KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 26 June 2024
Revised 25 July 2024
Accepted 01 August 2024
Published online 01 January 2025

KMAN Counseling & Psychology Nexus

Volume 3, pp 1-11

E-ISSN: 3041-9026

Comparison of the Effectiveness of the Central Nervous System Reorganization Method (Doman-Delacato) and Neurofeedback on Improving Reading Skills in Children with Dyslexia

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A r t i c l e   I n f o

Article type:
Original Research
Section:
Developmental Psychology

How to cite this article:
Darabi, G., Ebrahimpour, M., Sahebdel, H., & Dastjerdi, R. (2025). Comparison of the Effectiveness of the Central Nervous System Reorganization Method (Doman-Delacato) and Neurofeedback on Improving Reading Skills in Children with Dyslexia. *KMAN Conseling and Psychology Nexus, 3*, 1-11.
http://doi.org/10.61838/kman.dp.psynexus.3.3

A B S T R A C T

The present study aimed to compare the effectiveness of the central nervous system reorganization method (Doman-Delacato) and neurofeedback on improving reading skills in children with dyslexia. This research is applied in terms of its objective and is a quasi-experimental study with a pre-test, post-test, and control group design in terms of the nature of the data. The statistical population included all students aged 10 to 13 with reading disorders who attended the Omid Learning Disorders Center in Quchan during the 2019–2020 academic year. The sample consisted of 45 participants selected through convenience sampling based on inclusion and exclusion criteria and randomly assigned to three groups: experimental group 1 (15 participants), experimental group 2 (15 participants), and a control group (15 participants). Data collection was conducted using the Reading and Dyslexia Test by Karami Nouri and Moradi (2005). Before implementing the independent variables, namely the central nervous system reorganization method (Doman-Delacato) and neurofeedback, the participants in all three groups were assessed using a pre-test measuring reading skills in children with dyslexia. Experimental group 1 underwent the central nervous system reorganization method (Doman-Delacato), and experimental group 2 underwent neurofeedback training, while no independent variable was applied to the control group. At the end of the intervention, the dependent variable (reading skills in children with dyslexia) was measured in all three groups using a post-test. For statistical analysis, parametric one-way analysis of variance (ANOVA) and repeated measures ANOVA were performed using SPSS software. The results of the ANOVA test, conducted to examine differences in mean scores between the groups at the pre-test, post-test, and follow-up stages for reading skills, revealed no statistically significant differences between the groups at any stage ($p > 0.05$). However, the results of the repeated measures ANOVA indicated that over time, significant differences in mean scores were observed in the Doman-Delacato and neurofeedback groups ($p < 0.05$), while no significant difference was found over time in the control group. The findings of the study and the hypotheses testing demonstrated that the central nervous system reorganization method (Doman-Delacato) and neurofeedback are effective approaches for improving reading skills in children with dyslexia.

Keywords: *Central Nervous System Reorganization Method (Doman-Delacato), Neurofeedback, Reading Skills, Dyslexia.*

1. Introduction

Learning disorders are common childhood conditions, with reading disorder being the most prevalent type (Tiengsomboon & Luvira, 2024). Dyslexia is a form of learning disorder characterized by difficulties such as confusing similar words, reversing word sequences, guessing words based on initial and final letters, significant challenges in spelling, difficulty distinguishing parts from the whole, and a lack of motivation or aversion to learning to read (Luna, 2024). Approximately 4% to 8% of school-aged children in the United States experience dyslexia, which encompasses various deficits in reading, spelling, and comprehension. Additionally, dyslexia is observed in nearly 75% of children and adolescents with specific learning disabilities involving reading impairments (Lievore, 2024). Rao and colleagues (2017) reported a dyslexia prevalence rate of 13.67% (Rao et al., 2017).

Children with dyslexia exhibit a combination of difficulties in learning the connection between sounds and abstract symbols of letters. Consequently, they struggle with recognizing letters, breaking down words into phonemes, combining phonemes into words, spelling, and writing. Indeed, it seems that they face challenges across all levels of information processing and in various academic domains (Smith-Spark et al., 2019). Dyslexic students also experience difficulties in employing phonological strategies (particularly when words are presented auditorily) and recognizing vocabulary (Schneider et al., 2019). The most common challenges among dyslexic children include issues with identifying, manipulating, encoding, and decoding words. Performance in these tasks is considered one of the most realistic predictors of reading ability (Meiran et al., 2019).

The alphabetic method, which includes phonological and morphological information, has demonstrated that not only phonemes but also morphemes are processed in this approach. Morphological awareness refers to a student's understanding of a word's structure as a combination of meaningful units (Ghaemi et al., 2016; Ghaemi et al., 2010).

The manifestations of reading disorders are diverse. Children with visual perception deficits struggle with encoding, identifying shapes, phonemes, and meaningful units, leading them to rely on guessing words based on their appearance (Major & Tetley, 2019).

Recently, neuropsychological approaches have focused on addressing the challenges faced by these children. According to this perspective, dyslexia arises due to dysfunctions in the nervous system, particularly the central nervous system, with various models and hypotheses proposed in this area. Baker's balance model suggests that different brain regions are involved at various stages of learning to read, and any deficits in these stages lead to reading difficulties. Similarly, the Delacato model attributes reading impairments to irregular neural development, which can be reorganized through specific activities and exercises to reduce the severity of these impairments (Pour Abbas Vafa et al., 2015).

According to the central nervous system reorganization theory, Doman and Delacato propose that the nervous system develops in a predictable pattern. In humans, this system matures by the age of eight, and disruptions at any stage can lead to subsequent impairments. Delacato emphasizes that specific skills, such as walking, speaking, and reading, depend on the complete development of the nervous system. Many learning difficulties are attributed to dysfunctions in this system caused by genetic factors, prenatal infections, or environmental deprivation. He posits that providing activities to promote neural growth at each stage can reduce learning disorders. In this view, readiness to read is linked to the nervous system, and inadequate neural functioning in children often stems from environmental deprivation. His therapeutic approach involves reorganizing the central nervous system through movement-based programs and neuro-muscular retraining exercises, such as rolling, crawling, walking on all fours, and walking, to mobilize and utilize lower brain regions (Delacato, 1963, 1966; Delacato, 1998; Delacato, 1992).

Research on the impact of the Delacato neuropsychological method on the reading performance of dyslexic students has yielded mixed results. While some studies report that the Delacato neuropsychological method improves reading performance in dyslexic students

(Hashemi Nejat, 2004; Hines, 2001; Kakhi & Movahedi, 2016; Momeni & Bahrami, 2002; Salimi Teymoori, 2007), others have found no significant effects (Bahamin, 2002).

Another modern intervention for dyslexia is neurofeedback, a method recently applied to address electroencephalogram (EEG) abnormalities. Neurofeedback, a neuropsychological educational and therapeutic technique, uses operant conditioning processes to help individuals learn to alter their brain's electrical activity (Zoefel et al., 2011). This method involves repetitive training sessions (e.g., 2,000 repetitions in a 40-minute session) without punishment, negative reinforcement, or emotional content, making verbal communication unnecessary. Neurofeedback allows individuals to normalize their cortical profile by reducing slow-wave activity and increasing fast-wave activity, enhancing attention and focus while improving arousal (Rajabi, 2015).

Jacobs (2006) demonstrated the effectiveness of neurofeedback in improving symptoms in two boys with multiple diagnoses, including attention-deficit/hyperactivity disorder (ADHD), learning disorders, mood disorders, social issues, and developmental delays (Jacobs, 2006). Walker (2006) reported case studies indicating that neurofeedback improved EEG abnormalities in children with reading disorders, leading to enhancements in reading level, speed, and behavior (Walker, 2006). Fernandez et al. (2007) showed that neurofeedback improved behavior immediately post-treatment and altered brain wave patterns two months later in children with learning disorders characterized by a high theta/alpha ratio (Fernández et al., 2007). Other studies have reported the impact of neurofeedback on visual-motor perception (Azizi et al., 2017; Behzadi et al., 2014), reading speed (Ghaemi et al., 2016), learning disorders (Hyman, 2016; Sajjadi et al., 2014), EEG and balance performance (Sadeghi Naeini et al., 2013), dyslexia (Li & Chen, 2017), and ADHD symptoms (Lee & Jung, 2017). However, Thornton and Carmody (2006) reported a lack of neurofeedback efficacy on reading disabilities (Thornton & Carmody, 2005).

Given the contradictory findings, the persistent challenges faced by dyslexic children, and the importance of enriching their learning environment, further investigation is necessary to address these symptoms. This study aimed to compare the effectiveness of the central nervous system reorganization method (Doman-Delacato) and neurofeedback on improving reading skills in children with dyslexia.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a quasi-experimental design with a pre-test, post-test, and control group. The statistical population consisted of all students aged 10 to 13 with reading disorders who attended the Omid Learning Disorders Center in Quchan during the 2019–2020 academic year. A total of 45 children with reading disorders were selected through convenience sampling and randomly divided into three groups of 15 participants each.

Participants included in the study were required to meet the following criteria: a formal diagnosis of a reading disorder, an age range of 10–13 years, normal intelligence levels, and the absence of comorbid conditions such as ADHD or significant psychological or physical disorders. Additionally, all participants and their guardians provided informed consent to participate in the study.

2.2. Measures

2.2.1. The Reading and Dyslexia Test

The Reading and Dyslexia Test, standardized by Karami Nouri and Moradi (2005), was used to assess reading abilities. It includes ten subtests: (1) Word Reading Test with three lists of 40 words across varying frequencies, yielding Cronbach's alpha values of 0.98, 0.99, and 0.91; (2) Nonword Reading Test, where participants read 40 nonwords (e.g., soora, dalibal), with a Cronbach's alpha of 0.85; (3) Word Comprehension Test with 30 multiple-choice questions assessing word meaning; (4) Word Chain Test, requiring segmentation of a continuous 109-word text, with a Cronbach's alpha of 0.65; (5) Text Comprehension Test, containing grade-specific texts and multiple-choice questions to assess comprehension; (6) Rhyme Test, involving the identification of rhyming words among 20 options; (7) Picture Naming Test, consisting of two versions with 20 images each, requiring participants to recall names; (8) Phoneme Deletion Test, where participants pronounce words after removing specified phonemes; (9) Letter Signs Test, which involves recalling words starting with specific letters; and (10) Category Words Test, assessing recall of words related to given categories (e.g., fruits, colors). The test was administered individually, and a cut-off score of ≤157 (≥114 errors) indicated dyslexia. The instrument demonstrated strong reliability, with Cronbach's alpha

E-ISSN: 3041-9026

values ranging from 0.48 to 0.98 across subtests, and factor analysis confirmed its validity (Mahmoodiasl et al., 2024).

2.3. Intervention

2.3.1. Doman-Delacato Treatment

The Delacato treatment was guided by a structured protocol consisting of four stages over 86 individual, daily sessions at scheduled times (Delacato, 1963, 1966; Delacato, 1998; Delacato, 1992; Hashemi Nejat, 2004; Hines, 2001):

Stage 1 (3 weeks): This stage involved unilateral crawling for 5 minutes (~80 repetitions), specific stomach exercises, auditory exercises for 8 minutes, and visual exercises for 8 minutes. These activities were designed to promote initial neural organization and sensory integration, totaling 21 minutes per day.

Stage 2 (3 weeks): Activities included cross-pattern crawling for 30 minutes, auditory-speech exercises for 4 minutes, auditory-reading exercises for 15 minutes, and visual exercises for 4 minutes. This stage aimed to enhance cross-lateral coordination and auditory-visual integration, totaling 53 minutes daily.

Stage 3 (6 weeks): Participants engaged in cross-pattern walking for 20 minutes, auditory exercises for 8 minutes, visual training for 8 minutes, general body coordination exercises for 30 minutes, and right-left orientation training for 10 minutes. This stage emphasized whole-body coordination and spatial orientation, with a total duration of 76 minutes per day.

Stage 4 (8–10 weeks): This final stage focused on lateral dominance and fine motor skills, including writing (20 minutes), throwing (10 minutes), foot dominance (15 minutes), ear dominance (10 minutes), winking (4 minutes), staring (4 minutes), aiming (4 minutes), and peeking through a hole (4 minutes). These activities aimed to refine higher-order motor and sensory integration, lasting 60–90 minutes daily.

2.3.2. Neurofeedback

The neurofeedback treatment consisted of 16 sessions, each lasting 30 minutes, conducted in 2019 to assess the effectiveness of neurofeedback on reading skills in children with dyslexia.

Participants were seated comfortably, and sensors (electrodes) were placed on the scalp and earlobes. Baseline assessments were conducted in brain regions F4, FZ, F3, CZ, and PZ under five conditions (eyes open, eyes closed, reading, listening, and drawing).

Manual filter adjustments were applied for beta (15–22 Hz) and SMR (12–15 Hz) bands, with automated threshold setting to encourage self-regulation through reward-based learning. The Flexicomp Infiniti system, a 10-channel device by Thought Technology (Canada), was used, featuring advanced sampling rates and compatibility with various analytical software.

2.4. Data Analysis

Descriptive statistics were used to summarize data from variables and therapeutic interventions. Assumptions for parametric analysis were tested, including the Shapiro-Wilk test for normality and Levene’s test for homogeneity of variances. One-way ANOVA and repeated measures ANOVA were then applied to analyze the data.

3. Findings and Results

As shown in Table 1, pre-test scores for reading skills and their components across the three groups showed minimal differences. Additionally, the mean scores for reading skills and components in the two experimental groups increased from pre-test to post-test. However, no significant changes were observed in the control group's scores between pre-test and post-test.

Table 1

Descriptive Statistics for Reading Skills and Their Components by Group and Test Stage

Variable	Group	Pre-Test		Post-Test		Follow-Up	
		Mean	SD	Mean	SD	Mean	SD
Reading Skills	Doman-Delacato	350.73	42.55	361.40	38.46	354.73	37.70
	Neurofeedback	343.07	34.03	361.40	33.88	358.73	34.97
	Control	346.53	58.48	355.47	48.56	355.80	48.04
Word Reading	Doman-Delacato	104.07	9.39	105.40	9.75	104.87	8.74
	Neurofeedback	103.27	8.01	105.67	7.51	105.53	7.46
	Control	96.93	25.38	103.80	8.65	104.13	8.78
Word Chain	Doman-Delacato	42.80	17.36	45.40	17.80	43.73	17.15

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	Neurofeedback	37.80	12.29	41.47	12.81	40.87	12.63
	Control	46.53	18.79	46.93	18.69	46.73	18.22
Rhyme Test	Doman-Delacato	11.80	2.78	12.93	2.71	12.13	2.64
	Neurofeedback	13.20	2.86	14.53	2.92	13.73	2.84
	Control	13.40	3.14	13.27	3.01	13.27	2.87
Picture Naming	Doman-Delacato	35.53	1.88	35.93	1.62	35.93	1.62
	Neurofeedback	36.33	2.19	36.80	1.93	36.93	1.79
	Control	35.87	2.29	36.00	2.27	36.00	2.45
Text Comprehension	Doman-Delacato	14.07	1.98	14.60	1.84	14.40	1.96
	Neurofeedback	13.20	1.70	13.73	1.75	14.20	2.46
	Control	14.40	1.84	14.40	1.88	14.33	2.13
Word Comprehension	Doman-Delacato	20.20	4.00	20.53	3.07	20.33	3.24
	Neurofeedback	18.87	3.50	19.80	3.90	19.27	3.83
	Control	19.60	4.55	19.93	4.15	19.93	3.84
Phoneme Deletion	Doman-Delacato	17.33	3.39	18.53	3.98	17.60	3.72
	Neurofeedback	18.73	3.81	21.53	3.56	21.33	3.62
	Control	17.47	4.79	18.07	4.85	18.07	4.77
Nonwords and Pseudowords	Doman-Delacato	30.40	6.33	31.13	6.84	30.47	6.45
	Neurofeedback	29.13	7.64	31.87	7.46	31.00	7.48
	Control	27.73	7.13	28.20	6.52	28.20	6.44
Letter Signs	Doman-Delacato	21.27	5.80	23.40	5.97	21.87	5.18
	Neurofeedback	19.80	5.94	22.40	7.63	21.93	7.74
	Control	20.93	6.54	21.07	5.97	21.40	6.30
Category Signs	Doman-Delacato	53.27	9.31	53.53	8.37	53.40	8.69
	Neurofeedback	52.73	7.89	53.60	7.47	53.93	7.33
	Control	53.67	11.60	53.80	11.74	53.73	11.62

Since the significance levels obtained in the Shapiro-Wilk test for the research variables exceed the threshold of 0.05, it can be concluded that the distribution of the examined variables in the sample population is normal. Additionally, the results of the Levene's test indicated that, at no stage, did the central nervous system reorganization method (Doman-Delacato) or neurofeedback, compared to the control group, lead to an increase in reading skills ($p > 0.05$).

As shown in Table 2, the differences between the groups are not statistically significant. In other words, the components of reading skills in children with dyslexia do not show significant differences among the three groups.

Table 2

Results of Between-Group Effects Test for Reading Skills Components

Source	Sum of Squares	df	Mean Square	F	Significance	Partial Eta Squared
Intercept	16,937,489.810	1	16,937,489.810	3224.207	.000	.987
Groups	208.015	2	104.007	.020	.980	.001
Error	220,635.511	42	5253.226			

To perform pairwise comparisons of reading skills components in children with dyslexia across the three time points (pre-test, post-test, and follow-up), Table 3 was utilized.

Table 3

Pairwise Comparisons of Reading Skills Components Across Three Time Points

Time 1	Time 2	Mean Difference	Standard Error	Significance	Lower Bound (95% CI)	Upper Bound (95% CI)
Pre-Test	Post-Test	-12.644*	2.520	.000	-18.928	-6.361
	Follow-Up	-9.644*	2.430	.001	-15.703	-3.586
Post-Test	Pre-Test	12.644*	2.520	.000	6.361	18.928
	Follow-Up	3.000*	.591	.000	1.526	4.474
Follow-Up	Pre-Test	9.644*	2.430	.001	3.586	15.703
	Post-Test	-3.000*	.591	.000	-4.474	-1.526

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The results in Table 3 indicate that reading skills significantly differed across the three time points. From pre-test to post-test, the mean increased by 12.64, which is statistically significant. Similarly, from pre-test to follow-up, the mean increased by 9.64, which is also statistically significant at the 0.05 level.

Table 4

Pairwise Comparison of Groups for Reading Skills Components in Children with Dyslexia

Group 1	Group 2	Mean Difference	Standard Error	Significance	Lower Bound (95% CI)	Upper Bound (95% CI)
Doman-Delacato Method	Neurofeedback Group	1.2222	15.27995	1.000	-36.8809	39.3253
	Control Group	3.0222	15.27995	1.000	-35.0809	41.1253
Neurofeedback Group	Doman-Delacato Method	-1.2222	15.27995	1.000	-39.3253	36.8809
	Control Group	1.8000	15.27995	1.000	-36.3031	39.9031
Control Group	Doman-Delacato Method	-3.0222	15.27995	1.000	-41.1253	35.0809
	Neurofeedback Group	-1.8000	15.27995	1.000	-39.9031	36.3031

The results of Table 4 indicate that there are no statistically significant differences in reading skills among the different groups.

Table 5

Summary of ANOVA Results for Reading Components

Component	Group	F Value	P Value
Reading Skills	Doman-Delacato	8.973	0.001
	Neurofeedback	70.559	0.001
	Control	1.935	0.163
Word Reading	Doman-Delacato	3.349	0.05
	Neurofeedback	42.241	0.001
	Control	1.094	0.349
Word Chain	Doman-Delacato	4.157	0.026
	Neurofeedback	8.044	0.002
	Control	0.211	0.811
Rhyme Test	Doman-Delacato	2.899	0.072
	Neurofeedback	13.685	0.001
	Control	0.099	0.906
Picture Naming	Doman-Delacato	6.000	0.007
	Neurofeedback	8.301	0.001
	Control	0.293	0.748
Text Comprehension	Doman-Delacato	7.970	0.002
	Neurofeedback	2.003	0.154
	Control	0.085	0.918
Word Comprehension	Doman-Delacato	0.526	0.597
	Neurofeedback	8.562	0.001
	Control	0.642	0.534
Phoneme Deletion	Doman-Delacato	10.813	0.001
	Neurofeedback	28.362	0.001
	Control	2.842	0.114
Nonwords and Pseudowords	Doman-Delacato	1.254	0.301
	Neurofeedback	29.835	0.001
	Control	1.927	0.164
Letter Signs	Doman-Delacato	4.394	0.022
	Neurofeedback	11.471	0.001
	Control	0.447	0.644
Category Signs	Doman-Delacato	0.078	0.925

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	Neurofeedback	4.960	0.014
	Control	0.259	0.773

The analysis of variance (ANOVA) results for the effectiveness of the Doman-Delacato method and Neurofeedback on improving reading skills in children with dyslexia revealed key findings across various components. For Reading Skills, significant differences were observed in the Doman-Delacato group (F = 8.973, p = 0.001) and the Neurofeedback group (F = 70.559, p = 0.001), while no significant changes were found in the control group (F = 1.935, p = 0.163). In the Word Reading component, both the Doman-Delacato (F = 3.349, p = 0.05) and Neurofeedback groups (F = 42.241, p = 0.001) showed significant improvements, whereas the control group did not exhibit significant changes (F = 1.094, p = 0.349). For Word Chain, the Doman-Delacato group (F = 4.157, p = 0.026) and the Neurofeedback group (F = 8.044, p = 0.002) demonstrated significant improvements, but no significant differences were observed in the control group (F = 0.211, p = 0.811). Regarding the Rhyme Test, significant changes were detected in the Neurofeedback group (F = 13.685, p = 0.001), while the Doman-Delacato group (F = 2.899, p = 0.072) and the control group (F = 0.099, p = 0.906) did not show meaningful improvements. For Picture Naming, significant differences were noted in the Doman-Delacato (F = 6.000, p = 0.007) and Neurofeedback groups (F = 8.301, p = 0.001), but not in the control group (F = 0.293, p = 0.748). In Text Comprehension, the Doman-Delacato group displayed significant improvements (F = 7.970, p = 0.002), while the Neurofeedback (F = 2.003, p = 0.154) and control groups (F = 0.085, p = 0.918) did not. For Word Comprehension, the Neurofeedback group showed significant gains (F = 8.562, p = 0.001), but the Doman-Delacato (F = 0.526, p = 0.597) and control groups (F = 0.642, p = 0.534) showed no significant changes. In Phoneme Deletion, both the Doman-Delacato group (F = 10.813, p = 0.001) and the Neurofeedback group (F = 28.362, p = 0.001) exhibited significant improvements, whereas the control group did not (F = 2.842, p = 0.114). Similarly, for Nonwords and Pseudowords, significant differences were observed in the Neurofeedback group (F = 29.835, p = 0.001), while the Doman-Delacato (F = 1.254, p = 0.301) and control groups (F = 1.927, p = 0.164) did not show significant improvements. Regarding Letter Signs, the Doman-Delacato group (F = 4.394, p = 0.022) and Neurofeedback group (F = 11.471, p = 0.001) demonstrated significant improvements, but no significant changes were found in the control group (F = 0.447, p = 0.644). Lastly, for Category Signs, significant improvements were found in the Neurofeedback group (F = 4.960, p = 0.014), but the Doman-Delacato (F = 0.078, p = 0.925) and control groups (F = 0.259, p = 0.773) showed no meaningful changes. Overall, these results highlight the efficacy of both the Doman-Delacato and Neurofeedback methods in improving various reading components, with Neurofeedback showing greater effectiveness across more subtests compared to the Doman-Delacato method.

4. Discussion and Conclusion

The aim of this study was to compare the effectiveness of the Central Nervous System Reorganization Method (Doman-Delacato) and Neurofeedback in improving the reading skills of children with dyslexia. The results of repeated measures ANOVA indicated significant differences over time for the Doman-Delacato and Neurofeedback groups, while no significant differences were observed in the control group. This means that sensory-motor exercises from the Central Nervous System Reorganization Method (Doman-Delacato) significantly increased the mean scores in subtests such as reading skills, word chains, picture naming, text comprehension, phoneme deletion, and letter signs. Similarly, Neurofeedback significantly increased mean scores in reading skills, word reading, word chains, rhyme tests, picture naming, word comprehension, phoneme deletion, nonwords and pseudowords, letter signs, and category signs ($p < 0.05$).

The results showed no significant difference in the effectiveness of the Central Nervous System Reorganization Method (Doman-Delacato) and Neurofeedback in improving the reading skills of children with dyslexia.

In explaining these results, it can be argued that changes at the behavioral level reflect changes at the brain level. Neurofeedback, as a therapeutic method, directly focuses on brain waves, and behavioral changes can be considered consequences of changes in brain waves. However, these changes do not always occur simultaneously, meaning that we sometimes observe behavioral changes without measurable changes in brain waves. This can be explained by suggesting that attempts to modify brain waves through methods like Neurofeedback result in changes at the brain level. Any change in the brain's electrical activity following treatment reorganizes the entire bioelectrical system, which

E-ISSN: 3041-9026

in turn triggers a pervasive, natural, and reflexive normalization response in the brain, leading to improvement. Therefore, the relationship between brainwave changes and behavioral changes is neither linear nor reciprocal, where one automatically leads to visible changes in the other. Although the exact mechanism of these changes in the brain is unclear, they manifest at the behavioral level, making them observable and measurable.

On the other hand, in the present study, much of the improvement in reading difficulties can be attributed to compensating for environmental deprivation. This highlights the effectiveness of the Doman-Delacato method, which involves reorganizing the central nervous system. This method relies on movement-based programs and neuro-muscular retraining, such as rolling, crawling in various forms, cross-pattern crawling, cross-pattern walking, auditory exercises, visual exercises, and spatial orientation training, to mobilize and use movement patterns that were not acquired in the past from lower brain regions (Delacato, 1963, 1966). According to Delacato, readiness for reading and writing is linked to a fully developed nervous system, and 70% of children with inadequate nervous system functionality experience speech and writing challenges. The core assumption of this theory is that movement can be used to improve cognitive and perceptual skills and to treat children with learning disorders (Hines, 2001). Therefore, based on the results of this study, it can be concluded that by engaging in Doman-Delacato sensory-motor exercises, the brain reactivates sensory and motor functions, reducing learning disorders. In other words, while it is not possible to regenerate dead brain cells, numerous inactive living cells can be activated (Delacato, 1992).

The first step in the Doman-Delacato therapeutic method is identifying the dominant brain hemisphere. Subsequently, the opposite limbs of the dominant hemisphere are used more than the limbs on the other side, to strengthen the targeted hemisphere and make it more dominant (Delacato, 1963, 1966). Delacato believes that through this approach, hemispheric dominance is achieved, and reading and writing disorders gradually improve (Delacato, 1998; Delacato, 1992). Thus, in this study, based on this principle and the therapeutic steps outlined by Delacato, efforts were made to provide participants with opportunities to explore and manipulate their environment and to use their dominant sensory and motor organs more than the non-dominant ones, allowing the corresponding hemisphere to gain sufficient dominance over the other.

This finding aligns with prior studies by Kakhki and Movahedi (2016), which demonstrated that Doman-Delacato sensory-motor exercises improve dysgraphia in girls aged 9 to 11 (Kakhi & Movahedi, 2016); Pour Abbas Vafa and colleagues (2015), which found that central nervous system reorganization exercises improved speed and accuracy in linguistic dyslexia (Pour Abbas Vafa et al., 2015); Momeni and Bahrami (2002), which showed that the Doman-Delacato neuropsychological method improved symptoms in children with hyperactivity (Momeni & Bahrami, 2002); and Hashemi Nejat (2004), which reported a significant impact of the Doman-Delacato method on dictation disorders in dysgraphic students (Hashemi Nejat, 2004). Salimi Teymouri (2007) also demonstrated the effectiveness of the Doman-Delacato neuropsychological method in improving the reading abilities of girls with developmental dyslexia (Salimi Teymoori, 2007).

On the other hand, the results of Bahamin (2002) showed that the Doman-Delacato method was effective in reducing symptoms of hyperactivity and attention deficit but did not impact dyslexia (Bahamin, 2002). This discrepancy may be attributed to differences in the population, cultural factors, and therapeutic approaches.

The results of repeated measures ANOVA examining the differences in mean scores across pre-test, post-test, and follow-up stages for ten subtests (Tables 4-7 to 4-17) revealed that Neurofeedback significantly increased scores in reading skills, word reading, word chains, rhyme tests, picture naming, word comprehension, phoneme deletion, nonwords and pseudowords, letter signs, and category signs ($p < 0.05$).

As stated, the findings confirmed that Neurofeedback is effective in improving the reading skills of children with dyslexia. This finding aligns with studies by Azizi et al. (2017), which showed that Neurofeedback improves visual-motor perception in primary school students with specific learning disorders (Azizi et al., 2017); Ghaemi et al. (2016), which demonstrated that Neurofeedback enhances reading speed in children with learning disorders; Behzadi et al. (2014), which reported that Neurofeedback training increases visual perception and suppresses theta waves (Ghaemi et al., 2016); and Sajjadi et al. (2014), which indicated that Neurofeedback was effective in treating math learning disorders in third-grade children (Sajjadi et al., 2014). Additional supporting evidence includes findings by Sadeghi Naeini et al. (2013), which showed that Neurofeedback improves EEG and balance performance in children with reading disorders (Sadeghi Naeini et al., 2013);

E-ISSN: 3041-9026

Li and Chen (2017), which demonstrated positive effects of Neurofeedback programs on dyslexia (Li & Chen, 2017); and Lee and Jung (2017), which found Neurofeedback effective in treating ADHD symptoms (Lee & Jung, 2017). Hyman (2016) reported the benefits of Neurofeedback in treating learning disorders, and Walker (2006) highlighted its role in improving EEG abnormalities in children with reading disorders (Hyman, 2016). Fernandez et al. (2007) showed that Neurofeedback improved behavior immediately after treatment and altered brainwave patterns two months later (Fernández et al., 2007). However, Norizadeh et al. (2012) reported that Neurofeedback was ineffective in addressing learning disorders combined with ADHD, suggesting cultural and methodological differences as possible explanations (Norizadeh et al., 2012).

Overall, it can be concluded that the human brain is capable of self-healing, with Neurofeedback enabling the brain to relearn self-regulation mechanisms that are crucial for optimal functioning (Demos, 2005). Neurofeedback strengthens these self-regulation mechanisms by providing feedback to the brain on its recent activity and encouraging the brain to adjust and maintain optimal bioelectrical rhythms (Schneider et al., 2019). This process enables individuals to make desired behavioral changes over time.

In summary, the results of this study revealed no significant difference in the effectiveness of the Doman-Delacato method and Neurofeedback in improving the reading skills of children with dyslexia. Both methods demonstrated similar roles in enhancing reading abilities.

This study faced several limitations that should be considered when interpreting the results. The sample size was relatively small, which may restrict the generalizability of the findings. The participants were selected from a specific learning disabilities center, limiting diversity in socio-economic and cultural backgrounds. The study only focused on children aged 10 to 13, excluding younger and older age groups with dyslexia. Additionally, the lack of long-term follow-up limited insights into the sustained effectiveness of the interventions. Finally, potential biases due to reliance on self-reported outcomes and limited consideration of comorbid conditions may have influenced the results.

Future studies should include larger, more diverse samples to enhance generalizability across different populations. Longitudinal studies are recommended to evaluate the long-term impact of the Doman-Delacato and Neurofeedback methods on reading skills and cognitive functions. Researchers could explore the effectiveness of these interventions in combination with other therapeutic methods to determine their synergistic effects. Additionally, examining the neurobiological changes associated with these interventions using advanced imaging techniques would provide more robust evidence. Studies focusing on other age groups and comorbidities, such as ADHD or emotional disorders, would also contribute to a broader understanding of their applicability.

Practitioners and educators should consider integrating Doman-Delacato sensory-motor exercises and Neurofeedback training into intervention programs for children with dyslexia, as both methods have been shown to improve reading skills effectively. Training workshops for therapists, teachers, and parents could enhance the delivery and consistency of these interventions. Schools and learning centers should invest in accessible Neurofeedback equipment and promote sensory-motor activities as part of their curriculum. Policymakers should support funding and resource allocation for evidence-based treatments to help children with learning disorders achieve better academic and social outcomes.

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.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethical 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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E-ISSN: 3041-9026