Biofeedback as a Placebo:
Anxiety Reduction Facilitated by Training in Either Suppression or Enhancement of Alpha Brainwaves

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An experiment was conducted to assess the differential effects (on experiential reports of anxiety) of actual performance and perceived success at an EEG biofeedback task. Ten college students who were high in trait anxiety underwent training in either the suppression or enhancement of EEG alpha activity with the expectation that success at their biofeedback task would result in reductions of chronic anxiety levels. Both groups experienced significant reductions in both trait and state anxiety. Anxiety reductions were highly correlated with the trainees' ratings of perceived success at the feedback task but were unrelated to either the direction or magnitude of the changes in their alpha activity.

Early studies of electroencephalographic (EEG) alpha biofeedback training (Brown, 1970; Kamiya, 1968; Nowlis & Kamiya, 1970) reported that increases in alpha densities or amplitudes led to experiential reports of pleasant, relaxed, quasi-meditational states of consciousness. These findings led to two popular beliefs: (a) Alpha training can result in supranormal enhancement of alpha levels, and (b) these alpha increases lead, in turn, to experiences of relaxation and tranquility or at least to significant reductions in anxiety level.

More recently, however, considerable doubt has arisen concerning both of these beliefs. First, as we have reviewed elsewhere (Plotkin, 1978, 1979), there is absolutely no published evidence that the increases in alpha activity that are frequently seen during alpha training have ever constituted an unequivocal case of actual alpha enhancement above optimal prefeedback baseline levels. At the very least, it is safe to conclude that the vast majority of such alpha increases have been sub-baseline.

Furthermore, and contrary to the second belief, a considerable body of evidence supports the conclusion that a person's alpha levels, sub-baseline or not, have no direct or simple relationship to the experiential changes often reported during feedback training. Several studies (e.g., Beatty, 1972; Cott, Pavloski, & Goldman, in press; Lynch, Paskewitz, & Orne, 1974; Plotkin, 1976b, 1977; Plotkin & Cohen, 1976) have failed to replicate the early findings of a correspondence between alpha levels and calm, relaxed states. These findings have led a number of researchers to suggest and/or demonstrate that experiential reports during alpha training are not related to alpha levels but are instead a function of social psychological variables such as expectation, motivation, the demand characteristics of the experimental setting, and perceived success at the feedback task (in addition to those referenced above, see DeGood, Elkin, Lessin, & Valle, 1977; Lynch & Paskewitz, 1971; Peper, 1971; Plotkin, 1976a, 1978; Plotkin, Mazer, & Loewy, 1976; Valle & Levine, 1975). In one of the earliest studies examining the relationship of expectations to experience during alpha training, Walsh (1974) found that for an "alpha experience" to occur, both an appropriate expectancy set and alpha activity were necessary; either alone was insufficient. However, based on subsequent data, we have elsewhere (Plotkin, 1976b, 1979) offered a reinterpretation of Walsh's study that shows that Walsh's data do not constitute evidence for a direct, intrinsic, or causal relationship—even a weak and/or "blockable" one—between EEG al-
pha and either the alpha experience in general or reduced anxiety/increased relaxation in particular. Rather, the evidence supports the conclusion that Walsh only demonstrated a relationship between alpha suppression and external-sensory awareness.

Plotkin (1979), in a review of the research on the alpha experience, has identified eight distinct factors—including but not limited to the social psychological variables discussed above—that have been shown to be involved in the development of unusual experiential states during alpha training; EEG alpha enhancement was not one of them.

Concerning the specific relationship between alpha and anxiety, Orne and Paske-witz (1974) conducted an investigation of the alleged direct relationship between alpha activity and experiential reports of relaxation. They found that anticipation of electric shock did not depress alpha activity, even though it was associated with reports of anxiety and heightened autonomic arousal. These results cast additional doubt on the popular belief that a reduction in alpha activity is a necessary correlate of arousal or anxiety.

In spite of the evidence refuting any direct association between alpha enhancement and the experience of relaxation, Hardt and Kamiya (1978) have recently reported that biofeedback-facilitated alpha enhancement reliably reduced both state and trait anxiety in a group of persons with high levels of trait anxiety. They concluded:

Alpha increases result in state-anxiety decreases, while alpha decreases result in state-anxiety increases. This "completeness" implies that anxiety decreases during enhancement do not result from feelings of success, since success at suppression yields anxiety increases. Our data nowhere suggest factors other than alpha changes producing the anxiety changes. (p. 81)

These authors claim, moreover, that the relationship between alpha and anxiety holds only for persons with high trait anxiety.

However, we find Hardt and Kamiya's data and reasoning to be unconvincing. Although we accept their finding that EEG biofeedback training can be effective in evoking significant anxiety reductions, we find their methodology to be inadequate for correctly determining either (a) if there is a relation between anxiety change and the experience of success at the feedback task or (b) if there is truly a causal or intrinsic relationship between changes in alpha strength levels per se and anxiety changes. Unconsidered in their study were the effects of the trainees' specific expectations as they interact with experienced success at the feedback task, an interaction that has been demonstrated to be of foremost importance in determining the experiential and psychological effects of alpha training (Plotkin, 1977). In particular, it is possible that Hardt and Kamiya's high-anxiety trainees experienced anxiety decreases during alpha-enhancement training only because they expected such a change; likewise for anxiety increases during alpha decreases. Thus, contrary to Hardt and Kamiya's conclusions, it is possible that there is no intrinsic relation between alpha levels and either state or trait anxiety. What Hardt and Kamiya did not do in their study was to carefully separate the potentially confounded effects (on anxiety changes) of experienced success from actual performance at the alpha feedback task.

In light of the above considerations, we designed the present experiment to determine the separate effects of actual performance and perceived success on changes in both state and trait anxiety in persons with high trait anxiety. We hypothesized that the trainees' perceived success at an alpha feedback task that they believed led to anxiety reduction would be directly related to anxiety changes, whereas the actual EEG alpha changes, as well as the direction of contingency of the feedback task, would be unrelated to anxiety changes.

Our study was designed to replicate Hardt and Kamiya's high-trait-anxiety group as closely as possible while adding a second high-trait-anxiety group that received the same feedback training, except that, unknown to them, they received alpha-suppression training as a means of facilitating anxiety reduction.

Method

Research Participants

Our research participants were 10 undergraduates at the State University of New York at Albany (ages 18 to 29 years) who responded to posted notices requesting unpaid volunteers who would be interested in partici-
pating in an experimental biofeedback program in stress management and the control of chronically high anxiety levels, and who met the following criteria as used by Hardt and Kamiya (1978). Interested persons were accepted only if they (a) scored above 21 on the Welsh A (anxiety) scale of the Minnesota Multiphasic Personality Inventory (MMPI) (which resulted in a mean Welsh A score of 29.4 for our 10 participants, compared with a mean of 27.4 for Hardt and Kamiya’s participants) and (b) scored within acceptable limits of the MMPI validity scales ($L < 9, F^2 < 17$, and $K < 23$) in order to eliminate volunteers who were faking or dishonest. In addition, persons who were in psychotherapy at the time were not included. Out of 31 original volunteers, 15 met the above criteria, and 10 completed at least five training sessions. (Three from the alpha-enhancement group and 2 from the alpha-suppression group dropped out.)

**Apparatus**

The EEG was recorded by electrodes attached to the scalp over the occipital area (O$_2$) and to the right mastoid, with a forehead electrode as a ground. The EEG was amplified and filtered by a Bio-feedback Systems Model AT-2. The center frequency of the alpha filter on this unit is 10 Hz, with a 3-dB (SPL) attenuation of 7.5–8.5 Hz and of 15.0–17.0 Hz. The output of the AT-2 was fed to four locations: an audio feedback generator, a digital quantifier, a Lafayette strip chart recorder, and an oscilloscope. The audio feedback was in the form of an intensity-modulated tone appearing over a headphone set. The volume of the tone is proportional to the instantaneous alpha voltage.

The digital quantifier, Model DQ-1, also manufactured by Bio-feedback Systems, is a variable time base, four-digit accumulating counter. The integration time was set to automatically stop every 1 minute during baseline recording and every 2 minutes during EEG training and was manually reset after the DQ reading was recorded. The count accumulated over the 1- or 2-minute time period is proportional to the area under the curve of alpha strength versus time.

The Lafayette strip chart recorder and oscilloscope were used to monitor the unfiltered EEG for artifacts and to record the output of the DQ-1 in pulses. When electromyographic artifacts occurred (infrequently), the participant was reminded to keep his/her face, neck, and scalp muscles relaxed, and the effect of the artifact (as assessed on the strip chart recorder) was subtracted from the alpha strength count.

**Background**

Prior to the start of actual EEG training, all 10 participants were informed of the nature of biofeedback and of the potential benefits of alpha training for stress management. In particular, they were asked to read chapters 1 and 7 of Lawrence’s (1972) book Alpha Brain Waves. Special emphasis was given to the alleged relationship between EEG alpha enhancement and relaxed experiential states.

The participants were randomly assigned to one of two groups. The five persons assigned to the Alpha group were told that alpha enhancement would lead to anxiety decreases and that alpha suppression would lead to anxiety increases. On the other hand, the five persons assigned to the Beta group were told that they would receive training in the suppression and enhancement of beta brain waves. These participants were informed that although alpha enhancement is considered an effective means of facilitating anxiety reduction, the experimenters hypothesized that “beta suppression” may be a more direct and powerful way to reduce anxiety levels. However, participants in the Beta group were, in fact, receiving the same sort of feedback (alpha) as the Alpha group, so that when the Beta participants were engaged in what they thought was beta-suppression training (attempting to lower the tone volume), they were actually training in alpha suppression.

Each volunteer completed the entire MMPI prior to the start of actual EEG training, which yielded, among other measures, scores on the Welsh A and Taylor Manifest Anxiety scales (Dahlstrom & Welsh, 1960). At this time, volunteers also completed the A-Trait scale of the State–Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). Prior to the first training session, participants were given a pretraining questionnaire in which they were asked to rate (on 1–9-point scales) their predictions of the effectiveness of the biofeedback procedure, their confidence in that prediction, and the degree to which they were motivated to engage in the training program. Throughout the training program, we emphasized to the participants the importance of authenticity and honesty on all of their self-report questionnaires. They were each free to choose the number of feedback sessions (from five to seven) in which they would participate. The training period extended over approximately 3 weeks for each participant.

Each day, after the electrodes had been attached, the participant was seated in the experimental room and completed the STAI A-State scale. A 10-minute baseline recording was then conducted in which he or she was asked to close his or her eyes, and the lights in the experimental room were turned off.

On the first and second days of training, following the initial anxiety scale and baseline, we recorded from each participant: (a) 16 minutes of alpha-enhancement (or beta-suppression) feedback, (b) a second anxiety scale, (c) 8 minutes of alpha-suppression (or beta-enhancement) feedback, (d) a third anxiety scale, (e) 16 additional minutes of alpha-enhancement (or beta-suppression) feedback, (f) a final anxiety scale, and (g) a postsession questionnaire. Following the first 2 days of training, the 8-minute periods of alpha suppression (or beta enhancement) were eliminated (along with the two middle anxiety scales), so that following the baseline recording, each participant engaged in 40 uninterrupted minutes of his/her primary task of either alpha enhancement or beta suppression.

At the start of the training program, each participant was given instructions for home exercises in which he/she was to relax and try to induce the most relaxed feeling state experienced during biofeedback training. During training, feedback scores were read to the participants every 2 minutes. These three-digit numbers were ostensibly proportional to the preceding trial’s alpha (or beta) amplitudes. However, in order to separate the effects of perceived success and actual performance,
participants were read their actual scores only after the first 2-minute trial of any session. Subsequently, each actual alpha score was either increased (during alpha enhancement) or decreased (during beta suppression) by an additional (and accumulating) 1% of that day's baseline score for that participant. Thus, although these scores were still responsive to the participant's actual alpha amplitudes, and although the actual feedback tone was still being used, trainees in both groups were led to believe that they were succeeding at their task at a convincing rate. During alpha suppression (or beta enhancement), participants were read their actual integrated alpha scores.

The daily baseline score was double the highest 1-minute trial reading of the alpha-strength integrator of those recorded during the 10-minute baseline period. This doubling was necessary for the baseline score to be comparable to the 2-minute feedback trials. This method ensures that a person's optimal naturally occurring alpha level is used as a baseline, since (a) only the highest of the 10 1-minute trials is used, and (b) the 1-minute window is wide enough so that transient bursts of alpha do not overly inflate the baseline score.

After all sessions of EEG training had been completed, participants again completed the entire MMPI and the A-Trait scale.

Results

Anxiety Changes

Three measures of trait-anxiety change were used for each participant: the Welsh A, the Taylor Manifest Anxiety, and the A-Trait scales, taken before and after the 5–7-session training period. For each of these measures, we performed a $2 \times 2$ mixed analysis of variance (ANOVA) with repeated measures on the pre–post factor and with alpha training direction as the between-groups factor. All three ANOVAS produced significant main effects on the pre–post factor, $F(1, 8) = 20.27, p < .005; F(1, 8) = 25.71, p < .001$; and $F(1, 8) = 83.81, p < .001$, respectively, indicating significant reductions in trait anxiety for both the alpha-enhancement (Alpha) and alpha-suppression (Beta) groups. There were no significant between-group effects or interactions. The pre- and posttraining trait-anxiety means are shown in Table 1. In contrast to these reductions, three persons who met our criteria for high trait anxiety but who did not receive feedback training (a waiting-list control group) showed nonsignificant mean increases in trait anxiety of 2.3, 1.7, and 3.0 points, respectively, for the three trait-anxiety scales, each taken twice, 3 weeks apart.

Initial daily state-anxiety levels also decreased across sessions for both groups: A $2 \times 5$ ANOVA with one between-groups factor (feedback contingency) and one within-groups variable (five sessions) was performed on initial daily state-anxiety levels, indicating a significant main effect of days, $F(4, 32) = 3.56, p < .05$, but no effect of group and no interaction. The means for the initial daily anxiety levels were 49.4, 45.9, 39.4, 40.3, and 39.6. State-anxiety levels also decreased during alpha-enhancement periods for the Alpha group and during beta-suppression periods for the Beta group (which was actually alpha suppression). Mean reductions were 6.8 for the Alpha group and 6.0 for the Beta group. Likewise, state-anxiety levels increased during the Alpha group’s alpha-suppression periods and the Beta group’s beta-enhancement periods. Mean increases were 5.0 and 4.0, respectively.

Actual Performance

Actual changes in alpha-strength levels during training were computed three different ways in order to be sensitive to both tonic and phasic changes in alpha EEG. For the Alpha group, the first actual performance measure (AP-1; most tonic) was calculated as follows: $(M - B)/B$, where $M =$ the mean integrated amplitude score for the session’s 2-minute alpha-enhancement trials, and $B =$ that day’s baseline score. The AP-2 (intermediate) measure was calculated as

Table 1

Pre- and Posttraining Trait-Anxiety Means for Alpha and Beta Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Scale</th>
<th>Welsh A</th>
<th>TMAS</th>
<th>A-Trait</th>
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<tr>
<td>Alpha</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>5</td>
<td></td>
<td>31.0</td>
<td>37.2</td>
<td>60.6</td>
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<tr>
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<td></td>
<td></td>
<td>20.6</td>
<td>23.2</td>
<td>42.5</td>
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<tr>
<td>Beta</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>5</td>
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<td></td>
<td></td>
<td>14.0</td>
<td>16.8</td>
<td>38.8</td>
</tr>
</tbody>
</table>

Note. TMAS = Taylor Manifest Anxiety Scale.

For normal populations.

Note.
\((H - B)/B\), where \(H\) = the highest integrated amplitude measure of the last five 2-minute trials of the session. The AP-3 (most phasic) measure was the same as AP-2, except that the \(H\) score was the highest of all of the sessions trials. For the Beta group, the same AP scores were calculated, except they were made negative, so that increasing success for both groups would make their AP scores more positive. (This facilitates the combined-group correlation analyses discussed below.)

Analyses of variance on these AP measures indicated that, in general, persons in the Beta group were able to significantly suppress their alpha activity below eyes-closed baseline levels, whereas four of the five persons in the Alpha group failed at producing actual alpha enhancement. The one exception (in the Alpha group) succeeded at producing alpha levels substantially (over 800%) above baseline levels. His extraordinary performance is discussed in detail elsewhere (Plotkin & Rice, Note 1). Here we will only note that his degree of experienced success and the magnitude of his anxiety reductions were actually lower than the group means, despite his unusual success at alpha enhancement.

Since the inclusion of this participant's aberrant data would tend to distort results derived from the statistical analyses, we decided to eliminate his scores from one set of analyses and to perform an unequal-\(N\) ANOVA on each of the three AP measures. These results indicated that there were significant differences between the groups on all AP measures: For AP-1, \(F(1, 7) = 30.43, p < .001\); for AP-2, \(F(1, 7) = 19.90, p < .005\); and for AP-3, \(F(1, 7) = 15.71, p < .01\). They also supported our observation that persons in the Beta group were successful at decreasing their alpha activity during feedback, whereas four of the five persons in the Alpha group failed to produce alpha significantly above baseline levels (see Table 2).

### Table 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>AP-1</td>
<td>-.096</td>
<td>-1.013</td>
<td>-.016</td>
<td>-.220</td>
<td>-.111</td>
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<tr>
<td></td>
<td>AP-2</td>
<td>.067</td>
<td>-.053</td>
<td>.081</td>
<td>-.124</td>
<td>.055</td>
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<tr>
<td></td>
<td>AP-3</td>
<td>.161</td>
<td>.070</td>
<td>.132</td>
<td>-.065</td>
<td>.069</td>
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<tr>
<td>Beta</td>
<td>AP-1</td>
<td>.304</td>
<td>.379</td>
<td>.387</td>
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<tr>
<td></td>
<td>AP-2</td>
<td>.435</td>
<td>.434</td>
<td>.467</td>
<td>.484</td>
<td>.456</td>
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<tr>
<td></td>
<td>AP-3</td>
<td>.468</td>
<td>.505</td>
<td>.518</td>
<td>.519</td>
<td>.502</td>
</tr>
</tbody>
</table>

Note. \(n = 4\) for Alpha group; \(n = 5\) for Beta group.

### Perceived Success

Daily perceived success at the major feedback task was determined by the following question in the postsession questionnaire: “How successful did you feel at alpha enhancement (beta suppression)?” Participants rated their feelings of success on a 1–9-point scale ranging from complete failure to extremely successful. There were no significant differences between groups in their mean ratings (for Alpha, \(M = 5.74\); for Beta, \(M = 5.20\)).

### Correlations

For the combined group of 10 trainees, Pearson correlations were computed between trainees’ mean daily perceived-success ratings and their trait-anxiety reductions, producing significant \(r_s\) of .78, .70, and .75 \((p < .02)\) for the Welsh A, Taylor Manifest Anxiety, and A-Trait scales, respectively. Likewise, the trainees’ postexperimental appraisals of the effectiveness of the biofeedback program were significantly correlated with perceived success \((r = .90)\) as well as with the three measures of trait-anxiety change \((r_s = .82, .79,\) and .66). In contrast, there were no significant correlations between any of the trait-anxiety changes and any of the three alpha performance measures.

The trainees’ preexperimental predictions of the effectiveness of the biofeedback program in reducing anxiety were not significantly correlated with reported anxiety change; neither were the preexperimental ratings of their motivation level for engaging in biofeedback training.

### Discussion

The present study demonstrates that significant anxiety reduction can be facilitated
by the alpha biofeedback context independent of the effects of alpha training on alpha brain waves themselves. Indeed, we have demonstrated that anxiety reduction is just as effectively produced with feedback training for decreased alpha levels as it is with training for increased alpha levels (provided the trainees are not aware of the popular implications of the former contingency). The reductions in trait anxieties that we observed are greater than those found by Hardt and Kamiya (1978), who noted that their “reductions in trait anxiety were large enough to be useful in anxiety therapy” (p. 80).

The present results have, in addition, demonstrated the crucial importance of considering the biofeedback trainees’ specific expectations as well as their experiences of success or failure at the biofeedback task. Although our research participants’ anxiety reductions were unrelated to either the direction or magnitude of actual alpha changes, they were highly and positively correlated with the trainees’ ratings of perceived success at the biofeedback task, a task that they were led to expect would be effective at facilitating anxiety reduction. The overwhelming importance of perceived success in determining the extent of value obtained from the training is further underscored by the findings that reported anxiety reductions failed to correlate with either of two other social psychological factors: the trainees’ preexperimental predictions of the effectiveness of the biofeedback program and their preexperimental ratings of their motivation level for engaging in the training.

One of the major implications of these results for biofeedback research is the necessity of employing the sort of specially engineered methodology instantiated in the present study, a methodology that separates out the easily confounded effects (on experiential, psychological, and physiological outcomes) of actual performance from the effects of perceived success at a biofeedback task. Such a methodology is especially important when investigating or evaluating a training program for the self-regulation of a physiological process that is claimed or believed to be directly associated with psychological symptoms such as anxiety (Plotkin, Note 2).

The present study also demonstrates that Hardt and Kamiya’s (1978) observations of an inverse relationship between alpha and anxiety are, at best, inconclusive. We have shown that Hardt and Kamiya’s results may be totally explainable on the basis of a positive relationship between perceived success and anxiety reduction. However, it should be noted that the present study does not directly address the question of a possible direct association between alpha and anxiety. Our study by itself does not rule out the possibility that there is a weak inverse relationship between alpha and anxiety and that the trainees’ expectations and perceptions of success are significantly powerful to completely override and obscure such a relationship. However, previous research that has more explicitly addressed this issue has failed to produce empirical support for an intrinsic or consistent relationship between alpha and anxiety (e.g., Orne & Paskewitz, 1974; Plotkin, 1976b, 1978; Plotkin & Cohen, 1976; Travis, Kondo, & Knott, 1975). Furthermore, the one participant in the present study who achieved an extraordinary degree of above-baseline alpha enhancement did not find it to be particularly relaxing or calming, despite the fact that as a member of the Alpha group, he was led to expect an experience of relaxation. In any case, the clinical significance of a possible weak relationship between alpha and anxiety appears to be minimal, since social psychological factors such as expectation and perceived success have been shown to be relatively overpowering.

In conclusion, it is becoming increasingly evident that social psychological factors inherent in the biofeedback context are major determinants of the success of biofeedback treatment. For a variety of reasons specified elsewhere (Plotkin, 1979, 1980; Stroebel & Glueck, 1973; Plotkin, Note 2), the biofeedback context (independent of actual performance at the operant modification of physiological processes) may serve as a very powerful placebo that is highly effective in inducing experiential and behavioral changes by evoking the trainee’s latent self-control abilities. The present research supports this conclusion for the reduction of high trait anxiety. The degree to which this finding can
be generalized to other disorders and the long-term effectiveness of such procedures require additional study.

Reference Notes


References


Received March 30, 1981