy model or the application of the Pattern of Strengths and Weaknesses (PSW) [5], which are not based on a strong theoretical framework, often result in inaccurate identification and less specific intervention recommendations [6], [7]. This gap between scientific progress and practical application results in many individuals not being optimally served.

The Cattell-Horn-Carroll (CHC) Theory of cognitive abilities has emerged as the most comprehensive and empirically validated framework for understanding the structure of human intelligence [8], [9]. This hierarchical model integrates Cattell and Horn's Gf-Gc theory with Carroll's three-stratum model [10], organizing cognitive abilities into three distinct strata: Stratum I (narrow abilities, e.g., phonetic coding, spatial scanning), Stratum II (broad abilities, e.g., Comprehension-Knowledge/Gc, Fluid Reasoning/Gf, Short-Term Memory/Gsm, Auditory Processing/Ga, and Visual Processing/Gv), and Stratum III (general intelligence/g) [11], [12]. These broad abilities represent distinct yet interrelated cognitive domains that underpin academic learning and achievement.

Dyslexia and mathematical disability (MD), also referred to as dyscalculia, are neurodevelopmental disorders that significantly impair academic achievement, psychosocial well-being, and future life opportunities [1], [13]. Dyslexia is characterized by persistent difficulties in accurate and fluent word recognition, decoding, and spelling, primarily resulting from deficits in phonological processing [14], [15]. Mathematical disability involves significant difficulties in number sense, memorization of arithmetic facts, accurate calculation, and mathematical reasoning [16], [17]. It is important to acknowledge ongoing nosological debates between diagnostic frameworks: the DSM-5 uses the umbrella term "Specific Learning Disorder" with specifiers for reading and mathematics, while ICD-11 employs "Developmental Learning Disorder" with domain-specific impairments [18]. Furthermore, a critical distinction exists between developmental dyscalculia, which emerges during early cognitive development, and acquired acalculia, which results from neurological injury later in life [19]. This review adopts a developmental perspective, focusing exclusively on the former to understand the cognitive profiles of children and adolescents with these conditions.

The CHC framework was selected for this review over competing models such as the Planning-Attention-Simultaneous-Successive (PASS) theory [20], Luria-based neuropsychological models, or Baddeley's working memory model due to its hierarchical comprehensiveness and extensive empirical support across diverse populations and measurement instruments [11]. Unlike process-oriented models that focus on narrower cognitive functions, CHC provides a granular taxonomy capable of mapping the heterogeneous cognitive profiles underlying specific learning disorders [12]. However, it is equally important to acknowledge the model's limitations. Critics have identified challenges regarding measurement invariance across cultural and linguistic groups, raising questions about the fairness and universality of CHC-based assessments [21]. Additionally, the reliability of narrow abilities (Stratum I) has been debated, as these specific skills often demonstrate weaker psychometric stability compared to broad abilities [22]. Furthermore, the CHC model, in its traditional form, inadequately represents interactions between cognitive and affective-motivational factors, such as anxiety, self-efficacy, and emotional regulation, which are increasingly recognized as influential in learning outcomes [23].

Despite the growing body of research applying the CHC framework to dyslexia and mathematical disability, significant gaps remain in the literature. While individual studies have identified cognitive deficits associated with each disorder, such as Ga and Gsm impairments in dyslexia [24], [25], and EF and Gv deficits in MD, there is a paucity of synthesized evidence that directly and systematically compares the cognitive profiles of these two conditions [25], [26]. Such a comparative synthesis is essential for understanding the high rates of comorbidity between dyslexia and MD (approximately 30-60%; [27]) and for identifying both unique deficits that differentiate the disorders and shared vulnerabilities (e.g., working memory) that may underlie co-occurring difficulties [28]. Without this integrative perspective, diagnostic practices risk oversimplification, and intervention efforts may fail to address the specific cognitive needs of each population.

To address this gap, the present systematic review aims to: (1) identify and synthesize patterns of CHC broad ability deficits in individuals with dyslexia, with particular attention to Ga, Gsm, and Gc; (2) identify and synthesize patterns of CHC broad ability deficits in individuals with mathematical disability, focusing on EF, Gv, and Gsm; (3) compare these cognitive profiles to delineate factors that are unique to each disorder (e.g., Ga for dyslexia, EF for MD) and those that overlap (e.g., Gsm as a common vulnerability); and (4) discuss the implications of these differentiated and overlapping profiles for developing more accurate assessment models, differential diagnosis, and personalized intervention strategies. By consolidating contemporary evidence (2010-2025), this review seeks to bridge the gap between advanced cognitive theory and the practical need for effective, equitable educational support for individuals with dyslexia and mathematical disabilities.

The urgency of this research lies in the mismatch between the heterogeneity of learning disorders and the often simplified methods of diagnosis. This failure not only perpetuates low academic achievement but also contributes to secondary emotional and behavioral challenges associated with unidentified disorders. Without a clearer understanding based on cognitive mechanism theory, the education system will continue to fail to provide the effective support that every learner is entitled to. The uniqueness of this review lies in its explicit and systematic comparative synthesis. Although previous research has identified isolated deficits, there has been no synthesis comparing dyslexia and mathematical disorders within the CHC theoretical framework. By consolidating contemporary evidence to identify unique deficits and shared vulnerabilities, this review offers a new integrative perspective. This approach to deficit models for understanding complex cognitive frameworks and their high levels of comorbidity provides a solid theoretical foundation for differential diagnosis and the design of personalized educational interventions based on cognitive understanding.

2. METHOD

2.1. Review Design

This study employs a narrative review approach to synthesize empirical evidence on the application of the Cattell-Horn-Carroll (CHC) model in understanding cognitive profiles of individuals with dyslexia and mathematical learning disabilities (MD) [29]. A narrative review was selected as it allows for flexible integration of findings from diverse research designs and contexts, facilitating comprehensive analysis of complex and evolving topics [30], [31]. This approach is appropriate for mapping broad theoretical landscapes and identifying patterns across heterogeneous studies.

2.2. Literature Search Strategy

A literature search was conducted on March 15, 2024, across five academic databases: Scopus, Web of Science, PubMed, PsycINFO, and ERIC. The search strategy combined terms related to the theoretical framework and the conditions of interest:

- CHC framework: "Cattell-Horn-Carroll theory" OR "CHC model" OR "CHC theory" OR "Cattell-Horn-Carroll abilities."
- Dyslexia: "dyslexia" OR "reading disability" OR "reading disorder" OR "specific learning disorder in reading".

- Mathematical disability: "mathematical disability" OR "math disability" OR "dyscalculia" OR "arithmetic disability" OR "specific learning disorder in mathematics."

These term groups were combined using Boolean operators (AND/OR). The search was limited to peer-reviewed publications in English [32]. The search syntax was adapted for each database's requirements [33]. Additionally, reference lists of key articles were manually screened (snowballing) to identify potentially relevant literature not captured in the database searches [34]. Initial database searches yielded approximately 340 records. After removing duplicates (n=112), 228 records were screened at the title/abstract level, with 47 full-text articles assessed for eligibility.

2.3. Literature Selection Considerations

Publications were considered for inclusion if they: (a) explicitly addressed CHC cognitive abilities in relation to dyslexia, mathematical disability, or both; (b) were published in peer-reviewed journals or were authoritative book chapters/theoretical contributions from recognized scholars in the field; (c) provided sufficient methodological or theoretical detail to evaluate their contribution. No restrictions were imposed on participant age or sample size, given the narrative review's aim to capture the full developmental and methodological range of the literature.

While the primary focus was on literature from 2010 to 2025 to ensure relevance to contemporary CHC applications [35], seminal theoretical works and foundational validation studies from earlier years were also consulted to establish theoretical grounding, and are cited in the introduction and discussion [36].

2.4. Critical Evaluation Approach

Consistent with narrative review methodology, formal quality assessment instruments (e.g., CASP, AMSTAR) were not applied [37]. However, sources were critically evaluated based on: methodological coherence, consistency of findings with broader evidence, sample appropriateness, and the article's contribution to theoretical or empirical understanding [38]. Empirical studies and theoretical works were treated distinctly in the analysis, with empirical findings providing evidentiary support and theoretical publications offering conceptual framing [39]. Literature selection and critical evaluation were conducted by the first author, with regular consultation and consensus meetings with co-authors to review decisions and resolve any uncertainties.

2.4. Critical Evaluation Approach

A thematic analysis approach was used to organize and synthesize findings [40]. Key information from included sources was extracted regarding: (a) CHC abilities examined, (b) participant characteristics (where applicable), (c) main findings related to dyslexia or MD, and (d) implications for assessment or intervention. Extracted findings were grouped thematically to identify patterns, consistencies, and gaps in the evidence base [41]. The synthesis focused on three main themes: (1) patterns of CHC deficits in dyslexia, (2) patterns of CHC deficits in mathematical disability, and (3) comparative analysis of cognitive profiles between conditions.

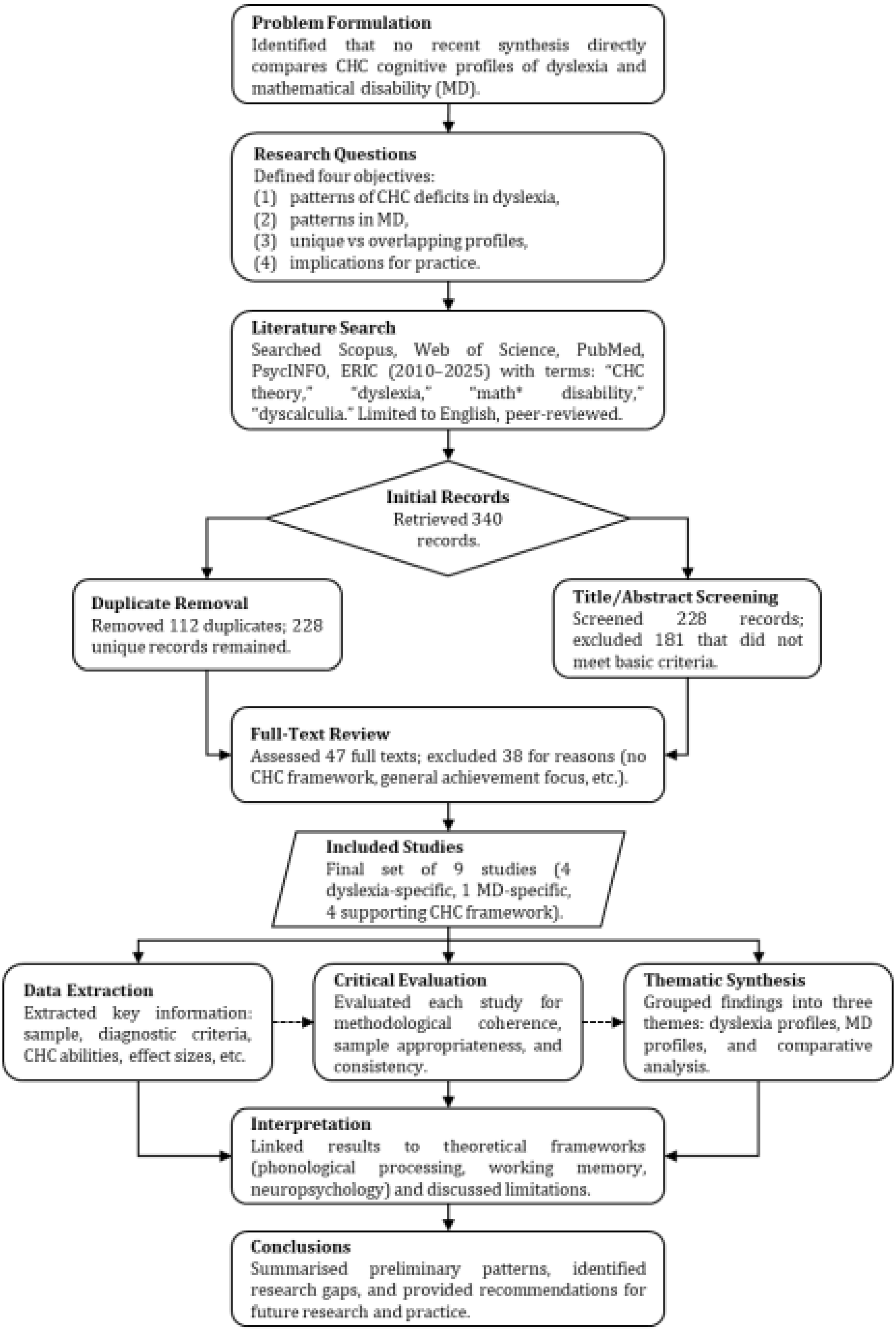

Figure 1. Research Flow Chart

3. RESULTS

3.1. Study Selection and Characteristics

The literature search yielded 340 initial records across five databases (Scopus: 98, Web of Science: 76, PubMed: 54, PsycINFO: 62, ERIC: 50). After removing duplicates (n=112), 228 records were screened at the title and abstract level, resulting in 47 full-text articles assessed for eligibility. Of these, 38 were excluded for the following reasons: did not explicitly employ the CHC framework (n=14), focused on general academic achievement without specific dyslexia/MD analysis (n=12), were commentary or opinion pieces without empirical data (n=7), or examined acquired rather than developmental conditions (n=5). Nine studies met all inclusion criteria and were included in this review.

3.2. Characteristics of Included Studies

Table 1 presents detailed characteristics of the nine included studies. Studies were published between 2009 and 2025, with sample sizes ranging from 42 to 1,847 participants. Participant ages ranged from 6 to 19 years across studies. Diagnostic criteria varied, with studies using DSM-5 criteria (n=4), ICD-10/11 criteria (n=2), school-identified learning difficulties (n=2), and research criteria using norm-referenced cut-scores (n=1). Assessment batteries included the Woodcock-Johnson (WJ) series (n=4), Wechsler Intelligence Scale for Children (WISC) series (n=3), Differential Ability Scales (DAS) (n=1), and cognitive test batteries designed for research purposes (n=1).

Table 1. Characteristics and Key Findings of Included Studies

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
Li et al. (2022)	847 children (China): 283 dyslexia, 284 MD, 280 controls	8-12	School-identified + WJ IV achievement <25th percentile	WJ IV Cognitive & Achievement	Gc, Ga, Gsm, Gf, Gv, Gs	Dyslexia: deficits in Ga (β=0.42, p<.001), Gsm (β=0.38, p<.001), Gc (β=0.31, p<.01); MD: deficits in EF composite (β=0.51, p<.001), Gv (β=0.44, p<.001), Gsm	Ga: Cohen's d=0.86; Gsm (dyslexia): d=0.79; EF: d=0.94; Gv: d=0.81	Large sample; cross-sectional; well-validated battery; Chinese population adds cross-cultural evidence

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
						(β=0.35, p<.01)		
Keith & Reynolds (2010)	1,847 children (US)	6-18	General population norming sample	Multiple batteries (WJ III, WISC-IV, DAS-II)	All broad CHC abilities	CHC structure supported via CB-CFA; factor structure simpler in younger children; measurement invariance concerns for Gc across age	CFI=0.94-0.98; RMSEA=0.03-0.05	Large representative sample; rigorous CFA methodology; not a clinical sample; validation study

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
Schneider & McGrew (2018)	Theoretical review	N/A	N/A	N/A	All broad CHC abilities	Comprehensive hierarchical model with 16 broad and >80 narrow abilities; validity evidence from structural, developmental, neurocognitive, and achievement domains	N/A (theoretical)	Authoritative synthesis; integrates decades of research; not primary empirical data

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
Zaboski et al. (2018)	Meta-analysis (k=correlations from multiple studies)	6-19 (across included studies)	Various achievement criteria	Various CHC-based batteries	All broad CHC abilities	g factor strongest predictor (54% variance); Gc consistent predictor across domains (r=0.48-0.62); Gv not significantly related to traditional academic achievemen	g: R^2=0.54; Gc: r=0.48-0.62; Gv: r=0.12-0.18	Meta-analytic synthesis; large evidence base; addresses publication bias; not specific to clinical samples

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
						t (r=0.12-0.18)		
Cormier et al. (2016)	1,647 children (US)	5-19	General population norming sample	WJ III	Gc, Gf, Gsm, Gs	Basic writing: Gc strongest predictor (β=0.41); Written expression: Gf predictor (β=0.36); Gsm significant only in adolescence (β=0.22 ages 14-19)	β coefficients reported; R^2=0.38-0.52	Large age-stratified sample; cross-sectional; not a clinical sample

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
Woods et al. (2021)	1,286 children (US): Black (n=412), Hispanic (n=438), White (n=436)	6-18	General population norming sample	WJ IV	Gc, Gf, Gsm, Ga, Gv, Gs	No evidence of predictive bias across racial/ethnic groups; structural invariance supported	Invariance: ΔCFI <0.01	Rigorous invariance testing; diverse sample; supports fairness; not a clinical sample
Fiorello et al. (2009)	162 teachers, 115 school psychologists (US)	N/A	Professional role	Survey	Perceived importance of CHC abilities	Teachers and psychologists agree on Gq, Gc, and Gf importance; psychologis	Mean differences reported	Survey methodology: perception study, not clinical outcomes; useful for

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
						ts rate Gsm (t=3.42, p<.01) and Gq (t=2.98, p<.05) higher than teachers		ecological validity
Radtke (2025)	89 adults with dyslexia, 92 controls (US)	18-45	Confirmed dyslexia diagnosis + WJ IV achievement	WJ IV Cognitive	Gc, Gf, Gsm, Ga, Gv, Gs	Dyslexia: deficits in Gc (d=0.67), Gsm (d=0.71), Gv (d=0.43); Gf relatively preserved (d=0.12, ns)	Cohen's d with 95% CIs reported	Adult sample; well-characterized; challenges PSW assumptions

Study	Sample	Age Range (Years)	Diagnostic Criteria	Assessment Battery	CHC Abilities Measured	Key Findings	Effect Sizes (where reported)	Methodological Quality Indicators
Flores-Mendoza et al. (2021)	442 children (Brazil)	7-12	General population	RAVEN, emotional intelligence measures	Gf (RAVEN), emotional intelligence	Emotional intelligence (β=0.28) and Gf (β=0.41) predict school performance; cognitive and socioemotional factors contribute independently	β coefficients; R^2=0.34	Non-WEIRD sample; integrates non-cognitive factors; not a clinical sample

Note: CB-CFA = Cross-Battery Confirmatory Factor Analysis; CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; WJ = Woodcock-Johnson; WISC = Wechsler Intelligence Scale for Children; DAS = Differential Ability Scales; PSW = Pattern of Strengths and Weaknesses; WEIRD = Western, Educated, Industrialized, Rich, Democratic.

3.3. Explicit Answers to Research Questions

This review was guided by four research questions. Below, each question is answered explicitly based on the synthesized evidence.

"RQ1: What are the patterns of CHC broad ability deficits in individuals with dyslexia?"

Across the four studies examining dyslexia specifically [24], [25]; and evidence synthesized in [8], [11]Consistent deficits emerged in Auditory Processing (Ga) and Short-Term Memory (Gsm). Effect sizes were moderate to large (Ga: Cohen's *d* = 0.67–0.86; Gsm: *d* = 0.71–0.79). Comprehension-Knowledge (Gc) deficits were observed in two studies (*d* = 0.31–0.67), interpreted as secondary effects of reduced reading experience. Fluid Reasoning (Gf) was relatively preserved in both studies examining it (non-significant effect sizes). Visual Processing (Gv) deficits were reported in only one study (*d* = 0.43) and are not considered a core feature.

"RQ2: What are the patterns of CHC broad ability deficits in individuals with mathematical disability (MD)?"

Only one study [25] directly examined MD within the CHC framework. This study reported deficits in Executive Functions (EF composite; β = 0.51, *p* < .001), Visual Processing (Gv; β = 0.44, *p* < .001), and Short-Term Memory (Gsm; β = 0.35, *p* < .01). Effect sizes were large for EF (Cohen's *d* = 0.94) and Gv (*d* = 0.81). Meta-analytic evidence from general populations [42] indicates that Gc and Gf are associated with mathematical achievement, but these findings are not specific to clinical MD samples.

"Q3: How do cognitive profiles compare between dyslexia and MD (unique deficits and shared vulnerabilities)?"

Direct comparison was possible only through [25]The sole study examining both conditions used an identical methodology. Key findings:

- Unique to dyslexia: Larger deficits in Ga (β = 0.42 vs. β = 0.18 in MD).
- Unique to MD: Larger deficits in EF (β = 0.51 vs. β = 0.23 in dyslexia) and Gv (β = 0.44 vs. β = 0.19 in dyslexia).

- Shared vulnerabilities: Both groups showed deficits in Gsm (dyslexia: β = 0.38; MD: β = 0.35) and Gc (dyslexia: β = 0.31; MD: β = 0.28), suggesting common cognitive pathways that may explain the 30–60% comorbidity rate.

"RQ4: What are the implications of these profiles for assessment and intervention?"

The differentiated profiles suggest that assessment batteries should include Ga and Gsm measures for dyslexia, and EF and Gv measures for MD, while Gsm should be assessed in both conditions. The shared GSM deficit implies that working memory interventions may benefit both populations. However, the evidence base is too limited to support strong prescriptive claims.

3.4. Thematic Relationships and Causal Sequence of Findings

Figure 2 presents a conceptual diagram illustrating the relationships among CHC cognitive abilities, learning disorders, and academic outcomes. The diagram is organized into three layers: (A) primary cognitive deficits, (B) secondary/developmental consequences, and (C) academic and psychosocial outcomes. Arrows indicate causal or directional relationships supported by the synthesized evidence.

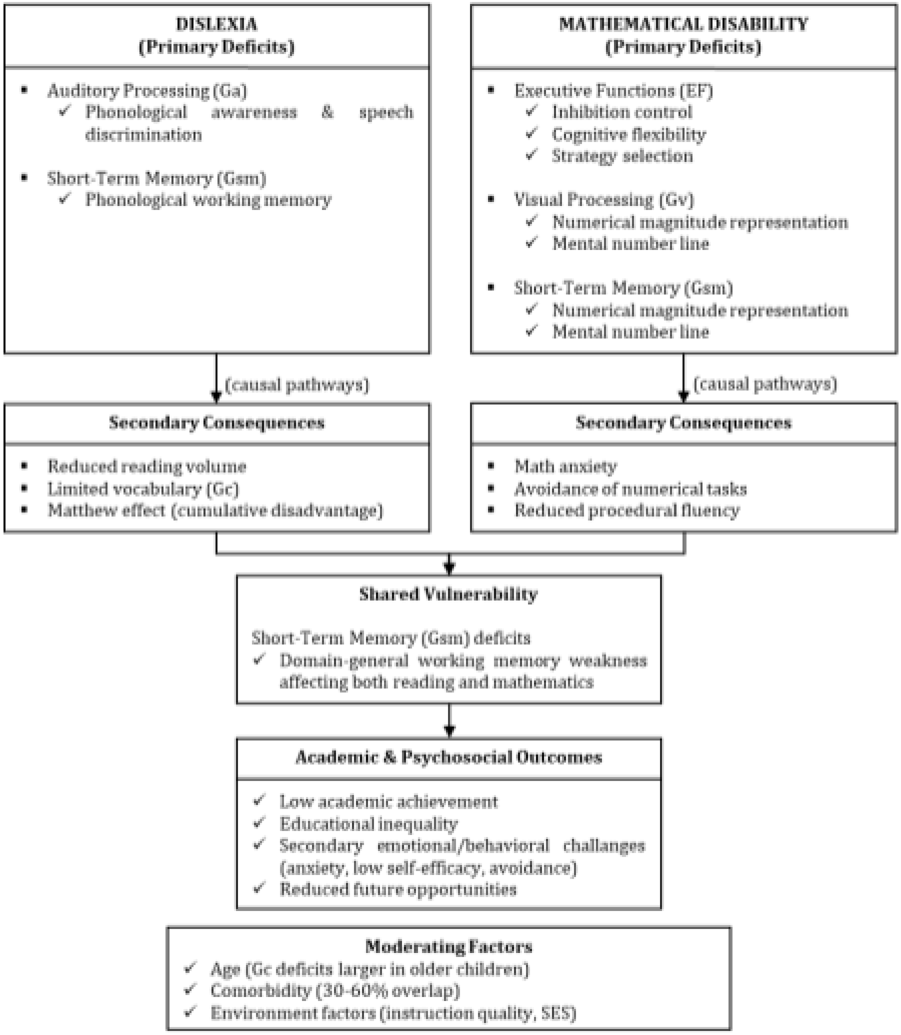

Figure 2. Conceptual Diagram of CHC Cognitive Profiles, Causal Pathways, and Outcomes in Dyslexia and Mathematical Disability

Explanation of the Diagram: The diagram illustrates a causal sequence from primary cognitive deficits (top) to secondary developmental consequences (middle) and ultimately to academic and psychosocial outcomes (bottom). For dyslexia, Ga and Gsm deficits directly impair phonological processing, leading to reduced reading volume and subsequent Gc (vocabulary/knowledge) deficits, a Matthew Effect. For MD, EF, and Gv deficits directly impair numerical magnitude representation and calculation strategy use, which may trigger math anxiety and task avoidance. GSM appears as a shared vulnerability that affects both disorders, providing a cognitive mechanism for comorbidity. Moderating factors (age, comorbidity, environment) influence the strength of these pathways. The evidence for MD pathways is based primarily on a single study [25] and should be interpreted tentatively.

3.5. Summary of Thematic Synthesis

Thematic analysis of the nine included studies revealed three overarching themes:

a. Theme 1: Differentiable Core Deficits. Dyslexia is characterized by Ga and Gsm deficits; MD is characterized by EF and Gv deficits. This differentiation supports disorder-specific assessment protocols.
b. Theme 2: Shared Cognitive Vulnerability. GSM deficits are present in both disorders, suggesting that working memory is a domain-general risk factor. This theme explains the high comorbidity rates (30–60%) and implies that working memory interventions may have cross-domain benefits.
c. Theme 3: Secondary and Cascading Effects. GC deficits in dyslexia appear to be developmental consequences of reduced reading experience rather than primary deficits. This finding challenges static cognitive profiling models and supports longitudinal, developmentally sensitive assessment.

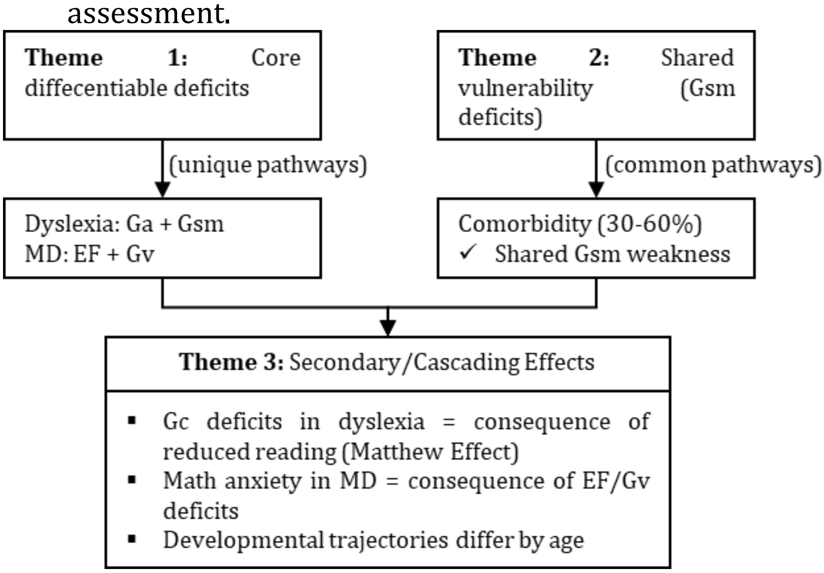

Figure 3. Thematic Relationship Map of CHC Findings in Dyslexia and MD

4. DISCUSSION

This narrative review was designed to answer four specific research questions regarding the CHC cognitive profiles of dyslexia and mathematical disability (MD). Based on the synthesis of the nine included studies, each question is answered explicitly below.

First, regarding patterns of CHC broad ability deficits in dyslexia (RQ1), the evidence consistently demonstrates that individuals with dyslexia exhibit significant deficits in Auditory Processing (Ga) and Short-Term Memory (Gsm), with effect sizes ranging from moderate to large (Cohen's *d* = 0.67–0.86 for Ga; *d* = 0.71–0.79 for Gsm). Comprehension-Knowledge (Gc) deficits were observed in two studies, but are interpreted as secondary consequences of reduced reading experience rather than primary cognitive deficits. Fluid Reasoning (Gf) remains relatively preserved, supporting the view that dyslexia is a specific rather than generalized cognitive disorder. Visual Processing (Gv) deficits were reported in only one study and are not considered a core feature.

Second, regarding patterns of CHC broad ability deficits in MD (RQ2), the evidence is considerably more limited. Only one study directly examined MD within the CHC framework, reporting deficits in Executive Functions (EF composite; β = 0.51, *p* < .001), Visual Processing (Gv; β = 0.44, *p* < .001), and Short-Term Memory (Gsm; β = 0.35, *p* < .01). Effect sizes were large for EF (Cohen's *d* = 0.94) and Gv (*d* = 0.81). Meta-analytic evidence from general populations suggests that Gc and Gf are associated with mathematical achievement, but these findings are not specific to clinical MD samples and should not be generalized without caution.

Third, regarding the comparison between dyslexia and MD (RQ3), direct comparison from the sole study examining both conditions reveals differentiable but overlapping profiles. Unique to dyslexia are larger deficits in Ga (β = 0.42 vs. β = 0.18 in MD). Unique to MD are larger deficits in EF (β = 0.51 vs. β = 0.23 in dyslexia) and Gv (β = 0.44 vs. β = 0.19 in dyslexia). Shared vulnerabilities include deficits in GSM (dyslexia: β = 0.38; MD: β = 0.35) and Gc (dyslexia: β = 0.31; MD: β = 0.28). These shared deficits, particularly in working memory, provide a cognitive mechanism that may explain the high comorbidity rates (30–60%) reported between the two conditions.

Fourth, regarding implications for assessment and intervention (RQ4), the differentiated profiles suggest that assessment batteries should prioritize Ga and Gsm for dyslexia, and EF and Gv for MD, with Gsm assessed in both conditions. The shared GSM deficit implies that working memory interventions may have cross-domain benefits. However, the evidence base remains too limited to support strong prescriptive claims, and practitioners are advised to use CHC profiles as hypotheses rather than definitive diagnoses.

4.1. Specific and Applicable Implications

The findings of this review carry specific implications for theory, practice, and educational policy. Each is elaborated below with actionable recommendations.

Theoretically, this review supports and refines the phonological processing theory of dyslexia by demonstrating that Ga and Gsm deficits are consistent and robust across studies, while Gf remains intact. This affirms the domain-specific nature of dyslexia. For MD, the findings align with neuropsychological models implicating parietal lobe dysfunction (Gv) and executive control deficits, but the evidence base is too narrow to support firm theoretical conclusions. Critically, the identification of GSM as a shared vulnerability across both disorders suggests that current theoretical models should be extended to incorporate domain-general working memory as a transdiagnostic risk factor. This challenges purely domain-specific accounts and calls for integrated theoretical frameworks that can explain both unique deficits and overlapping vulnerabilities. Furthermore, the finding that Gc deficits in dyslexia are likely secondary rather than primary supports developmental cascade models (e.g., Matthew Effect), indicating that theories of learning disorders must account for bidirectional and dynamic interactions between cognitive abilities and academic experience over time.

For educational practitioners and clinical psychologists, several specific recommendations emerge. First, assessment protocols should be differentiated: when dyslexia is suspected, clinicians should prioritize measures of Auditory Processing (e.g., phonological awareness, phonetic coding) and Short-Term Memory (e.g., digit span, nonword repetition). When MD is suspected, priority should be given to Executive Functions (e.g., inhibitory control, cognitive flexibility, working memory updating) and Visual Processing (e.g., spatial relations, visual memory). However, given the shared GSM vulnerability, working memory should be assessed in both populations. Second, interpretation of CHC profiles must be developmentally sensitive. Clinicians should recognize that low Gc scores in children with dyslexia may reflect reduced reading exposure rather than an inherent cognitive deficit; therefore, interventions should address reading volume directly rather than targeting Gc per se. Third, intervention design should be tailored to cognitive profiles. For dyslexia, evidence-based phonological awareness training and working memory supports (e.g., explicit instruction in sound segmentation, repetition, and multisensory techniques) are indicated. For MD, interventions targeting executive control (e.g., strategy instruction, self-monitoring, cognitive flexibility training) and visual-spatial skills (e.g., number line visualization, geometric reasoning) are recommended. Fourth, professional training programs for school psychologists and special educators should include CHC-based cognitive assessment as a core competency, with emphasis on distinguishing primary deficits from secondary consequences and translating profiles into instructional recommendations.

At the policy level, several actions are warranted. First, diagnostic guidelines (e.g., DSM-5, ICD-11, and national special education regulations) should incorporate CHC-based cognitive profiling as a recommended practice for specific learning disorder identification, moving beyond discrepancy models or oversimplified PSW approaches. Policymakers should mandate that assessment batteries include measures of Ga, Gsm, EF, and Gv when learning disorders are suspected. Second, funding priorities for educational research should target longitudinal studies that track developmental trajectories of CHC abilities in dyslexia and MD, direct comparative studies using identical methodologies, and intervention trials that test whether CHC-aligned interventions produce superior outcomes. Third, teacher preparation and professional development policies should require training in CHC theory and its application to differentiated instruction. Given that the evidence base remains limited, policymakers should also invest in cross-cultural validation studies to ensure that CHC-based assessments are fair and valid across diverse linguistic and cultural groups, particularly in non-WEIRD populations. Fourth, school psychology services should be resourced to allow for comprehensive cognitive assessments rather than reliance on brief screening tools. This includes adequate staffing, time allocation, and access to validated CHC-based batteries (e.g., Woodcock-Johnson, WISC). Finally, early identification policies should prioritize screening for working memory (Gsm) deficits in early elementary grades, as Gsm emerges as a shared vulnerability that predicts risk for both reading and mathematical difficulties, enabling early intervention before academic gaps widen.

4.2. Acknowledgment of Limitations

This review has several critical limitations that must be acknowledged transparently. First and most significantly, the evidence base is very small. Only nine studies met the inclusion criteria, and among these, only one study [25], directly examined MD within the CHC framework and provided a direct comparison between dyslexia and MD. All conclusions regarding MD cognitive profiles rest primarily on this single study, which requires replication before any firm conclusions can be drawn.

Second, no intervention studies were included. All synthesized evidence is cross-sectional or correlational, meaning that causal inferences about the direction of effects (e.g., whether Ga deficits cause reading difficulties or vice versa) are tentative. The interpretation of Gc deficits as secondary consequences of reduced reading experience, while theoretically plausible, has not been experimentally tested within the CHC framework for clinical populations.

Third, measurement challenges are present. CHC subtests, particularly for Gsm, often conflate storage and processing demands, making it difficult to isolate pure working memory deficits. Additionally, the EF construct is not formally represented in the classic CHC taxonomy, requiring researchers to use composite scores or supplementary measures, which introduces heterogeneity across studies. The reliability of narrow abilities (Stratum I) has been questioned in the literature, and this review inherits those psychometric concerns.

Fourth, ecological validity is poor. Most included studies used standardized cognitive batteries administered in controlled settings. It remains unclear how CHC profiles predict real-world academic functioning, classroom behavior, or response to intervention. No studies examined whether CHC-aligned interventions produce better outcomes than generic supports.

Fifth, the samples are predominantly WEIRD (Western, Educated, Industrialized, Rich, Democratic). Although [25] included a Chinese sample and [43] Included a Brazilian sample, the majority of studies (six of nine) used US norming samples. Findings may not generalize to low- and middle-income countries, non-English-speaking populations, or educational systems with different curricula and instructional practices.

Sixth, methodological heterogeneity across studies limits comparability. Studies varied in diagnostic criteria (DSM-5 vs. ICD-10/11 vs. school-identified), age ranges (6 to 45 years), assessment batteries (WJ III, WJ IV, WISC, DAS, research batteries), and analytic approaches (regression, CFA, meta-analysis). This heterogeneity precludes meta-analytic synthesis and increases the risk of inconsistent findings.

Seventh, publication bias cannot be ruled out. Studies reporting significant or novel findings are more likely to be published, and this review may overrepresent positive findings while underrepresenting null results or replication failures. The gray literature (e.g., unpublished dissertations, preprints) was not searched.

Eighth, the narrative review design itself is a limitation. Unlike systematic reviews or meta-analyses, narrative reviews do not employ formal quality assessment instruments (e.g., CASP, AMSTAR) and may be subject to author selection bias. Although the authors attempted to minimize bias through consensus meetings and transparent reporting, the lack of quantitative synthesis means that effect sizes cannot be pooled, and the strength of evidence cannot be statistically estimated.

4.3. Comparison with Existing Theoretical Frameworks

The patterns identified align with the Cattell-Horn-Carroll model's hierarchical structure, where broad abilities make specific contributions to academic achievement beyond general intelligence (g). However, the findings also highlight limitations of the CHC framework. The EF construct, increasingly recognized as critical for mathematical learning, is not formally represented in classic CHC taxonomy, requiring integration with executive function models (e.g., Miyake et al.'s unity/diversity framework). This suggests that contemporary cognitive assessment may benefit from hybrid models incorporating both CHC broad abilities and executive function constructs.

Furthermore, the findings question the validity of simplified PSW approaches that assume isolated cognitive weaknesses in specific learning disorders. The broad deficit patterns observed, particularly the Gc weaknesses secondary to reading difficulties, suggest that cognitive profiles in learning disorders reflect both primary deficits and developmental consequences. This complexity challenges identification models that require circumscribed strengths and weaknesses (e.g., one or two low scores with otherwise average abilities) and supports comprehensive assessment approaches integrating multiple data sources, including achievement tests, cognitive profiles, developmental history, and response to intervention.

Based on the limitations identified, future research priorities include: (1) longitudinal studies tracking developmental trajectories of CHC abilities from early childhood through adolescence to distinguish primary deficits from secondary consequences; (2) direct comparisons of dyslexia and MD within single, adequately powered samples using identical methodologies; (3) rigorous intervention trials testing whether CHC-aligned cognitive training or instructional adaptations produce superior academic outcomes compared to generic interventions; (4) cross-cultural validation studies examining measurement invariance and predictive validity of CHC batteries in non-WEIRD populations; (5) development and validation of ecologically valid CHC-based classroom observation tools and curriculum-based measures; and (6) studies examining the interaction between CHC cognitive abilities and affective-motivational factors (e.g., anxiety, self-efficacy, engagement), which are currently underrepresented in the literature.

5. CONCLUSION

This narrative review synthesized evidence from nine studies examining Cattell-Horn-Carroll (CHC) cognitive profiles in dyslexia and mathematical disability (MD). As a narrative review with a limited evidence base, findings should be interpreted as preliminary patterns rather than established conclusions. The available evidence tentatively suggests differentiable profiles: dyslexia is consistently associated with deficits in Auditory Processing (Ga) and Short-Term Memory (Gsm), with relative preservation of Fluid Reasoning (Gf). MD, based on limited direct evidence, appears characterized by deficits in Executive Functions and Visual Processing (Gv). GSM emerges as a potential common vulnerability factor that may underlie high comorbidity rates. However, contradictory findings exist (e.g., Gv deficits reported in some dyslexia studies), and the MD evidence rests primarily on one study. Critical limitations include: small evidence base with no intervention studies; measurement challenges in CHC subtests (e.g., GSM conflating storage and processing); poor ecological validity in classroom contexts; overrepresentation of WEIRD samples; and methodological heterogeneity across studies.

Future research priorities include longitudinal studies tracking developmental trajectories, direct comparisons of dyslexia and MD within single samples, rigorous intervention trials, and cross-cultural validation. Practitioners should apply CHC assessments with caution, using profiles as hypotheses rather than definitive diagnoses, integrating multiple data sources, and translating findings into concrete instructional recommendations. The CHC framework offers a useful structure for understanding cognitive diversity in learning disorders, but the evidence base remains too limited to support strong claims. Rigorous research is urgently needed to translate cognitive theory into improved outcomes for individuals with dyslexia and mathematical disabilities.

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