International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

The Significance of EEG Neurofeedback Method in the Treatment of Specific Learning Disorders

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DOI: https://doi.org/10.55248/gengpi.5.0524.1338

A B S T R A C T

Learning refers to the acquisition of new knowledge or changes in behavior resulting from experiences, which leave traces in the brain. Reading disorder, one of the most common specific learning disorders, is particularly significant as it impacts fundamental learning abilities. This study focuses on utilizing EEG neurofeedback as a treatment method for dyslexia, presented through a case study. The objective is to demonstrate how self-regulation of brain activity, facilitated by EEG neurofeedback, influences the mastery of reading skills.

To evaluate the effects of EEG neurofeedback training on reading proficiency, quantitative electroencephalogram (QEEG) and the three-dimensional reading assessment test by Kostić et al. (1983) were employed. The findings revealed that targeting specific brain areas associated with dyslexia and implementing EEG neurofeedback led to improvements in the child's awareness, concentration, and focused attention. Consequently, reading speed increased, error frequency and types decreased, and comprehension improved. The study demonstrated the effectiveness of protocols targeting the activation of high-frequency beta waves (>13 Hz) and the inhibition of slow waves in treating dyslexia in this case. The child exhibited enhanced organization, attention, and concentration, demonstrated by improved ability to connect letters into words, spell words, and faster transformation from graphemes to phonemes. Additionally, reading speed increased, and other errors diminished following EEG neurofeedback treatment. Combining EEG neurofeedback with speech therapy accelerated the development of reading skills.

Keywords: EEG Neurofeedback, Brain Waves, Learning Difficulties, Dyslexia.

1. Introduction

Learning represents any change that occurs under the influence of an experience, leaving traces in the brain that become part of an individual's knowledge. The knowledge gained through learning enables us to apply what we have learned in various life situations. Discrepancies in learning styles, information processing, and classification systems are defined as learning disabilities (Casey, 2012). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), specific learning disabilities are diagnosed when: a) performance on standardized tests in reading, mathematics, and written expression is significantly below the expected level for a particular age, schooling, and level of intelligence; b) these learning disabilities manifest in learning or in everyday activities requiring reading, writing, and math skills; and c) there is no sensory impairment (Fernandez et al., 2007).

Specific learning disorders may be accompanied by attention deficit hyperactivity disorder (ADHD), attention disorders, developmental coordination disorder, and autism spectrum disorder (ASD). Anxious and depressive disorders may also co-occur with specific learning disorders (APA, 2013).

One of the most common specific learning disorders is reading disorder. Reading disorder is the most significant specific learning disorder because reading forms the foundation of all learning abilities (Ghaemi et al., 2017). The World Federation of Neurologists (WFN) defines dyslexia as a specific developmental disorder in reading proficiency despite normal intelligence, good vision and hearing, systematic training, appropriate motivation, and other favorable educational, psychological, and social conditions (Critchley, 1970; Matejcek, 1968; Vladisavljević, 1991).

In 1994, The Orton Dyslexia Society Research Committee defined dyslexia as one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding, usually reflecting insufficient phonological processing. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalized developmental disability or sensory impairment. Dyslexia is manifest by variable difficulty with different forms of language, often including, in addition to problems with reading, a conspicuous problem with acquiring proficiency in writing and spelling (Lyon, 1995).

Three years later, in 1998, the British Dyslexia Association (BDA) defined dyslexia as a complex neurological condition which is constitutional in origin. The symptoms may affect many areas of learning and function, and may be described as a specific difficulty in reading, spelling and written language. One or more of these areas may be affected. Numeracy, notational skills (music), motor functional and organisational skills may also be involved. However, it is particularly related to mastering written language, although oral language may be affected to some degree (BDA, 1998).

Goswami (2003), Habib (2000), and Ramus et al. (2003) have described three neurocognitive deficits associated with dyslexia: the phonological theory, which refers to a specific deficit in the representation, storage, and retrieval of phonemes; the magnocellular theory, which suggests a deficit in the magnocellular cells of the primary visual area; and the cerebellar theory, which is based on the idea of lesions in the brainstem leading to deficits in automatization. Many testing techniques (fMRI, PET, stimulation techniques, MEG) indicate differences in functioning between individuals with dyslexia and those without dyslexia.

EEG neurofeedback is a technique used for learning to regulate one's own brain functions. This method has been employed worldwide for over 50 years and has been shown in numerous studies to be highly effective in practice with children, adolescents, and adults (Chapin et al., 2014). Neurofeedback is not considered a treatment, but rather a learning process achieved through continuous training, enabling individuals to understand their body and mind, comprehend their reactions in various situations, and learn to control them (Chapin et al., 2014). Using specific devices and EEG technology, information about specific frequencies of brain waves is obtained. Each mental state is associated with characteristic brain wave patterns. EEG neurofeedback involves presenting video animations to the client, which respond to the activation, inhibition, or enhancement of brain waves. The objective of neurofeedback training is to replace established patterns of brain function with new, desired patterns. This process follows established protocols aimed at achieving optimal values, including synchronizing EEG waves and attaining the desired mental state (Collura, 2014; Kopańska, 2022). EEG neurofeedback is a non-invasive method that allows real-time observation of brain activity and consciousness states. Cortical activity is detected through synchronous activation of a large number of pyramidal neurons, which transmit electrical impulses from deeper brain structures via the thalamocortical pathway to the cortex (Collura, 2014; Liechti, 2011).

Delta waves (0.5-3 Hz) are associated with deep sleep and are predominant in infants, also observable during wakefulness. In adults, they prevail during the deepest stages of meditation and non-REM sleep. Delta waves are linked to conditions such as illness, coma, degeneration, death, and defense mechanisms. Specific frequencies within the delta range stimulate the release of growth hormone, vital for body regeneration and the healing process, highlighting the importance of deep, restorative sleep for healing (Marzbani et al., 2016).

Theta waves (4-8 Hz) are slow oscillations primarily occurring during drowsiness, most commonly observed during sleep but also prominent during deep meditation, creativity, relaxation, intuition, and other extrasensory activities. They are associated with memory recall, particularly of unpleasant or painful memories and experiences (Marzbani et al., 2016).

Alpha waves (8-13 Hz) are indicative of relaxed states, unfocused attention, and creative activities. When present in appropriate temporal patterns, alpha waves promote optimal performance, reduce anxiety, enhance the immune system, foster positive thinking, integrate mind and body, boost intuition, introspection, emotional balance, feelings of happiness, inner awareness, and increase serotonin release (Ghaemi et al., 2017).

Sensorimotor rhythm (SMR, 13-15 Hz) waves are so named because they appear in the sensorimotor region and are associated with the inhibition of motor responses. They occur when there is reduced activity in the sensory and motor pathways passing through the thalamus, indicating decreased attention to sensorimotor input and reduced motor response. The individual is awake and ready to react, but the muscles are not tense. Reflexivity before action is increased. Therefore, SMR training is crucial for individuals with impulsivity and hyperactivity issues (Dempster, 2012).

Beta waves (15-32 Hz) are associated with complex mental activities, abstract thinking, wakefulness, focus, emotional stability, mathematical abilities, and increased metabolism through the dominance of beta waves in the brain (Ghaemi et al., 2017).

Gamma waves (32 Hz and higher) are associated with good memory, high-speed information processing, high levels of information processing, and learning complex tasks (Rubik, 2011).

Each individual has a specific pattern of brain activity and frequency associated with symptoms and disorders. According to Ghaemi et al. (2017), the most common differences in brain waves in children with learning disabilities are observed when theta wave activity is higher compared to peers, and the minimum amount of alpha wave activity at rest required for normal brain function in typical children and adults. This difference in theta and alpha wave values shows how important it is to reduce the theta-to-alpha ratio in children with learning disabilities, which can lead to improvements in reading, writing, mathematics, and drawing skills (Ghaemi et al., 2017).

Research has shown that various cortical areas are associated with dyslexia. Angelakis et al. (1999) highlighted the involvement of different cortical regions in specific linguistic skills. F7 is associated with phonological tasks, P3 and P4 are involved in semantic and mathematical abilities, while T5 and T6 are also linked to semantic tasks. Klimesch et al. (2001) found that children with dyslexia fail to desynchronize Beta1 activity during reading tasks in areas related to Broca's area (FC5 responsible for speech production and articulation) and the angular gyrus (CP5, P3 responsible for comprehension, semantics, and mathematical abilities). Simos et al. (2002) used fMRI to examine the processes associated with successful intervention in dyslexia. Consistent with the phonological theory, they found that the left superior temporal gyrus (T3) region is frequently involved after treatment compared to pre-treatment with EEG neurofeedback. Thornton and Carmody (2005) concluded that in children with dyslexia, the left temporal lobe is impaired and that this impairment exists before they learn to read. They also pointed out various deviations from normal functioning, including coherence disturbances. Ackerman and Dykman (1995) and Flynn et al. (1992) found reduced Beta waves in the right parietal and occipital regions during reading in children with dyslexia. Arns et al. (2007) found increased activity in Delta and Theta waves in the frontal and right temporal lobe, increased Beta1 activity in F7, and increased EEG coherence in the frontal, central, and temporal regions. While coherence of Delta and Theta waves was symmetrically increased, coherence of Alpha and Beta waves showed specific distribution in the right temporo-central region.

1.1. Research Objective

The objective of this study is to demonstrate the application of EEG neurofeedback method in the treatment of dyslexia through a case presentation.

The aim of the presentation is to illustrate the treatment of dyslexia using self-brain control and physiological function learning, i.e., how feedback on physiological functions (EEG neurofeedback) affects mastering the reading technique. To achieve the set goals, an initial assessment, implementation of a cycle of 40 treatments, and a final assessment, i.e., evaluation of treatment results, are required.

2. Methodology

A clinical case involving an eight-year-old child diagnosed with reading disorder is presented. The child exhibits no history of mental illness, brain injuries, neurological disorders, serious medical conditions, or familial neurological disorders. Speech therapy treatment employing EEG neurofeedback methodology is outlined.

The objective of the speech therapy intervention was to enhance reading proficiency by improving letter decoding and encoding skills, as well as their integration into words and sentences. Additionally, it aims to facilitate comprehension by mastering the interpretation of punctuation marks that demarcate sentence boundaries. This approach fosters the ability to construct meaning from a sequence of words, enhances vocabulary knowledge, and promotes understanding of word forms and relationships within sentences. Ultimately, it enables the child to transition from letter decoding to comprehension and critical thinking during reading, marking the onset of genuine reading skills. By reducing and eliminating resistance to reading, this intervention enhances learning outcomes, self-awareness, and self-confidence, which are pivotal factors in fostering healthy psychological development in children.

The goal of EEG neurofeedback therapy was to establish control over the individual's brain and physiological functions and to augment the effort and cognitive resources required for reading, while maintaining focus. EEG neurofeedback specifically targets areas of the brain affected by dyslexia, aiming to strengthen neural networks associated with reading skills.

2.1 Methods, Techniques and Instruments

To evaluate the efficacy of EEG neurofeedback training on self-regulation of brain and physiological functions, specifically its impact on mastering reading techniques, the following assessment tools were employed:

Quantitative Electroencephalogram (QEEG): QEEG, also known as "brain mapping," is a diagnostic tool used to measure electrical brain activity by analyzing patterns of brainwaves. It involves a quantitative analysis of EEG data, digitally encoded and subjected to statistical analysis using the Fourier transformation algorithm (Kopańska et al., 2022). QEEG data were obtained by measuring all brainwaves at the central points C3 and C4 according to the international 10-20 system, administered by a certified EEG neurofeedback practitioner using Elmiko, DigiTrack software.

The three-dimensional reading assessment test developed by Kostić et al. (1983) was employed to assess reading proficiency. This test comprises two texts, one tailored for younger students and the other for older students. It evaluates reading speed, error frequency, and comprehension.

3. Results and Discussion

3.1. Initial Assessment

Table 1 shows the values from QEEG at C3 and C4 points before treatment. From the QEEG analysis, high values of slow waves (Delta, Theta, and Alpha) and low percentage representation of fast waves (Beta1 and Beta2), as well as a low percentage representation of sensorimotor rhythm (SMR) waves, can be observed.

Table 1. Values from QEEG at C4 and C3 Points Before Treatment

Waves	**Normal amplitude values (μv)**	**%**	**C3**		**C4**	
			μv	**%**	**μv**	**%**
Delta	up to 20	29	38.49	38.4	36.98	38.3
Theta	up to 10	21	24.37	25.0	24.03	24.9
Alpha	up to 10	15	12.90	13.2	12.66	13.7
SMR	5-10	12	7.18	7.4	7.29	7.2

Beta 1	5-10	9	7.71	7.9	7.57	7.8
Beta 2	5-10	9	8.01	8.2	8.16	8.9

Table 2 displays the Theta/SMR and Theta/Beta ratios before treatment. The values of the Theta/SMR ratio indicate the strength of Theta waves relative to SMR and suggest emotional difficulties and challenges in controlling and regulating emotions. A high SMR/Theta ratio indicates pronounced emotional issues, impulsivity, and poor emotional control. The values of the Theta/Beta ratio indicate the frequency of slow waves in the brain's bioelectrical activity and suggest difficulties in concentration. The Theta/Beta ratio is associated with attention control. Increased Theta/Beta ratio is often observed in ADHD.

Table 2. Display of Theta/SMR and Theta/Beta ratios before treatment

Ratio	Typical values	C3	C4
Theta/SMR	1-2	3.39	3.30
Theta/Beta	1-2 for adults 2-3 for children	3.16	3.18

Table 3 presents the results obtained from the assessment of reading abilities. From the table, it can be observed that the child read the short text, consisting of 5 complex sentences, in 25 minutes, while making a large number of errors. Out of a total of 14 possible errors evaluated, the child made 13. Dominant errors in reading included difficulties in connecting two letters, omission of letters in words, repetition of initial letters or syllables, pauses in the middle of words, difficulty in reading multisyllabic words, substitutions, inversions, metathesis, disrupted reading tempo, difficulties in transitioning from line to line, inappropriate intonation, failure to observe punctuation marks, and disruption in logical reading with appropriate intonation and accentuation. The results of the comprehension assessment showed that the child did not understand the content. Out of a total of 10 facts that were to be recounted, the child mentioned only 1 fact (a snowy day).

Table 3. Presentation of results from the Three-Dimensional Reading Test before EEG neurofeedback treatment

Test	Type of Reading Assessment	Results
T1	Speed	25 min
T2	Errors	13
T3	Comprehension	1

3.2. Treatment Cycle

Table 4 shows the protocols, points, and frequency ranges used during the treatment.

Table 4. Presentation of protocols, points, and frequency ranges used during the treatment

Location	Protocol	Frequency Range	Treatment	Duration
		12-15 Hz	↑SMR	
C4	SMR/Theta	4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
	Beta/Theta	15-20 Hz	↑Beta1	
C3		4-8 Hz	↓Theta	10 sessions
		20-34 Hz	↓Beta2	
	SMR/Theta	12-15 Hz	↑SMR	
C4		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
	Beta/Theta	15-20 Hz	↑Beta1	
P3		4-8 Hz	↓Theta	5 sessions
		20-34 Hz	↓Beta2	

T5	Beta/Theta	15-20 Hz	↑Beta1	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
P4	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
C4	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
C3	Beta/Theta	15-20 Hz	↑Beta1	
		4-8 Hz	↓Theta	10 sessions
		20-34 Hz	↓Beta2	
C4	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
F8	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
F7	Beta/Theta	15-20 Hz	↑Beta1	
		4-8 Hz	↓Theta	5 sessions
		20-34 Hz	↓Beta2	
F8	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
C4	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	
C3	Beta/Theta	15-20 Hz	↑Beta1	
		4-8 Hz	↓Theta	10 sessions
		20-34 Hz	↓Beta2	
C4	SMR/Theta	12-15 Hz	↑SMR	
		4-8 Hz	↓Theta	
		20-34 Hz	↓Beta2	

The EEG neurofeedback treatment began at the central line of points C4 and C3. The central line is the safest place for training and is associated with many neural connections with the interior of the brain (thalamus). This training offers great opportunities and improves many functions. At point C4, the SMR/Theta protocol was used, where the values of SMR waves were increased at a frequency of 12-15 Hz, the values of Theta waves were decreased at a frequency of 4-8 Hz, and the values of Beta2 waves were also decreased at a frequency of 20-34 Hz. At point C3, the Beta/Theta protocol was implemented, where the values of Beta1 waves were increased at a frequency of 15-20 Hz, the values of Theta waves were decreased at a frequency of 4-8 Hz, and the values of Beta2 waves were also decreased at a frequency of 20-34 Hz. The aim of the C4-C3 protocol is to achieve sensorimotor integration.

After 10 sessions, work began at points P3, T5, and P4. At point P3, the Beta/Theta protocol was applied, where the values of Beta1 waves were increased at a frequency of 15-20 Hz, the values of Theta waves were decreased at a frequency of 4-8 Hz, and the values of Beta2 waves were also decreased at a frequency of 20-34 Hz. The goal of this protocol is to improve mathematical abilities, reading, perception, practice, verbal reasoning, understanding, and organizational skills. At point T5, the Beta/Theta protocol was also applied, aiming to improve logical verbal comprehension, word recognition, formation of mental representations of words, processing of sounds, rapid transformation from graphemes to phonemes, and short-term memory. At point P4, the SMR/Theta protocol was implemented, aiming for relaxation, physical calming, multimodal interaction, improvement of nonverbal understanding, visual processing, and spatial orientation. After 5 sessions, work resumed at points C4 and C3. The goal of the repeated SMR/Theta and Beta/Theta protocols is integration and stabilization of previously learned skills.

After 10 sessions, work commenced at points F8 and F7. At point F8, the SMR/Theta protocol was applied to improve working memory, visuospatial orientation, attention, emotion processing and expression, and mood regulation. At point F7, the Beta/Theta protocol was implemented to enhance verbal expression, short-term semantic memory (word recall), speech fluency, visual and auditory working memory, mood regulation, improvement of selective attention, and stimulation of Broca's area. After 5 sessions, work resumed at points C4 and C3 again, aiming for integration and stabilization of previously learned skills.

Concurrently with the EEG neurofeedback treatment, speech therapy was conducted, with a focus on acquiring pre-reading skills using the analytical-synthetic method, syllabic reading, and conscious synthesis of development.

3.3. Final Assessment

Table 5 presents the values of QEEG in points C4 and C3 before and after the treatment. From the QEEG analysis, a decrease in Delta waves from 38.49 μV to 37.82 μV, followed by a decrease in Theta waves from 24.37 μV to 19.6 μV, and a slight decrease in Alpha waves from 12.90 μV to 12.14 μV can be observed. Additionally, there is an increased percentage of Beta1 waves from 7.9% to 9.9% and of SMR waves from 7.4% to 8.1%. The child's awareness is increased, concentration and focused attention are improved. The child becomes more interested, attentive, and learns better.

Table 5. Display of QEEG values at points C4 and C3 before and after treatment

Waves	**Normal amplitude values (in μv)**	**%**	**Before the treatment**				**After the treatment**			
			C3		**C4**		**C3**		**C4**	
			μv	**%**	**μv**	**%**	**μv**	**%**	**μv**	**%**
Delta	up to 20	29	38.49	38.4	36.98	38.3	37.82	37.1	38.75	38.2
Theta	up to 10	21	24.37	25.0	24.03	24.9	19.02	19.6	19.25	19.2
Alpha	up to 10	15	12.90	13.2	12.66	13.7	12.14	12.5	12.56	12.7
SMR	5-10	12	7.18	7.4	7.29	7.2	7.86	8.1	8.22	8.3
Beta 1	5-10	9	7.71	7.9	7.57	7.8	9.58	9.9	9.79	9.9
Beta 2	5-10	9	8.01	8.2	8.16	8.9	10.38	10.7	10.37	10.5

Table 6 shows the Theta/SMR and Theta/Beta ratios before and after the treatment. The values of these coefficients gradually normalize, indicating an improvement in concentration and greater emotional self-control.

Table 6. Presentation of the Theta/SMR and Theta/Beta ratios before and after the treatment

Ratio	**Typical values**	**Before the treatment**		**After the treatment**	
		C3	**C4**	**C3**	**C4**
Theta/SMR	1-2	3.39	3.30	2.42	2.36
Theta/Beta	1-2 for adults 2-3 for children	3.16	3.18	1.98	1.97

Table 7 shows the results obtained from the assessment of reading abilities before and after the EEG neurofeedback treatment. From the table, it can be seen that the child, who previously took 25 minutes to read a short text composed of 5 complex sentences, can now read it in 10 minutes after the treatment. Before the treatment, the child made 13 errors out of a possible 14, which have now reduced to 7. Some of the remaining errors include longer pauses at the beginning of words, difficulties in reading complex words, substitutions, inversions, metatheses, inappropriate intonation, and ignoring punctuation marks. The results of the comprehension assessment before the neurofeedback treatment showed that the child did not understand the content.

Out of a total of 10 facts that the child was supposed to recall, they only recalled 1 fact. After the treatment, there is improvement in this aspect as well. The child managed to recall 3 facts (one snowy day, on the mountain, snow) during the retelling.

Table 7. Results of the Three-Dimensional Reading Test before and after EEG neurofeedback treatment

Test	Type of Reading Assessment	Results before the treatment	Results after the treatment
T1	Speed	25 min	10 min
T2	Errors	13	7
T3	Comprehension	1	3

3.4. Discussion

The aim of this study was is demonstrate how establishing control over one's own brain and physiological functions affects reading improvement, specifically strengthening the child's ability to stay focused on reading. The results showed that by targeting the areas of the brain that influence dyslexia and conducting EEG neurofeedback treatment in those areas, the child's awareness, concentration, and focused attention improved. Consequently, reading speed increased, the number and type of errors decreased, and the child became more aware of the content being read. The results indicated that the ratio between Theta/Beta and Theta/SMR brainwaves is crucial for reading improvement. Decreasing the Theta/Beta ratio improves concentration and attention control. Similarly, reducing the Theta/SMR ratio enhances emotional regulation, indirectly influencing reading improvement.

Similar results were obtained by Walker et al. (2006), who treated 12 dyslexic subjects. After conducting QEEG analysis, all abnormalities that were significantly increased decreased, while all abnormalities that were significantly decreased increased. Increasing activity in the 16-18Hz range in the T3 area (left mid-temporal area) was found to be beneficial for improving reading speed and comprehension. This combined approach yielded positive results in all 12 subjects after 30-35 sessions (Walker et al., 2006).

According to Ali Nazari et al. (2012), EEG neurofeedback treatment is an effective intervention for regulating EEG abnormalities and improving behavioral problems in children with reading disorders. They examined reading ability and phonological awareness in 6 children aged 8 to 10 years, applying 30 sessions of neurofeedback treatment, followed by monitoring for two months after treatment completion. The results showed significant improvement in phonological awareness and reading ability. EEG analysis did not reveal significant changes in the values of frontal brainwaves (Delta, Theta, and Beta), but rather normalization of coherence in Theta brainwaves in the T3-T4, Delta brainwaves in Cz-Fz, and Beta brainwaves in Cz-Fz, Cz-Pz, and Cz-C4. These significant changes in coherence suggest the possibility of integrating sensory and motor areas, explaining the improvement in reading ability and phonological awareness (Ali Nazari et al., 2012).

Breteler et al. (2010) found only a few improvements that did not differ significantly from the control group in many aspects but observed significant improvements in spelling. They suggest that any dyslexia training involving neurofeedback should be based on individualized assessments using QEEG analyses since there may be different subtypes of dyslexia, and neurofeedback can make an important contribution to dyslexia treatment.

The results of this study have practical and clinical implications, providing information for better understanding dyslexia and the possibilities of incorporating EEG neurofeedback into its treatment. They also have scientific implications as they open up possibilities for new discoveries and trends in this area, promoting the idea for future research.

4. Conclusion

Reading is one of the fundamental skills for exchanging information in society. It provides access to new information and knowledge, making it essential in both the educational system and personal development. Proper acquisition of reading requires many linguistic and other "non-linguistic" skills and abilities, some of which are acquired even before formal education begins. Difficulties in reading significantly impact everyday life and a person's education. Children with reading difficulties manifest numerous language deficits, such as a lack of ability to discriminate between spoken sounds, difficulty blending sounds into words, naming objects, letters, numbers, and colors, especially if it needs to be done quickly. They also have deficits in processing and using semantic and syntactic aspects of language, difficulties with complex language structures, as well as phonological difficulties.

Effective treatment for children with reading disorders includes exercises to develop phonological awareness, fluent reading, vocabulary development, and comprehension. The selection of the best techniques and methods should correspond to the child's weaknesses and strengths. EEG neurofeedback therapy can make a significant contribution to dyslexia treatment. EEG parameters reflect specific brain dysfunctions of the disorder. The child can cognitively alter the brain's functioning, and these changes are associated with increases or decreases in these parameters. The brain can memorize the new working mode and retain it for a longer time, not only in clinical conditions but also in other contexts. EEG rhythms can be sensitive indicators of brain activity during various physiological tasks. In some disorders, normal EEG rhythm mechanisms may be disrupted in the form of rhythm slowing or decreased EEG frequency. These disruptions can occur in various unusual places in the brain. EEG neurofeedback treatment must be strictly individualized. Protocols for activating high-frequency Beta waves (> 13 Hz) and protocols for inhibiting slow waves have been shown to be effective in treating dyslexia in this particular case. The child became more organized, attentive, and concentrated. They began connecting letters into words, spelling words, and the transformation from graphemes to phonemes became faster. Reading speed increased, and other errors present before EEG neurofeedback treatment began to decrease. The results of this study show that by combining EEG neurofeedback treatment with speech therapy, reading competence is strengthened more quickly.

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