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Reading Comprehension and Recorded Academic Performance During a CHC-Informed Cognitive and Reading Intervention in Five Students with Reading Difficulties

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A B S T R A C T

This study aimed to describe within-case changes in reading-comprehension and recorded academic-performance scores during a Cattell–Horn–Carroll (CHC)-informed cognitive and reading intervention. Five students aged 8–12 years, identified in the study records as having specific learning disorder in reading, contributed two baseline, five intervention-phase, and two follow-up observations. The Tavanesh program comprised 10 planned sessions of 120 minutes and combined cognitive exercises with direct reading-comprehension activities. Individual trajectories, phase means, and percentage of nonoverlapping data (PND) were examined descriptively. Mean reading-comprehension scores across cases increased from 7.30 at baseline to 12.44 during intervention and 15.20 at follow-up; corresponding recorded academic-performance scores were 5.20, 11.48, and 14.90. All five intervention measurements for every case exceeded that case's highest baseline measurement on both outcomes (PND = 100%). Higher recorded scores coincided with the intervention phase and were present at two follow-up assessments. The uncontrolled A–B–follow-up design, two-point baselines, and insufficiently specified outcome measures preclude causal attribution, normative interpretation, or conclusions about the clinical importance and duration of the changes. The contributions of cognitive training, direct literacy instruction, and repeated testing cannot be separated.

Keywords: *Cattell–Horn–Carroll theory; specific learning disorder in reading; reading comprehension; academic performance; cognitive intervention; single-case design.*

1. Introduction

Reading is a foundational academic competence that enables learners to access curriculum content, construct meaning from written information, and participate effectively in increasingly complex educational tasks. Difficulties in reading therefore extend beyond the language classroom and may affect learning across mathematics, science, social studies, and other subjects in which written materials constitute a major source of instruction. Students with specific learning difficulties in reading often experience persistent problems with word recognition, reading fluency, decoding, and comprehension, and these difficulties may accumulate over time as academic demands become more cognitively and linguistically complex. Contemporary conceptualizations of reading disorders increasingly emphasize that reading difficulties are heterogeneous and may arise through interacting weaknesses in phonological processing, oral language, vocabulary, comprehension, cognitive processing, and educational experience rather than through a single underlying deficit. In particular, oral-language competencies play an important role in explaining why some children who acquire adequate word-reading skills nevertheless continue to struggle with constructing meaning from text (1). Consequently, the design of interventions for children with reading difficulties requires attention not only to decoding but also to the broader cognitive and linguistic processes that support comprehension and academic functioning.

One of the most influential theoretical accounts of reading comprehension is the Simple View of Reading, according to which successful reading comprehension is determined by the interaction between word recognition or decoding and linguistic comprehension (2). From this perspective, fluent identification of printed words is necessary but insufficient for effective comprehension because readers must also understand vocabulary, grammatical relations, propositions, discourse structures, and the broader meanings communicated by the text. More recent elaborations of the Simple View have emphasized that reading difficulties cannot always be reduced to rigid diagnostic categories because weaknesses in decoding and language comprehension exist along continua and can combine in different ways across individual learners (3). Such heterogeneity is particularly important for intervention research, because students presenting with the same general label of reading difficulty may differ substantially in the cognitive and linguistic mechanisms that constrain their performance. Accordingly, intervention approaches that assess and target multiple processes relevant to reading may offer a useful framework for individualized educational planning.

Reading comprehension itself is a complex outcome emerging from the coordination of lower- and higher-level processes. Readers must identify words, retrieve their meanings, maintain information in active memory, establish semantic and syntactic relations across clauses, make inferences, activate background knowledge, monitor understanding, and integrate information into a coherent mental representation. Educational approaches that explicitly engage these processes may therefore be particularly relevant for students who have persistent reading problems. Innovative instructional activities have increasingly been used to strengthen students' active engagement with texts, organize meaning, and facilitate comprehension through structured interaction with reading materials. For example, instructional approaches incorporating Tarsia-based activities have been proposed as means of making reading comprehension more interactive and of helping learners establish relationships among textual components and meanings (4). Such developments reflect a broader movement away from viewing reading intervention as a narrowly repetitive decoding exercise toward approaches combining explicit literacy instruction with cognitively engaging learning experiences.

The importance of effective intervention is supported by a substantial body of reading-intervention research. A systematic review and meta-analysis covering approximately four decades of intervention studies among elementary students with or at risk for dyslexia found that reading interventions can generate positive effects on reading outcomes, while also demonstrating considerable variability according to the nature of the intervention and the reading domain assessed (5). This variability suggests that intervention effects should not be regarded as uniform across decoding, fluency, vocabulary, and comprehension. It also highlights the need to specify the theoretical basis and instructional components of intervention packages. For students whose reading problems are accompanied by

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weaknesses in memory, language processing, attentional control, processing speed, or related cognitive functions, combining direct reading activities with carefully selected cognitive exercises may be educationally plausible, provided that the relationship between trained cognitive processes and meaningful academic outcomes is evaluated cautiously.

The Cattell–Horn–Carroll (CHC) theory offers one of the most comprehensive contemporary taxonomies for conceptualizing human cognitive abilities. The CHC framework describes cognitive functioning hierarchically, incorporating broad abilities such as comprehension-knowledge, fluid reasoning, short-term working memory, long-term storage and retrieval, visual processing, auditory processing, processing speed, and other abilities that can be further differentiated into narrower skills (6). In educational and psychoeducational contexts, the framework can support systematic consideration of cognitive processes potentially relevant to academic tasks. For reading, abilities associated with acquired knowledge, auditory processing, working memory, lexical retrieval, processing efficiency, and comprehension may all contribute to aspects of performance. The CHC model therefore provides a theoretically organized basis for selecting cognitive activities that can be coordinated with direct reading instruction rather than relying on an undifferentiated concept of general cognitive training.

Empirical evidence supports meaningful associations between cognitive abilities and academic performance, although the strength and specificity of these associations differ across domains. A meta-analysis examining relationships between academic achievement and broad CHC abilities indicated that cognitive abilities are systematically related to academic outcomes, while also showing that general ability and specific broad abilities do not contribute equally to every form of achievement (7). Such findings are relevant to intervention design because they suggest that cognitive assessment can help identify potentially important learning-related strengths and weaknesses. At the same time, correlations between cognitive abilities and achievement should not be interpreted as proof that training a cognitive ability will necessarily transfer to improved academic performance. The distinction between identifying cognitive correlates of achievement and demonstrating causal benefits of cognitive training is essential when developing CHC-informed educational interventions.

This caution is particularly important in light of findings from the cognitive-training literature. Working-memory and related cognitive-training programs often produce improvement on trained or closely related tasks, yet evidence for generalized transfer to intelligence or distantly related academic outcomes has been considerably less convincing. A major meta-analytic review concluded that working-memory training does not reliably produce meaningful far-transfer effects on intelligence or other substantially different cognitive outcomes (8). Therefore, a CHC-informed intervention should not be understood as assuming that practicing an isolated cognitive process automatically enhances general academic competence. A more defensible approach is to integrate cognitive exercises with activities directly related to the academic outcome of interest, thereby increasing the conceptual proximity between trained processes and functional educational tasks. In the context of reading difficulties, exercises involving auditory discrimination, lexical retrieval, verbal working memory, semantic relationships, and comprehension strategies may be educationally meaningful when embedded within reading-focused instruction.

Recent research has also drawn attention to cognitive flexibility as an important factor in the academic functioning of students with reading difficulties. Cognitive flexibility enables learners to shift between strategies, reinterpret information, adapt to changing task demands, and modify ineffective approaches when comprehension breaks down. Among students experiencing reading problems, interventions targeting academic self-assurance have been reported to improve cognitive flexibility and cognitive processing, suggesting that cognitive functioning may be influenced not only by task practice but also by psychological and learning-related factors that shape students' engagement with academic challenges (9). Similarly, comparative intervention research among elementary students with specific learning disabilities in reading has indicated that both emotional cognitive-regulation strategies and self-regulated learning strategies may contribute to improvements in academic self-concept and cognitive flexibility (10). These findings support a multidimensional interpretation of reading intervention in

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which cognition, self-regulation, motivation, and academic experience interact.

Self-regulated learning is particularly relevant because successful reading requires learners to plan, monitor, control, and evaluate their own cognitive activity. Skilled readers do not merely decode words; they set purposes for reading, allocate attention, select strategies, detect comprehension failures, reread difficult passages, regulate effort, and evaluate whether they have understood the material. Research in academic reading has demonstrated that motivational and volitional factors contribute to the use of self-regulated learning strategies, indicating that learners' capacity to sustain effort and strategically manage reading tasks is influenced by both motivational orientation and purposeful self-control (11). Similarly, research in online English-learning environments has shown relationships among active participation, self-regulated learning, internet self-efficacy, academic satisfaction, and reading skills, further underscoring that reading performance is embedded in a wider system of learner engagement and self-management (12).

Related evidence from other literacy domains reinforces the importance of affective and self-regulatory processes. In second-language writing contexts, academic buoyancy and emotions have been linked with students' use of self-regulated learning strategies, illustrating how learners' emotional responses to academic challenges may influence the way they select and maintain learning behaviors (13). Although writing and reading are distinct skills, both require sustained cognitive control, monitoring, strategic processing, and persistence when tasks become difficult. For students with reading difficulties, repeated experiences of failure may undermine motivation, confidence, and willingness to engage deeply with texts. Intervention programs that combine structured cognitive activities with meaningful academic tasks may therefore have value not only because of the targeted cognitive processes themselves but also because repeated successful engagement may support adaptive learning behaviors.

The relationship between reading and broader academic achievement provides an additional rationale for examining changes beyond reading scores alone. Reading functions as a gateway skill through which students access instructions, explanations, assessment questions, textbooks, and digital learning materials. Accordingly, limitations in reading comprehension may constrain performance across multiple academic subjects even when students possess adequate domain knowledge. Research among middle-school students has shown that learning strategies can mediate the relationship between reading and academic achievement, indicating that reading competence may contribute to performance partly through the ways students organize and regulate learning (14). This finding is particularly relevant for intervention studies that assess both reading-related outcomes and broader indicators of academic functioning because changes in reading may coincide with improvements in students' capacity to engage with school learning more generally.

Interventions that integrate reading with active, problem-oriented learning activities may be particularly useful for increasing engagement among students who have experienced repeated reading failure. STEM-based activities, for example, can create opportunities for students to use reading in purposeful and contextualized tasks requiring interpretation, reasoning, sequencing, and problem solving. Research examining STEM activities among students with reading problems has reported improvements in academic performance, suggesting that structured interdisciplinary activities may provide a meaningful context in which literacy processes and academic learning interact (15). These findings complement the broader argument that reading intervention does not necessarily need to be restricted to isolated word-level drills; rather, reading-related cognitive and comprehension skills can also be practiced within activities that demand application, reasoning, and integration of information.

Nevertheless, intervention research with students who have reading difficulties requires methodological caution. Improvements observed during or after an intervention can arise from multiple sources, including the intervention itself, continued classroom instruction, repeated exposure to assessment materials, maturation, increased adult attention, motivational changes, or practice effects. These issues become particularly important in small-sample and single-case research, where conclusions depend heavily on the stability of baseline observations, repeated measurement, phase changes, and evidence that changes are systematically associated with introduction of the intervention.

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Contemporary recommendations for single-case experimental design research emphasize transparent reporting, appropriate visual and quantitative analysis, careful evaluation of within-case patterns, and restraint in causal interpretation when experimental control has not been adequately demonstrated (16). Such principles are especially relevant when interventions are evaluated through repeated observations across baseline, treatment, and follow-up phases.

For this reason, descriptive single-case evaluations can be valuable while still requiring clear limits on inference. They allow researchers to examine individual trajectories that may be obscured by group averages and are particularly useful during preliminary investigation of intervention packages developed for specialized populations. Repeated measurement can show whether scores change in level, trend, or overlap after an intervention begins, while follow-up observations can provide preliminary information about whether elevated performance remains observable after the active treatment phase. However, without randomized or staggered intervention onset, a sufficiently stable baseline, independent replication of effects, and well-specified measurement procedures, changes should be described as temporal patterns rather than definitive evidence of treatment efficacy. The current study adopts this cautious orientation by examining changes in recorded reading-comprehension and academic-performance scores across baseline, intervention, and follow-up observations rather than assuming that any observed improvement can be attributed exclusively to a CHC-based treatment mechanism.

Within this framework, the intervention evaluated in the present study combined CHC-informed cognitive exercises with direct reading-related educational activities. The program incorporated activities related to auditory discrimination, lexical and semantic processing, active processing and working memory, comprehension integration, visuomotor functioning, and review of learned skills, thereby addressing multiple processes potentially relevant to reading and classroom performance. Such a multicomponent approach is theoretically consistent with the heterogeneous nature of reading difficulties, yet it also makes component-specific interpretation difficult because any observed change may reflect the combined influence of cognitive practice, comprehension instruction, repeated academic engagement, and nonspecific intervention factors. Consequently, the principal value of a preliminary evaluation is to characterize the pattern of observed change accurately and establish whether further, more controlled investigation is warranted.

The need for such evaluation is reinforced by the growing educational emphasis on individualized intervention for students whose learning difficulties do not respond adequately to ordinary instruction. Reading difficulties may involve different combinations of decoding weaknesses, language-comprehension limitations, processing inefficiencies, strategy deficits, motivational barriers, and cognitive inflexibility. Accordingly, a theoretically organized intervention that links cognitive exercises with reading-comprehension activities may represent a useful avenue for exploration, but its outcomes must be examined at the level of individual learners and interpreted within the limitations of the research design. The present study therefore occupies a preliminary position between theoretical formulation and controlled efficacy research: it uses CHC theory to organize intervention targets, incorporates direct reading-related activities, and evaluates repeated observations in a small number of students in order to describe whether meaningful phase-related patterns are evident.

The aim of the present study was to describe within-case changes in reading-comprehension and recorded academic-performance scores across baseline, CHC-informed cognitive and reading intervention, and follow-up phases in five students with reading difficulties.

2. Methods and Materials

2.1. Design, setting, and participants

The evaluation used an uncontrolled, repeated-observation A–B–follow-up sequence in five students aged 8–12 years in Isfahan, Iran. Each participant contributed two baseline observations (A1 and A2), five observations during intervention (B1–B5), and two follow-up observations (F1 and F2). No randomized or staggered intervention onset was documented. Accordingly, the five cases do not constitute replicated demonstrations of experimental control. The observation labels indicate order within phases, not equal time intervals or specific treatment sessions.

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Eligibility criteria specified age 8–12 years, residence in Isfahan, an identified specific learning disorder in reading, ability to participate in sessions and assessments, and parental or guardian permission. Withdrawal of guardian permission, repeated nonattendance, inability to participate, and incomplete assessment information were stated exclusion criteria. The available records identify the children as having reading-related specific learning disorder but do not document the diagnostic instruments, diagnostic assessor, or case-level confirmation procedure. Case-specific age, sex, grade, severity, co-occurring conditions, and concurrent educational or therapeutic supports were also unavailable, limiting characterization of the sample.

2.2. *CHC-informed intervention*

The Tavanesh package comprised 10 planned sessions of 120 minutes, equivalent to 20 planned contact hours. This is the intended program dose, not verified attendance or completed exposure. The package combined CHC-oriented cognitive targets with reading-related educational activities. Five specialists in relevant fields reviewed the proposed content. Although the development records refer to content validity ratio and content validity index procedures, numerical results are unavailable; expert review is therefore not treated as established quantitative content validation. Table 1 summarizes the documented training components.

Table 1

Main components of the CHC-informed Tavanesh intervention

Component	Selected exercises and training focus	Learning-related rationale
Auditory analysis	Auditory discrimination and sequencing; identifying speech amid competing noise	Attending to and distinguishing spoken information
Lexical and semantic processing	Rapid naming, lexical fluency, identification of word and concept relationships	Access to word meanings and organized retrieval
Active processing	Verbal and visuospatial working-memory activities	Maintaining and integrating verbal information during tasks
Comprehension integration	Strategies for understanding and relating ideas; integrated tasks and skill review	Combining language knowledge and reading-task demands

The program also included visuomotor tasks and end-of-program review and practice planning. Session frequency, breaks, individual or group delivery, trainer qualifications, attendance, and implementation-fidelity records were not documented. The five intervention-phase assessments cannot be assigned to particular sessions from the available information. Neither the timing of the two follow-up assessments nor the duration between phases was recorded in the materials analyzed here.

2.3. *Outcomes and measurement considerations*

The first outcome comprises scores labeled “reading comprehension” in the results dataset. The test name, administration language, passages or item content, possible score range, scoring rubric, assessor, and evidence of measurement reliability were not documented. It is also unknown whether repeated assessments used the same material or equivalent forms. The series is therefore analyzed as recorded task performance, without a claim of standardized or validated measurement. Reading comprehension is distinct from the WISC-IV Verbal Comprehension Index; no repeated index scores were available, and no change in that construct is inferred.

The second outcome comprises academic-performance scores recorded at the same nine observation occasions. The methodology refers to a 48-item questionnaire with five-point response options, whereas the observed series ranges from 4 to 17. The response coding, possible total-score range, respondent, and any transformation linking questionnaire responses to these values are undocumented. The values cannot therefore be identified as raw questionnaire totals, grades, percentages, or standardized scores. Analyses retain the original values and describe their trajectories only; differences in points have no established normative or educational interpretation.

2.4. *Data Analysis*

Individual series were examined descriptively for phase-related changes in level, trend, and overlap. Baseline, intervention, and follow-up means were computed from two,

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five, and two observations per case, respectively. PND was calculated for a favorable increase as 100 × [number of intervention observations strictly exceeding the highest baseline observation]/5 (Scruggs et al., 1987). With five intervention observations, PND changes in increments of 20 percentage points. A value of 100% indicates complete observed nonoverlap with two baseline values; it is not a significance test, a confidence estimate, or evidence of clinical effectiveness. The two-point baseline provides insufficient information to establish stable pre-intervention performance, and PND does not adjust for baseline trend, measurement error, or dependence between repeated observations. Phase means across cases are descriptive summaries, not independent replications of an experimental effect. No inferential p values, confidence intervals, or between-group comparisons were calculated. Interpretation follows the distinction between descriptive change and experimental control emphasized in single-case guidance

3. Findings and Results

The reading-comprehension series are reproduced in Table 2 and displayed in Figure 1. Each student's five intervention observations exceeded their individual baseline maximum. Across participants, the mean of the two baseline observations ranged from 6.0 to 8.0 points. Scores increased during treatment and were consistently higher at the two follow-up measurements. Changes were most gradual for student P3, who rose from a baseline average of 7.5 to an intervention average of 11.2, and greatest in phase-average difference for student P2 (6.0 to 12.6).

Table 2

Reading-comprehension scores across nine observations

Case	A1	A2	B1	B2	B3	B4	B5	F1	F2
P1	7	8	11	12	13	15	16	15	16
P2	6	6	10	12	12	14	15	15	15
P3	8	7	9	10	11	12	14	15	15
P4	7	8	10	11	12	12	13	14	14
P5	8	8	11	13	14	14	15	16	17

The mean of the five case-level phase means increased from 7.30 at baseline to 12.44 during intervention and 15.20 at follow-up. For P1–P5, the baseline–intervention phase-mean differences were +5.9, +6.6, +3.7, +4.1, and +5.4 points, respectively. This upward pattern is descriptive and should not be interpreted as evidence of improved WISC verbal comprehension or of causal treatment efficacy.

All five students also showed higher recorded academic-performance scores during the intervention than at either baseline occasion (Table 3). Individual data patterns in Figure 2 show progressive increases across the five intervention measurements, with continued high values in both follow-up observations. Baseline averages ranged from 4.5 to 6.0 points, and intervention-phase means ranged from 10.6 to 12.2 points.

Table 3

Recorded academic-performance scores across nine observations

Case	A1	A2	B1	B2	B3	B4	B5	F1	F2
P1	5	6	9	10	10	11	13	14	14
P2	4	5	8	10	12	12	13	14	15
P3	6	6	9	11	12	13	15	14	15
P4	4	5	7	10	13	13	15	16	16
P5	6	5	9	11	12	14	15	15	16

Note. The scores reproduce the observed study values. They are not asserted to be untransformed scores on the 48-item academic-performance questionnaire described in the methodology.

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The aggregate average of case-level phase means increased from 5.20 at baseline to 11.48 during intervention and 14.90 at follow-up. Within-person intervention-minus-baseline average differences were +5.1, +6.5, +6.0, +7.1, and +6.7 points for P1–P5. Without a confirmed scoring key and instrument metric, absolute academic-performance levels and comparisons with external norms cannot be established.

Table 4 summarizes the two outcomes by case. Every intervention observation for each student exceeded that student's highest baseline score in both outcomes, yielding PND = 100% across all ten case-by-outcome series. The two follow-up observations for each series also remained above the corresponding baseline maximum. In total, 50 intervention-phase observations across the two outcomes met the nonoverlap criterion; these are repeated measures within five children, not 50 independent participants.

Table 4

Case-level means, phase differences, and percentage of nonoverlapping data

Outcome	Case	A mean	B mean	F mean	B − A	F − A	PND
Reading comprehension	P1	7.5	13.4	15.5	+5.9	+8.0	100%
	P2	6.0	12.6	15.0	+6.6	+9.0	100%
	P3	7.5	11.2	15.0	+3.7	+7.5	100%
	P4	7.5	11.6	14.0	+4.1	+6.5	100%
	P5	8.0	13.4	16.5	+5.4	+8.5	100%
Academic performance	P1	5.5	10.6	14.0	+5.1	+8.5	100%
	P2	4.5	11.0	14.5	+6.5	+10.0	100%
	P3	6.0	12.0	14.5	+6.0	+8.5	100%
	P4	4.5	11.6	16.0	+7.1	+11.5	100%
	P5	5.5	12.2	15.5	+6.7	+10.0	100%

Figure 1

Case-level reading-comprehension scores across baseline, intervention, and follow-up phases.

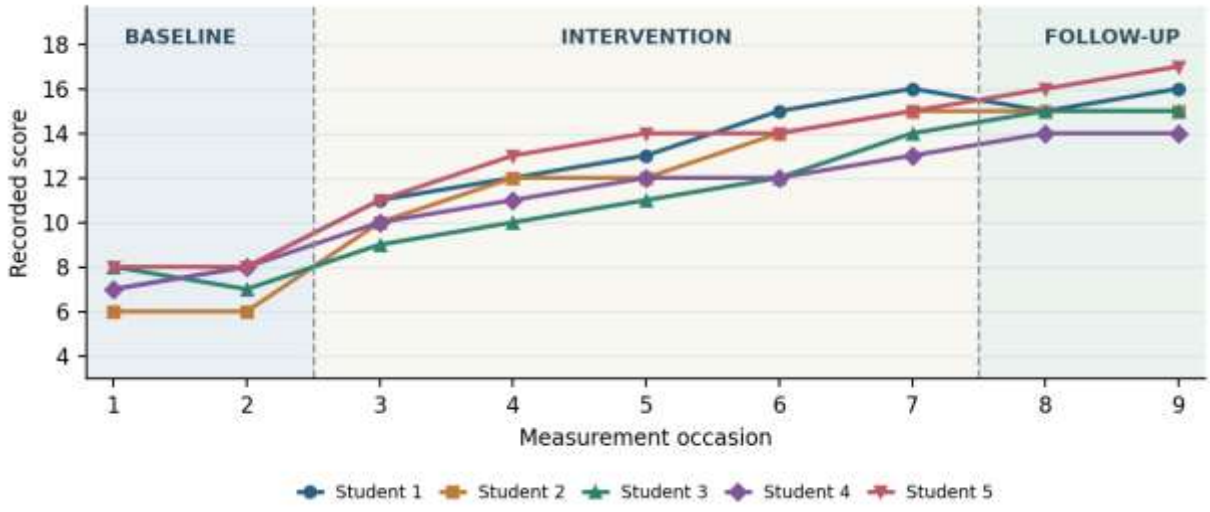

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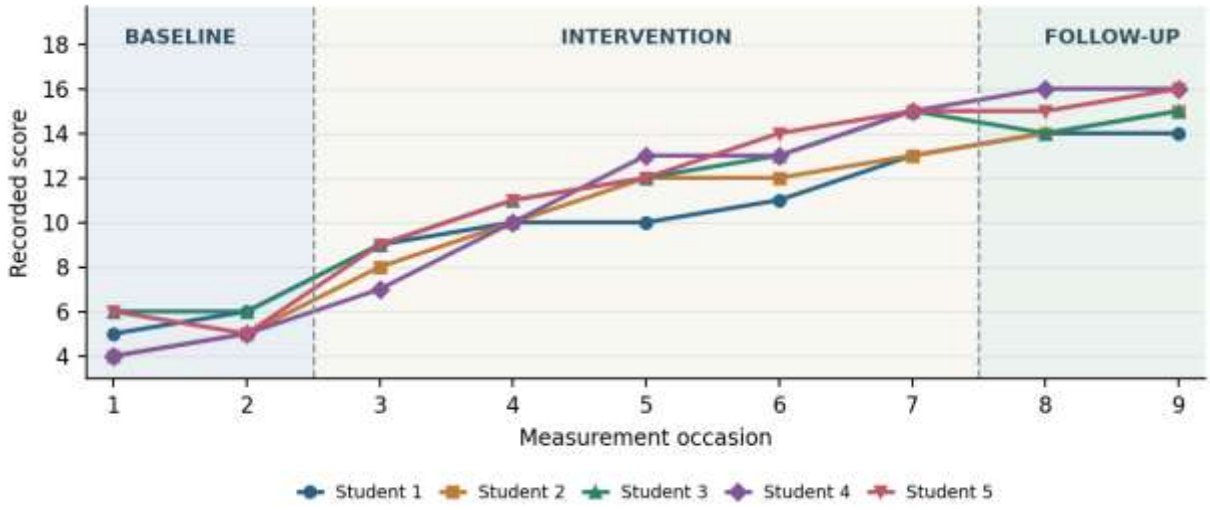
Figure 2

Case-level recorded academic-performance trajectories across the three phases.



4. Discussion and Conclusion

The findings of the present study showed a consistent upward pattern in both reading-comprehension and recorded academic-performance scores across the baseline, intervention, and follow-up phases among the five participating students with reading difficulties. For reading comprehension, the aggregate mean increased from 7.30 during baseline to 12.44 during the intervention phase and reached 15.20 at follow-up. At the individual level, intervention-minus-baseline mean differences were +5.9, +6.6, +3.7, +4.1, and +5.4 points for participants P1 through P5, respectively. A similar pattern was observed for recorded academic performance, for which the aggregate mean increased from 5.20 at baseline to 11.48 during intervention and 14.90 at follow-up. Corresponding intervention-minus-baseline differences were +5.1, +6.5, +6.0, +7.1, and +6.7 points. Moreover, all five intervention observations for every participant exceeded the highest baseline observation for both outcomes, resulting in a percentage of nonoverlapping data of 100% across all ten case-by-outcome series. The two follow-up observations for each participant also remained above the corresponding baseline maximum. These findings indicate a clear descriptive phase-related improvement in the recorded outcomes, although, given the uncontrolled single-case sequence, they should be interpreted as changes temporally associated with the intervention rather than definitive evidence of causal treatment efficacy.

The observed improvement in reading comprehension is theoretically compatible with the Simple View of Reading, which conceptualizes successful reading comprehension as the product of both word-recognition processes and linguistic comprehension (2). The intervention used in the present study did not focus solely on decoding or repeated reading but incorporated activities related to auditory analysis, lexical and semantic processing, memory, rapid retrieval, and explicit comprehension strategies. These components may have supported several processes necessary for constructing meaning from written material. Contemporary elaborations of the Simple View similarly emphasize that reading difficulties may emerge from different combinations and degrees of weakness in word recognition and language comprehension, rather than constituting a single homogeneous condition (3). The variation observed among the five students in the magnitude and trajectory of change is therefore consistent with the expectation that students with reading difficulties may respond differently because their underlying cognitive and linguistic profiles are not identical.

The findings are also compatible with the broader literature emphasizing the importance of language processes in reading disorders. Snowling and Hulme have argued that oral language plays a critical role in both the development and remediation of reading difficulties, particularly when

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comprehension problems extend beyond basic decoding (1). The present intervention included lexical fluency, semantic relationships, auditory discrimination, and comprehension-integration activities, all of which can plausibly contribute to students' ability to access word meaning and integrate information across a text. The progressive increases observed across the five intervention measurements may therefore reflect, at least partly, greater familiarity with strategies for processing verbal information and integrating ideas. However, because the intervention contained several cognitive and reading-related components simultaneously, the current data cannot determine whether improvements were associated primarily with linguistic activities, comprehension strategies, repeated practice, or the combined program.

The present findings also align with the accumulated evidence demonstrating that structured reading interventions can improve reading outcomes among students with or at risk for reading disorders. In their systematic review and meta-analysis spanning four decades of intervention research, Hall and colleagues reported an overall positive effect of reading intervention on norm-referenced reading outcomes in elementary students with or at risk for dyslexia, although the magnitude of effects differed according to intervention characteristics and the specific reading domain examined (5). The consistent increase observed in the present study is broadly compatible with that literature, particularly because the Tavanesh program incorporated direct reading-comprehension activities alongside cognitive exercises. At the same time, the present findings should not be treated as equivalent to the controlled effects summarized in meta-analytic research because the current design did not include randomization, a comparison group, staggered intervention onset, or standardized outcome documentation.

The findings can additionally be interpreted within the framework of CHC theory. CHC theory organizes cognitive functioning into broad and narrow abilities, including comprehension-knowledge, auditory processing, short-term working memory, processing speed, long-term retrieval, and other cognitive domains relevant to learning (6). The intervention was developed around several of these areas, including auditory analysis, lexical and semantic processing, working-memory activity, and comprehension integration. The rise in reading-related scores during the intervention is therefore compatible with the educational logic of targeting processes that contribute to comprehension tasks. Meta-analytic evidence further indicates meaningful relationships between CHC broad abilities and academic achievement, although the strength of these associations varies across academic domains and specific abilities (7). Thus, the current findings support the feasibility of organizing intervention content through a CHC-informed framework, but they do not establish that modification of a particular CHC ability was the mechanism responsible for the observed improvements.

This distinction is particularly important because improvements on trained cognitive tasks do not necessarily transfer to broader academic outcomes. Research on working-memory training has demonstrated that near-transfer effects are generally more reliable than far-transfer effects and that cognitive training alone does not consistently produce generalized improvement in intelligence or distantly related academic performance (8). The current program differs from isolated cognitive training because it incorporated both cognitive exercises and direct reading-comprehension activities. This combination may partly explain why changes were observed on an outcome explicitly labeled reading comprehension. The findings are therefore more reasonably interpreted as reflecting performance changes associated with a multicomponent educational program than as evidence that training broad cognitive abilities independently produced generalized academic gains.

The improvement in recorded academic-performance scores may also be understood through the close relationship between reading competence and broader school achievement. Reading comprehension is essential for accessing instructional materials, understanding written directions, extracting information from textbooks, and responding to assessments across multiple academic subjects. Yim found that learning strategies play an important mediating role in the relationship between reading and academic achievement, indicating that the benefits associated with stronger reading may partly operate through more effective approaches to learning (14). From this perspective, students who become more proficient at identifying relevant information, maintaining task-related content, organizing meaning, and monitoring

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comprehension may also engage more effectively with wider academic demands. The parallel increase in the two outcomes in the present study is consistent with such an interpretation, although the unspecified metric of the recorded academic-performance variable prevents conclusions about improvement in standardized achievement or actual school grades.

Self-regulatory processes may also provide a plausible explanation for part of the observed change. Academic reading requires students to sustain attention, monitor understanding, select strategies, regulate effort, and respond flexibly when comprehension breaks down. Dewi and Kuswandono showed that motivational and volitional factors are meaningfully associated with self-regulated learning in academic reading, highlighting the role of purposeful persistence and strategic engagement in successful reading activity (11). Similarly, Nejati reported relationships among active participation, self-regulated learning, self-efficacy, academic satisfaction, and reading skills, suggesting that reading performance develops within a broader system of cognitive, motivational, and behavioral engagement (12). Repeated participation in structured intervention sessions may therefore have provided the students with opportunities to practice not only cognitive and comprehension skills but also persistence, task monitoring, and strategic engagement with academic activities.

Related evidence concerning emotion and academic resilience further supports a multidimensional interpretation of the findings. Xu and Wang demonstrated that academic buoyancy and emotional experiences are related to the use of self-regulated learning strategies, indicating that students' responses to academic challenges influence how effectively they regulate learning behaviors (13). Children with persistent reading difficulties frequently encounter repeated experiences of academic failure, and such experiences may reduce confidence and willingness to engage with demanding reading tasks. A structured intervention that provides repeated guided practice and achievable challenges may potentially increase sustained engagement even when the intervention is not explicitly framed as motivational training. Accordingly, the progressive increases observed across intervention measurements may reflect the combined influence of skill practice, cognitive engagement, strategy use, and greater willingness to participate in increasingly demanding tasks.

The present results are also consistent with research emphasizing cognitive flexibility and adaptive strategy use among students with reading difficulties. Bahadori Khosroshahi reported that academic self-assurance training was effective in improving cognitive flexibility and cognitive processing in students with reading difficulties (9). Similarly, Far and colleagues found that emotional cognitive-regulation strategies and self-regulated learning strategies contributed to academic self-concept and cognitive flexibility among elementary students with specific learning disabilities in reading (10). Cognitive flexibility may be relevant to comprehension because readers must shift between interpretations, adjust strategies when understanding is incomplete, integrate new information with prior knowledge, and select alternative approaches when an initial strategy fails. Although cognitive flexibility was not directly measured in the present study, intervention activities involving semantic relations, working memory, comprehension integration, and varied cognitive exercises may have required students to engage in flexible information processing.

The results can also be situated within emerging research on active and innovative instructional approaches for students with reading problems. Aktamış and colleagues found that STEM activities could positively influence academic performance among students experiencing reading problems, suggesting that educational activities integrating cognitive engagement, problem solving, and meaningful academic content may support learning beyond conventional isolated reading drills (15). Similarly, Zakaria and colleagues highlighted the potential of interactive Tarsia activities to enhance engagement with reading-comprehension materials by encouraging learners to recognize relationships among pieces of textual information (4). Although the Tavanesh program differed substantially from both STEM and Tarsia approaches, all of these interventions share an emphasis on active processing rather than passive exposure. This commonality may be relevant to the present findings because students repeatedly engaged in tasks involving discrimination, retrieval, integration, and comprehension rather than simply receiving conventional instruction.

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The continued elevation of scores at the two follow-up observations represents another notable descriptive feature. Reading-comprehension means increased further from 12.44 during intervention to 15.20 at follow-up, while recorded academic-performance means rose from 11.48 to 14.90. This pattern may suggest continued application of learned strategies, ongoing school learning, delayed consolidation of intervention-related skills, or continued developmental change. It is also possible that repeated exposure to the assessment process contributed to progressively higher performance. Because the intervals between intervention and follow-up were not documented, the findings cannot establish the duration or stability of maintenance. Nevertheless, the absence of an immediate return toward baseline levels is descriptively encouraging and provides a rationale for investigating maintenance more systematically in future controlled studies.

The methodological characteristics of the present study require particular attention when interpreting the complete baseline-intervention nonoverlap. A PND value of 100% for all participants and both outcomes indicates that every intervention score exceeded the highest baseline score in the corresponding series. While such a pattern is visually striking, contemporary standards for single-case research emphasize that nonoverlap alone is insufficient for establishing experimental control. Stronger inference requires adequate baseline data, systematic replication, clear phase transitions, appropriate measurement, and analyses capable of addressing trend, variability, and dependence among repeated observations (16). In the present study, only two baseline measurements were available and intervention onset was not randomized or staggered. Consequently, the results demonstrate consistent temporal improvement but cannot rule out maturation, ordinary classroom teaching, practice effects, expectancy, increased adult attention, or other concurrent influences.

Overall, the findings provide preliminary descriptive support for further evaluation of a CHC-informed intervention that integrates cognitive exercises with direct reading-related activities. The patterns are compatible with theoretical models that emphasize the combined contributions of linguistic comprehension, cognitive processing, strategy use, and active engagement to reading and academic functioning. They also accord with previous evidence showing benefits of structured reading intervention, self-regulated learning, cognitive flexibility, and active educational methods (5, 9, 14, 15). At the same time, the findings should not be interpreted as demonstrating that CHC-based cognitive training independently caused the observed changes. The intervention was multicomponent, the outcome measures were incompletely documented, and the design did not provide experimental control. The most appropriate conclusion is therefore that higher reading-comprehension and recorded academic-performance scores coincided consistently with the intervention and remained elevated at the available follow-up observations, providing a basis for more rigorous examination of the program.

The present study has several limitations that restrict the strength and generalizability of its conclusions. First, the sample consisted of only five students, limiting representation of the heterogeneity typically observed among children with reading difficulties. Second, only two baseline observations were available for each participant, which was insufficient to establish stable pretreatment levels or trends. Third, all students followed the same baseline-intervention-follow-up sequence without randomization, staggering, or a comparison condition, preventing experimental control over alternative explanations. Fourth, the diagnostic procedures, severity of reading difficulty, concurrent educational support, and several participant characteristics were insufficiently documented. Fifth, the reading-comprehension measure was not fully specified with respect to administration, scoring, reliability, equivalent forms, and possible score range, and the recorded academic-performance values could not be clearly reconciled with the questionnaire described in the study materials. Sixth, treatment fidelity, attendance, trainer qualifications, session frequency, and the exact timing of follow-up assessments were unavailable. Finally, because the intervention combined cognitive exercises with direct reading activities, the contribution of individual program components could not be separated.

Future research should evaluate the intervention using more rigorous experimental designs and larger, more diverse samples of students with clearly documented reading difficulties. Multiple-baseline designs with staggered intervention onset, randomized controlled studies, or carefully matched comparison conditions would strengthen

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causal inference. Studies should employ standardized and psychometrically established reading-comprehension and academic-achievement measures, document equivalent forms when repeated testing is required, and report diagnostic procedures and participant characteristics in sufficient detail. Follow-up assessments should be conducted at predetermined intervals so that short- and longer-term maintenance can be distinguished. Future studies should also measure hypothesized cognitive mechanisms, such as working memory, auditory processing, lexical retrieval, cognitive flexibility, and comprehension-knowledge, before and after intervention to determine whether changes in these processes are associated with changes in reading outcomes. Component analyses comparing direct reading instruction, cognitive training, and their combination would be especially valuable for determining whether CHC-informed activities provide incremental benefit beyond established literacy instruction.

In practice, the present findings suggest that educators and learning-disability specialists may consider integrating structured cognitive activities with explicit reading-comprehension instruction rather than treating cognitive and literacy development as entirely separate domains. Activities may include auditory discrimination, vocabulary and semantic association, rapid lexical retrieval, verbal working-memory exercises, comprehension monitoring, integration of ideas across sentences, and guided practice in selecting reading strategies. Such activities should supplement rather than replace systematic evidence-based reading instruction. Practitioners should individualize intervention according to each student's reading profile, monitor progress repeatedly, and modify activities when performance does not improve. Academic outcomes should be evaluated with clearly defined and reliable measures, and progress should be interpreted in relation to both baseline performance and meaningful educational goals. Close collaboration among teachers, psychologists, learning specialists, and families may also help ensure that strategies practiced during intervention are reinforced in classroom and home learning contexts.

Authors' Contributions

All authors equally contributed to the study and to manuscript development, and all approved the final version.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study placed a high emphasis on ethical considerations. Informed consent obtained from all participants, ensuring they are fully aware of the nature of the study and their role in it. Confidentiality strictly maintained, with data anonymized to protect individual privacy. The study adhered to the ethical guidelines for research with human subjects as outlined in the Declaration of Helsinki.

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