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# Emg biofeedback ;: controlled for three placebo conditions.

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EMG BIOFEEDBACK:  
CONTROLLED FOR THREE PLACEBO CONDITIONS

A Thesis Presented

By

JEFFREY L. LUKENS

Submitted to the Graduate School of the  
University of Massachusetts in partial fulfillment  
of the requirements for the degree of

MASTER OF SCIENCE

April 1976

Psychology

EMG BIOFEEDBACK:  
CONTROLLED FOR THREE PLACEBO CONDITIONS


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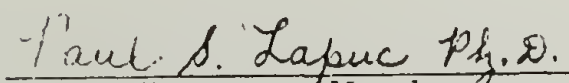
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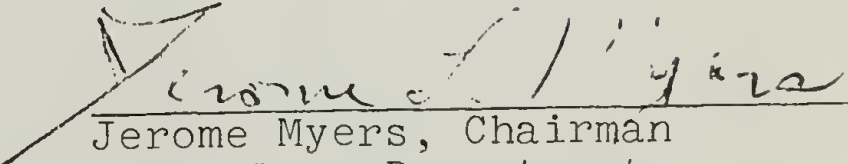
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## C H A P T E R I

Part I--Review of the LiteratureIntroduction

The popularization and clinical use of biofeedback is everywhere in evidence. Newspaper, magazine, and professional articles on biofeedback are greatly increasing. Biofeedback societies, clubs, clinics, newsletters, journals, annuals and books are burgeoning. There is a rapid growth of biofeedback instrumentation, from small, inexpensive, portable units to the most complex and sophisticated automated devices. The uses of biofeedback extend from training trumpet, trombone and clarinet players to relax their upper lip and develop more skill (Gillies, 1972) to rehabilitating those afflicted with muscular disorders, from changing states of consciousness to altering the heart rate and blood pressure differentially. Literally every aspect of clinical symptomology (somatic, psychosomatic, neurotic, psychotic) is being approached with biofeedback. But some important problems have developed in the biofeedback literature (Shapiro, 1972).

Many researchers are now concerned that the uses of biofeedback, both clinical and otherwise, far outstrip any solid base of research. Johann Stoyva (1971) echoes the sentiment that little is known for certain, especially in the use of biofeedback with humans. During 1972 the problem became more

apparent than previously as Neal Miller and his researchers failed to replicate their own earlier experiments on learned control of heart rate in rats. This was a severe blow to biofeedback for the early Miller experiments (1967, 1968, 1969) on the curarized rat had been assumed by all biofeedback researchers to have supplied the overall foundation on learned autonomic control. In his preface to the 1973 Biofeedback and Self-Control Annual, Neal Miller calls for research much more rigorous than that before. He cites the urgent need for replication, but also for more rigorous controls, especially with human subjects. In particular, he urges future research to control for the various possible placebo effects.

There still remains a dearth of basic research, let alone good research, into the central questions about the nature and efficacy of biofeedback, especially EMG biofeedback. In other biofeedback areas (especially EEG, blood pressure and heart rate) there has been significantly more research, and certainly more elegant designs for control of placebo effects. However, the EMG modality of feedback is clinically just as important as these other areas. Consider, for example, that our muscles make up roughly 50% of our bodily mass. This has consequences for the amount of proprioceptive input to the brain, the psychologicalizing of somatic problems and the somaticizing of psychological problems. Further, consider the widespread observation that

this is the age of anxiety with all its associated bodily and muscular ills. It is also of importance that EMG biofeedback is at present being used extensively in various clinical settings. Given all this, the paucity of pure EMG biofeedback research on man is all the more significant.

### Biofeedback Controls

Previous biofeedback studies with humans, other than in EMG, have controlled for some of the placebo effects. Using heart rate or blood pressure, Fey (1975), Meyer-Osterkantz et al. (1972), Lang (1967, 1970), Schwartz (1972), Shapiro (1972), Stern and Botts (1972), Miller and DiCara (1967), Miller et al. (1968), Miller (1969), and others too numerous to mention have used the controls of non-contingent success, non-contingent not success, and no feedback in various combinations. However, none have used all three of these placebo controls in one experiment.

The biofeedback studies with humans have mainly focused on clinical applications or just on the effectiveness of real EMG biofeedback itself without controls. Some have compared the effectiveness of EMG biofeedback in reducing muscular tension (actually its correlate, peak-to-peak muscle action potential recorded from the skin) with other forms of relaxation (Haynes, 1974; Haynes, Morely, & McGowan, 1975; Rein-king et al., 1975), tracking tasks, and psychotherapy (Townsend, Hanne, & Addurio, 1975). Examples of these other me-

thods of relaxation are Jacobson's relaxation procedures (Staples & Coursey, 1975), yoga, Schultz and Luthe's Autogenic training, Wolpe's desensitization, and the Budzynski and Stoyva (1971) and Green, Green, and Walters (1974) combined relaxation and biofeedback procedures.

The studies in EMG biofeedback with humans which have used controls are surprisingly scarce. Controls of non-contingent success, non-contingent not success, steady tone feedback, no feedback, different instructions, and different types of feedback (e.g. auditory, visual) have been used, alone and in various combinations (Alexander & Hanson, 1974; Budzynski & Stoyva, 1969, 1971, in press; Coursey & Frankel, 1974; Haynes, 1974; Kinsman, 1975; Montgomery et al., 1974; Rubow & Smith, 1971; Steffen, 1975; Wickramasekera, 1972).

### Conclusions

The relevant conclusions to be drawn from the controlled studies of human EMG biofeedback are:

1. EMG biofeedback seems to work, given the controls which have been used up to now. That is, both in terms of lowered EMG MAP (muscle action potential) and several other indices of tension (hypnotic suggestability, subjective report, less call for medication, GSR, EEG, blood pressure and heart rate), feeding back one's current MAP (the frontalis is used most frequently) enables a subject to change the tension level of that muscle (often generalizes to other parts of the

body), and to lower or raise the tension level of that muscle.

2. The greatest amount of improvement in terms of lowered MAP often occurs within the first biofeedback session (10-30 mts. of biofeedback time), and almost always there is some improvement. It is significant that subjects easily learn to control their MAP to some degree even without specific instructions or prior relaxation techniques, using only their past experience with their own internal cues as now aided by instrumented feedback in a trial and error fashion. However, previous relaxation therapy techniques or specific instructional "tips" do increase the feedback effect.

3. Contingent feedback is more effective than the controls, and often much more effective. However, the controls (noncontingent success, not success, and no feedback) have all had a positive effect (lowered MAP from the resting state) as well, but comparisons among studies are almost impossible to make because these conditions were tested in different experiments with different procedures, different quantifications, varying baseline resting states, and different equipment and procedures. In general, bogus success feedback has been the most successful control, but there is confusion about the inconsistent results, depending on whether the measure of relaxation is taken during or after the experimental treatments. Non-contingent not success feedback most often has not been effective and has sometimes proven too frustrat-

ing. The no feedback control has generally demonstrated little change one way or the other. It does seem to promote less attentiveness than the other conditions.

4. The instructional set is important. For example, if subjects were told nothing about relaxation but merely told to follow a moving needle or listen to a changing tone (essentially a tracking task) which might be actual feedback of their own MAP, there is little decrease in MAP. But if a subject is told that the sound or needle registers the amount of tension in a muscle, whether it actually does or not, seems to produce a greater decrease in MAP, and much greater if the feedback is not bogus. Valins and Ray (1967) and Valins (1968) stress the importance of the cognitive labeling process in man which seems to be responsible for this effect, which explains the lack of comparability with animal studies.

Bandura (1969), Barber (1970, 1975), Lang (1967), Valle (1975), Walsh (1974) and others have demonstrated that the effectiveness of reinforcement procedures (feedback) may be enhanced by verbal instructions, or, from another perspective, that relaxation instructions are one of the significant antecedent variables which increase suggestibility. It may be that instruction and expectancy increase relaxation and relaxation increases the effect of the instructions. Again, certainly specific relaxation "tips" or instructions, such as keeping a slack jaw, increase the effectiveness of EMG



biofeedback.

5. Subjects receiving bogus (non-contingent) feedback almost never discover that they have been fooled. Even with non-contingent not success feedback, which might seem to be frustrative and cause the subject to question the feedback, invariably the subject changes his cognitive set about his own internal cues rather than question the experiment (Valins & Ray, 1967, 1968).

6. There are no obvious differences in the amount of muscle tension (change in MAP) with regard to sex differences, education, or IQ. However, females tended to have higher MAPs. There also is some indication that the curve of the change and the amount of the change in MAP does vary with the initial baseline resting state in a comparison of a highly elevated resting state MAPs (often labeled as high anxiety, resting MAPs above 20 microvolts) and a more "normal" resting state (average 10-20 microvolts). The biofeedback literature does not report MAP differences with respect to age, but research on MAPs report higher voltage levels with increasing age and an increase in the duration of the mean action potential during movement due to age (there are some conflicting experiments) (Goldstein, 1972).

Also, the atmospheric temperature has been found to be positively correlated with resting EMG surface amplitude (Goldstein, 1972) but room temperature is not stated in the biofeedback literature.

7. The frontalis is the most frequently used muscle in these studies and is the most frequently used for clinical applications. Further "only the frontalis maintained its high level of reliability throughout all (experimental) conditions" (Goldstein, 1972, p. 339). The test-retest reliabilities for the frontalis in a relaxation (or any) condition are around 0.8, far above that of any other tested muscle (the highest being .46), including the Gastrocnemius, Tibialis, Forearm flexors and extensors, Trapezius, and the Masseter (Goldstein, 1972).

8. The relationship between physiological measures of relaxation (MAP) and subjective reports tends to show little to no significant correlation (Alexander & Hanson, 1974; Alexander, French, & Sobelman, 1975; Haynes, Morley, & McGowan, 1975; Mehearg & Eschette, 1975). Jordan and Schullow (1975), however, found a significant correlation.

The EMG Biofeedback literature indicates that there remains confusion about the relative effectiveness of the placebo controls with one another as a function of real feedback. There are difficulties in comparatively interpreting the studies and in discerning the differences in the placebo effects when the subjects are in the experimental treatments and after the treatments. There is need for an experiment to contrast the three placebo controls (non-contingent success, not success, and no feedback) with real feedback in a design incorporating a baseline, experimental trials, a post trial,

and subjective reports, as determined from a review of the literature and from a personal communication with T. X. Barber (1975).

## Part 2--Statement of Problem

### The Problem

The relaxation effect, often thought to be demonstrated once a subject has been given the appropriate feedback and set, is being questioned in the literature. Does feedback itself, of the type and under conditions most popularly used in clinical settings, enable a subject to reduce forehead tension significantly? The focal problem is whether the EMG modality of feedback itself is significantly responsible for the apparent relaxation effect observed in one session or whether the relaxation can be attributed to one or more placebo effects.

### Definition of Biofeedback

The definition of EMG biofeedback relies on the concept of a closed output-input loop wherein the subject alone is the effective agent of change within the system. The subject is given immediate and continuous presentation of encoded information (the input--audible clicks) about his Muscle Action Potential (the output--the MAP of the frontalis fore-

head muscle). The subject, given the proper set or motivation, can potentially change the overall level of the system. Most relevant to clinical application, the subject can change the MAP of his forehead.

### Controls in Previous Studies

Previous studies have attempted to discern various aspects of the total biofeedback system. For example, the effect of technical aspects of the feedback on learning have been tested. These include a patterned or unpatterned noise, varying the time of the interval between clicks, requiring increased proficiency in order to receive feedback, and varying the proportionality between the MAP and the click rate. Some experimenters have varied the instructional set as noted in the literature review.

The relevant controls for the purposes of this experiment in EMG biofeedback include some form of "non-contingent feedback" or "no feedback." Various experimenters have used different combinations of these types of feedback (Budzynski & Stoyva, 1969; Fey, 1975; Haynes, 1974; Kinsman, 1975; Rachman, 1968; Steffen, 1975; Wickramasekera, 1971). These experiments have tested three types of placebo effects--bogus or non-contingent feedback of success, bogus or non-contingent feedback of not success, and no feedback--but no single experiment has tested all three types together as controls for real feedback.

The first two types of placebo controls, non-contingent success and non-contingent not success feedback, test the closed loop part of the definition of biofeedback. Once the loop is opened, as in non-contingent feedback, the subject no longer receives his own feedback, no longer is he the effective agent of change. If everything else stays the same, can the observed relaxation be attributed mostly to the receiving of some type of stimulus, which in fact is non-contingent with the physiological state of the subject? Explanations for why a non-contingent stimulus might produce relaxation include that of attention and/or tracking, induction of non-veridical cognitions, cognitive labeling and expectation, or some mysteriously induced effect produced by a repetitive stimulus. In any event, relaxation produced by a non-contingent stimulus which was not significantly different from that produced by real biofeedback would undermine the operant conditioning paradigm which has been central to the explanation for the biofeedback effect. A subject in a non-contingent setting would be receiving continuous stimuli which he might interpret as being his own immediate and contingent feedback. Although he might feel this stimulus is a kind of reward or punishment, nevertheless it is not his own and in no consistent way would it positively or negatively act as a reinforcer.

### Placebo Controls in This Study

This experiment was designed to pull together the disparate, contradictory, and incompatible experiments which have used the relevant placebo controls in various combinations, but never all three at one time. These controls are non-contingent feedback of success, non-contingent feedback of not success, and no feedback. Previous experiments have not always clearly defined the nature of "success", "not success", and "no feedback", nor have they made these controls truly comparable to the real feedback.

The non-contingent feedback of success in this experiment approximates the average signal of the average successful subject in a previous pilot study and was adjusted, as required, to match the real group in this experiment. This design will more closely match the two groups for everything but the non-contingency, and should induce in the subjects a sense of success. This bogus feedback has been found to be the most successful of the three placebo controls and occasionally almost as effective as the real feedback.

The non-contingent feedback of not-success will be a random signal also created to stay within the average limits of the real feedback subjects and will vary randomly around their mean level of feedback. This type of feedback has occasionally been found to produce relaxation, but then often much less than either the real feedback or non-contingent feedback of success.

The random feedback is expected to be somewhat frustrating. The subject will be unsuccessfully trying to get control over the feedback and there will not be a cognitive manipulation for success. It is expected that this random feedback will be less successful in producing relaxation than the feedback of success. Because even the random feedback may be more interesting to the subjects than no feedback, it is expected to be more successful than the no feedback group.

The last of the bogus conditions, no feedback, is a condition in which the subject receives no audible feedback signal. This standard control has often been used previously as a way of determining the effect of time on a subject who is trying to relax. Past studies using the no feedback control have introduced at least one condition which may make for lack of comparability with the other conditions. In most other studies the subjects did not wear earphones which help block out external noise and may allow for more attention to internal cues. Further, in no previous studies were the subjects asked to attend to an internal source of control similar to the feedback of the other groups. To make up for this deficiency, in this experiment the subjects wore earphones and were given a set to attend to non-existent feedback which they thought was merely inaudible and "subliminal".

The no feedback control group has occasionally shown some lowering of the MAP in previous studies although less relaxation than in the other two bogus conditions. This may

indicate that the set and setting themselves have importance in inducing relaxation over a period of time. This experiment increases the similarity in set and setting between this no feedback group and the other experimental groups. It is expected that this condition will produce some relaxation, but less than the others.

### Rationale for These Placebo Controls

The rationale for the choice of these particular placebo controls being used in one study is that they will enable determination of the effectiveness of real feedback. It is thought that an induced feeling of success, an induced cognition of control which the success engenders, focused attention on an external stimulus, and time spent in a set and setting which are heavily loaded for relaxation will account for some of the relaxation produced by real biofeedback. The use of all three controls, well defined and comparable to the real feedback except for the manipulation of one variable, will allow more accurate determination of the extent of the placebo effect. It is expected that the amount of real feedback not controlled in the placebo conditions will account for most of the relaxation.

### The Experimental Design

In addition to the proper placebo controls the experimental design is crucial for determining the effectiveness of



real biofeedback. Five designs using five measures have been used previously: 1) the experimental trials, 2) a post-experimental trial without feedback, 3) subjective reports, 4) meeting some predetermined criterion of success and maintaining it for a specified period of time, and 5) observation of other behavioral changes.

This experiment utilizes a combination of the first three designs. It is expected that this combination will provide what is necessary and sufficient to allow each of the experimental groups to show their maximum effect both physiologically and subjectively. Further, this design, in providing three perspectives in which to look at the data, will allow discrimination of the complex interplay of subjective and physiological events.

The overall experimental design is one of repeated measures (twelve 100 second trials separated by 30 second rests) preceded by a baseline trial and questionnaire, and followed by another questionnaire and post-experimental trial without feedback. The instructions for the baseline, experimental trials, and post trial are heavily loaded to induce a relaxation set. However no specific methods of relaxation are given in any of the phases.

### Three Measures

1. The Experimental Trials measure tests the effect of a given type of feedback in that feedback condition. The

type of feedback may influence the amount of relaxation by inducing a sense of control, of success, or of frustration. The groups are expected to be ordered, from most to least relaxation, as follows: Real Feedback, Bogus Success, Bogus Random, and Bogus No Feedback. The Real Feedback group is expected to quickly gain a sense of control and success. This should maintain attentiveness and encourage discrimination of subtle, internal, physiological cues. The Bogus Success group should be cognitively induced to think they are successful but the non-contingency of the stimulus might act as a distraction and interfere with a sense of control. The Bogus Random group is not expected to have a sense of control nor of success. The random signal should be frustrative and if there is successful relaxation it will be due to the effects of what amounts to a tracking task. The No Feedback group should not develop a sense of control, nor of success, nor occupation with a tracking task. Any relaxation will be due to time, set, and setting. The control groups are expected to show more variability than the Real group because of the lack of control over the stimulus. Fatigue and lack of task motivation might occur in those groups where control and success are not experienced.

2. The Post Experimental measure assumes little direct transfer of physiological relaxation from the last experimental trial. The transfer should be minimized by a five minute intervening period during which subjects fill out a

questionnaire. The Post measure should show the same results as the experimental trials measure in terms of the order of groups. However, the groups are expected to show less relaxation than they did in the Experimental Trials. The instructions for the Post measure are that subjects should try to relax as much as possible without feedback assistance. This measure will test to what extent subjects have learned relaxation skills. If a sense of success is all that is necessary for relaxation, then the bogus success group should be close to the real group on this measure. The effects of fatigue, of frustration, and of tracking will here be minimal and will contrast with the experimental trials measure.

3. The subjective reports are expected to help determine the extent of non-veridical cognitive manipulation compared with the subjective experience of real feedback. Discrepancies and congruencies between the subjective feeling of having relaxed and the physiological measures of relaxation are expected to throw additional light on how the placebo controls work and on the interaction of cognitions and physiological events. The subjective reports will also serve as a check on detection of the bogus nature of the controls and will ask for the methods subjects used to try to relax. It is anticipated that these questionnaires will be consistent with the physiological measures in terms of the ordering of groups in relaxation.

## C H A P T E R   I I

MethodSubjects

There were 48 subjects (24 males and 24 females) drawn from a university population of undergraduate volunteers for a biofeedback experiment. They received credit which counted toward their psychology course grades in return for their participation in the study. The only selection criteria were no prior biofeedback experience and not presently on medication.

The ages of the subjects ranged from 18 to 29, the mean age was 21.1. Goldstein (1972) reported little or no difference in change of MAP (Muscle Action Potential) due to age, and negligible resting state differences due to age if the age bracketing was relatively narrow (e.g., 10 years).

The first available 48 subjects to volunteer were selected with the restriction of half male and half female. The subjects were selected randomly and thus are assumed to represent a typical cross section of undergraduates. All 48 subjects which started the experiment finished, and none were disqualified as none unequivocally detected the bogus conditions (only one female had any doubts).

The subjects were counterbalanced in each of the four groups for sex and time of day of the sessions. A few experiments have matched subjects for resting state MAP, but

most did not and this experiment assumed random distribution with a normal undergraduate population. Any subjects who had a "high anxiety" resting state MAP ( $>20\mu\text{v}$ ) were to be rejected, but none did. The subjects were otherwise randomly assigned to the four experimental conditions so that there were 12 per group.

### Procedure

#### Preparation: Subjects, equipment, and pre-questionnaire.

All subjects arriving at the experiment only knew they had volunteered for an experiment in biofeedback. They were first given the following consent form with a brief description of the experiment:

This experiment is to test the effectiveness of one type of Biofeedback. I am testing the effectiveness of very good equipment in carefully controlled experimental conditions to help subjects learn to relax the muscles of their forehead. The relaxation of the forehead appears to be important clinically in many areas. These include helping people relax their overall level of tension, treating tension headaches, and in the desensitization to phobias.

This muscle or EMG form of Biofeedback is wholly passive, with no shock, without discomfort or risk, the only electrical activity coming from your own muscles and picked up with surface antenna-like pick-ups from your skin. In fact, the relaxation that you produce yourself is enjoyable. You learn by yourself, by trial and error, what you have to do to get more relaxed. You and only you are in complete control of the process of relaxation. The equipment is only to let you know how comparatively relaxed you are at any given time.

The experiment has three phases:

1. An initial period for getting used to the room, getting the pick-ups hooked up, answering two questions, and getting used to the experimental conditions. During the end of this period your level of muscle tension will be recorded. This period lasts 10 minutes.

2. The experimental period during which you will receive feedback and your muscle tension will be recorded. This consists of five minutes during which a short questionnaire will be given, followed by one last 100 second trial, but this time without feedback.

All inquiries concerning the procedures will be answered. You are free to withdraw consent and discontinue participation in the project at any time.

I agree to participate:

Once the consent form had been signed and any questions answered, the experimenter instructed the subjects how to apply Brasivol Skin Cleanser to their forehead, and then supervised the scrubbing. The purpose of the gritty Brasivol is to remove the skin's electrical insulation, oils, and the top layer of dead skin. This greatly helps to cut down on artifacts at the electrode site. The subjects received this explanation. They were then seated in a reclining chair (tilted to the first reclining position) in a dimly lit and soundproof room and asked to make themselves comfortable and to relax. Once seated they had a ten-minute interval before the baseline measure was taken, the more likely that all subjects, regardless of previous activity, would truly reach a similar resting state. During this time the use of the two-way intercom was explained (voice activated without pushing

buttons), the headband was applied, a tape recorded message was played, the equipment tested, a questionnaire was given, and the earphones were fitted.

The headband is a one inch wide rubber band with velcro fasteners and spaces for the insertion of surface disc type electrodes, all made by the Biofeedback Systems Company (BFS). The electrodes were inserted in the band so the two outside, active electrodes were four inches apart and the reference or ground electrode centered in between. The cups of the three electrodes were filled with Grass electrode paste and the headband applied snugly, but not tightly, so the electrodes were approximately 1 inch above the eyebrows and centered on the forehead. During a previous pilot study the electrodes were individually tested for a resistance of less than 5 K Ohms following the foregoing procedure. Without exception the electrodes always measured less than 5 K Ohms both during the pilot study and during the experiment. The resistance check was unobtrusively made during the playing of the tape. The purpose of the resistance check in insuring low resistance is to minimize the possibility of the electrodes acting like independent antenna and picking up electrical noise, to balance the resistance of the electrodes, and to avoid their possible polarization. Further, the site of the subject had been previously tested for electrical noise, as recommended by the BFS manual and found to be free of electrical "noise" from the standpoint of the BFS Feedback System.

The tape recorded message gave the purpose of the experiment, what they would hear, what their task was, and an outline of the events to follow. Short of having given specific relaxation tips, the tape was heavily loaded for relaxation. During the playing of the tape, the experimenter left the subjects' experimental room for the adjacent, sound-proof, equipment room, made a resistance check and checked the operation of the equipment. He then returned to the subjects' room at the end of the tape.

There was one tape for the first three treatment groups (Real, Bogus Success, Bogus Not Success) and one for the fourth (Bogus No Feedback), almost identical to the first. The first tape said:

The purpose of this experiment is to see how much you can relax the muscles of your forehead in one twenty minute session with the aid of biofeedback. As you probably already know, the pick-ups on your forehead are wholly passive, like an antenna, and only serve to pick up the subtle electrical activity in the muscles of your forehead. After an initial resting baseline period you will hear clicks through the earphones. The rate of the clicks will tell you how much electrical activity is present in the underlying muscles which is roughly related to the amount of tension there. It's very difficult to be aware of the amount of electrical activity which is in the order of millionths of a volt, but through this sophisticated biofeedback equipment you can be fed back the amount of your own electricity in terms of clicks and learn to control it through trial and error. The higher the click rate the more electrical activity and the more tension. Your task is to lower the click rate as far as you can and try to keep it as low as you can. After an initial baseline of 100 seconds without the click feedback you will be given twelve 100 second feedback periods, each separated by a 30



second rest period. After the last feedback period there will be another questionnaire and then another 100 second baseline without feedback to see if you can relax without the feedback. The equipment is very sensitive so try to keep reasonably still throughout the experiment. Try anything you think might help you relax during the experiment but keep your eyes open, close them only to blink, and try not to doze off or fall asleep.

The tape for the Bogus No Feedback group said:

The purpose of this experiment is to see how much you can relax the muscles of your forehead in one twenty minute session with the aid of biofeedback. As you probably already know, the pick-ups on your forehead are wholly passive, like an antenna, and only serve to pick up the subtle electrical activity in the muscles of your forehead. After an initial resting baseline period you will be given very high frequency clicks, too high to hear through the earphones. The rate of the clicks will tell you, hopefully subliminally, how much electrical activity is present in the underlying muscles which is roughly related to the amount of tension there. It's very difficult to be aware of the amount of electrical activity which is in the order of millionths of a volt, but through this sophisticated biofeedback equipment you can be fed back the amount of your own electricity in terms of clicks and learn to control it through trial and error. The higher the click rate the more electrical activity and the more tension. Your task is to lower the subliminal click rate as far as you can and try to keep it as low as you can. After an initial baseline of 100 seconds without the very high frequency feedback you will be given twelve 100 second feedback periods, each separated by a 30 second rest period. After the last feedback period there will be another questionnaire and then another 100 second baseline without feedback to see if you can relax without the feedback. The equipment is very sensitive so try to keep reasonably still throughout the experiment. Try anything you think might help you relax during the experiment but keep your eyes open, close them only to blink, and try not to doze off or fall asleep.

The questionnaire given to the subjects in this preliminary phase, before the experimental condition, contained two items, each rating subjective units of tension (SUTs). Subjects rated their level of tension on a 10-point graphic rating scale. The end points of the scale were defined by the following adjective clusters: "calm, relaxed, at ease," and at the other end, "jittery, nervous, tense." The first item asked how relaxed/tense their forehead felt. The second item asked how relaxed/tense they felt overall. A sample form of this questionnaire (#1) is found in the Appendix. The earphones were then fitted and the experimenter left for the equipment room.

Baseline and experimental treatment phase. The remainder of the 10-minute resting period was now allowed to expire and the equipment readied depending on which group the subject was in. Through the two-way intercom all subjects were then given a 15-second warning preparatory to the resting state baseline measurement. The message was: "The measurement of your resting state baseline trial will start in 15 seconds. There will be no feedback during the trial." Marking the start of this baseline trial it was announced: "Begin the baseline trial." During the next 100 seconds the accumulated MAP was measured and then recorded. At the end of the trial it was announced: "End of baseline trial. The first of twelve relaxation trials with feedback will begin in 30 seconds." During the next 30 seconds the counter was re-

set and the equipment checked to make sure it was ready for the twelve experimental trials.

The relevant equipment (tapes and tape recorder, EMG Device, cables and connectors) had to be prepared differently for each of the four experimental groups:

A. If the subject was in the Real group (real contingent feedback) the earphone cable was patched directly into the audio output jack of the EMG device.

B. If the subject was in the Bogus Success group (Bogus or non-contingent feedback of success) the earphone cable was patched into the tape recorder and the pre-recorded tape approximating the average success of the Real group was engaged.

C. If the subject was in the Bogus Random group (bogus or non-contingent random feedback) the earphone cable was patched into the tape recorder and the pre-recorded tape (click rate overall stays the same over trial, the mean and range approximating that of the Real group) was engaged.

D. If the subject was in the Bogus No Feedback group the earphone cable was completely disengaged.

The experimental treatment phase began 30 seconds after the resting state baseline trial, as mentioned above. Fifteen seconds before the first experimental trial this announcement was made to the Real, Bogus Success, and Bogus Random groups: "In fifteen seconds, when you hear the feed-

back, the first relaxation trial begins." The Bogus No Feedback group heard this: "In fifteen seconds the first relaxation trial begins." The subjects in the first three groups (Real, Bogus Success, and Bogus Random) thus began their trials when they heard clicks through the earphones and ended when the clicks ceased. The Bogus No Feedback group was told "begin" at the start of their trials and "end" at the end of their trials.

Ten seconds prior to the start of the first experimental relaxation trial for all subjects the chart recorder was started and kept recording for the duration of the twelve 100 second trials and the 30 second rest periods between each trial. It was shut off after the last of the 12 trials.

The timing of the trials and rest periods was done manually with a stop watch and rotation of the volume control on the EMG device to inaudible (rest periods) and up to full (trials). For the Real feedback group this was performed live, for the Bogus Success and Bogus Random groups it was pre-recorded and for the Bogus No Feedback group the timing was done live and starts and stops voiced over the intercom. The volume level was pre-set on the tape recorder to correspond with full volume on the EMG device. After the first trial (during the first part of the rest period) all subjects were asked via the intercom if they were comfortable, and thereafter every third trial. This had been found to be an aid in keeping subjects awake during a pilot study and keep-

ing a check on any difficulties with the headband or earphones and feedback. The experimental treatment phase ran for 20 minutes treatment time, 5-1/2 minutes rest time, or for a total of 25-1/2 minutes.

Post questionnaire, post experimental trial, last data gathering. The end of the twelfth trial marked the end of the experimental treatment phase. The chart recorder was turned off for all groups, the volume control was turned to inaudible for the Real feedback group, and the tape recorder was turned off for the Bogus Success and Bogus Random feedback groups. The EMG device and the counter-timer was left on so as to be ready (warmed up) for the post experimental trial. It was announced over the intercome that the feedback sessions were over, that the subjects should stay seated and that the experimenter would be right in.

The experimenter entered the experimental room and gave a questionnaire (#2) to the subject. This questionnaire is found in the Appendix. The first two items are identical to those of the first questionnaire. There were, in addition, two other items on this second questionnaire. The third item asked how they relaxed: "How did you relax? What did you do to try to relax?" The final item asked for comments. These subjective reports, besides giving a subjective indication of the effect of the treatment conditions, helped provide a check against detection of the bogus conditions. They also gave an idea of the subjects' awareness of their state

of relaxation compared with the EMG data, an indication of any overall relaxation effect generalizing from forehead relaxation, and provided further clues as to what techniques seemed to work best comparatively to produce relaxation.

The subjects were told to complete the questionnaire, that the experimenter was returning to the equipment room, and that the subject should notify the experimenter when they had finished the questionnaire. They were reminded that there would then be one more 100 second trial, this time without feedback. They were told that the purpose of their last trial was to see how much they could now relax without the aid of feedback and that the earphones and headband must therefore stay in place until after their last trial. Five minutes was allowed for all subjects between the end of the last experimental trial and the beginning of the final trial without feedback.

The procedure for this final trial was identical to that for the baseline trial. They were given a fifteen second warning and told when to begin and when to end. To make sure there was no chance of any noise through the earphones the earphone cable was disengaged. The 100 second accumulated clicks for this trial were displayed on the countertimer and recorded. When the trial was over the experimenter announced over the intercom that the experiment was over, that they were to stay in place until he came in to unhook them, and that he wanted to ask them a few questions.

The experimenter proceeded into the experimental room and helped the subject remove the earphones and removed the wire connection to the electrodes of the headband. The headband was left on so as not to increase the drying out of the electrode paste, which would make its removal more difficult.

The subjects were then asked their age, their GPA, their SAT scores, verbal and mathematical, whether they were meditators, and if so often or moderately, whether they were athletes, and if so whether they were moderately or very active at present, and the frequency of their headaches, if any. The experimenter then went over the final questionnaire with them, inquiring further about how they relaxed and about their comments. In this interaction with the subjects, as in all others, a consistently warm, relaxed, casual but business-like atmosphere was maintained. They were then told they could find out the results of the experiment on or after a specified date. The headband was removed, they were provided with facilities for washing off the electrode paste, and they were given credit slips for their participation.

Overview of the procedure---in brief. The experiment tested the comparative effectiveness of EMG biofeedback on the frontal muscle with three placebo controls: the bogus controls for non-contingent success, random non-contingent feedback, and the standard control of no feedback, all similarly loaded with a positive instructional set for relaxation

without specific relaxation instructions or "tips." The four independent variables, then, were:

1. Real contingent feedback given by means of a click rate directly proportional to the peak-to-peak surface potential of the frontalis.

2. Bogus success, non-contingent feedback (overall lowering click rate over trials). This was a taped signal created by the experimenter after a pilot study, and then after 25% of the subjects in the real feedback group were run. Thereafter, the real feedback group's click rate was monitored to see if the non-contingent success group's feedback tape need be adjusted to approximate the click rate of the real group. It did not have to be readjusted again. The average number of clicks across subjects within trials for the real feedback group, and the mean and approximate range determined and this average success curve was produced on tape. This did three things:

- a. The subjects in the two groups, real feedback and non-contingent success, were approximately matched as to total amount of feedback per trial and across trials, on the average.

- b. All the subjects in the non-contingent success group were given the same stimulus which minimized the variance which a yoked design would otherwise introduce.

- c. All subjects in this group were assured of



getting a successful feedback curve. If they were yoked with the real feedback group there would always be the chance that a subject in the real feedback group would not be successful.

3. Bogus Random, non-contingent feedback (not success-click rate overall stays the same over trials). This was a pre-recorded signal created by the experimenter so that there was no overall change, or random change, in the feedback within trials. The mean and approximate range was determined and adjusted as with the Bogus Success group.

4. The Bogus No Feedback condition. There was no external stimulus other than the instructional set and the experimental atmosphere. The subjects also wore earphones and were told they were to receive very high frequency subliminal feedback.

The dependent variable was the clock rate (number of clicks per 100 second trial). The clicks were digitized and accumulated on a counter-timer and its correlate, EMG potential in micro-amperes, was displayed on a continuous chart recording. Both outputs of the EMG device, click rate and variable current, were directly proportional to the peak-to-peak surface EMG potential in microvolts and the conversion was easily made for the final analysis, write-up, charts, and graphs.

The overall design was of one treatment (20 Mts. total treatment time), divided in 12 trials (100 seconds each),

with a pre-treatment (100 seconds) baseline and a post-treatment trial (100 seconds). There was a 30 second rest between all trials, including the baseline and trials. But there was a 5 mt. break between the experimental trials and the post trial. During this 5 mt. period the subjects were allowed to do anything while staying in the recliner, the better to "shake off" any relaxation transfer from the experimental trials. Before the baseline trial the subjects were given a two-item questionnaire and after the last treatment trial they were given a four-item questionnaire. When a subject entered the experimental room there were 10 mts. of no experimental conditions. This allowed for the subjects to be at the same activity level and allowed time for the hook-up. Following this was a short tape-recorded message. There was also a short tape-recorded message after the questionnaire and preceding the post trial instructing the subjects to relax their forehead without feedback.

There were three types of data collected:

1. Digitized readout of a Monsanto Model 100A Counter-timer. The EMG device's audio output is a click rate which varies from 0 to 100, proportional to the electrode pickup in microvolts. The numerical display on the Counter-timer is the total number of clicks for each 100 second trial, and for each 100 second baseline. The total number of clicks (the numerical display) divided by 100 yields the click rate. Biofeedback Systems, Inc., Denver, Colorado, had specially

supplied a graph plotting click rate as a function of the electrode pickup in microvolts. However, the experimenter made his own graph and chart so this EMG device had its own individual chart of click rate vs. microvolts. The converted microvolt level was used in the statistical analyses.

2. A continuous chart recording of the total treatment phase, trial, and rests served as a check against the digitization, provided a visual slope for each subject over trials, both between and within, and helped to explain any possible anomalies in the data.

3. Two subjective reports from each subject (see Appendix). Each subject was given, before the baseline, a two-item tension-rating questionnaire, each item with ten subjective units of tension (10 SUTs). Subjects rated their level of tension on a ten-point graphic rating scale. The end points of the scale are defined by the following adjective clusters: calm, relaxed, at ease, and at the other end, jittery, nervous, tense. One item asked how relaxed/tense their forehead feels now. The other asked how relaxed/tense they feel overall.

The second questionnaire was given during the five-minute hiatus. This contained four items:

a. How relaxed/tense they feel now on a 10-point SUT scale.

b. How relaxed/tense they feel overall on a 10-point SUT scale.

- c. How they relaxed.
- d. Comments.

### Equipment

Picking up an EMG signal on the order of 2-40 microvolts requires sophisticated equipment along with sound procedure. Artifacts such as 60 HZ noise and the heart and brain's electrical activity must be filtered out without losing the small EMG potential. Some of the equipment on the market is almost worthless, while often the good ones are so different that there is little chance for comparability and replication of experiments. In an excellent article comparing and evaluating commercial EEG and EMG feedback devices in 1975, Rugh and Schwitzgebel write that there is:

. . . little uniformity among devices with respect to many critical characteristics. . . EMG filter bandwidth varied from 55 HZ to 5900 HZ. Differences of this magnitude make the results of laboratories using different devices extremely difficult to compare and may account for some discrepant findings in research literature (1975, p. 89).

A good EMG biofeedback device is electrically safe, has low internal noise, a sharp high pass filter to eliminate signals below 95 HZ, shielded electrode leads and a high impedance differential input amplifier with high common mode rejection to help eliminate 60 HZ noise. A feedback device with these characteristics is produced by Biofeedback Systems, Inc. of Denver, Colorado (BFS #PE-2 or the B-1), and

is the one used more frequently in the literature. The counter-timer must be highly accurate, sensitive, and have a large capacity. With this in mind, the following equipment was used:

1. BFS EMG Device, model PE-2, specially adapted for the counter-timer, with earphones, headband, disc type surface electrodes, and monitoring meter, and cables.
2. Chart Recorder, Rustrak model 288, Gulton Industries, Inc., Manchester, New Hampshire
3. Monsanto model 100A Counter-Timer, West Caldwell, New Jersey
4. Sony Cartridge Tape Player-Recorder, model TC-92.
5. Callettra Multi-Tester, model H3-355.
6. Grass Electrode paste.
7. Brasivol Skin Cleanser.
8. Maxell tapes.
9. Assorted cables and connectors, batteries, chart paper, and a stop watch.

## CHAPTER III

Results

The results are divided into four sections. The first section is the Baseline, then the Biofeedback Trials, then the Post Trial, and finally the Questionnaires. The physiological data was transformed from the click rate back into microvolts before the analyses were performed. The rationale for this transformation is that the click rate (produced by the EMG device for feedback) is not linearly related to the Muscle Action Potential (MAP) in microvolts. A rough conversion chart was prepared specially by Biofeedback Systems, Inc., and this was modified by the experimenter for use with this EMG device.

Baseline

Since the subjects were assigned randomly to groups it was assumed that the groups would not differ significantly at the baseline. Using the Statistical Package for the Social Sciences (Nie et al., 1975) computer program, a one-way analysis of variance revealed, in fact, that the groups did not differ at the baseline,  $F(3,44) < 1$ , n.s. As expected, the females had a higher baseline MAP than the males,  $F(1,40) = 4.29$ ,  $p < .05$ ;  $M_s = 8.9, 7.2$  microvolts, respectively. Table 1 gives the baseline means broken down by group and sex.

Table 1  
Group Means and Variance for the Baseline

Groups	Male	Female	Overall	Variance
Real Feedback	7.2	8.5	7.9	16.91
Bogus Success	6.3	10.5	8.4	9.68
Bogus Random	8.3	9.5	8.9	4.82
Bogus No Feedback	7.1	7.0	7.1	2.16
Overall Mean	7.2	8.9	8.1	

Note. Computer program BMD, P2V.

N = 48, 12/group.

Scores are in microvolts. They represent Muscle Action Potential means in a 100 second trial without feedback.

A justification test was performed for the correlation between the baseline and the mean of the twelve experimental trials for each group. The SPSS Pearson Correlation analysis revealed a high and significant correlation for each group:

Real Feedback,  $r(10) = .62$ ,  $p < .025$ .

Bogus Success,  $r(10) = .89$ ,  $p < .001$ .

Bogus Random,  $r(10) = .64$ ,  $p < .025$ .

Bogus No FB,  $r(10) = .70$ ,  $p < .01$ .

These significant correlations indicated that the use of the baseline measure as a covariate warranted the loss of 1 df. The means and variance for the groups at the Baseline are listed in Table 2. Figure 1 at the end of this chapter portrays the baseline means in the context of the overall results.

### Biofeedback Trials

The amount of relaxation (lower MAP) in the biofeedback trials was expected to be different for each of the groups. An analysis of covariance (EMD, P2V) revealed the predicted difference in relaxation due to groups,  $F(3,39) = 8.41$ ,  $p < .001$ . The trials by group interaction also was significant,  $F(33,440) = 1.46$ ,  $p < .05$ . The full analysis of covariance is presented in Table 2.

The four groups were expected to show a relaxation ef-



Table 2  
 Analysis of Covariance for the Experimental Trials

Source	df	MS	F	Probability F Exceeded
Mean	1	895.73669	17.14863	.000
Groups	3	439.22655	8.40887	.000
Sex	1	37.20356	.71225	.404
Groups X Sex	3	88.38143	1.69204	.185
Covariate-Prebase- line	1	951.46556	18.21554	.000
Error	39	52.23371		
-----				
Trials	11	5.19069	1.49127	.131
Trials X Group	33	5.09522	1.46384	.050
Trials X Sex	11	2.05843	.59138	.836
Trials X Sex X Group	33	3.10309	.89151	.644
Error	440	3.48072		

Note. Computer program BMD, P2V.

N = 48, 12/Group.

fect (lowering of the MAP). It was predicted they would be ordered from most relaxation to least relaxation as follows: Real Feedback > Bogus Success > Bogus Random > Bogus No Feedback. Comparisons between all pairs of these groups were of interest. Thus six contrasts were planned. To guard against an inflated Type 1 error the analyses were first done using the conservative Bonferroni t-test (Myers, 1972). When these proved not significant a standard 1 df F-test (Myers, 1972) was used and the results of both are reported.

The results of the six planned contrasts were:

1. As predicted, the Real Feedback group significantly relaxed more than the Bogus Success group, Bonferroni  $t = 5.097$ ,  $p < .005$ , one-tailed;  $M_s = 6.0, 8.8$  microvolts, respectively.
2. As predicted, the Real Feedback group significantly relaxed more than the Bogus Random group, Bonferroni  $t = 3.975$ ,  $p < .005$ , one-tailed;  $M_s = 6.0, 10.8$  microvolts, respectively.
3. As predicted, the Real Feedback group significantly relaxed more than the Bogus No Feedback group, Bonferroni  $t = 2.887$ ,  $p < .05$ , one-tailed;  $M_s = 6.0, 7.4$  microvolts, respectively.
4. Contrary to prediction, the Bogus Success group did not significantly relax more than the Bogus Random group, Bonferroni  $t = 1.488$ ,  $p > .10$ , one-tailed;  $M_s = 8.8, 10.8$  microvolts, respectively. A 1 df F test was also

not significant,  $F(1,43) < 1$ , n.s.

6. Contrary to prediction, the Bogus Random group relaxed less than the Bogus No Feedback group and the contrast was not significant, Bonferroni  $t = 1.189$ ,  $p > .10$ ;  $M_s = 10.8$ ,  $7.4$  microvolts, respectively. A one df F-test was marginally significant,  $F(1,43) = 2.574$ ,  $p < .10$ .

The means and variance of the four groups are listed in Table 3. As expected, the variance is least in the Real Feedback group. The variance follows the means in terms of success in relaxation. Figures 1-4 at the end of this chapter portray the biofeedback trials in the context of the overall design.

#### Post Experimental Trial

The four groups were expected to show a relaxation effect (lowering of the MAP below baseline). Four contrasts were planned comparing the post trial of each group with the baseline for each group. The results of these planned contrasts were:

1. The Bonferroni test revealed that the Real Feedback group did relax significantly more on the post trial than they did on the baseline,  $t = 12.566$ ,  $p < .01$ , two-tailed;  $M_s = 6.15$ ,  $7.9$  microvolts, respectively.
2. The Bonferroni test revealed that the Bogus Success group did not relax significantly more on the post trial than they did on the baseline,  $t = 2.028$ ,  $p >$

Table 3  
Group Means and Variance for Feedback Trials

Groups	Means	Mean-Baseline	Variance
Real Feedback	6.0	-1.9	4.07
Bogus Success	8.8	0.5	11.24
Bogus Random	10.8	1.9	20.55
Bogus No Feedback	7.5	0.4	6.13

Note. Computer programs BMD P2V and SPSS Condescriptive  
N = 48, 12/Group

Scores are in microvolts. They represent the MAP means for the average of twelve 100 second trials.

- .05, one-tailed;  $\underline{M}_s = 7.2, 8.4$  microvolts, respectively. The one df F-test revealed that the Bogus Success group did relax significantly more on the post trial than they did on the baseline,  $F_{1,44} = 4.148, p < .05$ , two-tailed.
3. The Bonferroni test revealed that the Bogus Random group did not relax significantly more on the post trial than they did on the baseline,  $\underline{t} = 1.744, p > .10$ , one-tailed;  $\underline{M}_s = 9.5, 8.9$  microvolts, respectively. The one df F test was also not significant,  $F_{1,44} = 1.037, p > .10$ .
4. The Bonferroni test revealed that the Bogus No Feedback group did not relax significantly more on the post trial than they did on the baseline,  $t < 1$ , n.s.;  $\underline{M}_s = 7.5, 7.1$  microvolts, respectively. The one df F test was also not significant,  $F_{1,44} < 1$ , n.s.

The amount of relaxation (lower MAP) in the Post Trial was expected to be different for each of the groups. An analysis of covariance (BMD, P2V) revealed the predicted difference in amount of relaxation due to groups,  $F(3,43) = 3.284, p < .05$ . It was predicted that the four groups would be ordered from most relaxation to least relaxation as in the Experimental Trials, Real Feedback > Bogus Success > Bogus Random > Bogus No Feedback. Comparisons between all pairs of these groups were of interest. Therefore six contrasts were planned again. The Bonferroni t-test and Myers' 1 df F-test

were used as before.

The results of the six planned contrasts were:

1. The Bonferroni test revealed that the Real Feedback group did not relax significantly more than the Bogus Success group,  $t < 1$ ,  $M_s = 6.5, 7.2$  microvolts, respectively. The 1 df F-test was also not significant,  $F(1,43) < 1$ , n.s.
2. The Bonferroni test revealed that the Real Feedback group was marginally significant in relaxing more than the Bogus Random group,  $t = 2.531$ ,  $p < .10$ , one-tailed;  $M_s = 6.5, 9.5$  microvolts, respectively. The 1 df F-test was significant,  $F(1,43) = 5.754$ ,  $p < .05$ .
3. The Bonferroni test revealed that the Real Feedback group did not relax significantly more than the Bogus No Feedback group,  $t = 2.17$ ,  $p > .10$ , one-tailed;  $M_s = 6.5, 7.5$  microvolts, respectively. The 1 df F-test was significant,  $F(1,43) = 4.892$ ,  $p < .05$ .
4. The Bonferroni test revealed that the Bogus Success group did not relax significantly more than the Bogus Random group,  $t = 1.997$ ,  $p > .10$ , one-tailed;  $M_s = 7.2, 9.5$  microvolts, respectively. The 1 df F-test was significant,  $F(1,43) = 4.535$ ,  $p < .05$ .
5. The Bonferroni test revealed that the Bogus Success group did not relax significantly more than the Bogus No Feedback group,  $t = 1.310$ ,  $p > .10$ , one-tailed;  $M_s = 7.2, 7.5$  microvolts, respectively. The 1 df F-test

was marginally significant,  $F(1,43) = 3.774$ ,  $p < .10$ .

6. The Bonferroni test revealed that the Bogus Random group did not relax significantly more than the Bogus No Feedback group,  $t < 1$ , n.s.;  $M_s = 9.5$ ,  $7.5$  microvolts, respectively. The 1 df F-test was also not significant,  $F(1,43) < 1$ , n.s. Contrary to prediction, the Bogus Random group was less relaxed than the Bogus No Feedback group, but not significantly so.

Two post hoc analyses involving the Post Experimental Trial were also performed. These were:

1. A pooling of the Real Feedback and Bogus Success groups contrasted with a pooling of the Bogus Random and Bogus No Feedback groups. As predicted post hoc, a Newman-Keuls test revealed that the Real and Bogus Success groups together did relax significantly more than the Bogus Random and Bogus No Feedback groups together,  $p < .05$ . A 1 df F-test was also significant,  $F(1,43) = 9.145$ ,  $p < .01$ .
2. An analysis of covariance (BMD, P2V) testing the post hoc prediction that the amount of relaxation for the last three Experimental Trials and the Post Trial would be affected by the treatments (groups), the trials, and the trials by group interaction. The analysis revealed that the groups differed significantly,  $F(3,39) = 6.683$ ,  $p < .001$ . The Trials were also significant,  $F(3,120) = 3.030$ ,  $p < .05$ . The Trials by Group interaction was

marginally significant,  $F(9,120) = 1.731, p < .10$ .

The means and variance of the four groups are listed in Table 4. Figures 1-4 at the end of this chapter portray the post trial in the context of the overall design.

#### Questionnaires: Subjective Measures

The amount of subjective relaxation (measured in Subjective Units of Tension, SUT) was tested in questionnaires. Each item on the questionnaires had a ten-point graphic rating scale with 1 being the most relaxed and 10 the most tense. The results were defined in terms of the difference between the Pre-Questionnaires (administered before the Experimental Trials) and the Post-Questionnaires (administered after the Experimental Trials and before the Post Trial).

The data on the questionnaires were combined in three ways:

1. The first way is the summation score of both items on each questionnaire. The first item asks how relaxed/tense the forehead feels and the second item asks how relaxed/tense the subject feels overall. A one-way analysis of variance on the difference of the summed items on the Pre- and Post-Questionnaires [ $QD \text{ combined} = (Q1\text{Post} + Q2\text{Post}) - (Q1\text{Pre} + Q2 \text{Pre})$ ] was not significant for the predicted relaxation effect due to groups,  $F(3,44) < 1$ . Because the predicted relaxation effect was not significant the planned comparisons were not performed. The means are presented in Table 5.



Table 4  
Group Means and Variance for Post Experimental Trial

Groups	Mean	Mean-Baseline	Variance
Real Feedback	6.5	-1.4	10.05
Bogus Success	7.2	-1.2	6.34
Bogus Random	9.5	0.5	12.94
Bogus No Feedback	7.5	0.3	5.29
Overall	7.7	-0.5	8.66

Note. Computer programs BMD P2V and SPSS Condscriptive  
N = 48, 12/Group

Scores are in microvolts. They represent the MAP means for the average of one 100 second trial.

Table 5  
Means for Questionnaire Items

Questionnaire Items	Groups			
	Real	Success	Random	No Feedback
<u>Pre</u>				
Forehead	4.25	4.08	4.83	4.17
Overall	4.50	4.42	5.25	4.58
Forehead + Overall	4.38	4.25	5.04	4.38
<u>Post</u>				
Forehead	3.08	2.50	3.83	3.92
Overall	2.92	2.25	3.50	2.83
Forehead + Overall	3.00	2.38	3.67	3.38
<u>Post - Pre</u>				
Forehead	-1.17	-1.58	-1.00	-0.25
Overall	-1.58	-2.17	-1.75	-1.75
Forehead + Overall	-1.38	-1.87	-1.37	-1.00

Note. Computer program SPSS, Condscriptive.

N = 48, 12/Group

Scores are Subjective Units of Tension. Each item had a 10-point graphic rating scale.

1.00 = Most relaxed.

10.00 = Most tense.

2. The second way is the difference score for the first item only, forehead relaxation. The one-way analysis of variance for the difference of the first item on the Pre- and Post-Questionnaires ( $Q1D = Q1Post - Q1Pre$ ) was not significant for the predicted relaxation effect due to groups  $F(3,44) = 1.593, p > .10$ . The planned contrasts were not performed. The means are presented in Table 5.
3. The third way is the difference score for the second item only, relaxation overall. The one-way analysis of variance for the difference of the second item on the Pre- and Post-Questionnaires ( $Q2D = Q2Post - Q2Pre$ ) was not significant for the predicted relaxation effect due to groups,  $F(3,44) < 1$ . Again, planned comparisons were not performed. The means are presented in Table 5.

The relationship (correlation) for the amount of subjective relaxation for forehead and overall relaxation and for the Pre- and Post-questionnaires is given in Table 6. As can be seen, the strongest associations between the Pre- and Post-Questionnaires for forehead relaxation occur in the Real Feedback and Bogus Success groups. The overall relaxation item is significant for the Bogus Success group and Bogus Random group. The correspondence between forehead relaxation and overall relaxation is consistently strongest for the Post Questionnaire and significant in all four groups.

Table 6  
Subjective Measure  
Pearson Correlations of Questionnaire Items

Groups	Relaxation Overall-Pre	Forehead Relaxation-Post
Forehead Relaxation-Pre Real Feedback	$r(10) = .25$ $\underline{p} > .10$	$r(10) = .73$ $\underline{p} < .01$
Relaxation Overall-Post	$r(10) = .17$ $\underline{p} > .10$	$r(10) = .72$ $\underline{p} < .01$
Forehead Relaxation-Pre Bogus Success	$r(10) = .75$ $\underline{p} < .01$	$r(10) = .88$ $\underline{p} < .001$
Relaxation Overall-Post	$r(10) = .73$ $\underline{p} < .01$	$r(10) = .86$ $\underline{p} < .001$
Forehead Relaxation-Pre Bogus Random	$r(10) = .62$ $\underline{p} < .05$	$r(10) = .44$ $\underline{p} < .10$
Relaxation Overall-Post	$r(10) = .51$ $\underline{p} < .05$	$r(10) = .78$ $\underline{p} < .001$
Forehead Relaxation-Pre Bogus No Feedback	$r(10) = .45$ $\underline{p} < .10$	$r(10) = .31$ $\underline{p} > .10$
Relaxation Overall-Post	$r(10) = .29$ $\underline{p} > .10$	$r(10) = .56$ $\underline{p} < .05$

Note. Computer Program SPSS, Pearson Correlation

N = 48, 12/Group

Pre = Pre Questionnaire; Post = Post Questionnaire

The relationship (correlation) between the amount of relaxation on the subjective measure and that on the physiological measure before the Experimental treatment is given in Table 7. Only the Bogus Success group shows a significant correlation and then only for the subjective measure of forehead relaxation. The relationship between the amount of relaxation on the subjective measure and that on the physiological measure after the Experimental treatments is given in Table 8. None of the groups demonstrates a significant correlation.

Table 7  
 Correlations of Subjective vs. Physiological Measure  
 Before Experimental Treatments

Physiological Measure Groups	Subjective Measure	
	Q1Pre Questionnaire	Q2Pre Questionnaire
Real Baseline	-.11, $p > .10$	-.28, $p > .10$
Bogus Success Base- line	.61, $p < .05$	.17, $p > .10$
Bogus Random Baseline	-.10, $p > .10$	-.19, $p > .10$
Bogus No Feedback Baseline	-.06, $p > .10$	.40, $p > .10$

Note. Computer Program SPSS, Pearson Correlation

N = 48, 12/Group.

Q1 = Forehead Relaxation.

Q2 = Overall Relaxation.

Table 8  
 Correlations of Subjective vs. Physiological Measure  
 After Experimental Treatments

Physiological Measure Groups	Subjective Measure	
	Q1Post Questionnaire	Q2Post Questionnaire
Real Post Trial	-.43, p > .10	-.25, p > .10
Bogus Success Post Trial	.14, p > .10	.09, p > .10
Bogus Random Post Trial	.08, p > .10	-.02, p > .10
Bogus No Feedback Post Trial	.00, p > .10	.31, p > .10

Note. Computer Program SPSS, Pearson Correlation.

N = 48, 12/Group.

Q1 = Forehead Relaxation.

Q2 = Overall Relaxation.

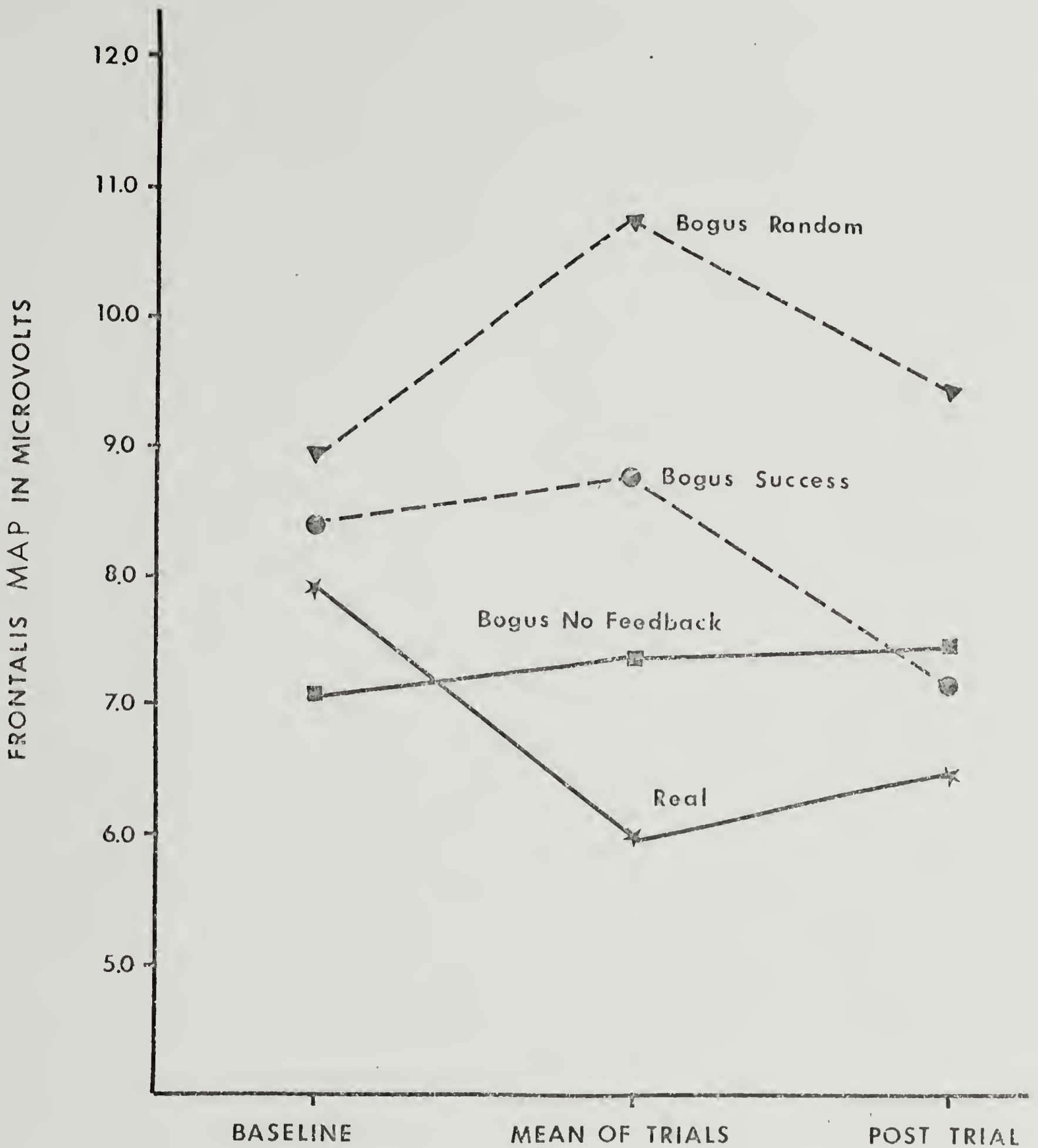


Figure 1. Frontalis MAP of the Four Groups for Baseline, Mean of Trials, and Post Trial.

Note: Baseline-Males = 7.2, MT- M = 7.6, Post- M = 7.2  
 Females = 8.9 F = 9.0 F = 8.1



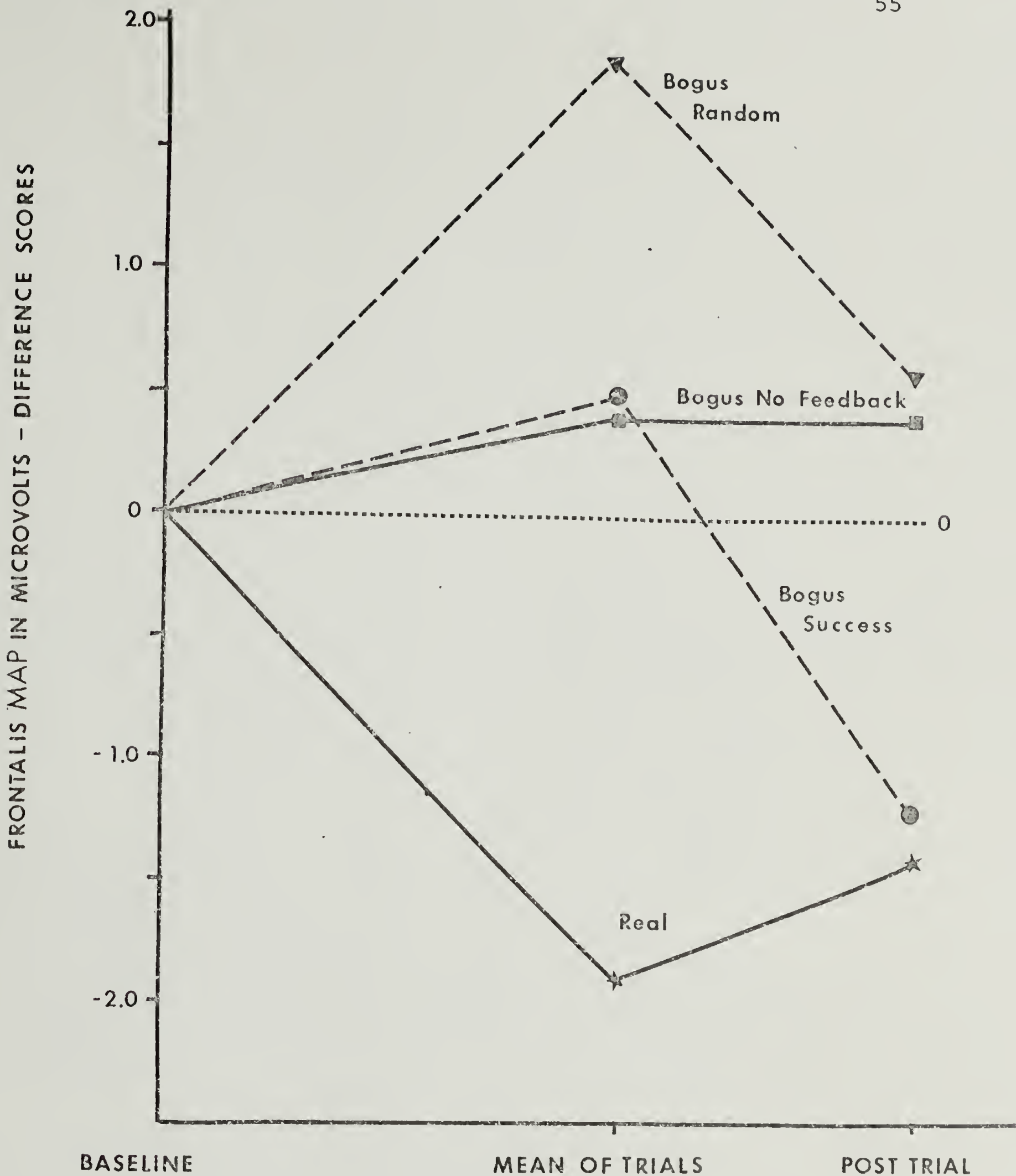


Figure 2. Difference Scores (Baseline subtracted) of Frontalis MAP for Mean of Trials and Post Trial (without feedback).

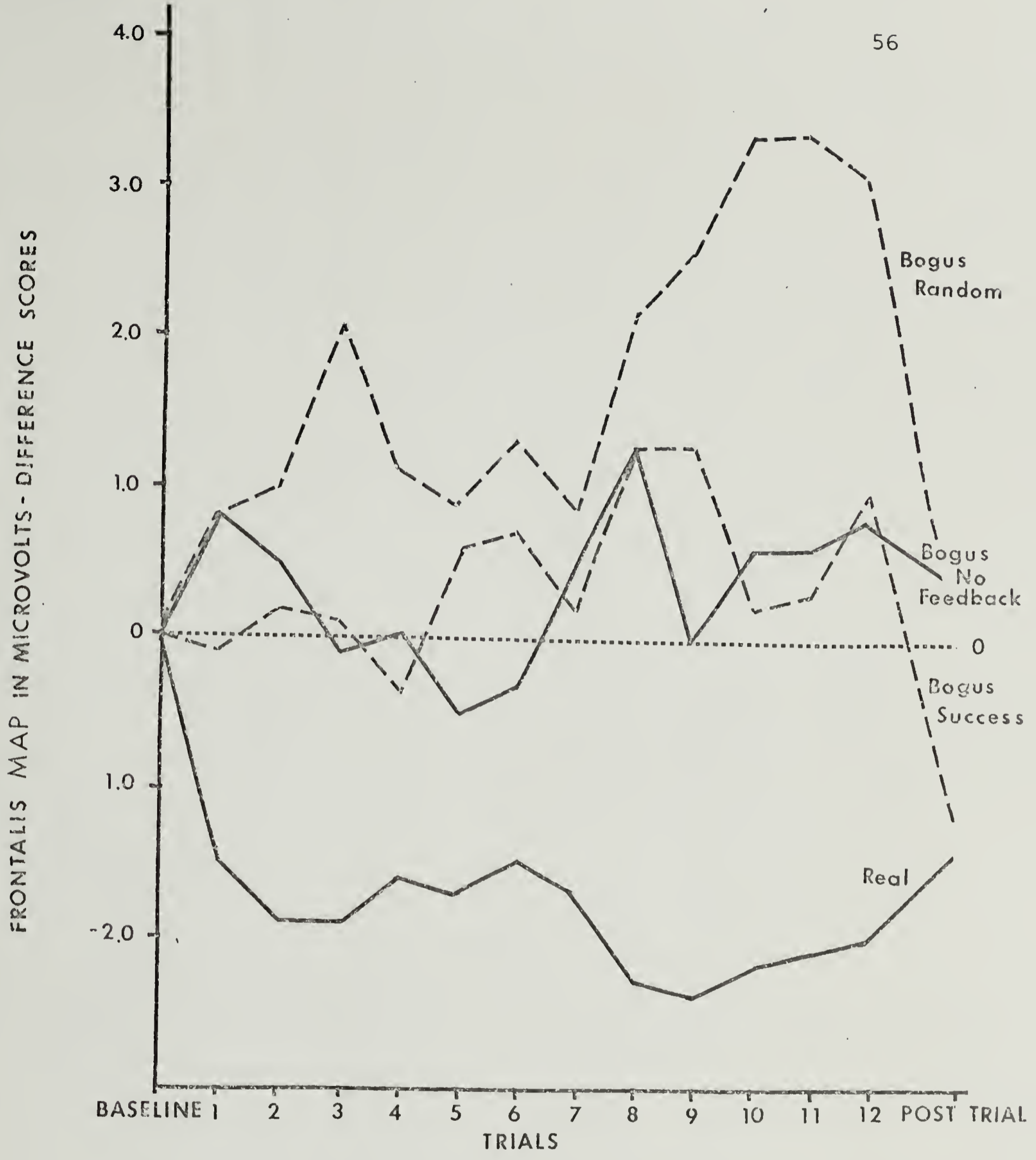


Figure 3. Difference Scores (Baseline subtracted) of Frontalis MAP for the Twelve Experimental Trials and Post Trial.

FRONTALIS MAP IN MICROVOLTS - DIFFERENCE SCORES

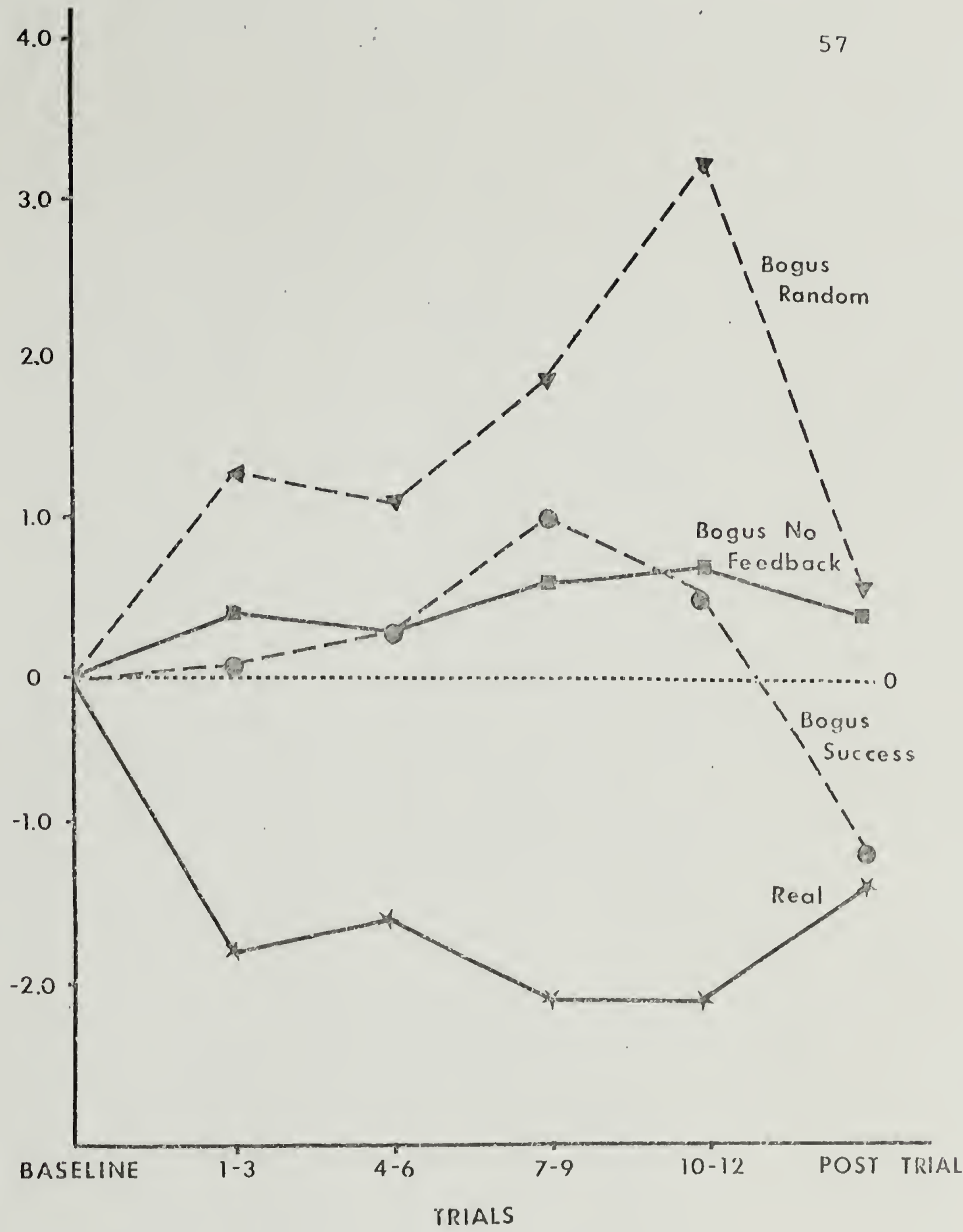


Figure 4. Difference Scores (baseline subtracted) of Frontalis MAP for the Twelve Experimental Trials Grouped into Fourths and the Post Trial.

## C H A P T E R I V

DiscussionIntroduction

The data support the hypothesis that the standard, clinically used, closed loop form of auditory EMG feedback is significantly more effective in producing relaxation of the frontalis than the three placebo controls of Bogus Success, Bogus Random, and Bogus No Feedback. Of the four groups, only the Real feedback group showed a consistent and quickly learned ability to significantly lower its MAP (Muscle Action Potential) during the experimental trials. This is in accord with the majority of the literature, clinical observation, and in support of an operant learning model.

As can be seen in Figure 1 the baseline measures varied from 7.1 microvolts (Bogus No Feedback) to 8.9 microvolts (Bogus Random), with an overall Baseline mean of 8.1 microvolts. These differences, however, were not significant and indicate that the groups did not differ at the baseline. As expected, females had a higher baseline (8.9 microvolts) than the males (7.2 microvolts), consistent with the literature and with the expected effect of a male experimenter. In physiological experiments like this, there is possibly a "ceiling-basement" effect. In this study this effect was insignificant for group differences as they were not significantly different at the baseline and the means and ranges are con-

sistent with the literature. Further, the mean of the Real Feedback group at the baseline was approximate with the overall mean for all subjects at the baseline.

### The Three Perspectives

Biofeedback trials. The interaction between groups and trials was significant; therefore the shape of the graph for each group will be discussed. The groups were ordered differently than expected on the biofeedback trials. It was expected that the Real Feedback would be more relaxed than the Bogus Success would be more relaxed than the Bogus Random would be more relaxed than the Bogus No Feedback. The order of the groups in terms of successful relaxation was as follows (refer to figures 1-4):

1. Real feedback (6.0 microvolts, difference score is -1.9). Only this group was significantly different from the others in producing relaxation. Only the Real Feedback group learned to relax during the experimental trials. It is clear that biofeedback, of the type and under conditions popularly used in clinical settings, enables a subject to significantly reduce forehead tension (the MAP of the frontalis) compared with these placebo controls. This effect happens quickly, within the first one or two 100 second trials, and can be maintained for 20 minutes of trials. The variance of the Real Feedback group (4.07) was less than for the other groups. The curve of this group is similar to a normal learning curve

with the most successful relaxation occurring in approximately the last third of the trials (trials 8-12, after 11.7 minutes).

2. Bogus No Feedback (7.4 microvolts, difference score is 0.4). Bogus No Feedback had a variance of 6.13. The mean of this group is higher than its baseline mean (7.1 microvolts) indicating that the subjects did not learn to relax. This group is not significantly different from the other bogus controls. The curve of the Bogus No Feedback group when smoothed out by dividing the trials into thirds approximates a straight line with a small rise above its baseline.

3. Bogus Success (8.8 microvolts, difference score is 0.5). The Bogus Success group has a variance of 11.24. The mean of this group is higher than its baseline mean (8.4 microvolts) indicating that they did not learn to relax. This group is not significantly different from the other bogus controls. The smoothed curve of the Bogus Success group is similar to that of the Bogus No Feedback.

4. Bogus Random (10.8 microvolts, difference score is 1.9). The Bogus Random group has a variance of 20.55. The mean of this group is higher than its baseline mean (8.9 microvolts) indicating that they did not learn to relax. This group is not significantly different from the other bogus groups. The curve of the Bogus Random group is similar to the curves of the other bogus groups until the last third of its trials when it rises sharply.

The biofeedback trials have demonstrated that these three placebo controls, though well defined and comparable to the Real Feedback, do not account for any of the relaxation shown by the Real Feedback group during the experimental trials. There is no indication in this part of the experimental design that induced feelings of success, an induced sense of control, focused attention on an external stimulus, or time spent in a set and setting heavily loaded for relaxation, account for any part of successful relaxation in themselves. However, the post experimental trial produces another perspective on the effects of these treatments and complicates this finding.

Post experimental trial. The post experimental trial tests the amount the subjects can relax without feedback after the experimental treatment phase. The post trial demonstrated marked differences from the experimental trials and there were several unexpected results. At the post trial there was a significant difference in relaxation due to groups.

The Real group, as was expected, did almost as well on the post trial as it did on any of the experimental trials. The variance of the Real group was unexpectedly high. The Bogus Success group dropped 2.2 microvolts from the last experimental trial to the post trial. The variance of the Bogus Success group also dropped appreciably, well below its baseline. The Bogus No Feedback group scored approximately

the same on the post trial as it did on the last experimental trial. The Bogus Random group dropped from 2.6 microvolts from the last experimental trial to the post trial. The variance of the Bogus Random group also dropped appreciably.

When the groups were contrasted using the conservative Bonferroni t-test the results revealed that none of the groups were significantly different from one another in terms of relaxation. The Real and Bogus Random group contrast revealed marginal significance. Using the less conservative 1 df F-test and the Newman-Keuls test the groups demonstrated a significant and unexpected arrangement (see Figures 1-4). These results will be used in all that follows.

The Real group proved to be significantly more relaxed than the Bogus Random and Bogus No Feedback groups. It was not significantly more relaxed than the Bogus Success group. The Bogus Success group was significantly more relaxed than the Bogus Random group. The Bogus Success group achieved only marginal significance in being more relaxed than the Bogus No Feedback group. The Bogus No Feedback group was not significantly more relaxed than the Bogus Random group. The Real and Bogus Success groups pooled together were significantly more relaxed than the Bogus No Feedback and Bogus Random groups pooled together.

This unexpected arrangement of groups on the post trial suggests that Bogus Success can successfully produce almost the same amount of relaxation as a real, contingent feedback



stimulus, but only after the stimulus has ceased. The Bogus Success group, which had only three experimental trials below its baseline, in the post trial demonstrated a substantial relaxation effect of  $-1.2$  microvolts, very close to the relaxation effect of the Real group ( $-1.4$  microvolts). It further appears that during the experimental trials something in common was engendered in the Real and Bogus Success groups and something different was engendered in common for the Bogus No Feedback and Bogus Random groups.

An analysis of variance for the last three experimental trials and the post trial revealed that the group by trials interaction was only marginally significant. This suggests that the slope of the change from the experimental trials to post trial may have importance, but this must be approached with caution because of the marginal significance. Since the subjects were never given specific relaxation instructions and since there is little direct transfer of actual physiological relaxation, it appears that relaxation skills and some cognitive manipulations were engendered in the Real and Bogus Success groups during the experimental trials and transferred to the post trial. Speculations about these matters must wait for the addition of a third perspective, the Questionnaire and Comments.

Questionnaires and comments. None of the questionnaire items revealed a significant amount of the subjective experience of relaxation. This contrasts with the physiological

measure and is consistent with the literature. This may be due to the difficulty in learning to attend to internal cues in one session, a task which takes many sessions as indicated by the clinical literature and highlighted by the lack of significant differences in the subjective measure at the post trial. If this is the case, then there is more support for the notion that significant differences among groups during trials are probably due less to attention to internal cues in learning to relax than to other things.

The correlations between the Pre-Questionnaire and Post-Questionnaires for item #1, forehead relaxation, indicates the predictability of the subjective report of relaxation from one time in the experiment to another time. In this case the Experimental treatment conditions are interposed between these two reports and might, in light of the other evidence, be said to have a differential effect on the relationship of these reports. There are no significant differences for the amount of relaxation among the groups on these reports, however, so assertions about the differential Experimental treatment effects on these reports must be taken with caution. The Real and Bogus Success groups demonstrate the strongest correlations (.73 and .88, respectively) and the Bogus No Feedback and Bogus Random groups show the weakest correlations (.44 and .31, respectively). This may indicate that an experimentally induced cognitive labeling for success and control predictably influences a sub-

ject's report more than the effect of fatigue, frustration, and distraction. The latter effect (Bogus Random and Bogus No Feedback groups) appears to have a more random effect on subjects' reports. The Bogus Success group shows the strongest correlation between the Pre- and Post-Questionnaires for both forehead relaxation and overall relaxation. This suggests that they had the strongest induction of a feeling of success, a finding that is corroborated by the Comments.

The relationship between a subjective sense of forehead relaxation and overall relaxation is consistently strongest in the post-questionnaire. Actual physiological generalization of forehead relaxation cannot be discussed from the data of this experiment. The findings of this experiment do suggest that thinking one was relaxed overall would tend to induce physiological relaxation without distracting non-contingent stimuli.

There is a lack of relationship between the subjective and physiological measures of relaxation, both before and after treatments. This indicates that subjects have little awareness of their physiological state of relaxation, at least initially and after one session.

The comments on the post-questionnaire indicate that Real and Bogus Success subjects thought they were especially successful and in control though they utilized different relaxation strategies within each group. The Bogus No Feedback subjects had little to say though many thought the ex-

periment too long. The Bogus Random subjects reported frustration, fatigue, and distraction.

### Combining the Three Perspectives

Although not significant, the questionnaire items do indicate some speculative trends. Combined with the statements of the subjects and along with the analyses, there are now clues as to why, despite its non-contingency, the Bogus Success group showed a sudden relaxation effect. The statements of the subjects indicate that many of them in the Bogus Success group felt they actually were relaxing, that the lowering click rate was perceived as success. They often went on at great length describing in detail how they "successfully" relaxed. For example:

First I thought of pleasant-evoking thoughts. When that didn't work I just kind of blurred my mind out. That seemed to work. Another thing I did was to make one pattern out of decorations on the wall and concentrated on that.

or again,

I relaxed by letting all my muscles relax and by being in a comfortable position. Breathing normally seemed to be better than trying to breath deeply. I would relax my mind by not thinking about anything important. I would look at the patterns in the acoustic paneling and let a calm, quiet song run through my head. At first I concentrated on the clicks too much. If I just let the sound run in the back of my mind I could relax more. It seemed best not to listen to the clicks fully but to just note when they increased.

The subjects attributed many different explanations for the lowering click rate, and none doubted that they were responsible for it. The comments of the Bogus Success subjects indicated that they tended to tune out the clicks. The Bogus Random groups also indicated that they tended to eventually tune out the clicks. The difference between the Bogus Success and Bogus Random reports is that despite both groups not fully attending, the Bogus Success group reported a feeling of success and control not reported by the Bogus Random group. This adds more support to the notion that the Bogus Success group was influenced by the success set. It is hypothesized that this feeling of success and control, this cognitive labeling, has a profound effect once the subject is freed from, essentially, a non-contingency tracking task.

The lack of relationship between the subjective and physiological measures of relaxation provides evidence for asserting that subjects learn to relax without awareness of internal cues. The Real group learned to relax during the Experimental trials and the Real and Bogus Success groups demonstrated the learned ability to relax all without the necessity of our positing the explanation of awareness of internal physiological cues. This fits the data for the Bogus Success group which was able to demonstrate relaxation in the Post Trial after incorrectly thinking it was relaxing during the Experimental trials. If internal cues come into play at all in terms of the subject's awareness of phy-

siological relaxation, they have an effect only after more than one session of Biofeedback.

The data indicate that what the Real and Bogus Success groups have in common is a positive feeling, a sense of success and possibly of control and that this alone, without recourse to explanations of learning relaxation skills, is sufficient to produce relaxation without feedback. Subjects, when given a sense of success, stay attentive.

The MAP means of Bogus No Feedback and Bogus Random groups, well above the means of the other two groups on the post trial, also are above their own baseline means. Both these groups report the experiment being long and tiresome and a consequent (or antecedent) loss of attentiveness. Neither group reports any sense of success. Rather, they report a lack of control and, for the Bogus Random group, a sense of frustration. The great variance with these two groups supports this subjective account. Neither of these groups had "learned" to relax, perhaps no different from the other two groups, but they also had no sense of success, no positive feeling, no sense of control, and a fair amount of distraction and fatigue.

A more concise explanation of the results is possible, but it requires more assumptions about the subject. Assumptions about the subject in the biofeedback literature, other than that he be given the proper set and be capable of learning in an operant learning paradigm, have remained implicit.

It is our contention that to more adequately define biofeedback, to account for the observed placebo effects, more assumptions about the subject need to be made explicit.

### The Subject in Biofeedback

Surprisingly little has been said about the subject in biofeedback research. Much more has been said about technical aspects of the feedback system. The subject, it is assumed, whether human or rat, is interchangeable. The interplay between cognition and feeling in man and his inventive strategies in problem solving, once given strong expectations, have been given little attention. Lazarus (1975) and Schachter and Singer (1962) view emotional processes and their self-regulation in biofeedback as products of mediating cognitive appraisals. Lazovik (1963) thought that the tedious muscular relaxation procedures of the time could be replaced by a seeming placebo effect. He would eliminate phobias by inducing non-veridical cognitions about internal events. These researchers and others (Valins, 1974; Valins & Ray, 1967) have highlighted the significance of cognitive labeling and the induction of false cognitions. This in combination with the methods employed by naive subjects to relax requires more explication. Subjects seem to perform somewhat differently, for example, during the experimental trials than they do in subsequent trials without feedback. No overall schema has been given as an explanatory base for these dif-

ferences.

We propose that subjects have an idea of methods or strategies to use in relaxing their forehead even though many subjects first thought forehead relaxation "silly". Once in the biofeedback situation they begin to try out various strategies and the treatments affect this "trying out" quite differently.

The Real group is quickly reinforced for finding an effective method which in turn engenders feelings of success and control. The Real group is rewarded for paying attention to their successful strategy at the very beginning and throughout the trials. Consequently they lower their Muscle Action Potential during the experimental trials. Once the feedback is removed, even after five minutes, they still have their effective strategy along with the confident glow of success and control.

The Bogus Success group at first tries out different strategies, none of which are initially reinforced by the clicks. As the trials proceed they begin to feel successful and stick to the strategy they are using then. Given the increasing feeling of success (questionnaires and comments) they begin to feel confident about their strategy. However, they have partially "tuned out" the specific clicks (comments). They cannot gain control over the clicks so they partially tune them out rather than give up the sense of success. Because they do not try to gain control over the non-



contingent stimulus they do not experience frustration like the subjects in the Bogus Random group. However, their energies are still going into tuning out the clicks and this distraction of the clicks prevents them from employing their strategy and relaxing during the experimental trials. Once the clicks are removed they put their full attention on their strategy and together with the relaxed feeling of having done a job well they show relaxation almost indistinguishable from the Real group on the post trial.

The No Feedback group receives no reinforcement for their strategies. Without specific instructions for relaxation they are not likely to be successful enough to have their vague internal cues act as reinforcement in one session. Therefore their Muscle Action Potential stays pretty much the same during experimental trials and on the post trial. Their variance would also be greater than the other two groups because they are in search of a strategy and experience fatigue and distraction because they have nothing to do for 30 minutes.

The Bogus Random group tries fruitlessly to come up with a strategy to control the clicks and live up to the expectations of the instructional set. Without the cognitive manipulation of success they never get stuck on one strategy and never develop a sense of success or of control. After six or seven trials they become frustrated, fatigued, and distracted. Consequently their Muscle Action Potential rises and they

show great variance. On the post trial, with the frustrating clicks removed, their MAP drops. They become similar to the Bogus No Feedback group because they are without a strategy, a sense of success, or a sense of control.

Further research needs to be done to test this hypothesis. For example, a design in which the group treatments were reimposed after the post trial would help determine the effects of the treatments during the experimental trials.

Another question that merits study is the difference between one session of biofeedback training (this experiment) and intensive biofeedback training. It is known that deeper levels of relaxation can be attained after intensive training. The long term effects of the placebo controls used in this study remain untested. The relationships between operantly learned relaxation skills, awareness of internal cues, and cognitive labeling are still unknown.

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APPENDIX

QUESTIONNAIRE #1

Put a check in the appropriate space between the lines:

1. How relaxed/tense does your forehead feel?

/ / / / / / / / / / /

Calm, relaxed  
at ease

Jittery, ner-  
vous, tense

2. How relaxed/tense do you feel overall?

/ / / / / / / / / / /

Calm, relaxed  
at ease

Jittery, ner-  
vous, tense

QUESTIONNAIRE #2

Put a check in the appropriate space between the lines:

1. How relaxed/tense does your forehead feel?

/ / / / / / / / / / /

Calm, relaxed  
at ease

Jittery, ner-  
vous, tense

2. How relaxed/tense do you feel overall?

/ / / / / / / / / / /

Calm, relaxed  
at ease

Jittery, ner-  
vous, tense

3. How did you relax? What did you do to try to relax?

4. Comments





