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Comparative Effects of Infinite Tomatis Sound Therapy, Vestibulo-Cerebellar Training, and Their Combination on Working Memory in Children with Reading-Specific Learning Disorder

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ABSTRACT

Objective: Children with specific learning disorders related to reading often exhibit deficits in working memory such as attention, concentration, and working memory. While sound-based and sensorimotor interventions have shown promise, few studies have directly compared their individual and combined effects. This study aimed to compare the effectiveness of Infinite Tomatis sound therapy, vestibulo-cerebellar skills training, and their combination on working memory—specifically attention and concentration—in students diagnosed with reading-related specific learning disorder.

Methods and Materials: Using a quasi-experimental pretest-posttest-follow-up design with a control group, 60 children aged 8–12 were selected via convenience sampling and randomly assigned to one of four groups (n=15 each): (1) sound therapy, (2) vestibulo-cerebellar training, (3) combined therapy, and (4) control. Interventions were delivered over multiple sessions, and assessments included the IVA-2, Go/No-Go, and N-Back tests. Repeated measures ANOVA was used to analyze changes over time.

Findings: All three intervention groups demonstrated significant improvements in auditory and working memory from pretest to posttest and follow-up ($p < .001$). The combined intervention group showed significantly greater gains compared to single-method groups and the control. No adverse effects were reported.

Conclusion: Multimodal interventions combining auditory and vestibular stimulation may offer superior benefits for enhancing working memory in children with reading-specific learning disorders. These findings support the integration of multisensory approaches into educational and therapeutic programs. Future studies should explore long-term outcomes and larger, more diverse samples.

Keywords: Working memory, attention, Tomatis therapy, vestibulo-cerebellar training, learning disorder, reading difficulties.

Introduction

Learning is one of the brain's most complex and fundamental processes. Given its multifaceted nature, learning can be influenced by a variety of factors. Some students face serious challenges in the learning process due to specific learning disorders, particularly in the domain of reading (Abedi et al., 2025; Moll et al., 2016). Specific learning disorder characterized by reading difficulties is among the most common features observed in children with learning disorders (Crisci et al., 2021). Students who struggle with reading often encounter difficulties across various academic areas, leading to academic underachievement. These children tend to develop negative perceptions of their abilities and may lose interest in educational activities (Ceccato et al., 2006).

Despite having normal intelligence, some children with learning disabilities exhibit significant delays in motor coordination compared to their peers, to the extent that addressing these motor difficulties becomes essential before teaching other skills. It has been suggested that the cerebellum plays a crucial role in motor skill automation and the control of adaptive learning (Snowling et al., 2019). From a neuropsychological perspective, developmental dyslexia is associated with structural and functional impairments in the cerebral hemispheres. According to this view, dyslexia stems from dysfunctions in either the left, right, or both hemispheres (Peterson & Pennington, 2012).

One of the major difficulties in children with dyslexia is impaired executive functioning, which has received increasing attention over recent decades. Working memory are believed to play a critical role in social development, academic success, and educational achievement (Moll et al., 2016). Working memory are crucial in regulating and guiding behavior and are essential for successful adaptation and functioning in daily life. These functions enable individuals to initiate and complete tasks, remain resilient when facing challenges, recognize unexpected situations, rapidly design appropriate strategies, manage daily stressors, and prevent the emergence of inappropriate behaviors (Moshtaghy Sharifzadeh et al., 2021).

The term *working memory* refers to a broad construct encompassing various processes such as decision-making, planning, inhibition, and organization, which

rely on higher-order cognitive skills like attention, working memory, perception, language, and creative thinking (Rezaei & Sharifi, 2020). Overall, executive functioning includes focusing on and maintaining attention to relevant information (attention and inhibition), shifting focus between tasks (task management), sequencing actions to achieve goals (planning), updating and monitoring working memory content to determine the next steps (monitoring), and encoding information in working memory (encoding). These functions involve the integration of multisensory inputs, generating varied responses, set maintenance, goal-directed behaviors, adaptation to environmental changes, and self-assessment abilities (Moll et al., 2016).

Among working memory, attention is a fundamental and complex factor impacting education and learning. In fact, one of the most prevalent issues among students, especially those with dyslexia, is a lack of attention, which significantly reduces their academic performance. Attention includes the ability to plan goals and action plans and to maintain focus despite distractions (Sacarin, 2013). According to (Sternberg, 2015), attention comprises dimensions such as selective attention, sustained attention, and shifting attention. To improve working memory in students with specific learning disorders characterized by reading difficulties, various therapeutic approaches can be employed, including sound therapy with Infinite Tomatis, vestibulo-cerebellar skills training, and the combination of both methods.

The Tomatis method is an innovative therapeutic approach developed based on Alfred Tomatis's neurological theories. It posits that active listening can enhance cognitive performance and thus help address learning problems (Tomatis, 2019). In the Infinite Tomatis method, specially modulated sounds are used to stimulate the vestibular system and auditory cortex directly, thereby improving focus and concentration in students with learning disorders (Sacarin, 2013). Multiple studies have shown that this method can positively influence cognitive processing and working memory such as working memory and response inhibition (Gilmor, 1999).

Moreover, recent research has indicated that simultaneous stimulation of the vestibular and auditory systems can lead to greater improvements in cognitive and executive domains, a process referred to as

vestibulo-cerebellar training (Abedi et al., 2025). This multisensory approach, combining sound therapy with vestibulo-cerebellar skills training, not only capitalizes on the benefits of each method but also creates a synergistic effect that produces significant improvements in cognitive and motor abilities (Corbett et al., 2008). This combination has been particularly beneficial for students with learning disorders who experience difficulties in reading and concentration (El-Tellawy et al., 2022).

A review of previous studies indicates that both sound therapy and vestibulo-cerebellar training can enhance working memory. However, a direct comparison of the effectiveness of these two methods—and their combination—specifically in students with specific learning disorders has not yet been conducted (Peterson & Pennington, 2012).

Given the growing recognition of multisensory therapeutic approaches as effective interventions for improving executive functioning, a comparative investigation of these methods could play a critical role in selecting appropriate therapeutic strategies for students with learning difficulties. Accordingly, the present study aims to investigate and compare the effectiveness of sound therapy with Infinite Tomatis, vestibulo-cerebellar skills training, and the combination of both methods on working memory in students with specific learning disorder characterized by reading difficulties. The primary objective is to assess the impact of these interventions on enhancing attention and concentration, two core components of executive functioning. Considering the crucial role of executive function improvements in academic and social success, this study can offer valuable insights for teachers, educational counselors, and families.

Methods and Materials

Study Design

This study employed an applied, quasi-experimental design with a pretest-posttest-follow-up format and a control group. The statistical population included all students with reading difficulties in Tehran in 2024 who sought treatment at counseling and rehabilitation clinics across the city. A sample of 60 students was selected through convenience sampling and randomly assigned to four groups: sound therapy using Infinite Tomatis

(n=15), vestibulo-cerebellar skills training (n=15), a combination of both interventions (n=15), and a control group (n=15). After completing the intervention sessions, participants in the three experimental groups completed the research questionnaires again. The required sample size was determined based on similar studies and the recommendations of (Gall et al., 2017), suggesting that 15 participants per group are sufficient for semi-experimental designs.

Inclusion criteria were: diagnosis of specific learning disorder characterized by reading difficulties based on the NAMA Reading and Dyslexia Test, age between 8 and 12 years, consent from both the child and parents to participate, and absence of any severe or chronic physical or psychological conditions. Exclusion criteria included: missing two or more training sessions, non-cooperation, and failure to complete assigned tasks during the intervention period.

Data Collection Instruments

N-back Working Memory Enhancement Test: This test is a cognitive performance task related to executive functions that assesses the participant's short-term memory. It was first introduced by (Kirchner, 1958). The validity of this test in the study by (Khayyer et al., 2017), and its reliability in the studies by (Khayyer et al., 2017) were reported to be above 0.78. Furthermore, in (Kirchner & Klatzky, 1985) study, the reliability of this test was reported as 0.78 and its discriminant validity as 0.61.

IVA-2 Test: The IVA-2 is a 13-minute continuous performance test that evaluates response control and attention through a computerized system. It is suitable for individuals aged 6 years and above. Based on DSM-IV criteria, the test helps diagnose ADHD subtypes and is also used for assessing issues such as self-regulation problems following brain injuries, sleep disorders, depression, anxiety, learning disabilities, dementia, and other medical conditions. The test, developed by BrainTrain in the USA, has demonstrated high sensitivity (0.92) and predictive accuracy (0.89) for ADHD diagnosis. Test-retest reliability correlations ranged between 0.46 and 0.88 (Rafikhah et al., 2025).

Go/No-Go Test: Developed by Hoffman, (1984), this test measures behavioral inhibition, attentional control, sustained attention, and impulsivity. Participants must respond to "Go" stimuli (triangles) and inhibit responses to "No-Go" stimuli (other geometric shapes) presented

on a computer monitor 60 cm away from the participant. Stimuli are presented for 500 milliseconds each. Reaction times and response errors are recorded. Shafiee-Kandjani et al., (2017) reported a reliability coefficient of 0.87 for this test.

Therapeutic Interventions

Infinite Tomatis Sound Therapy: The first experimental group received Infinite Tomatis sound therapy for 30 sessions, three times a week, each lasting two hours. Sessions were conducted by a psychologist and a certified sound therapist. Children, paired in isolated rooms equipped with Vegas systems, listened to filtered high-frequency sounds (e.g., Mozart, Beethoven, Gregorian chants) through special headphones while engaged in play activities.

Vestibulo-Cerebellar Skills Training: The second experimental group received 20 sessions of vestibulo-cerebellar training, each lasting 40 minutes, three times a week, based on the protocols by (Kephart, 1971) and (Ayles, 1974).

Combined Intervention: The third experimental group underwent a combined intervention involving both vestibulo-cerebellar training and Infinite Tomatis sound therapy over 30 one-hour sessions, three times per week.

Procedure

Initially, one learning disability treatment center was randomly selected from District 8 of Tehran. Sixty students with reading difficulties were selected via convenience sampling and randomly assigned to three experimental groups and one control group. In the first phase, all participants completed the questionnaires and assessments over two sessions, and the obtained scores were considered as pretest scores. Following this, each intervention was implemented according to the assigned group: The first group received Infinite Tomatis sound therapy. The second group underwent vestibulo-cerebellar training. The third group received the combined intervention. The control group received no intervention during the study period but was promised

therapeutic sessions upon study completion if the interventions proved effective. Three months post-intervention, a follow-up assessment without any additional intervention was conducted. Ethical considerations were strictly observed. Participants and their parents were informed about the study's objectives, assured about confidentiality, and given the freedom to withdraw at any point. Written informed consent was obtained from all participants.

Ethical Considerations

All participants received verbal information about the study and participated voluntarily with informed consent. They were free to leave the study at any time. Confidentiality was strictly maintained, and personal identifiers were not recorded. The therapists committed to providing effective treatments to the control group upon study completion.

Data Analysis

Descriptive statistics, including frequency tables, graphs, means, and standard deviations, were used. Inferential statistics included MANCOVA and repeated measures ANOVA. Assumptions were tested using Levene's test (homogeneity of variances), Shapiro-Wilk test (normality), homogeneity of regression slopes test, Box's M test, and Mauchly's test of sphericity. Data analysis was conducted using SPSS version 22.

Findings and Results

Given the quasi-experimental design, a total of 60 participants were evenly matched and assigned into four groups: Sound Therapy with Infinite Tomatis (Experimental Group 1), Vestibulo-Cerebellar Skills Training (Experimental Group 2) and Combined Intervention (Experimental Group 3) and Control Group. Each group consisted of 15 students. The means and standard deviations, as key descriptive statistics for the working memory component of accuracy and concentration based on pretest, posttest, and follow-up assessments, are reported in Table 1.

Table 1

Descriptive Statistics for working memory Scores Across Groups and Time Points

Time point	Group	n	Mean	SD
Pretest - Working memory	Experimental 1	15	69.266	3.712
	Experimental 2	15	69.266	3.712
	Experimental 3	15	69.266	3.712

Posttest - Working memory	Control	15	70.066	3.555
	Total	60	69.466	3.595
	Experimental 1	15	87.800	4.345
	Experimental 2	15	89.600	4.468
	Experimental 3	15	93.266	3.514
Follow-up - Working memory	Control	15	70.200	4.647
	Total	60	85.216	9.882
	Experimental 1	15	84.600	3.996
	Experimental 2	15	88.466	4.642
	Experimental 3	15	93.200	3.802
	Control	15	69.666	3.477
	Total	60	83.983	9.701

Given the small group sizes, the Shapiro-Wilk test was used to examine the normality of the working memory scores across the three time points. The results indicated that the assumption of normal distribution was met for all groups and time points ($p > .05$). Homogeneity of Variance (Levene's Test): Pretest: $F(3,56) = 0.266, p > .05$; Posttest: $F(3,56) = 0.478, p > .05$ and Follow-up: $F(3,56) = 1.061, p > .05$. Thus, the assumption of

homogeneity of variance was satisfied. Box's M Test: $F(11081.816,18) = 4.815, p < .05$. The assumption of homogeneity of covariance matrices was violated, necessitating the use of Pillai's Trace for multivariate analyses. Mauchly's test indicated a violation of sphericity ($p < .05$). Thus, the Greenhouse-Geisser correction was applied.

Table 2

Multivariate Test Results (Pillai's Trace)

Test	Effect	Value	F	df1	df2	p	Partial Eta Squared
Pillai's Trace	Time	.975	1060.928	2	55	.001	.975
	Time × Group	1.162	25.881	6	112	.001	.581

The results showed a significant main effect of time and a significant interaction effect between time and group.

Table 3

Repeated Measures ANOVA Results (Greenhouse-Geisser Correction)

Source	SS	df	MS	F	p	Partial Eta Squared
Time	9206.344	1.763	5221.728	1276.267	.001	.958
Time × Group	3401.033	5.289	643.008	157.161	.001	.894
Error	403.956	98.733	4.091			

The main effect of time ($F = 265.506, p < .001$) and the interaction effect ($F = 56.584, p < .001$) were both significant.

Table 4

Pairwise Comparisons (Bonferroni Correction) for working memory

Group	Time (I)	Time (J)	Mean Difference (I-J)	SD	Sig
Sound Therapy	Pretest	Posttest	-18.533*	.322	.001
	Pretest	Follow-up	-15.333*	.485	.001
Vestibulo-Cerebellar	Pretest	Posttest	18.533*	.322	.001
	Pretest	Follow-up	3.200*	.439	.001
Combined	Pretest	Posttest	15.333*	.485	.001
	Pretest	Follow-up	-3.200*	.439	.001

Control	Pretest	Posttest	-20.333*	.681	.001
	Pretest	Follow-up	-19.200*	1.001	.001

All experimental groups showed significant improvements from pretest to posttest and follow-up. No significant changes were observed between posttest

and follow-up stages. The control group showed no significant changes across time points.

Table 5

Between-Group Comparisons for Working memory (Tukey Test)

Group I	Group J	Mean Difference (I-J)	SD	Sig
Sound Therapy	Vestibulo-Cerebellar	-1.889	1.342	.988
	Combined	-4.689*	1.342	.006
	Control	10.578*	1.342	.001
Vestibulo-Cerebellar	Combined	-2.800	1.342	.249
	Control	12.467*	1.342	.001
Combined	Control	15.267*	1.342	.000

Discussion and Conclusion

Based on the obtained findings, it can be observed that there is a significant difference in working memory scores between the combined training group and the sound therapy group, with the combined training group showing higher working memory scores than the sound therapy group. However, there is no significant difference between the sound therapy group and the vestibulo-cerebellar skills training group. Likewise, no significant differences were found between the vestibulo-cerebellar skills training group and either the sound therapy group or the combined training group. In addition, all three experimental groups differed significantly from the control group in terms of working memory scores: the sound therapy group scored higher than the control group, the vestibulo-cerebellar skills training group scored higher than the control group, and the combined training group also scored higher than the control group. Subsequently, a comparative graph of the four groups on the response inhibition variable was presented. The results of these findings are consistent with the studies of (Tobari et al., 2018; Abedi et al., 2025; El-Tellawy et al., 2022; Haghightzadeh et al., 2020; Moshtaghy Sharifzadeh et al., 2021; Sacarin, 2013; Vervoort et al., 2008; Yang et al., 2022).

To interpret these findings, it can be noted that specific learning disorders, particularly in the domain of reading, are among the major challenges faced by educational systems. These disorders not only negatively affect students’ academic performance, but can also lead

to deeper cognitive problems such as weaknesses in working memory. Working memory is one of the key components of the brain’s executive functions and enables the simultaneous storage and processing of information. This capacity plays a crucial role in activities such as reading, problem solving, comprehension, and learning new concepts. Weakness in this domain can cause serious difficulties for students in processing and using information (Moll et al., 2016).

To explain these results, it is necessary to consider the mechanisms through which each intervention influences working memory. Sound therapy using the Infinite Tomatis method is based on stimulation of the auditory system and, through the delivery of specific sound frequencies, enhances cognitive and neural processes related to working memory. By improving the ability to process auditory information and increasing concentration, this method helps the brain retain and process information more efficiently. Children whose learning problems stem primarily from weaknesses in auditory processing generally benefit more from this approach (Snow, 2011).

In contrast, vestibulo-cerebellar skills training focuses more on motor coordination and sensory integration. The vestibular system and the cerebellum play a key role in processing motor information and regulating the brain’s executive functions. Exercises targeting this system strengthen neural connections between the cerebellum and the prefrontal cortex, and this connectivity directly affects executive functions such as working memory (Gilmor, 1999). Children whose weaknesses are more pronounced in this area typically

show substantial improvements in working memory and information processing following vestibulo-cerebellar training. However, the most important finding of this study was the superior performance of the combined training group. This group, which simultaneously received both types of neural stimulation, achieved the best outcomes in working memory (Liang et al., 2022).

The reason for this difference may lie in the interaction of cognitive systems and the integrative processing of information in the brain. Combining sound therapy with vestibulo-cerebellar skills training appears to strengthen multiple processing pathways in the brain, including the connections between the auditory cortex, cerebellum, prefrontal cortex, and other executive regions. This synergy enhances the capacity to retain, process, and retrieve information, ultimately leading to greater improvements in working memory among these children (Finn et al., 2014). From a cognitive neuroscience perspective, working memory is a multidimensional process that requires coordinated functioning of several brain regions. The prefrontal cortex, as the central hub of executive control, works in concert with the cerebellum and the auditory system to support information processing and cognitive control. In sound therapy, auditory pathways are strengthened and the processing of speech and verbal information is improved (Peterson & Pennington, 2012). In vestibulo-cerebellar skills training, pathways involved in motor regulation and balance are reinforced, which in turn facilitates more efficient cognitive processing. The combination of these two methods strengthens the connectivity between these regions, thereby producing greater gains in working memory (Van Hecke et al., 2019).

The results of this study are also consistent with recent findings in cognitive neuroscience such as those reported by (Evans & Burke, 2024). Recent research indicates that multisensory and multidimensional interventions that simultaneously activate several cognitive and neural systems are more effective in enhancing executive functions than single-modality methods. Concurrent use of auditory stimulation and motor exercises can strengthen brain structures associated with working memory, and this is particularly beneficial for children with learning disorders, leading to more stable improvements in their cognitive abilities (Wittlin, 2010).

In summary, all three interventions in this study demonstrated a positive effect on improving working memory in students with specific learning disorders. However, the combined approach—integrating sound therapy with vestibulo-cerebellar skills training—had the greatest impact and enhanced children’s cognitive performance more than the other methods. These results highlight the importance of multidimensional interventions and show that combining treatment approaches can produce remarkable improvements in cognitive functioning. Educational and therapeutic professionals can use these findings to design more effective intervention programs and help children with learning difficulties maximize their cognitive potential.

Based on the findings of this study and previous research, it can be concluded that combining sound therapy and vestibulo-cerebellar skills training is an effective approach for improving attention and concentration in children with specific learning disorders. This method not only enhances cognitive processing but also strengthens neural networks associated with attention and concentration through multisensory stimulation. Thus, the use of multidimensional interventions could represent an efficient strategy for the rehabilitation and education of children with learning disabilities. Ultimately, it is essential to emphasize the integration of these methods into educational and therapeutic environments. Educators and therapists can contribute to the academic success of children by incorporating these interventions into their educational programs. Future research should explore the long-term effects of these methods and their combination with other cognitive and behavioral interventions, providing even more effective strategies for the rehabilitation of children with specific learning disorders.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. Ethical considerations in this study were that participation was entirely optional.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contribute to this study.

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