

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

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ABSTRACT

Neurofeedback (NFB) represents an emerging non-invasive technique for treating psychiatric disorders enabling the individuals to monitor and modify brainwave patterns through brain-computer interfaces based on electroencephalography (EEG) principle. This mechanism leverages neuroplasticity that reveals the capacity of the brain to reorganize neural pathways and also facilitate lasting improvements in mental health conditions. Major Depressive Disorder (MDD), shows neurobiological aberrations such as frontal alpha asymmetry and limbic system dysregulation which provides specific targets for neurofeedback interventions. While traditional therapies including pharmacological interventions and electroconvulsive therapy (ECT) are commonly employed, neurofeedback offers a promising adjunct or alternative, especially for populations hesitant about medication use. This review synthesizes findings from 15 rigorous clinical trials between 2008 and 2024, spanning multiple countries, to evaluate the efficacy of neurofeedback training in depression. The evidence indicates that specific NFB protocols includes alpha wave asymmetry training, beta reinforcement, and targeting peak alpha frequency that can significantly decrease the symptoms of depressive disorders such as fatigue, rumination, and anxiety whereas it can improve executive functioning and quality of life. Neurofeedback demonstrates specific potential in treatment-resistant depression and comorbid conditions such as multiple sclerosis. Most studies report clinically meaningful improvements sustained at follow-up, although limited sample sizes and varying methodologies temper conclusions. The findings of the study highlight the importance of tailored neurofeedback protocols aligned with neurophysiological targets.

Keywords: *Neurofeedback, Depression, Major Depressive Disorder, Mental Health*

Neurofeedback (NFB) is considered to be one of the prominent non-invasive techniques for treating psychiatric disorders. Through brain mapping, an individual's brain wave functions can be determined and modified through different training modules based on electroencephalography principles. Neurofeedback training utilizes brain-computer interface (BCI) technology, which has demonstrated efficacy across a variety of psychiatric and neurological conditions through cognitive training. This approach has shown positive improvements across various age groups, from children to older adults.

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The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

A key mechanism of NFB is neuroplasticity, which is the brain's ability to reorganize itself, promoting long-lasting changes in neural pathways (Sitaram et al., 2017). Neurofeedback is increasingly integrated with other therapeutic approaches, such as cognitive-behavioral therapy (CBT), to enhance overall treatment efficacy (Mehler et al., 2018). Technological advances in NFB systems allow for portable and user-friendly setups, enabling use in clinical settings or even at home (Kao et al., 2017; Kober et al., 2022; Liu et al., 2022). Ethical considerations in NFB include informed consent, transparency of treatment goals, and careful monitoring to prevent unrealistic expectations, making it a safe and promising tool in the field of mental health (Marzbani et al., 2017).

Major Depressive Disorder (MDD) as defined by DSM- 5 as a persistent low mood, anhedonia, cognitive difficulties like diminished working memory and executive function, and emotions dysregulation. Neurobiological indicators include irregularities in frontal alpha asymmetry and the activity of the limbic system, particularly in the amygdala and anterior cingulate cortex. Neurofeedback offers a method for patients to learn how to adjust these dysfunctional neural patterns through feedback-driven training, potentially resulting in symptom reduction.

Contemporary depression treatment encompasses various therapeutic modalities beyond pharmacological interventions. ECT remains utilized as a treatment but many patients seek alternative treatment due to the side effects of pharmacotherapy and potential dependency. Hence, NFB is used as an alternative treatment modality, although it is less adopted in India as compared to western countries.

METHODOLOGY

This narrative review examines the effectiveness of Neurofeedback training in treating depression. The primary data collection was through various database like PubMed, Science Direct, Google Scholar, Frontiers, Springer, Taylor & Francis using key terms such as “Neurofeedback”, “Major Depressive Disorders”, “EEG”, “Depression” and “Psychiatric Illness”.

A total of 15 peer reviewed empirical papers published from 2008 to 2024 were selected. Most of the studies were conducted in China, the United States, South Korea and a few European countries. The inclusion criteria were that the studies had to be clinical trials, pilot study, double blind studies with $N > 10$. Studies which were in the extremities were not considered for the review.

RESULTS

Choi et al. (2011) conducted a Randomized Controlled Trials examining the “efficacy of alpha wave neurofeedback (NF) targeting frontal EEG asymmetry on 24 patients with depressive disorder”. Using the ‘asymmetry protocol,’ the NF training aimed to increase left frontal brain activity by decreasing alpha power in the left midfrontal region or increasing it in the right. The study employed 10 NF sessions over five weeks and compared outcomes with a psychotherapy placebo group. The results showed that the NF group experienced significant increases in left frontal activation (measured by alpha power asymmetry) during eyes-open conditions, along with marked reductions in depressive symptoms assessed by standard scales (BDI-II, HAM-D) and improvements in executive functions, including verbal fluency and cognitive control, as measured by Stroop tasks. The findings support the neurophysiological model of depression involving left frontal hypoactivation, though the small sample size and single-blind design limit generalizability.

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

Choobforoushzadeh et al. (2014) evaluated the impact of neurofeedback (NF) training on alleviating depression and fatigue in 24 patients with multiple sclerosis. Participants were randomly divided into two groups: one received 16 sessions of NF over eight weeks, focusing on decreasing theta and alpha EEG waves and increasing beta activity at the left prefrontal cortex (F3), while the control group continued with treatment as usual (TAU). The results revealed significant reductions in both depression and fatigue in the NF group compared to controls, with benefits maintained at follow-up. Effect sizes were moderate (Cohen's *d* approximately 0.29 for depression and 0.33 for fatigue). Overall, the study supports NF as a promising adjunctive therapy for managing depression and fatigue in MS, warranting further large-scale, controlled investigations to clarify underlying mechanisms and confirm long-term efficacy.

Lee et al. (2019) investigated neurofeedback efficacy in 24 adults with treatment-resistant depression through an open-label pilot study. The patients were split into two groups: one group got neurofeedback along with their medication, and the other just continued with their regular medication. The neurofeedback group had 12 to 24 sessions over 12 weeks. The results showed that people in the neurofeedback group had fewer depression symptoms and less disability, and their quality of life improved more than those in the other group. About 58.3% of the neurofeedback group had a good response to treatment, and 50.0% achieved remission. There were no big changes in BDNF levels in either group. The study suggests that neurofeedback could be a useful, non-invasive way to help people with treatment-resistant depression feel better and function more normally.

Wang et al. (2019) compared two neurofeedback protocols—alpha-asymmetry (ALAY) and high-beta down-training—in 87 patients with MDD and comorbid anxiety symptoms. These sample were divided into three groups: one got ALAY neurofeedback, another got Beta neurofeedback, and the third was a control group that didn't get any treatment. Both neurofeedback groups had ten sessions of training. Before and after the sessions, the participants took tests called the Beck Depression Inventory II (BDI-II) and the Beck Anxiety Inventory (BAI), and had their brain activity measured using EEG. The results showed that both the ALAY and Beta groups had lower scores on the BDI-II and BAI, meaning their symptoms improved. But there was no big difference between the two groups. Looking at the brain activity, the Beta group had less high-beta brain waves in a part of the brain called the parietal cortex (P3), while the control group had more, and the ALAY group didn't change much. The study concluded that both neurofeedback methods helped reduce depression and anxiety symptoms. However, the Beta method was better at changing high-beta brain activity, suggesting that neurofeedback could be a helpful, non-invasive treatment for people with both depression and anxiety.

Escalona et al. (2014) conducted a “Controlled study on the Cognitive Effect of Alpha Neurofeedback Training in Patients with Major Depressive Disorder” The study included 60 participants, split into a neurofeedback group (*n* = 40) and a control group without intervention (*n* = 20). The aim of the study was to increase individual upper alpha power in the parieto-occipital scalp region. Assessments of working memory, attention, and executive functions were conducted before and after the intervention, along with EEG recordings during eyes-closed resting and task-related conditions. Following the training, the NF group showed significant improvements in working memory and processing speed, accompanied by increased upper alpha power, especially during task performance. Additionally, there was a marked rise in alpha band (8–12 Hz) current density in the subgenual anterior cingulate cortex. A positive relationship was also identified between gains in processing speed and

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

increases in beta power at both sensor and brain source levels. The findings suggest that alpha neurofeedback training effectively enhances cognitive deficits, particularly working memory, in patients with MDD.

Cheon et al., (2015) did a study on "The Efficacy of Neurofeedback in Patients with Major Depressive Disorder: An Open Labeled Prospective Study," The researchers involved the sample of 20 people who had been diagnosed with MDD. The study lasted 8 weeks and was open-label, meaning everyone received the treatment. Participants had training sessions twice or three times a week. Each session was 30 minutes long and involved beta training. The results showed that depressive symptoms, anxiety levels, and the overall seriousness of the illness all improved. Based on the HAM-D scores, 35% of people had a positive response by week 4 and 75% by week 8. For full recovery, 15% had fully recovered by week 4 and 55% by week 8. However, there was no big change in the difference in alpha brain wave activity between the left and right brain hemispheres. The study had some weaknesses, like a small group of people and no control group. But it suggested that neurofeedback could be a useful, non-invasive treatment for reducing depressive symptoms and other related problems in people with MDD.

Peeters et. al., (2014) conducted a pilot study to see if neurofeedback could help reduce frontal alpha-wave asymmetry in people with major depressive disorder. Neurofeedback has been looked at because it might help balance the usual imbalance in brain activity between the left and right front parts of the brain. In depression, more activity is often seen on the left side, which is linked to lower mood and negative feelings. The study included nine people with depression who had up to 30 neurofeedback sessions over 10 weeks. The study also found that as the sessions went on, the brain activity imbalance decreased in a pattern that matched their improvement in symptoms. Even though the results suggest that focusing on frontal alpha asymmetry with neurofeedback might help reduce depression, the study had some issues, like not being a controlled trial and possible placebo or natural recovery effects. So, bigger, more controlled studies are needed to really know if neurofeedback is a good treatment for depression.

Ramirez et. al., (2015) introduced an innovative neurofeedback (NF) approach that allowed older adults to modulate musical elements—such as volume and tempo—based on their emotional states. The study included ten participants, primarily women, with an average age of 84 years and normal hearing. Each participant completed ten NF sessions, scheduled twice per week, lasting 15 minutes each. Brain activity was recorded using the Emotiv EPOC device, which assessed emotional responses by monitoring frontal brainwave patterns. The system adjusted musical parameters according to two specific neural markers: the beta-to-alpha ratio determined volume, while interhemispheric differences in alpha activity-controlled tempo. During sessions, participants sat comfortably and listened to preferred music, with the goal of increasing volume and tempo in accordance with their emotional engagement.

Following the intervention, six participants were reassessed using the Beck Depression Inventory (BDI). Results showed an average 17.2% reduction in depressive symptoms. EEG data further indicated a notable decrease in left-hemisphere alpha activity, a change associated with improved mood regulation. Although preliminary, these findings suggest that combining music with neurofeedback may represent a promising, non-invasive method for supporting emotional well-being in older adults with depressive symptoms. However,

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

further research with larger samples and controlled designs is needed to confirm its effectiveness.

Wang et al., (2016) did a study to see if neurofeedback (NFB) could help people with major depressive disorder (MDD). They looked at how NFB might change the way electricity moves in the brain, especially between the left and right sides of the front part of the brain. This difference in activity, called alpha asymmetry, is thought to be linked to depression. The study included 14 people with MDD. They split the group into two: one group got NFB training once a week for six weeks, each session lasting an hour. The training was meant to change the brain's alpha waves in the front. The other group didn't get any training. Before and after the training, they measured brain activity using EEG at two spots on the forehead—left (F3) and right (F4). They calculated something called the asymmetry index (AI) to see how brain activity changed. The results showed that the control group had a decrease in asymmetry over time, but the NFB group saw a big increase in the asymmetry index, which means their brain activity became more balanced. People who improved with NFB had lower scores for anxiety and depression, while those who didn't improve had worse symptoms. The study suggests that NFB might help balance brain activity in people with MDD, especially if they have too little activity on the left side or too much on the right. This could help with emotional and anxiety problems. However, since this was a small study and a first look, more research is needed to confirm the results and make real-world guidelines for treatment.

Yu et. al., (2020) did a study on “A Neurofeedback Protocol for Executive Function to Reduce Depression and Rumination: A Controlled Study”. The researchers looked into how a specific type of neurofeedback that targets peak alpha frequency (PAF) in the prefrontal area could help with depression and rumination. The study involved 30 people who were feeling down and had symptoms of depression. These participants were split into two groups: one received neurofeedback training, and the other was in a control group that didn't get the training. Before and after the treatment, the researchers checked how much depression, rumination, and executive function had changed. Over 20 sessions, the group that got neurofeedback saw big improvements in their executive function, along with a big drop in both depression and rumination, compared to the control group. The study showed that increasing the target PAF was closely linked to better executive function, which helped reduce depression and rumination. The authors said this neurofeedback method, based on cognitive neuroscience, is a useful way to treat depression by targeting its underlying causes and gives important information about how to approach treatment.

Young et. al., (2017) conducted a randomized clinical trial titled “Randomized Clinical Trial of Real-Time fMRI Amygdala Neurofeedback for Major Depressive Disorder: Effects on Symptoms and Autobiographical Memory Recall.” The study examined whether real-time functional magnetic resonance imaging neurofeedback (rtfMRI-nf) targeting the amygdala could alleviate depressive symptoms and enhance autobiographical memory in individuals with major depressive disorder (MDD). The study included 36 adults who weren't taking any medication and had been diagnosed with major depressive disorder (MDD). These people were split into two groups. One group had two sessions of rtfMRI-nf that focused on the amygdala, while the other group had the same treatment but focused on a brain area not linked to emotions. The results showed that people in the amygdala group had more activity in their amygdala, a bigger drop in depression symptoms (12 people had their scores drop by more than 50% on the MADRS), and better ability to remember positive memories compared to the other group. Also, six people in the experimental group met the

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

standards for full recovery from depression, while only one person in the control group did. The study shows that training neurofeedback on the amygdala can help reduce depression and improve the ability to recall positive memories, highlighting the importance of the amygdala in overcoming depression.

Young et. al., (2017) did a study called “Real-Time Functional Magnetic Resonance Imaging Amygdala Neurofeedback Changes Positive Information Processing in Major Depressive Disorder”. The researchers looked into whether real-time fMRI neurofeedback, which tries to make the amygdala more active during positive memory recall, could help people with major depressive disorder process emotions better. The study involved 34 people with MDD, split into two groups. One group (18 people) got amygdala neurofeedback, while the other group (16 people) got feedback focused on the parietal area. Both groups had two neurofeedback sessions and were tested before and after with behavioral tasks and imaging. The tests included a backward-masking task, which looked at how the amygdala responded to emotional faces shown very quickly, and the Emotional Test Battery, which checked how fast and accurately people could recognize emotional faces and words. The results showed that the group with amygdala neurofeedback had stronger amygdala responses to happy faces and weaker responses to sad faces compared to the control group. They also reacted faster to positive faces and words and were more alert to positive things. The study suggests that amygdala-focused real-time fMRI neurofeedback might help process positive emotions in a way similar to antidepressant treatments, showing it could be a useful, non-invasive treatment for Major Depressive Disorder.

Cheon et. al., (2015) conducted a study on "Effects of Neurofeedback on Adult Patients with Psychiatric Disorders in a Naturalistic Setting". The study included 77 adults, and the most common condition was depression, affecting about 24.7% of them, while anxiety disorders were next, affecting 23.4%. Most of the people in the study, around 89.6%, were also on medication during the treatment. On average, patients had about 17 neurofeedback sessions, with nearly half getting more than 10. The results showed that both the doctors and the patients noticed big improvements in their symptoms after receiving neurofeedback. Even though the study had some weaknesses, like not having a group that didn't get treatment and having a mix of different patient types, it still suggests that neurofeedback could be a helpful addition to other treatments for adults with mental health problems.

Misaki et. al., (2024) conducted a study on "Clinical Response to Neurofeedback in Major Depression Relates to Subtypes of Whole-Brain Activation Patterns During Training". The researchers looked into how well real-time functional MRI neurofeedback (rtfMRI-NF) works for treating Major Depressive Disorder (MDD). They studied data from 95 people with MDD, of whom 67 got active neurofeedback training meant to boost left amygdala activity by helping them recall positive memories, while the other 28 were in a control group. The group that had the active training had a bigger drop in depressive symptoms compared to the control group. But the amount of left amygdala activation didn't fully explain why some people improved more than others. The results suggest that it's the overall brain network activity during neurofeedback, not just activity in one specific area, that's important for treatment success. This means that tailoring neurofeedback treatments based on these brain activity patterns might help make therapy more effective for individuals with Major Depressive Disorder.

Baehr et. al., (2008) did a study titled “*The Clinical Use of An Alpha Asymmetry Protocol in the Neurofeedback Treatment of Depression*”. The study presented case studies of two

The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

women diagnosed with depression. Each participant underwent over 34 sessions of EEG biofeedback (neurofeedback) based on the Alpha Asymmetry protocol. The main goal of the intervention was to explore whether depression symptoms could improve by training the participants to increase activation in the left hemisphere and/or decrease activation in the right hemisphere of the brain. Personality changes, including depressive symptoms, were measured using the MMPI-2 before and after the neurofeedback training. The findings indicated that Alpha Asymmetry neurofeedback might be a valuable supplementary approach to conventional psychotherapy, demonstrating improvements in mood and personality factors. This suggests that neurofeedback can serve as an effective non-invasive intervention for treating specific mood disorders.

CONCLUSION

By reviewing the papers, it can be concluded that neurofeedback training can be used in treating depression. The different modules available in the process of feedback mechanisms may target different regions of the brain depending on whether the waves are inhibitory or excitatory. It is important to note that this alone may not be sufficient but can be always an adjunct to those who may not prefer medications.

Neurofeedback (NFB) training resulted in significant reductions in depressive symptoms in most clinical trials, as measured by standard scales (BDI-II, HAM-D). Both EEG-based (alpha asymmetry, beta, peak alpha) and fMRI-based NFB protocols were effective, with additional benefits in executive function, memory, and cognitive control.

NFB showed notable efficacy in special cases-

- Treatment-resistant depression: Higher remission rates and functional recovery observed in several studies.
- Comorbid populations: Reduction in depression and fatigue in multiple sclerosis patients; elderly benefited from music-modulated NFB.
- Improvements often sustained at follow-up, though longer and more intensive protocols generally yielded greater effects.
- NFB protocols resulted in increased left frontal activation and shifts in EEG rhythms associated with mood improvements.

The main limitation was that the studies that have been conducted are not in large samples. Especially in countries like India where people are not completely aware of this treatment, trials on this population can have significant impact on the psychiatric treatment with other neuromodulations. Awareness by clinicians such as psychologists and psychiatrists will help the patients choose the desired module of treatment.

NFB is promising as an adjunct/alternative, especially when medications are undesirable or less effective. May benefit mild to moderate depression, anxiety, stress, ADHD, or OCD. Calls for wider clinical awareness and larger RCT's especially in less-studied populations.

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The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

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The Effects of Neurofeedback Training on Depressive Disorders: A Narrative Review

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Conflict of Interest

The author declared no conflict of interest.

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