A Review of EEG Biofeedback Treatment of Anxiety Disorders

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Key Words
Alpha-Enhancement
Alpha-Suppression
Alpha-Theta-Enhancement
Generalized Anxiety Disorder
Obsessive-Compulsive Disorder
Phobic Anxiety Disorder
Post-traumatic Stress Disorder
Theta-Enhancement

INTRODUCTION

There are at least five types of anxiety: Generalized Anxiety Disorder, Phobic Disorder, Obsessive-Compulsive Disorder, Post-traumatic Stress Disorder and Panic Disorder.[1] Since they have different treatments and outcomes, they are reviewed separately in this article. To be included in this review, papers had to have been published in peer-reviewed journals, patients had to have a clinical diagnosis of one of the anxiety disorders, and volunteers had to have objective evidence of high anxiety levels. No Panic Disorder papers met these criteria.

GENERALIZED ANXIETY DISORDER

Alpha-enhancement and alpha-suppression

Hardt and Kamiya[2] assessed 100 college male volunteers with the MMPI Welsh A anxiety scale.[3] The 8 subjects who scored highest on trait anxiety (mean score 27.4) were compared with the 8 who scored lowest (mean score 4.3). There were 7 eyes-closed training sessions in 7 days. Each session started with state anxiety assessment, using the Multiple Affect Adjective Check List (MAACL).[4] This was followed by 8 minutes of resting baseline alpha, and then 32 minutes of alpha-enhancement. State anxiety assessment and collection of 8 minutes of resting baseline alpha were then repeated, followed by 16 minutes of alpha-suppression. The session ended with a final state anxiety measurement. After the seventh and final training session, trait anxiety was again assessed with the Welsh A anxiety scale. Alpha (8-13 Hz) was measured at Oz, O1, and C3, using linked ears for reference.

Percentage increase of the time above the alpha threshold of 10μV was reported for only two subjects. However, statistically significant negative correlations were found between alpha and anxiety levels. Alpha-enhancement reduced both state and trait anxiety in high-trait anxiety subjects, suggesting it would benefit anxious patients. As training progressed, alpha-enhancement and state anxiety reduction became more strongly associated. The two best alpha-enhancers reduced their trait anxiety scores to below average. Alpha-suppression increased state, but not trait, anxiety in these high-trait anxiety subjects. These findings imply that the improvement in anxiety was due to alpha-enhancement and not to other variables such as feelings of success. For example, the success involved in suppressing alpha did not reduce anxiety. Alpha training had no effects in low-trait anxiety subjects, which may explain why some papers report failure to reduce anxiety by alpha-enhancement. The baseline level of anxiety of the subjects in these studies may have been too low. Anxiety increased with alpha-suppression at the occipital but not central sites, suggesting that the location of the alpha-measurement is important. The benefits of alpha-enhancement were most marked after 2 hours of training, indicating that the duration of training is also important. The authors suggest that at least 5 hours are needed. The negative findings of some studies may be due to the training being too brief.

Plotkin and Rice[5] studied 10 undergraduate volunteers who reported chronic anxiety and scored at least 21, with a mean of 29.4, on the Welsh A anxiety scale. They also scored high on the State-Trait Anxiety Inventory (STAI)[6] and Taylor Manifest Anxiety Scale.[3] Electrodes were placed in the occipital area (Oz) and right mastoid, with one on the forehead for ground. Participants had at least 5 training sessions over 3 weeks. Five subjects had alpha-enhancement training, 5 had alpha-suppression training, and 3 on a waiting list served as controls. Each training session began with STAI assessment, followed by 10 minutes eyes-closed baseline. On days 1 and 2 these were followed by 16 minutes of alpha-enhancement (or alpha-suppression), STAI, 8 minutes alpha-suppression (or alpha-enhancement), STAI, 16 minutes alpha-enhancement (or alpha-suppression) and STAI. On subsequent days the 8

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minutes training period and the two middle STAI tests were eliminated. The true feedback score was read to the subjects after 2 minutes, following which their actual alpha-enhancement score was increased after every 2-minute trial by 1% of that day's baseline score. The alpha-enhancement group did not increase their alpha significantly, whereas the alpha-suppression group succeeded in reducing alpha. Both EEG groups improved in state and trait anxiety, while the control group did not change. The authors concluded that perceived success was the important variable that correlated with reduction in anxiety.

Rice, Blanchard and Purcell[7] studied 45 volunteers who had suffered from generalized anxiety (GAD) for an average of 3.8 years. Thirty-eight met DSM-III[8] criteria for GAD; positive for 3 of 4 symptom categories for at least 1 month. Seven were subclinical, in that they were positive for 2 of the 4 categories. Clinical and subclinical subjects did not differ in treatment outcome. The 45 subjects were randomly assigned to frontal EMG feedback, EEG alpha-increase feedback, EEG alpha-decrease feedback, pseudo-meditation or waiting list control. There were 9 patients in each treatment group. The 4 treatments were given in two 1-hour sessions weekly, for 4 weeks. Treatment sessions consisted of 5 minutes baseline, 3 minutes of self-control, and 20 minutes of feedback. Eyes-closed alpha was measured at the middle of the occipital lobe (Oz), with the right mastoid as reference and the forehead as ground. Both alpha treatment groups were given verbal feedback of success. Their scores were incremented by 2% every 2 minutes, leading them to believe they were being successful.

All 4 active treatments were effective as measured by STAI trait anxiety and by the Psychosomatic Symptom Checklist.[9] Alpha did not change from baseline levels for the enhancement group, whereas it decreased significantly in the suppression group. Only EMG and alpha-increase groups improved significantly on the Welsh Anxiety Scale. Only alpha-increase resulted in reductions of heart rate reactivity to stress. In contrast, alpha-suppression caused the heart rate to be more reactive. Improvements in anxiety were maintained 6 weeks after treatment. The authors suggested that future research should include larger numbers, longer treatment, and all subjects should have GAD. In DSM-III R[10] the criteria for GAD included worry as the essential feature and the duration was increased to 6 months. This more severe form of GAD might respond differently to biofeedback.

Theta-enhancement

Knowing that theta (3.5-7 Hz) is associated with the onset of sleep, Sittenfeld, Budzynski and Stoyva[11] used theta-enhancement training to achieve low arousal. Twenty volunteers who responded to advertisements were assessed for EMG levels. The 10 highest EMG subjects were compared with the 10 lowest. Five from each group received 8 sessions of theta-enhancement training, and the other 5 from each group received 4 sessions of EMG feedback followed by 4 sessions of theta-enhancement. In this second group theta biofeedback was accompanied by EMG visual feedback. Since the volunteers opened their eyes only occasionally for a few moments, the feedback was primarily auditory theta. Training sessions were held 2 or 3 times weekly. Alpha (8-12 Hz) and theta were measured from Oz-C4 electrodes for 64-second periods. If alpha was present, theta feedback was inhibited. This feature ensured that feedback for theta was given when the subjects were experiencing theta-like experiences such as drowsiness.

High-frontal-EMG subjects increased theta only if first trained in EMG biofeedback. In contrast, low-EMG subjects did better with theta training only. During the initial EMG feedback sessions, theta increased in the absence of theta-enhancement feedback. However, during theta-enhancement the EEG changes were feedback specific, with increases in theta and no change in alpha. This proved that the EEG changes were not simply reflecting a general relaxation. Theta is so lacking in the awake subject that there is little information to feed back to the subject, making theta-enhancement training very difficult. This is the likely explanation of the need for EMG feedback training to precede theta-enhancement training in high-EMG subjects. Since theta-enhancement is possible only in the presence of low EMG and theta is increased in drowsiness, the authors suggested that this form of feedback could be of benefit in anxiety and sleep-onset insomnia. Considering all 20 subjects, theta increased while EMG and heart rate decreased significantly. There was a significant negative correlation ($p < 0.05$) between theta and EMG.

PHOBIC DISORDER

Alpha-enhancement

Garrett and Silver[12] carried out two studies to determine whether alpha enhancement would benefit students suffering from test anxiety. In the first study 163 students were assessed with the Debilitating Anxiety Scale,[13] and 6 other questions about illness and muscle tension resulting from doing tests. Thirty-six who scored in the upper two thirds entered the study. Eighteen were assigned to biofeedback training and an equal number matched for level of test anxiety to an untreated control group. Half of the feedback group started with 8-13 Hz alpha-enhancement training, in which alpha in excess of 21 uV caused a feedback tone, and half started with EMG feedback. The voltage setting was reduced to 19 uV for 2 subjects, and increased to 23 uV for one. Electrode placement was right frontal-occipital with earlobe ground. Each alpha training session consisted of eight 5-minute periods. After each period the subject was allowed to stretch, and was informed how many seconds of alpha he had produced. The other 9 feedback subjects started with EMG training. After 2 sessions the training was switched for 2 sessions to the other type of feedback. Then training was switched again to one more ses-

Table 1

Alpha-enhancement, theta-enhancement, alpha-theta-enhancement

Author	Number of subjects	Number of sessions	Hours of biofeedback	Time over threshold	Clinical outcome
Generalized Anxiety Disorder					
Hardt, '78[2] (High-trait)	8 volunteers	7 alpha ⇑	3.7 hours	SS more time over 10 μV	TA1 ⇓, SA1 ⇓
Hardt, '78[2] (Low-trait)	8 volunteers	7 alpha ⇑	3.7 hours	SS more time over 10 μV	No change
Plotkin, '81[5]	5 volunteers	5 alpha ⇑	2.9 hours	No change	TA2 ⇓, SA2 ⇓
Rice, '93[7]	9 volunteers	8 alpha ⇑	2.7 hours	No change	TA1 ⇓, TA2 ⇓ HR ⇓
Sittenfeld, '76[11] (High-EMG)	5 volunteers	8 theta ⇑	NA	No change	EMG ⇓ HR ⇓
Sittenfeld, '76[11] (High-EMG)	5 volunteers	4 EMG ⇑ +4 theta ⇑	NA	SS increase	EMG ⇓ HR ⇓
Sittenfeld, '76[11] (Low-EMG)	5 volunteers	8 theta ⇑	NA	SS increase	EMG ⇓
Sittenfeld, '76[11] (Low-EMG)	5 volunteers	4 EMG ⇑ +4 theta ⇑	NA	No change	EMG ⇓
Phobic Anxiety Disorder					
Garrett, '76[12] (Study 1)	18 volunteers	3 alpha ⇑	2 hours	21% more time over 21 μV	Test anxiety ⇓
Garrett, '76[12] (Study 2)	10 volunteers	10 alpha ⇑	6.7 hours	33% more time over 21 μV	Test anxiety ⇓
Garrett, '76[12] (Study 2)	9 volunteers	5 EMG ⇑ +5 alpha ⇑	3.3 + 3.3 hours	45% more time over 21 μV	Test anxiety ⇓
Obsessive-Compulsive Disorder					
Mills, '74[14]	5 patients	7-20 alpha ⇑	4.7-13.3 hours	51, 22, 9,-2, -1% time over 20 μV	Ruminations ⇓ in all 5
Glueck, '75[15]	4 patients	20 alpha ⇑	20 hours	NA	1 of 4 improved
Post-traumatic Stress Disorder					
Peniston, '91[16]	15 patients	8F + 30 alpha-theta ⇑	15 hours	NA	All MMPI Scales ⇓ Medicines ⇓

F = Temperature feedback, HR = Heart Rate, NA = Not Available, SA1 = MAACL State Anxiety, SA2 = STAI State scale, SS = Statistically Significant, TA1 = Welsh-A Trait Anxiety, TA2 = STAI Trait Scale

sion of the original feedback, followed by one session of the other. Thus, each subject received 3 sessions of each type of feedback training. This was sufficient for 5 subjects to achieve 3 uV of EMG and for 16 to achieve 50% alpha. The 13 who did not meet the EMG criterion and the 2 who did not meet the alpha criterion had one more session of the appropriate training.

The alpha group improved alpha production from 64 to 78% of the time, and the EMG group reduced voltage from 5.84 to 3.49 uV. Eighty-three per cent reported being more relaxed in and out of the laboratory. Nine favored alpha, 4 EMG, and 5 thought they were equally effective in causing relaxation. Test anxiety scores of the trained group improved (50 to 32), while those of the untrained group were essentially unchanged (48 to 47), a statistically significant difference ($p < .001$). This study proved that combined alpha and EMG biofeedback can reduce test anxiety.

In their second study, of 50 students who scored above the median on the same anxiety questionnaire, Garrett and Silver[12] used the same methodology. Groups of 10 were randomly assigned to one of five treatments: alpha-enhancement, EMG voltage reduction, combined alpha-

Table 2

		Alpha-suppression			
Author	Number of subjects	Number of sessions	Hours of biofeedback	Time under threshold	Clinical outcome
Generalized Anxiety Disorder					
Hardt, '78[2] (High-trait)	8 volunteers	7 alpha ⇓	1.9 hours	SS more time under 10 μV	SA1 ⇑
Hardt, '78[2] (Low-trait)	8 volunteers	7 alpha ⇓	1.9 hours	SS more time under 10 μV	No change
Plotkin, '81[5]	5 volunteers	5 alpha ⇓	2.9 hours	SS decrease	TA1 ⇓, SA2 ⇓
Rice, '93[7]	9 volunteers	8 alpha ⇓	2.7 hours	SS decrease	TA2 ⇓, HR ⇑

enhancement and EMG reduction feedback, relaxation, or no training. One subject dropped out of the combined group and could not be replaced. Training was for 10 sessions over 10 weeks. The combined training group alternated between the two types of feedback, half starting with each type. The alpha group increased alpha time over baseline by 33%, and the EMG group decreased muscle tension by 50%. The combined group increased alpha time over baseline by 45%, and reduced muscle tension by 41%. The relaxation group increased alpha by 18%, and reduced muscle tension by 41%. All three feedback groups had a significant reduction in test anxiety. The relaxation group and the untreated control group had no significant reduction, suggesting that the improvement in the feedback groups was not merely a placebo effect.

OBSESSIVE-COMPULSIVE DISORDER

Alpha-enhancement

Mills and Solyom[14] treated 5 ruminating obsessive patients with 7 to 20 sessions of eyes-closed 8-13 Hz alpha-enhancement training. During the first 5 sessions instructions were minimal, to keep the tone on as much as possible. Subsequent sessions included information and verbal encouragement. Medicines were discontinued for 2 weeks before training began. Electrodes were placed at O1 and O2. Within each 1-hour session, 5-minute alpha training periods alternated with 2 minutes of rest. Alpha abundance was calculated as % of total time that alpha was at least 20 uV. One subject increased alpha after the first session, with continued significant increase until dropping out after session 7 when the total increase was 22%. Another increased alpha after 5 sessions, but dropped out after session 9 when the total increase was 51%. The other 3 each had 20 sessions without any significant increase in alpha (+9%, −2% and −1%). The extra information and encouragement after the first 5 sessions did not improve alpha production. The authors suggested that 5 hours training were sufficient to distinguish between learners and nonlearners. All 5 subjects improved, as measured by absence (in 4) or reduction (in 1) of ruminations during feedback. No generalization of reduced rumination occurred outside the laboratory. Three who improved did not significantly increase their alpha, suggesting that the benefits were due to factors other than alpha-enhancement.

Glueck and Stroebel[15] studied a large number of inpatients with a variety of psychiatric illnesses, including 4 with obsessive-compulsive disorder. They assigned 26 to 8-13 Hz alpha-enhancement training, 12 to autogenic training, and 187 to transcendental meditation (TM). EEGs were recorded from right and left frontal, parietal, temporal, and occipital leads. Alpha-enhancement patients had a total of 20 one-hour training sessions, but were able to control their alpha after 15 sessions. To equal the time spent in TM, the two other groups were expected to practice their technique 20 minutes twice daily for 16 weeks. Autogenic training consisted of voluntary muscle relaxation, starting with the toes and moving upwards to involve the whole body. All in autogenic training dropped out by the fourth week because of boredom. TM patients had an increase in alpha, in keeping with the known abundance of alpha and state of restful alertness reported in studies of yogis and Zen masters. The alpha first appeared in the dominant hemisphere, and within a few minutes spread to the other side. As the TM continued, theta (4-7 Hz) and high frequency beta (20-35 Hz) would also appear. Most patients reported relaxation during the alpha training, but follow-up at 4 weeks showed that this benefit had not continued outside the laboratory. TM was significantly better than either alpha-enhancement or autogenic training. The authors reported that in previous studies with volunteers, the higher the level of psychopathology the lower the ability to produce spontaneous alpha. Four of the 26 patients assigned to alpha-enhancement training had obsessive-compulsive disorder, and only 1 of the 4 experienced significant clinical improvement.

POST-TRAUMATIC STRESS DISORDER

Alpha-theta-enhancement

Peniston and Kulkosky[16] studied 29 Vietnam veterans with a 12 to 15 year history of chronic combat-related post-traumatic stress disorder (PTSD). They compared alpha (8-13 Hz)-theta (4-8 Hz)-enhancement training of 15 patients with traditional medical treatment of 14 patients. Alpha-

theta-enhancement sessions were held 5 days a week, and each was preceded by 5 minutes of baseline recording. Electrodes were placed 1 cm left of and above the inion at O1, on the left ear for reference, and on the right ear for ground. Each patient's alpha threshold was based on calibration of the feedback monitor. Based on previous experience the theta threshold was set 10 mV lower. Alpha and theta production was defined as the time that the voltage exceeded the preset threshold. All alpha-theta patients first received eight 30-minute temperature feedback sessions to achieve a temperature of 95 degrees Fahrenheit for 1 session. This was followed by thirty 30-minute sessions of eyes-closed alpha-theta-enhancement training.

The 15 alpha-theta feedback patients improved on all 10 clinical MMPI scales: Hypochondriasis; Depression; Conversion Hysteria; Psychopathic Deviate; Masculinity-Femininity; Paranoia; Psychasthenia; Schizophrenia; Hypomania; Social Introversion. The traditional treatment group improved in only one, the schizophrenia scale. The 14 alpha-theta feedback patients who were medicated all required less medication, compared with only 1 of 13 traditional treatment patients who were medicated. At 30 months 3 alpha-theta feedback patients had relapsed, compared with all 14 traditional treatment patients.

DISCUSSION

EEG-biofeedback was associated with clinical improvement in generalized anxiety, phobic disorder, obsessive-compulsive disorder and PTSD. A placebo effect was certainly present. Patients improved clinically when there was no change in alpha voltage compared with baseline,[7,11,14] and even when the voltage change was in the wrong direction.[5,7] However, alpha-enhancement was superior to suppression as shown by stress induced heart rate being reduced in the former and increased in the latter,[7] and clinical symptoms worsened after alpha-suppression in one study.[2] These findings suggest that the biofeedback induced changes in alpha and theta provided additional benefits to placebo effects.

The minimum duration of EEG-biofeedback training is unclear. Five hours have been suggested,[2] yet shorter periods have been shown to be effective.[5,7,12] Five hours have also been suggested as the minimum required to distinguish between learners and non-learners.[14] One important variable is whether the subject has high-trait or low-trait anxiety.[2] Paradoxically, the high-trait volunteers had a better outcome. The type of biofeedback training is also critical.[11] High-EMG subjects only increased alpha if first trained in EMG feedback, while low-EMG subjects only increased alpha if EMG feedback was omitted. Using too few electrodes may result in vital information being missed. A correlation between alpha-enhancement and reduced anxiety was seen only centrally, while a correlation between alpha-suppression and increased anxiety was seen only occipitally.[2]

Future research in EEG-biofeedback for anxiety disorders should use multiple electrode sites, at least 5 hours of training, and clinical patients (rather than volunteers) with high anxiety levels. Based on suggestions by Rice and Blanchard,[17] future research should answer the following questions affirmatively: (1) Was there evidence that the EEG-biofeedback training led to reliable change in the target waveforms? (2) Did the EEG-biofeedback training lead to more of the desired change than control conditions? (3) Was there significant anxiety reduction associated with EEG-biofeedback training? (4) Did the EEG-biofeedback training lead to more anxiety reduction than control conditions? (5) Is there evidence that EEG-biofeedback-mediated physiological change per se accounts for the observed anxiety reduction?

SUMMARY

Alpha, theta and alpha-theta enhancements are effective treatments of the anxiety disorders (Table 1). Alpha suppression is also effective, but less so (Table 2). Perceived success in carrying out the task plays an important role in clinical improvement. Research is needed to find out how much more effective they are than placebo, and which variables are important for efficacy. Variables needing study are: duration of treatment, type and severity of anxiety, number and type of EEG waveforms used, pretreatment with other kinds of feedback, position and number of electrodes, and presence of concomitant medication.

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