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Effects of alpha music neurofeedback training on attention in undergraduate students: A pilot study

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ABSTRACT

Neurofeedback training (NFT), particularly targeting alpha-band activity (8–12 Hz), has been explored as a non-invasive approach to enhance attentional regulation. However, the effectiveness of integrating alpha music into the NFT and the optimal number of training sessions remain unclear. This pilot study employed a quasi-experimental pre-test–post-test design to examine the effects of alpha music–based NFT on attention performance among undergraduate students. A total of 10 participants were recruited and divided into two groups: five-session NFT (n = 5) and eight-session NFT (n = 5). Participants were healthy undergraduates with no neurological or psychiatric conditions, and those with prior NFT experience or concurrent cognitive interventions were excluded. Attention performance was measured before and after the intervention using a standardised attention task. The results showed improvements in attention performance within both groups following NFT. However, no significant differences were observed between the two groups, suggesting that increasing the number of sessions did not provide additional benefits. In conclusion, the alpha-music–based NFT may support improvements in attention among young adults, though these findings should be interpreted with caution, given the small sample size. Further research with larger samples and controlled designs is recommended.

Keywords: Electroencephalogram (EEG), neurofeedback, attention, alpha music

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1 INTRODUCTION

Attention is a fundamental cognitive function that significantly influences learning, academic achievement, and everyday cognitive performance. It enables individuals to focus on relevant information while selectively suppressing distractions. Among undergraduate students, limitations in attentional control have been linked to poorer academic outcomes and increased cognitive fatigue (Alloway & Alloway, 2010; Xie et al., 2023). As cognitive demands in higher education continue to rise, there is a growing interest in effective, non-invasive methods to enhance this critical cognitive function. Neurofeedback training (NFT) has emerged as a promising approach for cognitive enhancement, allowing individuals to self-regulate their brain activity through real-time feedback. Utilising principles of operant conditioning, NFT reinforces desirable neural patterns, leading to gradual, sustained improvements in brain function (Hammond, 2005). Previous research has demonstrated that NFT can enhance attention and executive functions across both clinical and healthy populations (Gruzelier, 2014; Marzbani et al., 2016; Matsuzaki et al., 2023). However, the effectiveness of NFT varies based on training protocols, target frequency bands, and individual differences.

Alpha brainwave activity (8–12 Hz) is particularly associated with relaxed alertness and efficient cognitive processing. The inhibition-timing hypothesis posits that alpha oscillations are crucial for suppressing irrelevant information, thereby enhancing focused attention (Klimesch, 2012). Empirical studies have shown improvements in attentional performance following alpha-based neurofeedback training, particularly with upper-alpha protocols (Escolano et al., 2011; Mahmood et al., 2024; Nan et al., 2012). However, findings remain inconsistent, with some studies reporting limited or non-significant behavioural effects (Dekker et al., 2014). To optimise alpha NFT, recent research has investigated integrating auditory stimulation, such as alpha music or binaural beats. Alpha music aims to entrain neural activity toward the alpha frequency range, promoting a calm yet attentive mental state conducive to cognitive performance (Nguyen et al., 2022; Tran et al., 2021). Additionally, the optimal number of NFT sessions required to achieve meaningful cognitive changes remains unclear. Traditional protocols typically involve 20-40 sessions, but emerging evidence suggests that shorter interventions may still yield cognitive benefits, particularly in healthy young adults (Dobrakowski & Łebecka, 2019).

The number of sessions in neurofeedback training (NFT) is an important factor that may influence the intervention's effectiveness. Previous studies have shown that NFT protocols vary widely, ranging from a few sessions to more extended training programs, depending on the target outcome and population. For example, alpha neurofeedback studies have demonstrated that cognitive improvements can occur even within relatively short training durations, with noticeable changes in alpha activity emerging around the 5th to 7th sessions and becoming more pronounced after 8-12 sessions (Hsueh et al., 2016). In contrast, longer protocols (e.g., 20 or more sessions) have been associated with greater and more consistent improvements in cognitive function (Nan et al., 2012).

However, there is still no clear consensus on the optimal number of NFT sessions, particularly for healthy individuals, as findings remain inconsistent. A meta-analysis also suggested that protocols with fewer than 10 sessions may show limited or variable effects compared to longer interventions. This highlights the need to explore shorter, more practical NFT protocols, especially among undergraduate students, who may face time constraints that limit participation.

To date, the methodological approaches employing fewer NFT sessions in normal healthy individuals are limited. Despite the importance of attention, many studies have examined this domain independently without considering its broader implications. This study aims to explore the effects of alpha music neurofeedback training specifically on attention performance among undergraduate students, focusing on the influence of the number of NFT sessions. This study aims to analyse changes in alpha activity before and after eight sessions of alpha music neurofeedback training (NFT). It also measures changes in attention performance before and after five NFT sessions. In addition, the study compares attention performance between individuals who completed five sessions and those who completed eight sessions of NFT. By investigating these objectives, this study seeks to provide empirical evidence to optimise NFT protocols for effective, practical cognitive enhancement in educational settings.

2 METHODS

2.1 Participants and Design

The study employed a quasi-experimental pre- and post-intervention design to examine the effects of alpha music NFT on attentional performance. A total of 10 healthy participants from a local public university took part in the study. Participants were recruited using convenience sampling. Participants were selected from year 1 to year 4 final year students across various faculties and courses, preventing age bias and ensuring representation from diverse academic backgrounds. The ten participants (six females and four males) were further divided into two groups: an experimental group and a control group. Five participants (two males and three females) were assigned to the experimental group and received neurofeedback training (NFT) combined with alpha music. The remaining five participants (two males and three females) were assigned to the control group and received NFT only. The sample size for this pilot study was calculated using G*Power software (Version 3.1.9.4). The effect size (d) was set at 0.7, with a significance level of $p = 0.05$ and a statistical power of 0.15, resulting in a required sample size of 5 participants per group. Although the sample size is small, it is acknowledged and considered adequate for a small-scale study. Participants were selected based on specific inclusion and exclusion criteria. The participants were undergraduate students at UNIMAS, aged 18 to 25. All participants were right-handed and had no history of mental illness, neurological disorders, brain injury, or substance abuse. Participants with chronic physical diseases or disorders of the nervous system were excluded. Those with visual or hearing problems that could affect their participation in the study were also excluded. In addition, pregnant participants and those taking medications that may affect cognitive function were excluded from this study.

2.2 Neurofeedback Stimulation

During the NFT session, an auditory alpha stimulus was presented bilaterally to the experimental groups. At the same time, no alpha music or auditory stimulus was given to the control group. The alpha music used for this study was obtained from free online sources (Link: https://music.youtube.com/watch?v=fArl32oYHDM). The sound presentation lasted 35 minutes.

2.3 Experimental Setup

The main equipment used in this experiment was an electroencephalograph (EEG), a non-invasive device for recording electrical activity in the brain. The participants were seated in chairs facing the monitor screen. Electrodes were placed on the participants' foreheads at FP1 and FP2 to record brainwave patterns associated with cognitive states and levels of engagement. The reference electrode was placed on the left earlobe, labelled as A1. During the NFT sessions, the EEG system recorded participants' brain activity in real time. This allowed the researchers to monitor changes in alpha activity during the training. Two monitors were used in this setup: one laptop recorded brain signals, and the other displayed visual feedback to participants, as shown in Figure 1. The materials used included a consent form and an online attention test accessible at The Total Brain's Focus Test (Total Brain, 2023). The equipment utilised for the NFT was a Brain Trainer (Series no: ELUQHJHA) system. This system measured brain activity using electroencephalography (EEG). Participants listened to online alpha music while receiving auditory feedback based on their brain wave activity.

Figure 1. The neurofeedback experimental setup.

2.4 Experimental Procedure

Data collection for this study was carried out in three phases: pre-test, intervention, and post-test. Before the study began, participants were briefed on the objectives, procedures, and potential risks and benefits. They were then asked to review and sign an informed consent form to confirm their voluntary participation and understanding of the study. After consent was obtained, participants completed a pre-test to establish baseline measures of attention performance. This involved completing a standardised online attention test (Total Brain's Focus Test) to test sustained attention (Link: https://www.totalbrain.com/mental-health-assessment/focus-test/) and having their alpha brainwave activity recorded using EEG equipment. For the online attention test, interpretation primarily focuses on the time taken to complete the task, reflecting processing speed and attentional efficiency. A shorter completion time indicates better attention performance, suggesting faster information processing and more efficient focus.

In contrast, longer completion time reflects poorer attention performance, indicating slower processing speed and reduced attentional control. In this study, attention performance was evaluated by comparing the time taken between pre-test and post-test conditions—a reduction in completion time after the intervention was interpreted as an improvement in attention performance following NFT.

Participants were then divided into two groups: the experimental group (five students) and the control group (five students). The intervention phase consisted of 5 to 8 training sessions over 5 weeks, each lasting approximately 35 minutes. During the sessions, the experimental group listened to alpha music while receiving real-time neurofeedback training to enhance alpha brainwave activity. The control group did not listen to alpha music during the training sessions. All sessions were conducted in a quiet and distraction-free laboratory environment. After the intervention phase, participants completed the post-test following the same procedures as the pre-test. Attention performance was reassessed using the same standardised test, and EEG recordings were taken to examine changes in alpha brainwave activity. Data from both groups were analysed to compare pre- and post-intervention outcomes and to evaluate the effects of alpha music neurofeedback training on attention performance. Figure 2 illustrates the study procedure.

2.5 Data Analysis

Data were analysed using SPSS version 21.0, with all tests conducted at a 95% confidence level and significance set at $p < 0.05$. As the data violated the normality assumption and the sample size was small, the Central Limit Theorem could not be applied, so non-parametric tests were used. To address objective 1, the Wilcoxon Signed-Rank test compared attention scores within the control and experimental groups, analysing pre- and post-session measurements separately for the 5- and 8-session NFT interventions. Between-group comparisons of pre- and post-session scores were conducted using the Mann–Whitney test.

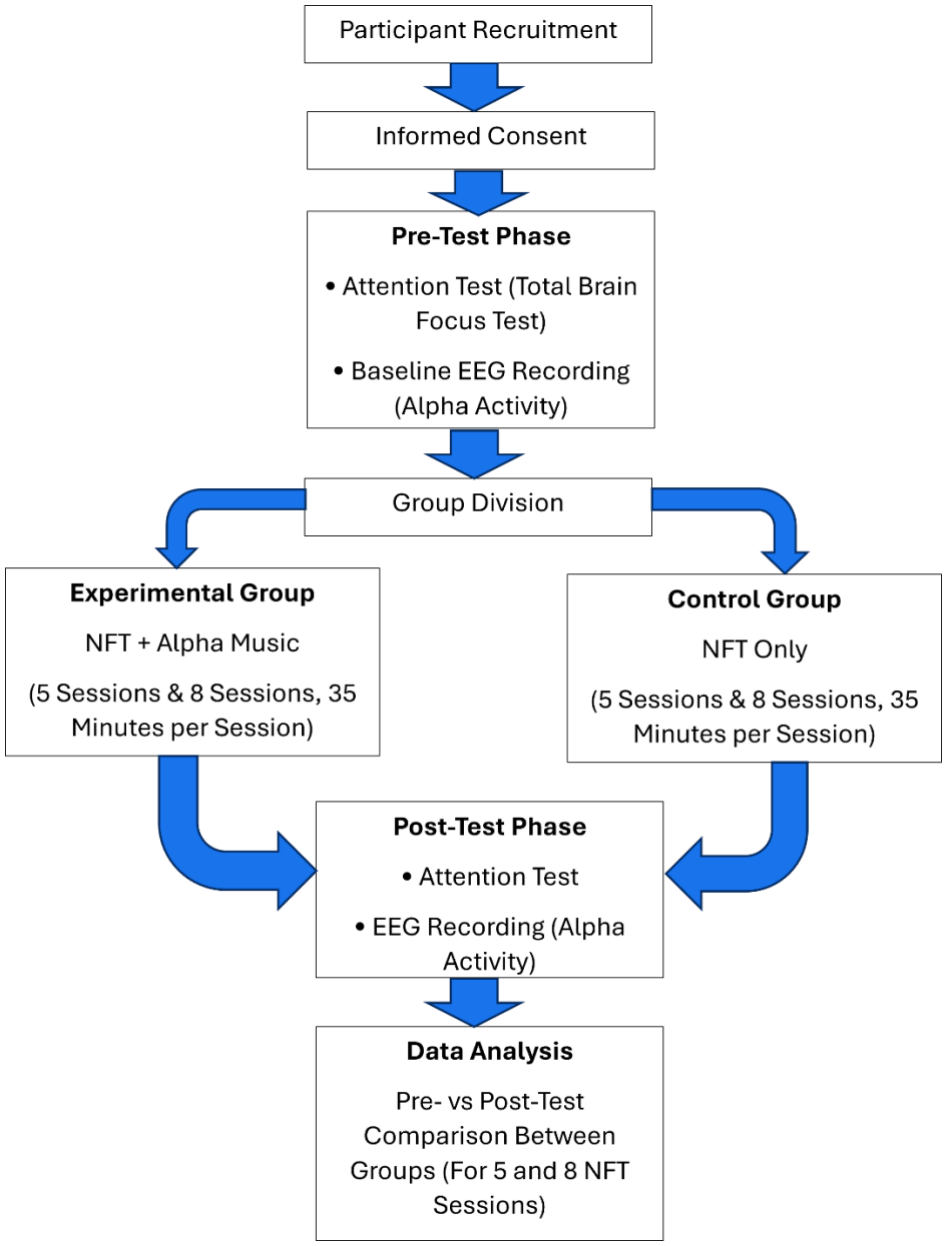

Figure 2. Flowchart of study procedures.

3 RESULTS

3.1 Eight NFT Sessions

As shown in Table 1, the Wilcoxon Signed-Rank test was used to examine changes in performance from pre- to post-intervention after eight NFT sessions within each group. In the experimental group, the results were statistically significant, with a Z value of -2.02 and a *p*-value of 0.04, indicating a significant improvement in attentional performance following the intervention. An

improvement can be suggested when the mean score (signifies duration in milliseconds) for attention performance during post-NFT is shorter than pre-NFT, indicating that the processing speed to initiate attention is faster after NFT. The experimental group showed a reduction in mean scores from 210.80 at pre-session to 53.79 at post-session, suggesting positive effects of the training over time. In contrast, the control group did not show a statistically significant improvement ($Z = -1.75$, $p = 0.08$). Although a numerical reduction in mean scores from 120.77 to 65.84 was observed, this change did not reach statistical significance. This may indicate that the improvement in the control group was less consistent across participants. As seen in Table 2, the Mann-Whitney U test was used to compare attention performance between the experimental and control groups. The pre-session comparison did not show a statistically significant difference ($U = 5.00$, $p = 0.12$), as expected, since the intervention had not yet begun. Similarly, the post-session comparison also did not show a significant difference between groups ($U = 17.00$, $p = 0.35$). These findings suggest that although within-group improvement was observed, the between-group differences after eight NFT sessions were not statistically significant.

Table 1. Within-group comparison of attention performance before and after eight NFT sessions.

Comparison	Statistic	Experimental Group	Control Group
Pre-test vs Post-test	Z-value	−2.02	−1.75
	p-value	0.04*	0.08
	Mean (Pre-test)	210.80	120.77
	Mean (Post-test)	53.79	65.84
	Median (Pre-test)	237.69	113.83
	Median (Post-test)	41.89	55.60

Table 2. Between-group comparison of attention performance before and after eight NFT sessions.

Comparison	Group	N	Median	IQR (Q1–Q3)	Mean Rank	U-value	*p*-value
Pre-NFT	Experimental	5	41.89	37.59–75.95	4.00	5.00	0.12
	Control	5	55.60	43.49–93.32	7.00		
Post-NFT	Experimental	5	41.89	37.59–75.95	6.40	17.00	0.35
	Control	5	55.60	43.49–93.32	4.60		

3.2 Five NFT Sessions

Table 3 presents the within-group analysis of attention performance before and after five neurofeedback training (NFT) sessions using the Wilcoxon Signed-Rank test. For the experimental group, a significant difference was found between pre-test and post-test scores ($Z = -2.023$, $p = 0.043$). The mean attention score decreased from 120.776 at pre-test to 62.494 at post-test, and the median score decreased from 113.840 to 60.307. This suggests improved attention performance following the five NFT sessions. In the control group, no significant difference was observed between pre-test and post-test scores ($Z = -1.214$, $p = 0.225$). Although the mean score decreased from 210.805 to 145.331 and the median score from 237.696 to 163.137, these changes were not statistically significant. Table 4 shows the between-group comparison of attention performance

using the Mann–Whitney U test. At pre-intervention, no significant difference was found between the experimental and control groups (U = 5.000, p = 0.117), indicating that both groups had similar attention performance. After five NFT sessions, the post-test comparison also did not show a significant difference between the two groups (U = 6.000, p = 0.175). The median and interquartile range values indicate that attention performance between the two groups remained comparable after the intervention.

Table 3. Within-group comparison of attention performance before and after five NFT sessions.

Comparison	Statistic	Experimental Group	Control Group
Pre-test vs Post-test	Z-value	-2.023	-1.214
	p-value	0.043*	0.225
	Mean (Pre-test)	120.776	210.805
	Mean (Post-test)	62.494	145.331
	Median (Pre-test)	113.840	237.696
	Median (Post-test)	60.307	163.137

Table 4. Between-group comparison of attention performance before and after five NFT sessions.

Comparison	Group	N	Median	IQR	U-value	*p*-value
Pre- NFT	Alpha	5	60.31	54.30–71.78	5.000	0.117
	Control	5	163.14	57.60–224.16		
Post- NFT	Alpha	5	60.31	54.30–71.78	6.000	0.175
	Control	5	163.14	57.60–224.16		

3.3 Five NFT Sessions versus Eight NFT Sessions

Table 5 compares post-intervention attention performance between participants who completed five NFT sessions and those who completed eight NFT sessions. The Mann–Whitney U test was used to compare attention performance between the two experimental groups. The results showed no statistically significant difference between the post-5 NFT group and the post-8 NFT group (U = 12.000, p = 0.917). The median attention score for the post-5 NFT group was 57.958 (IQR = 48.359–79.984), indicating similar attention performance between both groups.

Figure 3 presents the mean rank comparison of post-intervention attention performance between the 5 NFT and 8 NFT session groups. Additionally, Figure 3 compares the distributions of outcome scores between participants who underwent 5 sessions (5NFT) and 8 sessions (8NFT) of neurofeedback training, with each group comprising 5 participants. The mirrored bar chart shows that most scores in both groups are concentrated within a similar mid-range (approximately 40–80), with substantial overlap between the two distributions. Although the 8NFT group displays slightly wider variability, including a few higher values, this difference is not consistent enough to indicate a clear advantage. This observation is supported by nearly identical mean ranks (5NFT = 5.60; 8NFT = 5.40), suggesting minimal difference between the groups. Overall, the results indicate that increasing the number of sessions from five to eight does not lead to a meaningful

improvement in outcomes. However, the small sample size should be taken into account when interpreting these findings.

Table 5. Between-group comparison of attention performance after five and eight NFT sessions.

Comparison	Group	N	Median	IQR	U-value	*p*-value
Post five NFT vs Post eight NFT	Post five NFT	5	57.958	48.359–79.984	12.000	0.917
	Post eight NFT	5				

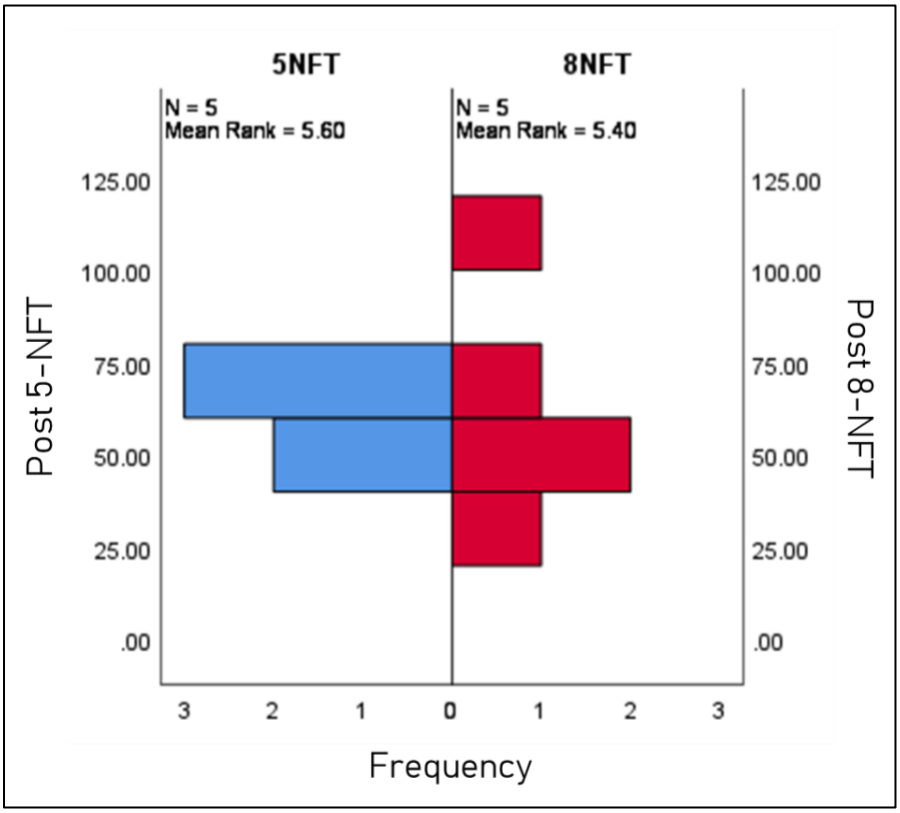

Figure 3. Post-intervention comparison of mean ranks in attention performance between the five- and eight-session NFT groups (Mann–Whitney U test).

4 DISCUSSION

This study examined the effects of alpha music neurofeedback training (NFT) on attention performance among undergraduate students, with particular emphasis on the number of training sessions. The findings suggest that alpha music NFT may be associated with improvements in attention performance within individuals; however, extending the training from 5 to 8 sessions did not appear to provide additional benefits.

Within-group analyses showed significant improvements in attention performance in the experimental groups after both five and eight NFT sessions. These findings suggest that alpha-based NFT may support attention regulation by promoting a more efficient cognitive state. Alpha oscillations have been widely linked to attentional control and the suppression of irrelevant information (López-Madrona et al., 2024), as described in the inhibition-timing hypothesis (Klimesch, 2012). The reduction in attention performance scores observed after the NFT sessions may reflect improved task engagement efficiency rather than simple performance gains. Despite these within-group improvements, between-group comparisons did not reveal statistically significant differences between the experimental and control groups. One possible explanation is that the participants were healthy undergraduate students with relatively stable baseline attentional abilities. In such populations, short-term interventions may lead to subtle changes that are difficult to detect when compared across groups. This may help explain why improvements were more evident within individuals than between groups.

The comparison between five and eight NFT sessions further showed that increasing the number of sessions did not improve attention outcomes. This suggests that a limited number of NFT sessions may be sufficient to produce short-term attentional changes in non-clinical populations. Additionally, the non-significant difference in post-intervention attention performance suggests that increasing the number of sessions within this range may not provide additional benefits. One possible explanation is that improvements in attention may occur during the early stages of training, where participants quickly adapt to the neurofeedback process. This is supported by previous studies showing that alpha neurofeedback can produce cognitive changes within a relatively small number of sessions, especially in healthy individuals (Enriquez-Geppert et al., 2017). Increasing the training duration may not necessarily enhance performance and may instead introduce factors such as mental fatigue, reduced motivation, or habituation to the training task. These factors could reduce the effectiveness of additional sessions, particularly when auditory stimulation is presented continuously. The use of alpha music during NFT did not produce strong additive effects when comparing across groups. Alpha music may help maintain a calm, focused mental state, which could help stabilise attention during training sessions. However, this stabilising effect may not be strong enough to generate clear behavioural differences when measured using short cognitive tasks. Recent studies on auditory entrainment have also reported that such stimulation may influence performance variability and consistency rather than producing large performance gains (Nguyen et al., 2022; Tran et al., 2021).

Several limitations should be considered. The small sample size reduced the analyses' statistical power and limited the generalisability of the findings. In addition, participants were limited to undergraduate students aged 18-25, which may further limit the generalisability of the results to other age groups. The quasi-experimental design and convenience sampling may also have introduced individual differences that influenced the results. Future research should involve larger samples, longer training periods, and follow-up assessments to examine the long-term effects of alpha music NFT. Including additional neurophysiological indicators may also provide deeper insight into how NFT influences attentional processes.

In summary, the present study suggests that alpha music neurofeedback training may support improvements in attention within individuals, even with a small number of sessions. However, increasing the number of sessions from five to eight did not lead to further improvements. These findings provide preliminary insight into the potential of short-duration NFT protocols for practical use in educational settings. Nevertheless, the relatively weak statistical evidence and the study's limitations indicate that these results should be interpreted with caution, and further research is needed to understand better and refine optimal training parameters.

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AUTHOR CONTRIBUTIONS

The first, second, and third authors designed the study. Data collection was performed by the second through fifth authors, and analysis and interpretation were conducted by the first through fifth authors. The first author supervised the data collection process. The first, sixth, and seventh authors contributed to the final manuscript and provided feedback on the results and discussion.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this study.

DATA AVAILABILITY STATEMENT

The raw data of this study are available upon request.

ETHICAL STATEMENT

This study was conducted in accordance with established ethical guidelines. Informed consent was obtained from all participants prior to their involvement in the study. Participants were clearly informed of the purpose of the study and their right to withdraw at any time. The confidentiality of participants' data was strictly maintained, and all information collected was used solely for research purposes.

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