Original Article

Individualized Neurofeedback Training May Help Achieve Long-Term Improvement of Working Memory in Children With ADHD

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Abstract

Background. Children with attention deficit hyperactivity disorder (ADHD) may suffer from working memory deficits, which can adversely affect their academic performance. Neurofeedback training may enhance working memory and provide a solution to this problem. *Aim*. To investigate the effect of frequency-neurofeedback on working memory in children with ADHD and to check if the effect is long-lasting. *Method*. Forty-eight children with ADHD (aged 6-12 years) were randomly assigned either to a neurofeedback with training parameters chosen to take into account each child's peak alpha frequency (PAF) or to a waiting list control group. Each trained child underwent 19-channel electroencephalography (EEG). All children had average intelligence and none were receiving treatment, such as medications, for ADHD. Prior to the training, MOXO and n-back tests were performed. Next, neurofeedback training sessions with frequency bands for theta and beta ranges determined using each child's PAF were carried out for 10 weeks. Training parameters were set to increase amplitudes in the low beta range and to decrease amplitudes in the theta and high beta frequency ranges. The n-back test was performed again right after the training and then a year later. *Results*. During the first n-back test, children from both groups responded correctly to more than 43% of the stimuli. During the second test, children from the waiting list responded correctly to an average of 49% of the stimuli, while children who underwent the neurofeedback training were correct, on average, 69% of the time (significant difference, $P < .001$). During the third n-back test a year later, children from the waiting list responded correctly to 53% of the stimuli, while those who underwent the neurofeedback training responded correctly to nearly 71%. *Conclusion*. This study found a statistically significant improvement in a measure of working memory in children who did 10 to 12 sessions of neurofeedback training with training frequency ranges for theta and beta defined according to each child's PAF. The beneficial effects were still present a year after training.

Keywords

neurofeedback, EEG, ADHD, working memory, peak alpha frequency, follow-up

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Introduction

Attention deficit hyperactivity disorder (ADHD) is the most common mental disorder diagnosed in children. It is believed that it affects 5% of the population, regardless of the geographical region.[1] People with ADHD have trouble paying attention, are easily distracted, are hyperactive, are impulsive, and have problems with social skills. Many researchers have noticed cognitive capacity deficits in children with ADHD. In Barkley's ADHD model, the problems concern inhibition of negative reactions, regulation of motivation, motor control, and working memory.[2] A meta-analysis involving over 6700 children showed deficits in response inhibition, vigilance, planning, and working memory.[3]

In general, working memory is defined as a system that temporarily stores and processes information.[4-6] Baddeley and Logie[7] distinguish the following working memory components: the phonological loop, the visuospatial sketchpad, the episodic buffer, and the central executive. In Baddeley's model, the superior role is attributed to the central executive. It is responsible for focusing attention on a single source of information, and at the same time blocking disruptive information and providing access to information stored in long-term memory.

Engle et al,[5] on the other hand, put stronger emphasis on the connection between memory and attention. They introduced the notion of controlled attention.[5] The bigger the memory capacity, the more resources can be allocated to control the

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performance of the task and to block the distractions. Controlled attention is required in the event of response competition, when there is high risk of error or when distractions are present. Controlled attention corresponds to Baddeley's central executive system to some extent. According to Engle et al,[5] stimuli can be stored in various codes, such as visual or phonological. The authors also suggest that controlled attention is closely related to the fluid intelligence level (Gf factor) in terms of paying attention and shifting attention to new information. Impaired functioning of the central executive and deficits in the phonological loop and the visuospatial sketchpad are likely to disrupt the basic learning processes. These also disrupt the process of gradual skill and knowledge acquisition in education facilities, which strictly depends on working memory.[8]

The relationship between the functioning of working memory and one's academic performance is clearly documented.[9,10] It can indicate the ADHD-related developmental delay of the prefrontal cerebral cortex, which is responsible for working memory, attention, and motor planning.[11]

For this reason, various ways to improve the functioning of working memory are being considered, with the aim to improve academic performance.[12] One such methodology may be EEG biofeedback, also termed neurofeedback. It builds on almost 40 years of experience in EEG signal analysis in children with ADHD. In this field, the clinical usefulness of neuroimaging markers is still at a very early stage. However, certain findings seem promising.[13]

Neurofeedback therapy is more and more often recommended for children with ADHD, and its effectiveness was evaluated in meta-analyses multiple times. The effects of neurofeedback therapy can be significant and distinctive. The results show improvement, especially in the area of attention disorders, and, to a lesser extent, in impulsiveness and hyperactivity.[14,15]

Lofthouse et al[16] consider neurofeedback therapy to have level 3 efficacy (probably efficacious) in treating children with ADHD. On the other hand, analysis by van Doren et al[17] emphasizes the longevity of the improvement, with therapy effects lasting for at least 6 months. There are also studies that do not show improvement in cognitive functioning using neurofeedback in people with ADHD.[18-20] What is common in such studies is that their results are based on fixed frequency ranges that, in addition, vary from study to study. In their meta-analysis, Cortese et al[21] did not confirm the efficacy of neurofeedback therapy in treating ADHD. These discrepancies probably result from different study inclusion criteria and different training protocols.

Using individually determined frequency ranges seems appropriate, especially considering the fact that in children the EEG activity changes significantly with age.[22] It seems surprising that only a few authors individualize EEG-neurofeedback training based on the peak alpha frequency (PAF).[23,24]

There is no single pattern found in the EEG records of children with ADHD. It is posited that there are several subtypes of ADHD that can be distinguished based on EEG patterns. The frontal slow (frontal theta), low alpha peak frequency (PAF $<$ 9 Hz), and low-voltage EEG (EEG power lowered in all frequency rates) subtypes are characteristic for children with ADHD.[25] Also, there are other classifications suggested; for instance, a subtype with delayed cortex maturation, a subtype with insufficient cortex activation, and a subtype with excess beta activity. In addition, there also exists a subgroup with excess alpha activity.[26]

The aim of our study was to check, if a small number of neurofeedback sessions (10-12) planned with the PAF in mind could objectively affect the functioning of working memory in children with ADHD. In Poland, the effectiveness of such training was evaluated by Pinkowicka.[27] However, she used fixed EEG frequency ranges.[27]

We were also interested in analyzing the longevity of the therapy's effect.

Materials and Methods

Participants

The study involved 48 children (37 boys and 11 girls) aged 6 to 12 years. The children were selected by experienced employees of a psychological and pedagogical counseling center; the selection was based on clinical interview, observation, and diagnosis made by psychiatrists. Every child met the *DSM-5* (*Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition) and ICD-10 (International Classification of Diseases, Tenth Revision) ADHD criteria. Children neither participated in any kind of therapy aimed at improving concentration nor took any medications to improve it.

The study exclusion criteria were as follows: intellectual disability (normal intellectual capacity was confirmed by an up-to-date examination performed in a psychological and pedagogical counseling center), chronic somatic diseases, long-term medication intake, and comorbid psychiatric diagnosis such as depression, restlessness, anxiety, psychosis, and so on. The participants were randomly divided into 2 groups of equal size (treatment and control group), 24 children each[28] (Table 1). All participants attended mainstream education schools. Every participant agreed to partake in the study. Children's parents expressed informed consent to participate in the study and for the obtained data to be used for scientific purposes.

Course of the Study

Children from both the treatment and the control group performed the n-back test, described below, as the primary outcome measure for working memory. Children who were randomly chosen for neurofeedback training underwent an eyes-open and eyes-closed EEG examination (19 electrodes using the standard 10-20 electrode placement system). In order to exclude any records showing paroxysmal discharges, the records were qualitatively evaluated by a neurologist specializing in electroencephalography. Next, the treatment group was administered the MOXO test, which is described below. The results of the attention test are shown in Table 2. For the next ten

Table 1. Descriptive Statistics of the Studied Groups.

	Treatment Group (n = 24)	Control Group (n = 24)	*P*
Boys, n (%)	20 (83)	18 (75)	.488
Girls, n (%)	4 (17)	6 (25)	
Age, years, mean ± SD	8.84 ± 1.40	8.61 ± 1.44	.724
IQ, mean ± SD	101.96 ± 13.57	100.6 ± 6.89	.657

Table 2. Distribution of Attention Criteria in the Treatment Group (MOXO Test) and n-Back Test Performance.

z-Score (MOXO Test)	Attention (MOXO Test), n = 24	% Correct Responses (n-Back Test)
$z \geq 0$ (high norm)	3	69.10
$0 < z < -0.825$ (middle norm)	4	64.55
$-0.825 < z < -1.65$ (low norm)	2	37.91
$-1.65 < z < -1.95$	2	39.23
$-1.95 < z < -2{,}25$	2	34.40
$-2.25 < z < -2.55$	2	27.12
$z \leq -2.55$	9	36.03

weeks children trained according to each child's individualized neurofeedback protocol. Children from both the treatment and the control group performed the n-back test once again at the end of the 10 weeks of training done with the treatment group. The n-back test was performed for the third time a year later. Twelve children (9 from the treatment group and 3 from the control group) did not register for the last examination. As a reason, their parents reported a lack of time. When asked, they did not report any additional health problems with children.

The MOXO Test

The computer-based MOXO-d-CPT test[29] is used to help diagnose ADHD. The advantage of using a computerized continuous performance test is that it provides an objective behavioral measure that is largely independent of the influence of the person making the diagnosis of ADHD.

The participant is required to maintain focus on a constant stream of stimuli and respond to a previously specified target. The test includes visual stimuli with visual and aural distractors. There are 8 stages. Each stage consists of 53 tasks and lasts for 115 seconds. The total test duration is 15 minutes. In each trial a stimulus (target or distraction) is displayed in the center of the computer screen for 0.5 or 3 seconds. Next, a blank screen is displayed for the same amount of time. This method allows for measuring the execution time, as well as reaction and accuracy. Children are instructed to respond to the target stimulus as quickly as possible by pressing the space bar once. They are also instructed not to respond to other stimuli or press other keys. Both the target stimuli and distractions are animated images without any letters or digits (so as to prevent potential disruptions caused by dyslexia or dyscalculia).

The MOXO test evaluates 4 factors: attention (the number of correct responses to the target stimulus), response time (average speed of response to target stimuli), impulsiveness (the number of incorrect responses to a distraction), and hyperactivity (the total number of all unnecessary responses that are not identified as impulsive responses, such as double or multiple hits of the space bar or pressing a key other than the space bar).

The test was scored according to the norms for age and sex and the normed scores for each factor were combined to provide a single z-score to indicate the overall deviation from the mean established for the normative group of same age children. The z-score deviations were then categorized into 4 levels of severity.

The least severe scores, level 1, were better than mid-average with z-scores >0. The second level was slightly below average with z-scores between 0 and -0.825. The third level was low normal range with z-scores between -0.825 and -1.65. The fourth level indicated an abnormal degree of problems with attention, indicated by z-scores that were more negative than -1.65. (Recall that z-scores are standard scores with a mean of 0 and a standard deviation of 1, so 2/3 of scores fall between -1 and $+1$ and 95% of scores fall between -2 and $+2$.)

The n-Back Test

This test evaluates memory functioning during simultaneous storing and processing of information. Thus, it is one of the most popular methods used in working memory studies. The performance quality of the test is also connected with fluid intelligence.[30]

The basic variable in the n-back task is the performance quality. The errors made are also analyzed. The first type of error is not responding to a presented stimulus. This error indicates attention disorders. The second type of error is responding to the presented element even though it differs from the previous element. Such error may indicate impulsiveness.[31]

In order to prepare the n-back test for our study, we used an open-source application called Brain Workshop 4.8.1 (developed by Paul Hoskinson and Jonathan Toomim).[32] Brain Workshop provides a number of task customization options.

In order to evaluate the visuospatial sketchpad and the phonological loop, we used a dual n-back test variant, which includes both visual and aural stimuli.[33] During the test, a participant is shown a board that is divided into 9 fields. A square is displayed in one of the fields at a time, and simultaneously a single syllable is played. The participant's task is to determine whether the displayed position of the square and/or the syllable played matches the previously presented element(s). The participant tracks the events sequence, memorizes the visual and aural stimuli, and after having identified them, makes a decision by pressing a relevant keyboard key (A = same field as previously displayed, L = same syllable as previously played). For the purpose of the study we set the number of tasks to 100, set 1-back movement, and the stimuli were presented every 4.5 seconds. We counted the number of correct responses to stimuli that required such a response. It was decided to use Polish syllables instead of recordings of the English alphabet sounds. Such decision was made based on pilot tests.

Neurofeedback Training

The training was performed using a 24-channel Deymed Truscan device with a 1024 per second sampling rate. The training lasted 10 weeks. During this period each child participated in at least 10 to 12 sessions. Each session lasted for 45 minutes and involved about 30 minutes of training. The training was performed with eyes open. It was supervised by a professional neurofeedback therapist who is a certified teacher and also a psychologist.

Before the experiment, we took care of providing identical training conditions: the same room, lighting, audio system, therapy time, and experiment supervisor. The therapist established a friendly relationship with the child and explained the aim of the training. The children were instructed to try self-regulation.

The neurofeedback intervention was described according to the description method proposed by Marzabani et al.[34] Electrodes placement was according to the 10-20 system,[35] the electrode impedance was kept below 5 kohms. We used a 50-Hz line filter, a high-pass filter and a low-pass filter (1 Hz and 40 Hz, respectively). The EEG data were derived from an active electrode placed on the scalp. With the C3 electrode active the beta1 rhythm was amplified (3 three-minute-long rounds), while with the C4 electrode active the low beta rhythm was amplified (7 three-minute-long rounds). In both cases the beta2 and theta rhythms were inhibited.[36] We used frequency/power neurofeedback. The reference electrode was placed on the contralateral ear lobe using a referential ("unipolar") montage, the ground electrode was placed on the ipsilateral ear lobe.

The individual frequency ranges were determined based on the subject's peak alpha frequency. Frequency showing the highest spectral amplitude within 7 to 15 Hz band was identified as the PAF. Lower and upper limits of the alpha band were determined where eyes open curve crossed the eyes closed curve closest to the PAF. Theta and beta bands were defined between 3 Hz and lower alpha limit, as well as between upper alpha limit and 20 Hz, respectively (Figure 1.).[23] From the frequency band we have isolated the low beta waves in the range from the upper alpha frequency to the upper alpha frequency +3 Hz, and beta1 waves in the range from the upper frequency of low beta to 20 Hz. Frequency above 20 Hz was considered high beta (beta2). Sample data derived from one of the participants:

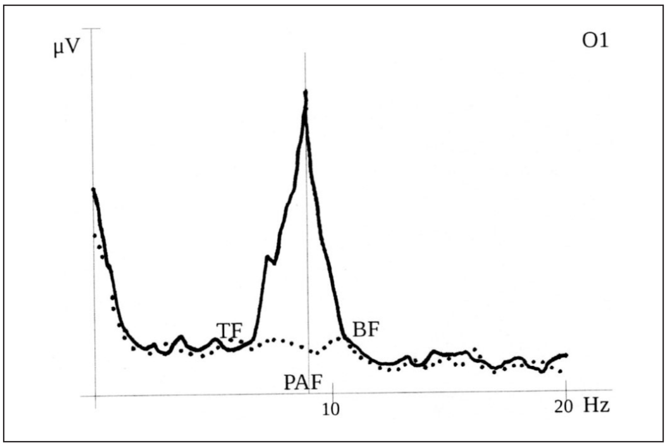

Figure 1. EEG spectral power in eyes-closed (solid line) and eyes-open (dotted line) conditions. PAF, TF, and BF represent peak alpha frequency, theta and beta transition frequencies, respectively.

> PAF 9 Hz (theta 3-6.5 Hz, alpha 6.5-10.5 Hz, low beta 10.5-13.5 Hz, beta1 13.5-20 Hz, beta2 20-35 Hz).

We used adaptive thresholding set to reward the participant in 70% of the cases.[37,38] We applied a modification similar to the one described by Dhindsa et al.[39] If for 30 seconds a given participant received rewards more often than for 70% of time, we raised the threshold by 10%. If during the whole 3-minute-long round they did not receive rewards for at least 70% of time, we lowered the threshold by 10% in the subsequent round. Thresholding was done manually by a trainer who was carefully watching the subject's performance. We used visual and auditory feedback simultaneously. After each training session we asked about adverse effects.

Statistics

The statistical analyses were performed using the IBM SPSS Statistics 23 software. The variable distribution normality was confirmed by the Kolmogorov-Smirnov test. We conducted a t test for independent groups, the U test, and a unidimensional variance analysis (ANOVA). The effect size based on average values was verified using Cohen's d. We assumed a statistically significant difference to be $P < .05$. We assumed an average effect size to be Cohen's $d > 0.4$, and large effect size to be Cohen's $d > 0.8$.

Table 3. *T* Test in Independent Groups and Analysis of Variances in 3 Measurements (Treatment Group and Control Group): The Average (M) of Correct Responses in n-Back Test.

	Group	N	Mean	SD	*t*	*df*	Cohen's *d*	*F*	η^2
I measurement	Treatment	24	30.958	9.967	1.10	46	0.32	1.21	0.03
	Control	24	27.583	11.263					
II measurement	Treatment	24	39.917	11.699	2.33*	46	0.67	5.42*	0.10
	Control	24	32.833	9.239					
III measurement	Treatment	15	45.933	11.171	3.62***	34	1.22	13.13***	0.28
	Control	21	34.667	7.512					

*$P < .05$, **$P < .01$, ***$P < .001$.

Table 4. *U* Tests for 3 Measurements (Coefficient, Treatment Group 1 and Control Group 2): Percentage of Correct Responses in n-Back Test.

	Group	N	% Correct Responses	Total Responses	Test *U*obl
I measurement	1	24	45.81	1622	0.81
	2	24	43.96	1506	
II measurement	1	24	69.04	1473	7.19***
	2	24	49.40	1595	
III measurement	1	15	70.88	972	7.49***
	2	21	53.22	1368	

*$P < .05$, **$P < .01$, ***$P < .001$.

Results

Considering both the treatment and the control group there was no significant difference in the n-back test performance quality at the beginning of our study (the Cohen's *d* value indicates a small difference between the averages, also the eta square (η^2) shows that the difference is small). However, the difference between the 2 groups becomes visible when we analyze the second (average difference, Cohen's $d = 0.67$; $\eta^2 = 0.10$) and the third measurement (significant difference, Cohen's $d = 1.22$; $\eta^2 = 0.28$; Table 3.).

These differences become even more evident, if we consider the percentage of correct responses. A significant difference ($P < .001$) was noticed when we compared the n-back test performance in the second trial, that is, when the treatment group had already undergone 10 neurofeedback sessions. In the control group the percentage of correct responses increased by 6.4%, and task performance quality increased by 14.3%. This change may result from getting accustomed to a new task. In the neurofeedback-trained group the percentage of correct responses increased by 19.2%, and task performance quality increased by 41.9%. A significant difference ($P < .001$) is also visible when we compare the n-back test performance in the third trial, that is, a year after the treatment group underwent the last EEG-biofeedback session. In the control group the percentage of correct responses was higher by 9.3% compared with the first measurement. This change may result from the maturation of cerebral functioning that might have occurred during this period. In the EEG-biofeedback-trained group the percentage of correct responses was higher by 25% compared with the first measurement, and by 5.9% compared with results obtained after a full series of training sessions. The results are shown in Table 4.

Only one child presented worse results than after the initial measurement. Proportionally, the training was mostly beneficial for children whose biggest difficulty was focusing attention. The correlation between the initial result of the n-back test and the improvement after the training was −0.541.

In order to compare the MOXO test results with the Brain Workshop application results, we checked the n-back test performance correctness for individual standard deviation ranges in the MOXO scale results. Considering the attention scale in the MOXO test, we can see a trend of better n-back test performance in children with smaller *z*-score deviations; that is, the less severe the ADHD symptoms, the better their performance. The scores divided well into 2 groups; namely, the 8 subjects who had *z*-scores no lower than −0.825 had 65% to 69% correct responses, whereas the subjects who had scores that were lower (more negative) than −0.825 had correct responses only 27% to 39% of the time (Table 2).

Discussion

There are many obstacles when evaluating the efficacy of the use of neurofeedback to treat symptoms of ADHD. The risk of subjective evaluation by the parent/teacher,[3,40] the theta/beta ratio probably requires reconceptualization,[41] the presence of several types of electrophysiological patterns in ADHD.[25] Also ethical doubts regarding the use of sham biofeedback and the ease of determining it by the trainee.[42]

We tried to minimize these factors. Computerized tests of attention add an objective behavioral measure to the subjective measures used when diagnosing ADHD. The training frequencies were individualized for each trainee after determining their peak individual alpha frequency. Working memory was chosen as the outcome measure because its improvement has a substantial positive impact on academic performance. The efficacy of training was evaluated by comparing performance of the trained subjects on a working memory task, the n-back test, with the performance of a wait-list control group on the same test. The groups did not differ significantly in terms of age, intelligence, or initial performance on the n-back test.

We decided not to use sham biofeedback in children. In 1976, Lubar and Shouse[43,44] showed that amplifying the theta band can intensify ADHD symptoms. We wanted to avoid such risk thus refrained from using sham biofeedback. Although there is not much being said about adverse effects of improper therapy, these have to be taken into account when preparing studies.[45,46]

In case of sham feedback such studies were properly conducted only by a handful of research teams.[47]

The n-back task, which included the visual sketchpad and the phonological loop turned out to be difficult for young children with ADHD. Initially, they responded incorrectly to more than half of the stimuli. After 10 EEG-neurofeedback training sessions on average 2/3 of the stimuli were responded to correctly. Relevant data can be obtained 1 year after the training. Performance quality rises by a few percentage points in both the treatment and the control group. This probably results from the maturation of brain's bioelectrical activity. An average of 70% of correct responses to the stimuli seems a convincing proof showing that it is possible to achieve a long-term improvement of working memory thanks to the neurofeedback therapy.

The observed highest improvement in children who initially had the biggest problem with the task may be a starting point for a discussion concerning the proper amount of neurofeedback training sessions. We may be under the impression that after the period of relatively fast improvement the subsequent training sessions are not that effective. However, we believe that the improvement is still present but takes place at a slower pace.

Our choice of the amount and frequency of training sessions (10-12 sessions done once a week) was determined by the fact that in Poland, in certain circumstances, such set of training sessions could be free of charge for children with ADHD. Though the existing literature concerning neurofeedback training in children with ADHD has suggested that several dozen (usually 40) training sessions are required, our results suggest that improvement in working memory can be seen after 10 to 15 sessions.

Further evidence that results can be obtained with fewer sessions comes from a triple-blind, randomized, controlled trial by Schönenberg et al[19] that involved adults with ADHD. By analyzing their work, one can notice that the highest effectiveness of the neurofeedback therapy is present during the first fifteen training sessions (in the sham neurofeedback group the first 15 out of 30 training sessions were performed in the same manner as in the real neurofeedback training group). In adults with ADHD, the effectiveness of neurofeedback training in that study was equal to that of cognitive behavior therapy.[19]

Other authors studied the influence of the neurofeedback training on working memory in ADHD. A research team under the supervision of Vollebregt compared neurofeedback and sham feedback in terms of improvement in auditory working memory in children with ADHD and found no difference.[20] Wang[48] obtained quite different results, showing a significant improvement in working memory after 10 training sessions. We managed to find only one study that evaluates the longevity of the effect of the neurofeedback therapy on working memory in ADHD children, and it does not show any additional effects of the therapy after a year of terminating the intervention.[18]

Our findings seem optimistic compared with the ones above. Comparing the very positive results of our study to the results found in other studies, relevant factors might include: We chose different points to place the electrodes, we monitored according to a specific task difficulty algorithm, finally, we measured the peak individual alpha frequency (PAF) for each subject and took those individual differences into consideration.

We think the last point seems particularly important. Promoting a "fixed" beta1 frequency range (12-16 Hz) in children who have a PAF of 8 Hz seems inappropriate. Bazanova et al[23] also found that neurofeedback is more effective when frequency ranges for training are set by taking the individual's dominant frequency (PAF) into account.

Conclusion

The findings of our research support the conclusion that neurofeedback training improves working memory in children diagnosed with ADHD and that this improvement is long-lasting. Initial improvement can be achieved even if the number of training sessions is limited to as few as 10 sessions. It seems possible to improve the effectiveness of the neurofeedback therapy while individualizing the frequency ranges used in training based on the child's individually determined alpha frequency band. The use of a theta/beta ratio with set frequency ranges of (4 to 8)/(13 to 21) Hz should perhaps be updated.[24] The use of individualized frequency ranges determined by measuring a child's PAF appears to be more appropriate, especially in young children who may have a PAF at 8 Hz or lower.

Our study has some limitations. Despite the group size being similar to that from previous studies, it is still rather small. We focused on evaluating the clinical effect, and not the changes in the EEG frequency bands, so we cannot state with certainty that the subjects in the study learned the task of changing their EEG patterns. The study does provide data for designing further studies that might include pre-post EEG changes.

Although it was not a placebo-controlled study and, thus, nonspecific factors cannot be ruled out, it seems unlikely that they would persist a year after termination of training.

Although we know that it is not always possible to determine the PAF in every individual, we did manage to determine the appropriate alpha range based on PAF for each individual in this study. Along with others,[49] we found that training while keeping PAF in mind was effective. Our findings additionally supplement the literature concerning findings of improved cognitive performance, in this case working memory enhancement, after neurofeedback training.

Author Contributions

Dobrakowski P. and Lebecka G. designed and conducted the study, including recruitment, data collection, and data analysis. Lebecka G. performed the neurofeedback trainings. Dobrakowski P. prepared the manuscript draft. Both authors approved the final manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

All procedures performed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975.

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Informed Consent

Informed consent was obtained from all participants included in the study.

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