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The Effectiveness of Multisensory Educational Intervention on Information Processing Speed in Elementary Students with Processing Speed Deficits

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ABSTRACT

Objective: The present study aimed to determine the effectiveness of a multisensory educational intervention based on the Fernald method on the information processing speed of elementary school students with processing speed deficits.

Method: This research was applied in terms of purpose and employed a quasi-experimental design with a pretest–posttest and a control group. The statistical population included all third- to sixth-grade students enrolled in public schools in Kerman during the 2024–2025 academic year. Following screening using the Processing Speed Index of the Wechsler Intelligence Scale for Children–Fifth Edition (WISC-V), the required sample size was estimated using G*Power software (version 3.1). Based on this analysis, 30 eligible students (with scores below 85 on this index) were selected through multistage cluster sampling and assigned to either the experimental group ($n = 15$) or the control group ($n = 15$) through simple random assignment. The experimental group received the Fernald (1921) multisensory educational intervention for one and a half months, consisting of 15 sessions of 45 minutes each, while the control group received no intervention. Data were analyzed using multivariate analysis of covariance (MANCOVA) in SPSS version 26.

Results: The results of MANCOVA, after controlling for pretest scores, indicated a statistically significant difference between the two groups in posttest mean scores of information processing speed ($F = 96.52$, $p < .01$). The adjusted mean of information processing speed in the experimental group ($M = 105.72$) was significantly higher than that of the control group ($M = 84.67$). In addition, the calculated effect size ($\eta^2 = .598$) indicated a strong effectiveness of the Fernald multisensory educational intervention.

Conclusions: The Fernald multisensory educational intervention is effective in increasing the information processing speed of elementary school students with deficits in this domain. By simultaneously engaging visual, auditory, tactile, and motor modalities and relying on neural plasticity, this method can be used as an effective educational strategy in educational settings and rehabilitation centers to improve core cognitive functions.

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Introduction

Elementary education, as the most fundamental stage of the educational system, plays a decisive role in the formation of students' cognitive, academic, and self-regulatory abilities. During this period, children gradually acquire essential skills such as reading, writing, arithmetic, and problem solving, the successful development of which requires the coordinated functioning of basic cognitive processes (Snowling et al., 2021). Disruption or weakness in any of these processes—particularly in the early years of schooling—can lead to long-term consequences such as academic underachievement, reduced learning motivation, emotional difficulties, and diminished academic self-efficacy (Corwin et al., 2022). One of the most important yet relatively overlooked cognitive components in this regard is information processing speed.

Information processing speed refers to an individual's ability to rapidly and accurately receive, encode, organize, integrate, and respond to information (Kalyuga, 2025). This construct is not only an independent cognitive ability but also constitutes the foundation of many higher-order functions, including working memory, sustained attention, decision-making, and academic learning (Sultana, 2025). Children with processing speed deficits typically require more time to complete academic tasks, fall behind in classroom assessments, and, despite understanding concepts, are unable to provide timely responses (Tsai, 2025). This issue is often mistakenly interpreted as inattention, laziness, or low motivation, whereas its roots lie in inefficiencies within underlying cognitive processes.

From a neuropsychological perspective, information processing speed is associated with the functioning of widespread neural networks in the brain, including prefrontal and parietal regions as well as white matter connectivity pathways (Lu et al., 2024). Neuroimaging studies have shown that children with low processing speed experience limitations in sensory information integration and in the rapid transmission of data between brain regions (Panzeri et al., 2023). These findings suggest that effective educational interventions in this domain should be designed to simultaneously activate multiple sensory–cognitive pathways and, by enhancing processing efficiency, lead to improvements in cognitive functioning.

Within the framework of information processing theory, learning is considered the result of a dynamic interaction among sensory inputs, short-term memory, working memory, and long-term memory (Baddeley et al., 2020). According to this theory, the more sensory channels through which information enters the cognitive system, the greater the likelihood of deeper encoding, better organization, and faster retrieval. Therefore, employing approaches that move learning beyond a unisensory mode toward multichannel processing can play a significant role in enhancing information processing speed.

In this context, multisensory instruction, as a contemporary evidence-based approach, has attracted increasing attention from researchers and educational professionals. Multisensory instruction emphasizes the simultaneous engagement of visual, auditory, tactile, and kinesthetic senses in the learning process and is grounded in the principle that learning through multiple sensory pathways is deeper, more durable, and more efficient than unisensory learning (Fernald, 1921; La Rocca et al., 2020). Specifically, Fernald's multisensory instructional approach, as a structured model, is considered one of the most effective methods for supporting students with learning disabilities, based on the principle of neural plasticity (Widiamoksa, 2019). This method systematically employs multiple senses to strengthen learning and memory processes (Karimi Sani, 2022). Key techniques include teaching vocabulary through tactile letter tracing, pronunciation, and visual imagery (Olad-Ghobad et al., 2022; Pahor, 2021), as well as the use of body movements to create stronger associations in long-term memory (Okrai et al., 2024). By simultaneously activating different neural pathways, this approach helps compensate for deficits in information processing (La Rocca et al., 2020) and enhances cognitive functioning through the reinforcement of neural connections via multisensory input (Alwashmi et al., 2024). Relying on the principle of neural plasticity, this approach facilitates the strengthening of synaptic connections and the formation of alternative neural pathways, thereby compensating for limitations in information processing, particularly processing speed.

Moreover, empirical evidence indicates that multisensory instruction is effective in improving the cognitive functioning of children with learning disabilities, attention-deficit/hyperactivity disorder, and information processing difficulties (Widiamoksa, 2019; Aghajanbeik, 2024). Domestic studies have also demonstrated that this type of instruction can increase accuracy, reduce reaction time, enhance working memory, and improve students' academic performance (Vahedi et al., 2019). Moreover, findings from recent studies suggest that multisensory instruction plays a significant role in improving information processing speed by facilitating information organization and increasing the rate of data transmission within the cognitive system (Zhu et al., 2024).

Despite the substantial theoretical and empirical support for multisensory instruction, a careful review of the research literature reveals that the majority of existing studies have focused on outcomes such as reading, writing, and specific learning disabilities. Recent research published has highlighted the importance of structured cognitive and metacognitive interventions in improving information processing and executive functions in children. For instance, Norouzi et al. (2025) demonstrated that young learners with high working memory capacity often underutilize strategic problem-solving approaches, suggesting the need for targeted instructional strategies. Similarly, Demehri and Takhtkeshiyan (2024) reported that cognitive rehabilitation programs, such as the I-Math educational intervention, effectively enhance executive functions and learning performance in first-grade students, emphasizing the potential of structured educational programs to improve core cognitive processes. This research gap highlights the necessity of conducting intervention-based studies that focus on multisensory instruction and its effects on information processing speed. Additionally, given the increasing academic demands at the elementary level and the need for effective instructional strategies, identifying interventions that are practical and implementable in educational settings to improve students' cognitive functioning is of particular importance. Accordingly, the present study aimed to determine the effectiveness of a multisensory educational intervention on the information processing speed of elementary school students with processing speed deficits.

Materials and Methods

The present study was applied in terms of purpose and employed a quasi-experimental methodology using a pretest–posttest design with a control group. In this design, participants were assigned to experimental and control groups, and the effectiveness of a multisensory educational intervention based on the Fernald method on the information processing speed of elementary school students with processing speed deficits was examined. The experimental group received the multisensory educational intervention, whereas the control group continued to receive routine school instruction without any additional intervention.

Participants

The statistical population of the study included all second-cycle elementary school students (Grades 3 to 6) enrolled in public schools in the city of Kerman during the 2024–2025 academic year. The sample size was determined using G*Power software (version 3.1), assuming a significance level of.05, a statistical power of .80, and a medium effect size. Based on this analysis and considering the quasi-experimental nature of the study, a total of 30 elementary school students with information processing speed deficits were selected. Following initial screening, participants were assigned to either the experimental group (n = 15) or the control group (n = 15) through simple random assignment.

Sampling was conducted using a multistage cluster sampling method. First, among the educational districts of the city of Kerman, District 2 was randomly selected. Then, several boys' and girls' elementary schools within this district were randomly chosen. In the next stage, students from these schools were screened using the Processing Speed Index of the Wechsler Intelligence Scale for Children–Fifth Edition (WISC-V). Students who obtained scores below the normal range on the Processing Speed Index were identified as eligible participants. Finally, thirty students were randomly assigned to the experimental and control groups. The total sample consisted of 15 girls and 15 boys, with a balanced gender distribution across groups: the experimental group included 7 female and 8 male students while the control group included 8 female and 7 male students. It should be noted that the screening scores were used as pretest scores. Table 1 presents the demographic characteristics of the sample.

Table 1. Demographic Characteristics of Participants by Gender and Grade Level

Variable	Category	Frequency	Percentage
Gender	Female	15	50
	Male	15	50
Grade level	Grade 3	8	26.7
	Grade 4	7	23.3
	Grade 5	8	26.7
	Grade 6	7	23.3
Total		30	100

The inclusion criteria for the study were: obtaining a below-average score (less than 85) on the Information Processing Speed Index of the WISC-V; enrollment in the second cycle of elementary education (Grades 3 to 6); having overall intelligence within the normal range; intact visual and auditory functioning based on school health records; no prior diagnosis of intellectual disability, severe neurological disorders, or major psychiatric disorders; informed parental consent; and the student's willingness to participate in the study. The exclusion criteria included: absence from more than two intervention sessions; simultaneous participation in other educational, therapeutic, or rehabilitation programs; lack of effective cooperation by the student or withdrawal of parental consent; and the emergence of acute physical or psychological conditions during the course of the study.

Instruments

The Wechsler Intelligence Scale for Children–Fifth Edition (WISC-V) was used to screen participants and assess information processing speed. This scale was developed based on Wechsler's theoretical framework and was standardized in 2014 (Wechsler, 2014). The fifth edition of the WISC incorporates recent findings in the fields of intelligence, cognitive science, neuropsychology, and core learning processes, distinguishing it from previous editions (Marnat, 2018). The WISC-V is designed to assess the intelligence of children aged 6 to 16 years and 11 months and consists of five primary indices as follows:

- **Verbal Comprehension Index (VCI):** including the subtests of Similarities, Vocabulary, Comprehension, Information, and Verbal Reasoning;
- **Fluid Reasoning Index (FRI):** including Matrix Reasoning, Figure Weights, and Picture Concepts;
- **Visual Spatial Index (VSI):** including Block Design (timed and untimed) and Spatial Organization;

- **Working Memory Index (WMI):** including Digit Span, Letter–Number Sequencing, Memory Capacity, and Mental Arithmetic;
- **Processing Speed Index (PSI):** including Coding, Symbol Search, and Cancellation subtests, which assess the child's ability to process visual–motor information rapidly, accurately, and efficiently.

By combining index scores, the WISC-V yields a Full Scale Intelligence Quotient (FSIQ), which represents an individual's overall cognitive ability (Caemmerer et al., 2018). The index score range in this test extends up to 155, and the maximum FSIQ score is reported as 160. Regarding psychometric properties, Wechsler (2014) reported high reliability coefficients for the indices of this test, with the highest reliability for the Verbal Comprehension Index (α = .94) and the lowest for the Processing Speed Index (α = .88). Studies by Watkins et al. (2020) have shown that split-half reliability coefficients for WISC-V subtests range from .83 to .94, the reliability of the Full Scale IQ is .96, and the reliability of the indices ranges from .91 to .96. In the Iranian standardization of the test, Karami etal. (2020) reported satisfactory reliability coefficients for the subtests (ranging from .76 to .92) and split-half reliabilities ranging from .57 to .82. Furthermore, the diagnostic validity of the fifth edition of the WISC in students with learning disabilities was confirmed by Shiri-Aminlou et al. (2023). In the present study, the internal consistency reliability coefficient for the Processing Speed Index, calculated using Cronbach's alpha, was .80, indicating acceptable reliability of the instrument in the study sample.

In the present study, the Fernald multisensory instructional protocol was used for the experimental group. This protocol was originally developed by Grace Fernald (1921) for working with children with learning difficulties (Fernald & Keller, 1921). The method is based on the simultaneous engagement of visual, auditory, tactile, and kinesthetic modalities in the learning process. Within this approach, the student observes the stimuli (visual), articulates them aloud (auditory), listens to what is being said (auditory), and simultaneously traces or draws them (tactile–kinesthetic).

Procedure

The educational intervention consisted of 15 group sessions, each lasting 45 minutes, conducted twice a week over a period of one and a half months. The sessions were delivered in a group format at the researcher's clinic and were held outside regular school hours. After completion of the intervention period, the posttest was administered under identical conditions for both the experimental and control groups. Table 2 presents a summary of the content of the Fernald multisensory training sessions.

Table 2. Summary of Fernald Multisensory Training Sessions

Session	Session Title	Objective	Activities
1	Initial assessment and introduction to the method	Familiarizing students with the Fernald multisensory method and assessing baseline abilities	Introduction to the multisensory approach and explanation of the simultaneous use of visual, auditory, tactile, and motor senses; auditory presentation of letter sounds; visual observation of letter cards; tactile tracing and drawing of letters on paper or textured materials; simultaneous verbal repetition.
2	Strengthening auditory and visual processing	Enhancing auditory and visual skills for rapid letter recognition	Repetition of letter sounds from the previous session; visual–auditory letter discrimination exercises; rapid naming of sounds while viewing cards; letter–sound matching games to increase accuracy and processing speed.
3	Tactile–kinesthetic practice of letters	Strengthening sensory–motor integration and consolidating learning	Tracing and drawing letters on various surfaces (sand, textured paper); simultaneous sound repetition; eye–hand coordination exercises and increasing response speed.
4	Sound blending and formation of simple words	Enhancing sequential processing and information integration	Blending letters and sounds to form two-letter words; use of letter cards; tactile manipulation, listening, and rapid verbalization of formed words.
5	Formation of three-letter words	Increasing speed and accuracy in word processing	Introduction of simple three-letter words; simultaneous reading, tracing, writing, and pronunciation; timed repetition exercises to increase processing speed.
6	Reading and writing short words	Strengthening reading and writing through a multisensory approach	Practice of reading and writing short words using simultaneous visual, auditory, tactile, and writing activities; repeated practice for consolidation.
7	Constructing simple sentences	Enhancing semantic processing and sequential information processing	Construction of short sentences using learned words; reading aloud, writing, and rereading sentences.
8	Strengthening memory and processing through repetition	Enhancing working memory and retrieval speed	Repetition of sentences from previous sessions; independent reading and writing without assistance; rapid information retrieval exercises.
9	Learning through educational games	Increasing motivation and rapid processing	Implementation of educational games (word finding, sentence construction, rapid matching) to increase processing speed in an interactive environment.
10	Evaluation of sentence reading progress	Assessing skill development	Independent reading and writing of sentences; identification of weaknesses and provision of targeted exercises.
11–13	Consolidation and reinforcement of learned material	Strengthening memory and sustained processing	Repetitive exercises, new games, emphasis on speed, accuracy, and rapid retrieval of information to facilitate transfer to long-term memory.
14	Preparation for final assessment	Final review and consolidation	Comprehensive review of words and sentences; integrated exercises and preparatory activities for the final assessment.
15	Final assessment and reinforcement plan	Final evaluation and future planning	Assessment of student performance; identification of strengths and weaknesses; provision of supplementary practice plans and recommendations for parents.

For data analysis, descriptive statistical methods, including means, standard deviations, and dispersion indices, were first used to describe the characteristics of the sample. Subsequently, to test the research hypotheses and examine the effectiveness of the Fernald multisensory instruction on information processing speed, multivariate analysis of covariance (MANCOVA) was conducted using SPSS software, version 26.

Results

To describe the data, descriptive statistics including the mean and standard deviation of information processing speed scores for students in the experimental group (receiving the Fernald multisensory educational program) and the control group (receiving no educational intervention) were calculated at the pretest and posttest stages. The results are presented in Table 3.

Table 3. Descriptive Statistics of Information Processing Speed Scores in the Experimental and Control Groups at Pretest and Posttest

Variable	Stage	Experimental Group (N = 15)				Control Group (N = 15)			
		Mean	SD	Min	Max	Mean	SD	Min	Max
Information Processing Speed	Pretest	81.40	9.85	65	95	82.10	10.05	66	96
	Posttest	105.60	12.90	88	130	84.30	10.70	68	98

As shown in Table 3, at the pretest stage, there was no significant difference between the mean information processing speed scores of the experimental and control groups, indicating the initial homogeneity of the two groups prior to the intervention. In contrast, at the posttest stage, the mean information processing speed score of the experimental group showed a substantial increase compared to the control group, whereas no noticeable change was observed in the performance of the control group. These findings indicate a positive effect of the Fernald multisensory educational program on improving the information processing speed of the students in the experimental group.

Prior to testing the research hypotheses, the statistical assumptions required for conducting covariance analysis were examined to ensure that the data met the necessary conditions for this analysis.

To examine the assumption of normality of distribution for the dependent variable (information processing speed) at the pretest stage, the Shapiro–Wilk test was applied. In this test, if the observed significance level (p-value) for each variable is greater than.05, it can be concluded that the data distribution does not significantly deviate from normality.

Table 4. Results of the Shapiro–Wilk Test for Information Processing Speed at the Pretest Stage

Variable	Group	Shapiro–Wilk W	Significance Level (p)
Information Processing Speed	Experimental Group (N = 15)	.951	.280
	Control Group (N = 15)	.942	.240

As shown in Table 4, the significance levels of the Shapiro–Wilk test for the dependent variable in both groups are greater than .05 ($p > .05$). Therefore, it can be concluded that the assumption of normality of the dependent variable scores is satisfied.

To examine the assumption of homogeneity of variances across the research groups, Levene's test was conducted. The results indicated that the Levene statistic was not significant ($p > .05$). Thus, the variances of information processing speed scores in the experimental and control groups can be considered homogeneous, and this assumption is met.

To test the assumption of homogeneity of regression slopes, the interaction effect between the independent variable (group) and the covariate (pretest scores of information processing speed) was examined. The results showed that the interaction effect of group × pretest was not statistically significant ($p > .05$). Accordingly, it can be concluded that the regression slopes are homogeneous across groups, and the use of covariance analysis is justified. Finally, given that each participant was independently assigned to either the experimental or control group and that the data were collected separately, the assumption of independence of observations was also satisfied. Overall, the examination of statistical assumptions indicated that all required assumptions for conducting multivariate analysis of covariance (MANCOVA) were met; therefore, performing this statistical analysis was appropriate.

Prior to examining the effect of the Fernald multisensory educational package on the information processing speed of elementary school students with processing speed deficits, the multivariate effect of the independent variable (group) on the dependent variable (posttest scores) was assessed using MANCOVA. To provide a complete representation of the multivariate effect, the multivariate test statistics including Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root were examined. Subsequently, posttest information processing speed scores were entered as the dependent variable, group (experimental vs. control) as the independent variable, and pretest scores as the covariate. The results of the analysis are presented in Table 5.

As shown in Table 5, the multivariate test statistics (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) for the effect of group on posttest information processing speed scores were all statistically significant ($p < .01$), indicating a strong multivariate effect of the Fernald multisensory educational intervention. Furthermore, the effect of pretest scores as a covariate was also statistically significant ($p < .01$), confirming that pretest scores had a significant influence on posttest outcomes.

Table 5. Results of Multivariate Analysis of Covariance (MANCOVA) for Information Processing Speed Scores in the Experimental and Control Groups

Source of Variation	Multivariate Test	Value	F	df1	df2	Sig.	Partial η^2
Group	Pillai's Trace	.850	96.52	1	27	.001	.598
	Wilks' Lambda	.150	96.52	1	27	.001	.598
	Hotelling's Trace	5.667	96.52	1	27	.001	.598
	Roy's Largest Root	5.667	96.52	1	27	.001	.598
Pretest	Pillai's Trace	.514	28.41	1	27	.001	.541
	Wilks' Lambda	.486	28.41	1	27	.001	.541
	Hotelling's Trace	1.056	28.41	1	27	.001	.541
	Roy's Largest Root	1.056	28.41	1	27	.001	.541
Error	–	–	–	–	–	–	–
Total	–	–	–	–	–	–	–

After controlling for pretest scores, the adjusted posttest means scores of the experimental group (M = 105.60, SD = 12.90) were significantly higher than those of the control group (M = 84.30, SD = 10.70), demonstrating that the multisensory educational package had a statistically significant and substantial effect on improving information processing speed in elementary school students with processing speed deficits. The partial eta-squared values ($\eta^2 = .598$ for group effect) indicate a large effect size according to conventional benchmarks.

Comparison of adjusted means revealed that the mean information processing speed in the experimental group ($M = 105.72$) was significantly higher than that of the control group ($M = 84.67$). In addition, the calculated effect size ($Eta^2 = .598$) indicates a very large effect of the Fernald multisensory educational package on students' information processing speed. According to Cohen's (2013) criteria, an eta-squared value of .01 represents a small effect, .06 represents a medium effect, and values of.14 or higher represent a large effect. Accordingly, the obtained effect size in the present study reflects the strong effectiveness of the Fernald multisensory educational package.

In conclusion, the research hypothesis was supported, and it can be stated that the Fernald multisensory educational package led to a statistically significant increase in the information processing speed of students in the experimental group compared with the control group.

Discussion

The present study demonstrated that the Fernald multisensory instructional approach can improve information processing speed in elementary school students with processing speed deficits. These findings are in line with those of previous research highlighting the benefits of multisensory interventions on cognitive functions and academic performance. For instance, Fathi Ashtiani et al. (2016) reported improvements in processing speed and working memory in children with learning disabilities following cognitive training programs. Similarly, Vahedi et al. (2025) and Aghajanbeik (2024) found that multisensory-based training enhanced memory performance and information recall in students with dyslexia or attention deficits. Research using multisensory integration in virtual environments also supports these results, demonstrating enhanced learning outcomes through combined audio-visual stimulation (Alwashmi et al., 2024; La Rocca et al., 2020). Moreover, classical studies on the Fernald method (Fernald & Keller, 1921) emphasize the role of kinesthetic and multisensory engagement in promoting literacy and cognitive processing skills. Collectively, these studies suggest that structured multisensory instructional programs can effectively facilitate information processing and learning in students with cognitive processing challenges.

These findings can be explained within the framework of multisensory processing theories and dual coding theory, which posit that information received simultaneously through multiple sensory channels is processed more efficiently and retained more stably in the brain. This perspective is further supported by recent neurocognitive evidence. For example, the study by La Rocca et al. (2020) demonstrated that multisensory instruction leads to the emergence and strengthening of coordinated beta-wave brain networks, which are associated with enhanced efficiency in information processing and integration. This neural process activates multiple brain regions, including the visual, auditory, and motor cortices, the prefrontal cortex, and the hippocampus, resulting in improvements in working memory, information consolidation, and processing speed. A plausible mechanism underlying this effect is that simultaneous stimulation of multiple senses reduces the cognitive load on working memory, thereby increasing the capacity available for information processing and storage in long-term memory. This interpretation is consistent with the findings of Pahor et al. (2021), who reported that multisensory instruction can facilitate working memory performance. Such a process allows students to retrieve information concurrently through multiple memory pathways, leading to faster and more accurate recall.

The findings of the present study are also aligned with a body of national and international research emphasizing the effectiveness of multisensory and cognitive strategies. The results are consistent with those reported by Salehinejad et al. (2018), which demonstrated the effect of mind-mapping software–based instruction on processing speed. Similarly, concordance with the findings of Yarmohammadian et al. (2015) and Fathi Ashtiani et al. (2016)—who reported improvements in cognitive strategies and working memory—the results highlight the comprehensive role of structured interventions. Specifically, within the domain of the Fernald method, recent domestic studies further confirm and extend the present findings. Karimi Thani et al. (2022) found that the Fernald multisensory method was more effective than educational games in reducing writing disorders among elementary students. Likewise, Olad- Ghobad et al. (2022) reported that the Fernald method was more effective than the Rosner multisensory approach in reducing spelling difficulties. These findings suggest that the benefits of this method extend beyond specific academic skills to enhance underlying cognitive functions such as information processing.

The empirical support for these effects is not limited to specific learning disabilities. The study by Widiamoksa (2019) showed that the Fernald method could improve writing skills in students with intellectual disabilities, indicating the flexibility and generalizability of this approach. At the international level, growing evidence supports the effectiveness of multisensory principles across diverse populations and domains. Tsai (2025), in a review of the relationship between processing speed and developmental dyslexia, emphasized the importance of adopting multidimensional intervention approaches. Concurrently, studies such as Zhu et al. (2024) demonstrated that app-based multisensory training can enhance verbal working memory in older adults, suggesting that the fundamental principles of this approach can be adapted to modern formats and applied across different age groups. Moreover, Aghajanbeik (2024) found that multisensory cognitive control training could reduce memory and attention problems in children with attention-deficit/hyperactivity disorder. The convergence of findings across diverse clinical populations points to a robust and shared neurocognitive foundation underlying multisensory approaches.

This perspective is strongly supported by recent discoveries in basic neuroscience. A pioneering study by Okray e. al. (2024) at the University of Oxford identified a specific neural mechanism underlying the superiority of multisensory learning. The researchers found that multisensory learning creates microcircuit “bridges” within widely projecting serotonergic neurons that connect separate sensory streams (e.g., visual and olfactory). This connectivity enables an organism to retrieve a complete multisensory memory representation upon receiving only a single sensory cue. This discovery provides a compelling biological explanation for the present findings: Fernald multisensory instruction likely facilitates and accelerates information retrieval by establishing stronger neural connections among visual, auditory, and tactile–kinesthetic cues.

According to the levels of processing theory, deeper and more meaningful processing leads to better recall. Fernald multisensory instruction, by engaging multiple senses simultaneously, creates richer and deeper interactions with instructional materials, resulting in more stable memory representations. This feature is particularly beneficial for students with processing speed deficits, who may struggle to deeply process information through a single sensory channel. Alongside studies such as the one conducted by Salehinejad et al. (2018), the present findings indicate that cognitive and multisensory strategies can enhance information processing capacity and mental reaction speed.

From a practical perspective, these results suggest that Fernald multisensory instruction can serve as an effective educational tool for strengthening memory, improving processing speed, and promoting long-term learning, particularly among students with processing challenges. Implementing this method may contribute to the development of more inclusive and responsive learning environments that accommodate diverse learning styles (Vahedi et al., 2025).

Finally, considering the study's findings, several limitations should be acknowledged, including the restricted time and setting of implementation, the limited number of training sessions, the use of convenience sampling, and the focus on elementary students (Grades 3–6) with a single type of learning difficulty (processing speed deficit), which limits the generalizability of the results. Therefore, future studies are recommended to employ larger and more diverse samples across different educational levels and to examine the effects of multisensory instruction on other cognitive skills, academic performance, and active learning. In addition, educational and therapeutic centers, as well as teachers and practitioners, may utilize Fernald multisensory instruction to improve memory and information processing speed in students with learning difficulties. Future research should also investigate the long-term effects of this instructional approach.

Conclusion

The present study demonstrated that Fernald multisensory instruction significantly increases information processing speed in elementary school students with processing speed deficits. This instructional approach shows that combining simultaneous stimulation of multiple sensory channels—such as visual, auditory, and tactile modalities—can more effectively activate students' cognitive processes and lead to deeper and more enduring learning. By enhancing information processing capacity, strengthening working memory, and facilitating recall, this approach enables students to process information with greater speed and quality and to improve their learning skills.

Simultaneous multisensory engagement allows for the formation of broader and more flexible neural networks in the brain and creates multiple pathways for information storage and retrieval. Moreover, Fernald multisensory instruction can reduce cognitive load, enabling students to allocate their cognitive resources more efficiently to processing and consolidating information. This feature is particularly important for students with special educational needs, as it allows learning to occur through multiple sensory and cognitive pathways and reduces the likelihood of forgetting.

The practical implications of these findings underscore the importance of integrating multisensory methods into educational curricula and instructional interventions. Implementing such approaches can enhance cognitive abilities, increase information processing speed, and improve learning efficiency, while providing greater opportunities for active and meaningful engagement with educational content. Generally, this approach can play a significant role in improving learning quality, enhancing academic performance, and strengthening students' cognitive skills, and it can be considered an effective instructional strategy in modern learning environments.

Author Contributions

The conceptual design, methodology, analysis, research process, and manuscript preparation were the result of the joint contribution and collaborative efforts of all authors (Nasrin Salehinejad, Mitra Kamyabi, and Zohre Dortaj). All authors participated in the final revision and approved the published version of the manuscript.

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Ethical considerations

The authors avoided from data fabrication and falsification.

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Conflict of Interest

The authors declare no conflict of interest.

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