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

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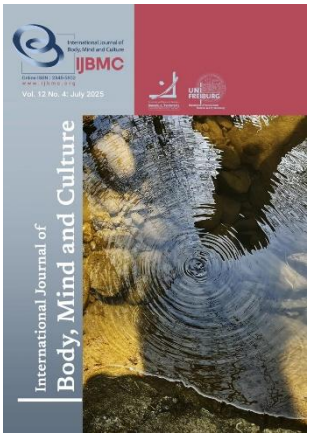

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ABSTRACT

Objective: This study aimed to compare the effectiveness of Infinite Tomatis sound therapy, vestibulo-cerebellar skills training, and their combination on executive functions—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 visual attention 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 group. No adverse effects were reported.

Conclusion: Multimodal interventions combining auditory and vestibular stimulation may offer superior benefits for enhancing executive functions 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: Executive functions, 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 (Luna, 2024; Materazzini et al., 2024). Specific learning disorder characterized by reading difficulties is among the most common features observed in children with learning disorders (Tiengsomboon & Luvira, 2024). 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 (Chiu & Li, 2017; Cortés Pascual et al., 2019).

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 (Tabrizi & Tabrizi, 2022).

One of the major difficulties in children with dyslexia is impaired executive functioning, which has received increasing attention over recent decades. Executive functions are believed to play a critical role in social development, academic success, and educational achievement (Alkhawaldeh & Khasawneh, 2023). Executive functions are crucial in regulating and guiding behavior and are essential for successful adaptation and functioning in daily life (Bulut et al., 2024). 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 (Woong et al., 2023).

The term executive functions 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 (Wang & Ji, 2025). 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 (Vervoort et al., 2008).

Among executive functions, attention is a fundamental and complex factor impacting education and learning. 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 (Rahmani & Estaki, 2019; Rahmani et al., 2019). According to Sternberg (2015), attention comprises dimensions such as selective attention, sustained attention, and shifting attention.

To improve executive functions 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 (Tabrizi & Tabrizi, 2022). 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. Multiple studies have shown that this method can positively influence cognitive processing and executive functions 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 (Fairleigh & Noame, 2014). 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 (Gori & Facoetti, 2014). This combination has been particularly beneficial for students with learning disorders who experience difficulties in reading and concentration (Rickson & Warren, 2018).

A review of previous studies indicates that both sound therapy and vestibulo-cerebellar training can enhance executive functions. 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 executive functions 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 and Participants

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, Borg, and Gall (2004), 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.

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.

Instruments

Reading and Dyslexia Test (NAMA): Developed and standardized by Karami Nouri et al. (2008), the NAMA test was used to assess reading abilities and diagnose dyslexia among elementary school students, both bilingual and monolingual. The test was standardized on 1,614 students across five elementary grades. Reliability, assessed via Cronbach's alpha, ranged from 0.43 to 0.98 across subtests, with an average of 0.88. The mean score was set at 100, with a standard deviation of 15. The test includes 10 subtests covering areas such as word reading, word chains, rhyming, picture naming, text comprehension, word comprehension, phoneme deletion, non-word reading, letter identification, and category identification.

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. It 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.

Go/No-Go Test: Developed by Hoffman in 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. Kadiri et al. (2006) reported a reliability coefficient of 0.87 for this test.

Intervention

Infinite Tomatis Sound Therapy: The first experimental group received Infinite Tomatis sound therapy for 30 sessions, three times a week, each lasting two hours. A psychologist and a certified sound therapist conducted sessions. 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 Ayres (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.

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), 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 visual attention component of accuracy and concentration based on pretest, posttest, and follow-up assessments, are reported in Table 1.

Table 1

Descriptive Statistics for Visual and Auditory Attention Scores Across Groups and Time Points

Time Point	Group	N	Mean	SD
Pretest - Visual Attention	Sound Therapy (Group 1)	15	74.266	6.329
	Vestibulo-Cerebellar (Group 2)	15	73.933	6.005
	Combined (Group 3)	15	74.400	6.231
	Control	15	71.533	7.443
	Total	60	73.533	6.466
Posttest - Visual Attention	Sound Therapy (Group 1)	15	79.600	6.219
	Vestibulo-Cerebellar (Group 2)	15	81.933	5.483
	Combined (Group 3)	15	85.466	7.170
	Control	15	69.866	6.947
	Total	60	79.216	8.604
Follow-up - Visual Attention	Sound Therapy (Group 1)	15	79.733	6.135
	Vestibulo-Cerebellar (Group 2)	15	82.066	5.391
	Combined (Group 3)	15	83.600	7.944
	Control	15	70.333	7.480
	Total	60	78.933	8.431
Pretest - Auditory Attention	Sound Therapy (Group 1)	15	52.400	9.671
	Vestibulo-Cerebellar (Group 2)	15	50.933	9.300
	Combined (Group 3)	15	53.133	11.198
	Control	15	49.800	9.397
	Total	60	51.566	9.753
Posttest - Auditory Attention	Sound Therapy (Group 1)	15	64.933	11.304
	Vestibulo-Cerebellar (Group 2)	15	63.333	12.233
	Combined (Group 3)	15	78.133	8.348
	Control	15	49.333	9.904
	Total	60	63.933	14.541
Follow-up - Auditory Attention	Sound Therapy (Group 1)	15	65.000	11.205
	Vestibulo-Cerebellar (Group 2)	15	64.200	13.175
	Combined (Group 3)	15	77.400	8.550
	Control	15	48.733	10.088
	Total	60	63.833	14.752

Given the small group sizes, the Shapiro-Wilk test was used to examine the normality of the visual attention 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	.890	222.073	2	55	.001	.890
Pillai's Trace	Time × Group	.989	18.265	6	112	.001	.495

The results showed a significant main effect of time and a significant interaction effect between time and group (Table 2).

Table 3

Repeated Measures ANOVA Results (Greenhouse-Geisser Correction)

Source	SS	df	MS	F	p	Partial Eta Squared
Time	1230.811	1.452	847.949	265.506	.001	.826
Time × Group	786.922	4.355	180.713	56.584	.001	.752
Error	259.600	81.285	3.194			

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 Visual Attention

Group	Time (I)	Time (J)	Mean Difference (I-J)	SD	Sig
Sound Therapy	Pretest	Posttest	-5.333*	.270	.001
	Pretest	Follow-up	-5.467*	.376	.001
Vestibulo-Cerebellar	Pretest	Posttest	-8.000*	.762	.001
	Pretest	Follow-up	-8.133*	.768	.001
Combined	Pretest	Posttest	-11.067*	.651	.001
	Pretest	Follow-up	-9.200*	1.001	.001
Control	Pretest	Posttest	1.667	.303	.081
	Pretest	Follow-up	1.200	1.439	.848

All experimental groups showed significant improvements from pretest to posttest and follow-up. No significant changes were observed between the posttest and follow-up stages. The control group showed no significant changes across time points.

Table 5

Between-Group Comparisons for Visual Attention (Tukey Test)

Group I	Group J	Mean Difference (I-J)	SD	Sig
Sound Therapy	Vestibulo-Cerebellar	-1.444	2.371	1.000
	Combined	-3.289	2.371	1.000
	Control	7.289*	2.371	.020
Vestibulo-Cerebellar	Control	8.733*	2.371	.003
Combined	Control	10.578*	2.371	.000

Table 6

Pairwise Comparisons (Bonferroni Correction) for Auditory Attention

Group	Time (I)	Time (J)	Mean Difference (I-J)	SD	Sig
Sound Therapy	Pretest	Posttest	-12.533*	2.035	.001
	Pretest	Follow-up	-12.600*	2.028	.001
Vestibulo-Cerebellar	Pretest	Posttest	-12.400*	2.097	.001
	Pretest	Follow-up	-13.267*	2.383	.001
Combined	Pretest	Posttest	-25.000*	2.338	.001
	Pretest	Follow-up	-24.267*	2.243	.001
Control	Pretest	Posttest	.467	.424	.869

Table 7

Between-Group Comparisons for Auditory Attention (Tukey Test)

Group I	Group J	Mean Difference (I-J)	SD	Sig
Sound Therapy	Control	11.489*	3.596	.014
Vestibulo-Cerebellar	Control	10.200*	3.596	.038
Combined	Vestibulo-Cerebellar	10.067*	3.596	.042
Combined	Control	20.267*	3.596	.001

All experimental groups showed significant improvements from pretest to posttest and follow-up. The combined group showed significantly greater improvement than the vestibulo-cerebellar group (about 10 points). All experimental groups significantly outperformed the control group.

Discussion and Conclusion

Based on the results, it was observed that there was a significant difference in auditory attention scores between the combined intervention group and the vestibulo-cerebellar training group, with the combined intervention group achieving higher scores. However, no significant differences were found between the sound therapy group and either the vestibulo-cerebellar training or combined intervention groups. Additionally, no significant difference was observed between the sound therapy and vestibulo-cerebellar training groups. Nevertheless, all three experimental groups showed significantly higher auditory attention scores compared to the control group. Specifically, the sound therapy group, the vestibulo-cerebellar training group, and the combined intervention group all outperformed the control group.

These findings are consistent with the results of previous studies (Abedi Kouhpaei, 2011; Abedi & Esteki, 2017; Bonthuys et al., 2017; El-Tellawy et al., 2022; Hemmati et al., 2022; Tabrizi & Tabrizi, 2022). To explain these findings, it can be noted that specific learning disorders, especially those affecting reading, represent one of the major challenges in educational systems. Such disorders profoundly impact academic performance, cognitive development, self-confidence, and social interactions among children. One of the recommended strategies to improve the performance of these children is the use of intervention methods such as Infinite Tomatis Sound Therapy, vestibulo-cerebellar skills training, or a combination of the two (Bonthuys et al., 2017).

In explaining the underlying mechanisms of improvement in attention and concentration, the role of sensory and cognitive systems must be considered. Infinite Tomatis Sound Therapy operates by stimulating the auditory system and enhancing auditory processing. It utilizes specific and diverse sound patterns that activate auditory processing pathways and strengthen neural connections (El-Tellawy et al., 2022). In contrast, vestibulo-cerebellar skills training is based on stimulating the vestibular system and sensory information processing. This method aids in improving motor coordination, balance, and cognitive processing, thus positively affecting attention and concentration. When these two methods are combined, their synergistic effects can result in even more significant improvements in children's cognitive functioning (Finn et al., 2014).

The differences in the effectiveness of these treatments may be attributed to how they target different brain systems. Sound therapy primarily influences the auditory cortex and related neural pathways and may be particularly beneficial for children with auditory processing issues. However, it has a lesser impact on systems related to balance and motor coordination. On the other hand, vestibulo-cerebellar training focuses on motor and balance systems and may be more effective for children with coordination and sensory integration difficulties. Therefore, combining both methods allows for the advantages of both systems to be leveraged, resulting in greater improvements in attention and concentration. This explains why the combined intervention group achieved the highest scores in this study (El-Tellawy et al., 2022; Hemmati et al., 2022).

Furthermore, the impact of these interventions can also be analyzed from the perspective of learning theories. From an information processing theory standpoint, children with specific learning disorders may have difficulties in efficiently processing sensory and cognitive information, leading to impairments in encoding, storing, and retrieving information.

Sound therapy and vestibulo-cerebellar skills training may enhance these processes by strengthening information-processing pathways (Peterson & Pennington, 2012). Additionally, from a multisensory learning theory perspective, combining auditory and motor stimuli can lead to more effective and durable learning. When children receive information through multiple sensory channels, their brains have a greater opportunity to process and consolidate that information (Yang et al., 2022).

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

By 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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