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Improving Visual and Auditory Perception in Students with Specific Learning Disorder with Impairment in Reading through a Multisensory Educational Package

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A B S T R A C T

This study aimed to examine the effectiveness of a multisensory educational package (Colored Cubes) on improving visual and auditory perception in students aged 7–11 years with Specific Learning Disorder (SLD) with impairment in reading. This quasi-experimental study employed a pretest–posttest design with a control group and follow-up assessments. The statistical population consisted of children diagnosed with SLD with impairment in reading according to DSM-5 criteria, attending psychological centers in District 12 of Tehran during the 2024–2025 academic year. Thirty eligible participants were selected through convenience sampling and randomly assigned to experimental and control groups (15 each). The research instruments included the Frostig Developmental Test of Visual Perception and the Wepman Auditory Discrimination Test. The experimental group received a structured multisensory intervention—comprising colored cubes, age-appropriate flashcards, and phonological awareness activities—across twelve 45-minute sessions, while the control group received no intervention. Data were analyzed using repeated-measures ANOVA in SPSS-26 at a significance level of $p < 0.05$. The results of repeated-measures ANOVA revealed significant group-by-time interaction effects across all dimensions of visual perception—eye–hand coordination, figure–ground discrimination, form constancy, spatial perception, and spatial relations—as well as auditory discrimination ($p < 0.001$). Bonferroni post hoc comparisons indicated that improvements in all perceptual domains were maintained in both three- and six-month follow-ups. Effect size estimates (η^2 = 0.17–0.64) confirmed a strong and stable impact of the multisensory intervention over time compared with the control group. The multisensory educational package (Colored Cubes) effectively enhanced and sustained visual and auditory perceptual functions in children with SLD and reading impairment. The integration of visual, auditory, and kinesthetic modalities provides a promising framework for educational and therapeutic settings targeting perceptual deficits in dyslexic learners.

Keywords: *Specific Learning Disorder; Multisensory Educational Package; Visual Perception; Auditory Perception; Educational Intervention.*

1. Introduction

Specific Learning Disorder (SLD) with impairment in reading—commonly referred to as dyslexia—is among the most prevalent neurodevelopmental conditions affecting children's academic performance and overall psychosocial adjustment (American Psychiatric, 2023). Defined by persistent difficulties in accurate and fluent word recognition, decoding, and spelling, this disorder occurs despite normal intelligence, adequate instruction, and social opportunity (Okey-Kalu, 2025). In Iran, prevalence estimates suggest that between 7% and 15% of primary school students experience reading-related learning difficulties that substantially interfere with their progress (Sedaghati et al., 2010). The consequences of these deficits extend beyond literacy, affecting motivation, emotional well-being, and long-term academic achievement (Sobhani et al., 2024). Neurocognitive studies indicate that SLD stems from deficits in phonological processing, auditory discrimination, and visual–spatial organization that jointly disrupt the acquisition of reading fluency and comprehension (Chokron et al., 2021; Rezaei, 2024).

Reading is a complex neuropsychological process requiring the integration of visual recognition, auditory sequencing, phonological encoding, and semantic retrieval (Bertoni et al., 2024; Flanagan et al., 2025). Children with SLD often exhibit atypical functioning in cortical networks connecting the occipito-temporal and temporo-parietal regions that support decoding and automatic word recognition (Economou et al., 2024). Neuroimaging evidence shows that pre-readers at risk for dyslexia demonstrate differences in cortical thickness and white matter integrity within these circuits (Meng et al., 2024). Such neurobiological abnormalities contribute to inefficiencies in the mapping of graphemes to phonemes, resulting in reduced activation of brain regions essential for fluent reading (Robertson et al., 2024). Although the phonological deficit theory has dominated research in this field, more recent perspectives argue that dyslexia arises from interactions among auditory, visual, and attentional processes rather than a single phonological impairment (Chokron et al., 2021; Okey-Kalu, 2025).

Visual and auditory perception play foundational roles in the early stages of literacy acquisition. Visual perception refers to recognizing and interpreting visual stimuli, including form constancy, spatial relations, and figure–ground discrimination (Basak & Yaman, 2023). Auditory perception involves discriminating, identifying, and sequencing sounds within words (Bakhtiari et al., 2012). Both functions are essential for efficient reading and spelling because they enable accurate identification of letters, phonemes, and spatial orientation within words (Flanagan et al., 2025). Deficits in visual–motor coordination, spatial awareness, and auditory discrimination hinder the decoding process and impede the integration of visual and phonological cues (Khademi Adel et al., 2024). These perceptual challenges are often observed in children with SLD and require targeted interventions that strengthen the coordination between sensory modalities (Sobhani et al., 2024).

Research has demonstrated that perceptual training programs can substantially enhance reading outcomes in dyslexic children. Eye-tracking and neuropsychological studies reveal that exercises improving visual scanning and fixation reduce the cognitive load during text processing and increase comprehension (Dostálová et al., 2024). Similarly, auditory rhythm and beat synchronization activities have been found to facilitate phonological awareness and temporal sequencing (Flanagan et al., 2025). Such findings support the conceptualization of reading as a multisystemic process involving dynamic interactions between sensory, cognitive, and motor systems (Iaia et al., 2024; Le Cunff et al., 2024).

The multisensory learning approach emerges as one of the most effective pedagogical models for addressing these multidimensional challenges. Grounded in neuropsychological theories of cross-modal integration, multisensory methods engage visual, auditory, tactile, and kinesthetic modalities simultaneously to reinforce neural connectivity (Rahmonovna, 2025). This strategy builds on the early Orton–Gillingham framework, which demonstrated that concurrent activation of multiple sensory channels strengthens phoneme–grapheme associations (Lim & Oei, 2015). Over the years, multisensory education has expanded to include technology-enhanced, game-based, and adaptive learning systems, increasing motivation and persistence among children with learning disabilities (Alkhawalde & Khasawneh, 2024; Ward et al., 2024).

Several studies confirm the effectiveness of multisensory learning in improving perceptual, linguistic, and motivational aspects of learning among students with dyslexia. These interventions have been linked to significant gains in reading accuracy, spatial reasoning, and phonological awareness (Fatimah et al., 2025; Khademi Adel et al., 2024; Kunasegran & Subramaniam, 2024). The approach not only enhances cognitive functioning but also

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fosters emotional resilience and positive self-concept in children who have historically experienced academic frustration (Iaia et al., 2024; Mosafer & Sadati Firouz Abadi, 2025). Teachers adopting multisensory instructional designs report better student engagement and greater transfer of learned skills to everyday reading tasks (Putri & Hendriani, 2024; Rahmonovna, 2025).

Technological innovation has significantly advanced the possibilities of multisensory teaching. Digital and assistive technologies—including artificial intelligence, virtual reality, and eye-tracking systems—enable individualized learning experiences for children with SLD (Adjiovski et al., 2024; Paudel & Acharya, 2024). Eye-tracking interventions monitor visual fixations and guide corrective feedback, improving reading fluency and attention (Dostálová et al., 2024). Likewise, AI-based text-to-speech applications allow dyslexic learners to access reading materials through auditory support, improving decoding and comprehension (Ward et al., 2024). Gamified platforms further increase engagement and provide immediate feedback, which enhances learning outcomes (Alkhawalde & Khasawneh, 2024; Patil et al., 2024). These developments represent a paradigm shift toward inclusive digital learning ecosystems that integrate cognitive, emotional, and sensory dimensions of education (Yenduri et al., 2023).

Cognitive rehabilitation and neuropsychological training packages have also gained prominence in addressing reading disorders. Programs focused on strengthening working memory, attention, and lateral dominance have demonstrated effectiveness in improving reading accuracy and perceptual integration (Esmaeili Anvar et al., 2023; Eyvazi et al., 2023). Interventions that emphasize self-regulated strategy development and metacognitive awareness are equally beneficial in enhancing comprehension and self-monitoring skills (Fattahi et al., 2025). Neuropsychological rehabilitation models highlight the interplay between sensory and executive functions, suggesting that restoring perceptual processing contributes to broader cognitive gains (Dashtipour et al., 2024; Rezaei, 2024).

At the neuroscientific level, multisensory training promotes neural plasticity by synchronizing cortical regions responsible for auditory and visual processing (Economou et al., 2024; Le Cunff et al., 2024). Engaging multiple sensory pathways enhances communication between the dorsal and ventral streams, facilitating efficient decoding and word recognition (Micheletti et al., 2024). Studies show that early intervention using multisensory exposure normalizes activation patterns in children at risk for dyslexia and leads to lasting improvements in literacy skills (Bertoni et al., 2024; Flanagan et al., 2025). Moreover, multisensory experiences can alleviate the anxiety and low self-esteem frequently observed in dyslexic learners by providing immediate corrective feedback and reinforcing success (Rahmonovna, 2025; Sarajar & Pratiwi, 2024).

Empirical research supports the idea that integrated perceptual–cognitive training yields superior outcomes compared to single-modality interventions. For instance, training packages combining visual and auditory exercises, such as matching shapes with phonemes or rhythmic tapping with reading aloud, improve decoding accuracy and retention (Fatimah et al., 2025; Khademi Adel et al., 2024). Morphological awareness and visual search exercises also contribute to greater reading fluency and spelling proficiency (Mendes & Kirby, 2024; Meng et al., 2024). In addition, structured programs like the Frostig Visual Perception Training have demonstrated significant enhancements in visual–spatial and perceptual discrimination skills among first-grade students with learning challenges (Basak & Yaman, 2023).

In Iran and other similar contexts, integrating cultural and linguistic factors into multisensory interventions has been shown to enhance their ecological validity and acceptance. Locally designed training programs that align with Persian orthography and phonological patterns yield higher engagement and retention rates (Amiri Ahmadi et al., 2023; Mirzaei et al., 2024). Parent-involved models further strengthen the continuity of learning and reinforce children's motivation at home (Guo & Keles, 2025; Sarajar & Pratiwi, 2024). These findings highlight the importance of designing culturally responsive, family-supported interventions that bridge the gap between clinical training and classroom application.

Despite the growing body of evidence on dyslexia interventions, many existing approaches remain limited in scope. Most studies focus either on phonological training or on digital technology use without fully addressing the integration of visual and auditory modalities (Donolato et al., 2022; Robertson et al., 2024). Additionally, the sustainability of these intervention effects over extended periods has not been adequately examined (Flanagan et al., 2025; Mendes & Kirby, 2024). There is therefore a need for comprehensive, evidence-based models that combine perceptual training with emotional and cognitive dimensions to achieve long-term reading improvement (Fattahi et al., 2025; Mirzaei et al., 2024).

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Integrating tactile, kinesthetic, and rhythmic elements within multisensory learning may enhance hemispheric synchronization and strengthen sensory–motor coordination (Khademi Adel et al., 2024; Micheletti et al., 2024). This holistic approach facilitates the transfer of perceptual gains into academic skills, promoting functional literacy and self-efficacy (Amiri Ahmadi et al., 2023; Kunasegran & Subramaniam, 2024). Moreover, the development of intelligent, gamified platforms and assistive devices provides promising avenues for sustainable implementation of these programs in mainstream and special education settings (Adjiovski et al., 2024; Paudel & Acharya, 2024).

In sum, empirical and theoretical evidence underscores the critical role of multisensory educational interventions in enhancing perceptual processing, cognitive development, and literacy acquisition among children with SLD. Integrating visual and auditory modalities in structured, interactive training can activate multiple neural networks, reduce cognitive load, and sustain learning over time (Mosafer & Sadati Firouz Abadi, 2025; Putri & Hendriani, 2024; Rahmonovna, 2025). Recognizing this gap in comprehensive, culturally adapted research, the present study aimed to develop and evaluate the effectiveness of a structured multisensory educational package on improving visual and auditory perception in students with Specific Learning Disorder with impairment in reading.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a quasi-experimental design with a pretest–posttest and control group, followed by a follow-up phase. The statistical population included all children aged 7 to 11 years in District 12 of Tehran during the 2024–2025 academic year who were referred to psychology centers and had received an official diagnosis of *Specific Learning Disorder with impairment in reading* from a child psychologist or psychiatrist, based on the DSM-5 criteria.

The research sample consisted of 30 eligible children selected through convenience sampling and randomly assigned to experimental and control groups (15 participants in each). Inclusion criteria included children aged 7 to 11 years with an official diagnosis of *Specific Learning Disorder with impairment in reading*, normal intelligence quotient, normal vision and hearing, and parental consent and cooperation to participate in all stages of the research. Exclusion criteria included absence from more than two sessions, withdrawal or persistent lack of cooperation by the child or parents, simultaneous receipt of other educational or therapeutic interventions, or the occurrence of acute medical or psychological problems during the research period.

Research instruments included the *Frostig Developmental Test of Visual Perception* to measure visual perception components (*Eye–Hand Coordination*, *Figure–Ground Discrimination*, *Form Constancy*, *Spatial Perception*, and *Spatial Relations*) and the *Wepman Auditory Discrimination Test* to assess *Auditory Discrimination*. The validity and reliability of these instruments have been confirmed in previous Iranian studies (Kord Noghaby & Dortaj, 2007).

The multisensory educational intervention was implemented as a package comprising colored cubes, educational flashcards, and skill-based games, supplemented with educational software, across 12 sessions of 45 minutes each for the experimental group. The sessions were conducted under the guidance of the principal researcher and supervised by a child psychology specialist, with parental participation in continuing and monitoring the exercises during the week. The content of the sessions included visual exercises for shape and letter recognition, phonological awareness, and enhancement of visual and auditory perception. The control group received no intervention; however, after completion of the study, educational sessions were held for them to uphold ethical considerations.

Before the intervention, briefing sessions were held for parents to familiarize them with the study's objectives and their role in the process. Pretests were administered to both experimental and control groups, followed by posttests and follow-up assessments conducted three and six months after the intervention. To ensure ethical compliance, confidentiality of participants' information was guaranteed, and informed consent was obtained from parents.

The content validity of the multisensory educational package was evaluated using Lawshe's Content Validity Ratio (CVR) and Waltz and Bausell's Content Validity Index (CVI) methods by ten experts in child psychology and learning disorders. The analysis results indicated that all components scored above the acceptable threshold (CVI > 0.79), and the necessity of the session content was statistically significant. This structured design and the use of validated instruments enabled precise evaluation of the effectiveness of the multisensory educational package.

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2.2. Measures

2.2.1. Frostig Developmental Test of Visual Perception

The *Frostig Developmental Test of Visual Perception* is a validated instrument for assessing visual–perceptual abilities in children, particularly at preschool and primary school levels, helping identify visual perception difficulties related to learning, reading, and writing (Kord Noghaby & Dortaj, 2007). This test consists of five subtests measuring different aspects of visual perception:

1. *Visual–Motor Coordination*, which assesses control over eye and hand movements;
2. *Visual Discrimination*, which evaluates the ability to distinguish shapes from similar backgrounds;
3. *Visual Constancy*, which measures recognition of constant shapes under changes in size or orientation;
4. *Position in Space*, which assesses understanding of location and direction of objects; and
5. *Spatial Relations*, which evaluates the ability to perceive relationships among objects. This test was standardized in Iran by Kord Noqabi and Dortaj (2007) and validated in a study of 448 first- and second-grade elementary students in Tehran. Due to its precision in detecting perceptual weaknesses, it is an effective tool for planning educational interventions for children with Specific Learning Disorder.

2.2.2. Wepman Auditory Discrimination Test

The *Wepman Auditory Discrimination Test* is a validated instrument for assessing auditory discrimination abilities in children, particularly those aged 4 to 12 years, designed to measure the ability to differentiate between sounds and words. Developed by Wepman in 1958, its revised versions were published in 1973 and 1987. The test includes 40 word pairs, consisting of 30 different and 10 identical pairs, and the child must determine whether the words are the same or different. The test is divided into four main categories: *place of articulation*, *manner of articulation*, *vowel*, and *voicing/unvoicing*, assessing auditory processing ability. Difficulties in auditory discrimination can directly affect reading and writing skills. The test has been standardized for the Persian language in Iran, with confirmed validity and reliability. Due to its precision in identifying auditory deficits, it is widely used for diagnosis and planning educational interventions for children with Specific Learning Disorder.

2.3. Intervention

The multisensory educational package (Colored Cubes) was designed to enhance visual and auditory perception, attention, concentration, eye–hand coordination, and reading skills in children aged 7 to 11 years with Specific Learning Disorder (SLD) with impairment in reading. The package included eighteen colored cubes (four of each color: red, blue, green, and yellow, along with two sound-producing cubes), an age-appropriate game manual, and two sets of flashcards. The first set of flashcards featured skill-based games designed to strengthen visual and auditory processing, perceptual differentiation, and psychomotor coordination. The second set included word-based flashcards for literacy exercises focusing on phonemic awareness—segmentation, blending, deletion, and substitution of phonemes—as well as rhyming, phoneme matching, and syllabic reading of one- to four-syllable words with varying frequencies. The exercises incorporated fluency drills, word-chain reading, color-coded "rainbow words," and short passages aimed at improving comprehension and retention. The intervention emphasized active parental involvement, gradual difficulty progression, and cultural alignment with the Persian script and phonological system to ensure accessibility and engagement. The content validity of the package was verified by a panel of experts, and its developmental impact had previously been recognized with multiple awards in national educational innovation festivals in 2023 and 2024.

The intervention consisted of twelve structured sessions, each building on the previous one. In the first session, parents were introduced to the study, the characteristics of children with SLD, and the educational goals of the program, emphasizing family collaboration as a crucial support factor. In the second session, parents and children participated in supervised play activities to practice the instructional games, while the therapist provided individualized guidance and corrective feedback. Sessions three through six involved progressively complex visual and auditory skill-based exercises using colored cubes and flashcards, beginning with simple discrimination and advancing to phonemic awareness tasks such as identifying, segmenting, blending, and matching phonemes, as well as recognizing rhymes and phonological similarities. Sessions seven to nine focused on reading words of increasing syllabic complexity (one- to

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four-syllable words) with varying frequency levels, chain-word reading, and fluency monitoring using checklists completed by parents. In sessions ten and eleven, "rainbow word" activities were introduced to reinforce visual–auditory memory by associating phonemes with specific colors, allowing children to connect letter shapes, sounds, and colors simultaneously. The final session involved reading simple sentences and short passages, followed by comprehension discussions to assess understanding. Throughout the program, families were instructed to practice the skill-based games at home for at least 30 minutes daily and to record the child's performance in structured checklists. The consistent home–school collaboration, combined with progressive, multisensory exercises, was aimed at reinforcing perceptual learning and achieving sustained improvement in both visual and auditory domains.

2.4. Data Analysis

Data were analyzed using SPSS version 26. Statistical assumptions, including normality of data distribution, homogeneity of variances, and sphericity, were examined using the Kolmogorov–Smirnov, Levene, and Mauchly tests. Results indicated that the assumptions were met; therefore, repeated measures ANOVA at a significance level of .05 was used to analyze the intervention's effectiveness.

3. Findings and Results

In this study, 30 students participated in two groups: experimental and control (15 participants in each group). The mean and standard deviation of participants' age in the experimental group were 11.9 ± 0.77 years, and in the control group 9.33 ± 0.92 years. In both groups, the gender composition consisted of 5 girls and 10 boys. Moreover, in both experimental and control groups, 5 students were in the second grade, 7 students in the third grade, and 3 students in the fourth grade of elementary school. Table 1 presents the mean, standard deviation, and Shapiro–Wilk index (significance level) for the components of visual and auditory perception across three stages—pretest, posttest, and follow-up—for the experimental and control groups.

Table 1

Mean, Standard Deviation, and Shapiro–Wilk Index (Significance Level) of Visual and Auditory Perception across the Three Stages of Implementation

Variable (Component)	Group	Pretest *M* (SD)	Posttest *M* (SD)	Follow-up *M* (SD)	Shapiro–Wilk *W* (Sig.) Pretest	Shapiro–Wilk *W* (Sig.) Posttest	Shapiro–Wilk *W* (Sig.) Follow-up
Eye–Hand Coordination	Experimental	16.47 (2.50)	20.80 (3.30)	21.53 (2.77)	.963 (.736)	.935 (.324)	.910 (.135)
	Control	16.40 (1.99)	16.60 (2.59)	16.60 (2.41)	.958 (.664)	.924 (.222)	.952 (.564)
Figure–Ground Discrimination	Experimental	13.53 (1.55)	15.93 (2.40)	16.33 (2.13)	.935 (.326)	.912 (.145)	.920 (.192)
	Control	13.33 (1.45)	13.60 (1.96)	13.60 (1.90)	.948 (.498)	.966 (.798)	.926 (.237)
Form Constancy	Experimental	7.44 (0.99)	8.79 (1.20)	8.96 (1.27)	.953 (.569)	.981 (.975)	.943 (.428)
	Control	7.14 (0.69)	7.42 (1.04)	7.39 (1.02)	.966 (.795)	.928 (.258)	.941 (.399)
Spatial Perception	Experimental	4.51 (1.14)	5.90 (1.09)	5.87 (1.20)	.920 (.192)	.937 (.352)	.959 (.672)
	Control	4.80 (0.93)	4.48 (0.72)	4.36 (0.90)	.961 (.712)	.956 (.626)	.965 (.770)
Spatial Relations	Experimental	4.67 (1.13)	5.87 (1.27)	6.17 (0.94)	.941 (.390)	.928 (.258)	.954 (.588)
	Control	4.44 (0.69)	4.93 (0.82)	4.70 (0.92)	.925 (.226)	.959 (.676)	.904 (.109)
Auditory Perception	Experimental	32.47 (1.85)	35.13 (1.69)	35.07 (1.79)	.935 (.326)	.964 (.755)	.947 (.481)
	Control	32.40 (2.03)	32.73 (1.75)	32.33 (1.72)	.920 (.191)	.947 (.475)	.927 (.250)

Table 1 indicates that the mean scores of visual and auditory perception components in the experimental group increased in the posttest and follow-up stages compared with the pretest stage. In contrast, no substantial changes were observed in the control group. To assess the assumption of normality of data distribution, Shapiro–Wilk values for

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dependent variables were examined. As Table 1 shows, the Shapiro–Wilk values for none of the visual and auditory perception components were statistically significant, indicating that the normality assumption of the dependent variables was satisfied.

In the present study, Levene's test was used to evaluate the assumption of homogeneity of error variances of dependent variable levels across groups, and results revealed no significant differences in error variance scores for any of the visual and auditory perception components between groups or across stages. This finding indicates that the homogeneity of variance assumption was met. Moreover, the assumptions of homogeneity of covariance matrices for dependent variables were examined using M. Box's test, and the sphericity assumption (equality of error covariance matrices) was examined using Mauchly's test. The results are presented in Table 2.

Table 2

Results of Equality Tests of Variance–Covariance Matrices and Equality of Error Covariance Matrices

Variable	M. Box	F	p	Mauchly's W	χ^2	p
Eye–Hand Coordination	11.47	1.67	0.120	0.803	5.94	0.051
Figure–Ground Discrimination	6.85	1.01	0.418	0.855	4.22	0.121
Form Constancy	7.93	1.17	0.321	0.528	17.26	0.001
Spatial Perception	13.45	1.98	0.065	0.834	4.92	0.086
Spatial Relations	19.54	2.88	0.008	0.836	4.82	0.090
Auditory Perception	11.96	1.76	0.103	0.880	3.46	0.178

According to Table 2, the results indicated that M. Box's statistic for the Spatial Relations component of visual perception was significant ($p = 0.008$). Although this result suggests a violation of the homogeneity assumption of covariance matrices for that component, given the equal sample sizes in both experimental and control groups and the robustness of ANOVA family tests against deviations from assumptions, this issue was not expected to influence the analysis results. Furthermore, Mauchly's test of sphericity showed a significant chi-square value for the Form Constancy component ($p = 0.001$), indicating that the sphericity assumption was not met for this component. Therefore, its degrees of freedom were corrected using the Greenhouse–Geisser method.

After assessing and confirming the assumptions, data were analyzed using repeated measures ANOVA. Table 3 presents the results of multivariate analysis examining the effect of the multisensory educational package on visual and auditory perception.

Table 3

Results of Multivariate Analysis of Variance (MANOVA) for Evaluating the Effect of the Independent Variable on Visual and Auditory Perception

Component	Wilks' Lambda	F	df	p	η^2	Power
Eye–Hand Coordination	0.397	20.49	2, 27	0.001	0.603	1.000
Figure–Ground Discrimination	0.610	8.63	2, 27	0.001	0.390	0.949
Form Constancy	0.608	8.72	2, 27	0.001	0.392	0.951
Spatial Perception	0.501	13.45	2, 27	0.001	0.499	0.995
Spatial Relations	0.702	5.73	2, 27	0.008	0.298	0.825
Auditory Perception	0.578	9.86	2, 27	0.001	0.422	0.971

According to the results presented in Table 3, the effect of the independent variable (implementation of the multisensory educational package) on all components—Eye–Hand Coordination (Wilks' $\lambda = 0.397$, $\eta^2 = 0.603$, $F = 20.49$, $p = 0.001$), Figure–Ground Discrimination (Wilks' $\lambda = 0.610$, $\eta^2 = 0.390$, $F = 8.63$, $p = 0.001$), Form Constancy (Wilks' $\lambda = 0.608$, $\eta^2 = 0.392$, $F = 8.72$, $p = 0.001$), Spatial Perception (Wilks' $\lambda = 0.501$, $\eta^2 = 0.499$, $F = 13.45$, $p = 0.001$), Spatial Relations (Wilks' $\lambda = 0.702$, $\eta^2 = 0.298$, $F = 5.73$, $p = 0.008$), and Auditory Perception (Wilks' $\lambda = 0.578$, $\eta^2 = 0.422$, $F = 9.86$, $p = 0.001$)—was statistically significant.

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Table 4 presents the results of repeated measures ANOVA explaining the effect of the multisensory educational package on visual and auditory perception.

Table 4

Results of Repeated Measures ANOVA Explaining the Effect of the Independent Variable on Visual and Auditory Perception

Variable	Effects	Sum of Squares	Error Sum of Squares	F	p	η²
Eye–Hand Coordination	Group Effect	211.60	460.67	12.86	0.001	0.315
	Time Effect	104.02	58.67	49.64	0.001	0.639
	Group × Time Interaction	103.27	61.83	24.50	0.001	0.467
Figure–Ground Discrimination	Group Effect	69.34	230.04	8.44	0.007	0.232
	Time Effect	35.27	37.67	26.22	0.001	0.484
	Group × Time Interaction	27.82	82.49	9.44	0.001	0.252
Form Constancy	Group Effect	26.24	80.26	9.16	0.005	0.246
	Time Effect	11.79	9.74	33.90	0.001	0.548
	Group × Time Interaction	6.99	12.85	15.22	0.001	0.352
Spatial Perception	Group Effect	17.34	63.36	7.66	0.010	0.215
	Time Effect	3.17	14.11	6.30	0.018	0.184
	Group × Time Interaction	15.46	22.16	19.53	0.001	0.411
Spatial Relations	Group Effect	17.34	53.05	9.15	0.005	0.246
	Time Effect	11.62	15.04	21.63	0.001	0.436
	Group × Time Interaction	5.81	27.59	5.90	0.005	0.174
Auditory Perception	Group Effect	67.60	173.69	10.90	0.003	0.280
	Time Effect	24.07	62.27	10.82	0.001	0.279
	Group × Time Interaction	31.67	100.58	8.82	0.001	0.239

Table 4 indicates that the Group × Time interaction is significant for Eye–Hand Coordination ($\eta^2 = 0.467$, $p = 0.001$, $F = 24.50$), Figure–Ground Discrimination ($\eta^2 = 0.252$, $p = 0.001$, $F = 9.44$), Form Constancy ($\eta^2 = 0.352$, $p = 0.001$, $F = 15.22$), Spatial Perception ($\eta^2 = 0.411$, $p = 0.001$, $F = 19.53$), Spatial Relations ($\eta^2 = 0.174$, $p = 0.005$, $F = 5.90$), and Auditory Perception ($\eta^2 = 0.239$, $p = 0.001$, $F = 8.82$). These findings indicate that the multisensory educational package significantly affected visual perception. Table 5 presents the Bonferroni post hoc test results for visual and auditory perception scores in the two groups across the three stages of implementation.

Table 5

Bonferroni Post Hoc Results for Visual and Auditory Perception

Dependent Variable	Time Points	Mean Difference	Standard Error	p-value
Time Comparisons (Within-Subject)				
Eye–Hand Coordination	Pretest vs. Posttest	−2.67	0.44	0.001
	Pretest vs. Follow-up	−2.63	0.37	0.001
	Posttest vs. Follow-up	−0.37	0.30	0.671
Figure–Ground Discrimination	Pretest vs. Posttest	−1.33	0.37	0.003
	Pretest vs. Follow-up	−1.53	0.30	0.001
	Posttest vs. Follow-up	−0.20	0.27	1.000
Form Constancy	Pretest vs. Posttest	−0.82	0.13	0.001
	Pretest vs. Follow-up	−0.89	0.15	0.001
	Posttest vs. Follow-up	−0.07	0.07	1.000
Spatial Perception	Pretest vs. Posttest	−0.54	0.16	0.007
	Pretest vs. Follow-up	−0.46	0.13	0.014
	Posttest vs. Follow-up	0.08	0.11	1.000
Spatial Relations	Pretest vs. Posttest	−0.84	0.21	0.001
	Pretest vs. Follow-up	−0.88	0.19	0.001
	Posttest vs. Follow-up	−0.04	0.14	1.000
Auditory Perception	Pretest vs. Posttest	−1.50	0.28	0.001
	Pretest vs. Follow-up	−1.27	0.29	0.008
	Posttest vs. Follow-up	0.23	0.36	1.000

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Group Comparisons (Between-Subject)				
Eye–Hand Coordination	Experimental vs. Control	3.07	0.86	0.001
Figure–Ground Discrimination	Experimental vs. Control	1.76	0.60	0.007
Form Constancy	Experimental vs. Control	1.08	0.36	0.005
Spatial Perception	Experimental vs. Control	0.88	0.32	0.010
Spatial Relations	Experimental vs. Control	0.91	0.29	0.005
Auditory Perception	Experimental vs. Control	1.73	0.53	0.003

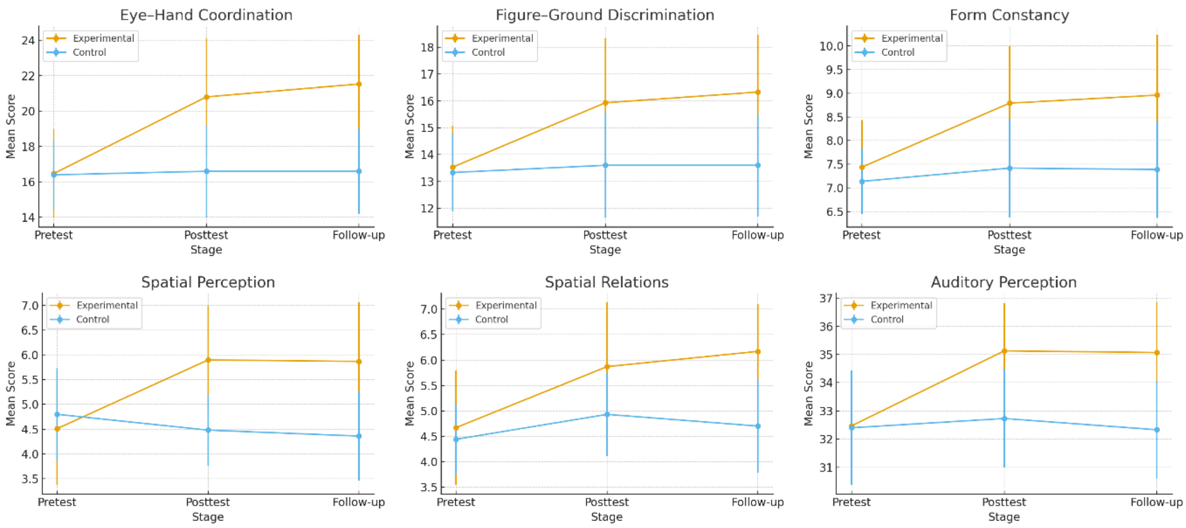
The Bonferroni results for time effects in Table 5 show that the mean differences in the five visual perception components and in auditory perception are statistically significant between the pretest–posttest and pretest–follow-up stages, whereas the mean differences between the posttest–follow-up stages are not significant.

Additionally, the Bonferroni results for group effects in Table 5 indicate that the mean differences in visual and auditory perception components between the experimental and control groups are statistically significant. Specifically, implementation of the multisensory educational package led to greater increases in the mean scores of visual and auditory perception components in the posttest and follow-up stages compared with the control group.

Consistent with the group-effect results in the Bonferroni tests, the trend of changes in component mean scores in the plots of Figure 1 shows that the changes resulting from implementation of the independent variable on visual and auditory perception persisted through the follow-up period. Accordingly, it was concluded that the multisensory educational package improves visual and auditory perception in students with Specific Learning Disorder. Figure 1 displays the plots for visual and auditory perception in the study groups at the three stages of pretest, posttest, and follow-up.

Figure 1

Plots of Visual and Auditory Perception in the Study Groups across the Three Implementation Stages



4. Discussion and Conclusion

The results of the present study demonstrated that the implementation of a structured multisensory educational package significantly improved all components of visual and auditory perception in students with Specific Learning Disorder (SLD) with impairment in reading. Findings revealed substantial increases in *eye–hand coordination, figure–ground discrimination, form constancy, spatial perception, spatial relations*, and *auditory discrimination* following the intervention, and these gains were maintained in three- and six-month follow-ups. These outcomes indicate that the designed multisensory approach effectively strengthened both visual and auditory processing pathways, confirming its efficacy in promoting sensory integration and perceptual development in children with dyslexia.

The significant improvement in visual perception components aligns with earlier research emphasizing the centrality of perceptual–motor coordination and visual

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discrimination in reading performance. Prior studies using the *Frostig Developmental Test of Visual Perception* have shown that visual–motor exercises can enhance figure–ground differentiation, spatial orientation, and stability of form recognition in students with learning disabilities (Basak & Yaman, 2023). Similarly, multisensory approaches that stimulate tactile, visual, and kinesthetic modalities concurrently have been reported to improve perceptual accuracy and speed in symbol recognition (Amiri Ahmadi et al., 2023; Khademi Adel et al., 2024). These findings support the current study's outcomes, suggesting that cross-modal stimulation encourages more efficient neural encoding of visual and spatial information, leading to better decoding performance during reading tasks. The improved eye–hand coordination observed here corroborates the findings of neuropsychological research showing that reinforcement of visuomotor connections facilitates smoother letter formation and word recognition (Dostálová et al., 2024).

In addition to visual gains, the present results showed marked enhancement in auditory discrimination, confirming the role of multisensory learning in strengthening phonological and auditory processing. Consistent with the phonological deficit theory, dyslexic learners often struggle with differentiating phonemes and recognizing subtle auditory contrasts (Okey-Kalu, 2025; Sobhani et al., 2024). By integrating auditory drills, rhythmic patterns, and sound–symbol mapping into learning sessions, the multisensory training provided an enriched auditory environment that enhanced the perception of phonemic distinctions. This is in line with previous evidence that rhythmic tapping and auditory–motor synchronization can improve temporal sequencing and phonological awareness (Flanagan et al., 2025). The observed posttest and follow-up improvements indicate the potential for long-term retention of auditory discrimination skills when sensory channels are trained in an integrated, repetitive manner.

The retention of perceptual improvements after three and six months also supports the argument that multisensory interventions have enduring effects on cognitive and sensory functions. Earlier longitudinal research suggests that when multiple sensory modalities are simultaneously engaged, neural plasticity is enhanced through the reinforcement of inter-hemispheric connectivity (Economou et al., 2024; Le Cunff et al., 2024). The durable nature of improvement observed in the current study reflects the activation and synchronization of cortical regions responsible for both visual and auditory processing, particularly those implicated in the dorsal and ventral reading pathways (Micheletti et al., 2024). Such findings affirm that sustained multisensory engagement facilitates deeper learning and automaticity, which are crucial for reading fluency.

A notable feature of this study was the use of colored cubes, flashcards, and interactive tasks that integrated visual–tactile–auditory elements. This design created a dynamic learning environment conducive to attention and motivation, consistent with the principles of the Orton–Gillingham approach (Lim & Oei, 2015). These findings correspond with those of (Rahmonovna, 2025), who reported that combining visual and auditory cues promotes effective encoding in students with learning disabilities. Moreover, the integration of kinesthetic activities, such as manipulating objects while sounding out letters or words, may have strengthened the children's embodied cognition and memory associations (Kunasegran & Subramaniam, 2024; Putri & Hendriani, 2024). As multisensory processing is experience-dependent, the combination of modalities likely helped in activating additional neural routes to compensate for deficits typical of dyslexia (Chokron et al., 2021).

The observed improvement in visual perception components such as spatial perception and spatial relations mirrors findings from prior Iranian and international studies. For example, (Esmaeili Anvar et al., 2023) found that training programs aimed at strengthening lateral dominance and visual perception significantly improved spatial awareness and figure–ground discrimination among children with SLD. Similarly, (Amiri Ahmadi et al., 2023) demonstrated that exposure to visual–phonological stimuli enhanced reading comprehension and decoding skills in dyslexic students. The present findings confirm that these perceptual capacities are malleable and can be modified through structured sensory experiences, thus providing further evidence for the plasticity of the visual–spatial system in young learners.

Furthermore, the consistent rise in performance across posttest and follow-up assessments supports the premise that multisensory interventions foster self-regulated learning and independent perceptual refinement. According to (Fattahi et al., 2025), cognitive strategies combined with sensory-based methods lead to greater generalization and transfer of learning to real-world tasks. The current study's structured design—featuring repeated exposure, parental collaboration, and guided practice—likely contributed to consolidation of these skills. Studies employing similar methods in other contexts have also reported enduring improvements in

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perceptual and academic outcomes (Mirzaei et al., 2024; Mosafer & Sadati Firouz Abadi, 2025).

It is also significant that participants demonstrated balanced progress in both visual and auditory modalities, suggesting that the intervention successfully activated multimodal neural networks rather than improving one channel at the expense of another. This dual enhancement aligns with findings from (Bertoni et al., 2024), who showed that action video games incorporating visual and auditory feedback normalized phonemic awareness in pre-readers at risk for dyslexia. Likewise, (Mendes & Kirby, 2024) emphasized that multisensory morphological awareness training strengthens both reading and spelling skills. The convergence of results across these studies underscores the interdependence of auditory and visual subsystems in the reading process.

The current findings also resonate with advances in educational technology that leverage multisensory designs. Tools incorporating AI-based text-to-speech and eye-tracking feedback have demonstrated effectiveness in improving attention and reading fluency among dyslexic learners (Adjiovski et al., 2024; Ward et al., 2024). Although the present intervention was delivered in a traditional setting, its structure parallels these digital systems by continuously engaging multiple sensory inputs to sustain focus. The positive outcomes thus highlight that both high- and low-tech multisensory methods share common mechanisms: cross-modal activation and attentional reinforcement (Paudel & Acharya, 2024).

From a cognitive neuroscience standpoint, the results lend further support to the principle that repeated, cross-modal stimulation strengthens functional connectivity between auditory and visual cortices, enhancing reading automaticity (Economou et al., 2024; Le Cunff et al., 2024). This effect can be explained by the Hebbian principle that "neurons that fire together wire together," suggesting that coordinated activation of sensory pathways creates lasting synaptic changes (Micheletti et al., 2024). The intervention's repetitive engagement of auditory and visual perception exercises may have contributed to more synchronized cortical activity, leading to the observed improvements in accuracy and processing speed.

The role of motivation and emotional well-being in these outcomes should not be overlooked. Dyslexic students often experience low self-efficacy and academic anxiety due to repeated failure (Iaia et al., 2024). By incorporating playful and cooperative tasks, the multisensory program likely reduced performance-related stress and increased intrinsic motivation. This interpretation is consistent with (Sarajar & Pratiwi, 2024), who found that interactive, visually engaging learning environments improved emotional engagement in dyslexic children. Moreover, the inclusion of parental involvement and feedback in the present study could have enhanced social reinforcement and learning continuity, consistent with findings by (Guo & Keles, 2025). Such family-supported designs appear to strengthen both the academic and psychological dimensions of learning.

The improvements in auditory discrimination further validate the cross-modal efficiency of multisensory interventions. Consistent with (Bakhtiari et al., 2012), training that emphasizes sound differentiation promotes phoneme awareness, a key component of reading fluency. In line with (Dashtipour et al., 2024), who compared various cognitive rehabilitation models, the integration of auditory training with visual supports results in faster progress in phonological processing. Similarly, (Fattahi et al., 2025) and (Amiri Ahmadi et al., 2023) emphasized the advantage of interventions combining self-regulated and cognitive strategies with sensory reinforcement. The present findings extend this body of knowledge by demonstrating that perceptual gains achieved through multisensory methods can be maintained over time, confirming their durability and ecological validity.

Another notable finding was the absence of regression in follow-up assessments, suggesting that once established, the perceptual and auditory improvements are stable when reinforced through consistent engagement. This is congruent with (Kunasegran & Subramaniam, 2024) and (Fatimah et al., 2025), who reported persistent improvements in reading and comprehension following extended multisensory instruction. The sustained enhancement observed in this study reinforces the notion that multisensory interventions lead not only to immediate skill acquisition but also to long-term cognitive restructuring.

From an applied perspective, these results validate the integration of multisensory pedagogy within special education curricula. The positive outcomes mirror global efforts to design inclusive learning environments that accommodate students with diverse neurocognitive profiles (Yenduri et al., 2023). As highlighted by (Alkhawalde & Khasawneh, 2024) and (Patil et al., 2024), the incorporation of gamified and interactive elements enhances learner engagement and fosters independent skill development. Therefore, educational systems aiming to support children with SLD can benefit from adopting similar structured,

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multi-modal programs tailored to cultural and linguistic contexts (Mirzaei et al., 2024; Rezaei, 2024).

Overall, the discussion of findings affirms that the multisensory educational package successfully improved visual and auditory perception among students with reading-related learning disabilities. The results confirm theoretical propositions that cross-modal integration enhances neural efficiency and learning retention (Le Cunff et al., 2024; Rahmonovna, 2025). The intervention's success can be attributed to its structured design, culturally adapted materials, and inclusion of family-based practice, all of which fostered meaningful sensory–cognitive engagement and long-term outcomes.

Despite its strengths, the study faced several limitations. The sample size was relatively small, comprising only 30 students from a single district, which may limit the generalizability of the findings to broader populations. The absence of gender-based and socio-economic subgroup analyses restricts understanding of how these variables may influence responsiveness to multisensory interventions. Additionally, the study relied primarily on behavioral measures rather than neuroimaging or electrophysiological data, which could have provided a deeper understanding of neural changes underlying the observed improvements. Another limitation concerns potential biases in parental involvement, as differing levels of home engagement may have contributed to variability in outcomes. Furthermore, the lack of comparison with alternative interventions—such as purely phonological or digital-assisted programs—prevents determining whether multisensory training offers unique advantages over other remediation methods.

Future studies should employ larger and more diverse samples across multiple regions to enhance external validity and assess the cultural adaptability of multisensory training programs. Longitudinal designs incorporating neuroimaging techniques such as fMRI or EEG are recommended to explore the neural mechanisms mediating sensory integration and literacy improvement. Comparative studies examining the relative efficacy of multisensory, cognitive–behavioral, and AI-based interventions would also be valuable in identifying optimal combinations for different learner profiles. Researchers are further encouraged to examine the role of emotional and motivational variables, including self-efficacy and anxiety, to better understand how affective factors influence the sustainability of intervention outcomes. Lastly, integrating digital and gamified components within multisensory frameworks may offer scalable solutions for resource-limited educational settings.

Practitioners working with children with SLD should incorporate multisensory principles into daily instructional routines, emphasizing cross-modal connections between visual, auditory, and kinesthetic modalities. Teachers should employ materials that are tactile, colorful, and interactive to strengthen perceptual and attentional engagement. Collaboration between educators, parents, and therapists is essential to ensure consistency of learning across home and school environments. Training workshops for teachers can promote awareness of multisensory pedagogy and equip them with strategies for individualized instruction. Educational policymakers should prioritize the integration of such interventions into national curricula to promote inclusive education and ensure that all learners—regardless of cognitive profile—can achieve meaningful literacy development.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

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 protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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