The Interaction of Instructional Set and Feedback Mode in the Acquisition of a Reduced Muscle Activity Response via Biofeedback Training.

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THE INTERACTION OF INSTRUCTIONAL SET AND FEEDBACK MODE
IN THE ACQUISITION OF A REDUCED MUSCLE ACTIVITY
RESPONSE VIA BIOFEEDBACK TRAINING

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in
The Department of Psychology

by
Kip Errett Patterson
B.S., Louisiana State University, 1971
M.A., Louisiana State University, 1974
May, 1977
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I would like to thank my parents for helping me learn to care about other people and about myself.

I would like to thank Nancy, my wife, for being.

There are a tremendous number of people who have helped me learn to love learning, exploring, and understanding our universe and I would like to thank all of you for your guidance.

There are several close friends who have helped me recently to understand the following story and that has made them very dear to me: Two monks argued about a flag. The first said, "The flag is moving." The second said, "The wind is moving." A Zen master happened to be passing and overhearing said, "Mind is moving."
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ABSTRACT

Although of considerable interest to the clinician wishing to use electromyographic biofeedback training in ameliorating stress related disorders, learning strategies for EMC BFT have not been extensively investigated. Two somewhat disparate learning strategies were investigated. One strategy was derived from Autogenic Training and the other from the Progressive Relaxation approach to muscle relaxation. The learning strategies were evaluated within the context of an interaction between the two types of instructions and two types of feedback signal, audio and tactile.

Subjects were able to reduce significantly the activity of their frontalis muscle during the training sessions but no significant differences in EMG levels were associated with the two types of learning strategies. Auditory feedback was, however, associated with significantly lower levels of muscle activity than was tactile feedback.

In all of the treatment conditions, subjects tended to adopt similar types of learning strategies, apparently using the research instructions as jumping off points. Many of the subjects adopted strategies which appeared to involve cognitive activity attributed predominantly to right hemispheric brain activity. The hypothesis that the right hemisphere could mediate EMC BFT, Autogenic Training, and Progressive Relaxation effects is discussed.

With regard to the optimal strategy to present to the client or
subject engaged in EMG BFT, it is suggested that having the person
program himself to relax the appropriate muscle and then having him
shift into right hemispheric activity, or simply block left hemispheric
activity, would produce the best results.
IN T R O D U C T IO N

Review of the Literature

Inhabitants of the environments of modern technological societies frequently experience intense stress reactions. Since the environment in most cases is relatively unchangeable, the clinician who is attempting to reduce the adverse effects of chronic stress must therefore help the individual adjust. Achieving some form of self-control of the physiological and psychological components of the individual's stress reaction is often a major component in the intervention process. In the recent past the approaches to acquiring self-control have been few in number and rather lengthy in the time required to achieve results. The development of sophisticated electronic equipment capable of transducing physiological processes into meaningful, useful information has greatly expanded the number of approaches available for helping the client achieve some control over the physiological component of his stress reaction.

"Biofeedback is simply the feedback of biological information to the person whose biology it is" (Brown, 1974, p. 4). A person engaged in biofeedback training is thus attempting to learn to voluntarily modify some aspect of his or her own biology with the aid of the information being fed back electronically. Human subjects have been able to demonstrate voluntary control of heart rate (Bell & Schwartz, 1975; Headrick, Feather & Wells, 1971; Lang & Twentyman, 1974; Levinson,
Of the many aspects of physiology which subjects have been able to learn to modify with biofeedback, the clinical usefulness of control of skeletal muscle activity has been the most clearly demonstrated. Prior to the advent of biofeedback the works of Jacobson (1938, 1970), Luthe (1969), Schultz & Luthe (1959) and Wolpe (1959) clearly demonstrated the usefulness of skeletal muscle relaxation to clinical intervention. Goldfried (1971), Goldfried & Trier (1974), Sherman (1975), Sherman & Plummer (1973), and Zenmore (1975) have demonstrated the benefits of these classic approaches to muscle relaxation for clinically normal populations.

The major difficulty with these classic techniques for teaching muscle relaxation is the relative inaccessibility to observation and measurement of the psychological and physiological processes involved in learning to relax the muscles. There is also the somewhat extended amount of time which is required to learn the appropriate "relaxed" response.

Myographic feedback instrumentation, however, gives the clinician
as well as the client accurate, reliable information on the actual tension levels of the client's muscles. Determining whether or not the client is actually relaxed no longer remains a matter of subjective opinion of the clinician and of the client; both have the same objective information. The clinician is therefore able to deal directly with the client's learning process and the client does not have to guess what being "relaxed" is or whether he or she is relaxed "enough." The clinician and the client can both know, with considerable precision, how relaxed or how tense the client's muscles really are.

Biofeedback training (BFT) also appears to facilitate considerably the speed with which subjects learn to decrease their muscle's electromyographic (EMG) activity. "Not only did biofeedback produce lower levels of frontalis EMG activity, it lowered EMG activity faster than the other methods of relaxation training" (Haynes, Moseley & McGowan, 1975, p. 550). Reiking & Kohl (1975) reported similar findings. Leibrecht, Lloyd & Pounder (1973) found in a study of voluntary control of single motor units of skeletal muscles that biofeedback increased the speed of learning six times. Subjects in their biofeedback and verbal feedback conditions seemed to learn the same skill, however. They cited the direct, instantaneous and more differentiated qualities of the biofeedback signal as the major factors influencing the greater speed of learning.

In clinical applications EMG BFT has been demonstrated to be effective in ameliorating tension headache (see Stoyva & Budzynski, 1974 and Yates, 1975 for reviews), reducing chronic anxiety (Raskin, Johnson & Rondestvedt, 1973; Townsend, House & Addario, 1975),
modifying chronic alcohol abuse (Steffen, 1975) and as an important first step in altering the manner in which people respond to stress (Stoyva & Budzynski, 1974). Additionally, EMG BFT appears to be quite effective in the desensitization of phobic anxiety (H. L. Russell, personal communication, 1976). Blanchard & Young (1974) have concluded that, "The work on the application of EMG feedback training to clinical problems is the oldest and soundest work in the biofeedback area" (p. 579).

The best procedure for teaching muscle relaxation via electromyographic biofeedback training is obviously of interest to the clinician who wishes to work with this approach to muscle relaxation. Although the exact process by which an individual learns voluntary control of the activity of his muscles via BFT is not entirely clear, research has been conducted which gives a fairly clear picture of some of the relevant factors involved. With regard to the neurological processes which may be involved, Basmajian (1963) has stated that in the voluntary control of single motor units of skeletal muscle, "pathways from the cerebral cortex can be made to stimulate single anterior horn cells while neighboring anterior horn cells remain dormant or are depressed" (p. 441). Smith, Basmajian & Vanderstoep (1974) have further validated this explanation. Tanji & Kato have stated that "the cortical motor potential related to discharge of a single motor unit is about the same size as that related to the contraction of whole muscles" (p. 346). They go on to state that such a large cortical potential "may suggest that cerebral mechanisms play some important role in singling out a motor unit" (p. 346). Green, Green & Walters (1974) have reported
that,

The chain of events involved in biofeedback for control of autonomic processes might be hypothesized as follows:
Perception of somatic behavior (through biofeedback) cortical (cognitive) elaboration $\rightarrow$ limbic (emotional) response $\rightarrow$ hypothalamic response $\rightarrow$ autonomic response $\rightarrow$ somatic response $\rightarrow$ perception of somatic behavior, etc. How volition enters into this scheme for self-regulation is not easy to say, but in any event each person becomes his own programmer, so to speak, when, through biofeedback, self-regulation of a physiological process is established (p. 158).

On a more molar level of discourse Brown has stated that,

the information being fed back by monitors is not simple sensory information to be perceived by the sensing organs. It is complex, ideational, abstract, symbolic, associational information requiring cognitive effort before it can be applied. In the bio-feedback phenomenon the mind seems to be capable of responding directly to an abstract symbol (p. 154).

It would appear that during EMG BFT subjects are engaged in some sort of cortical, consciously willful, cognitive process as they learn voluntary control of their muscle activity. The learning strategies and cognitive mechanisms involved in EMG BFT have yet to be clearly delineated and understood.

There are two factors which appear to be most clearly involved in the learning process of EMG BFT, the type of learning strategy given to the individual via instructions and the type of feedback signal available to the individual. Coursey (1975) has suggested that, "Achieving reduced levels of muscular tension ... may be like achieving any other motor skill. Although aspects of reducing muscle tension may consist of self-instruction, much of the tension reduction is accomplished in a nonverbal manner" (p. 832). Coursey's hypothesis appears directly related to Jacobson's approach to teaching reduced muscle tension.
Jacobson (1938, 1970) has emphasized the proprioceptive, control aspects of muscular activity; his Progressive Relaxation exercises are designed to enable the client to experience how his or her muscles work and how the muscles feel when they are at rest. Jacobson's technique has little or no emphasis on symbolic cognitive activity during the process of relaxation training. Autogenic Training (Luthe, 1969; Schultz & Luthe, 1959) however, primarily emphasizes symbolic cognitive activity. The cognitive activity of Autogenic Training consists of a mental contact with the part of the body and the aspect of physiology to be trained via visual (like seeing a neon sign) or verbal (repeated subvocally) standard formulas, such as "My arm is heavy," and of "passive concentration" on the part of the client.

The manner in which subjects have been instructed to gain control of their muscle activity in EMG BFT studies has been of two types: (1) the subject is instructed to lower muscle tension by lowering a tone or click rate which is directly proportional to the EMG activity level in the muscle being monitored, as used by Alexander (1975), Alexander, French & Goodman (1975), Budzynski & Stoyva (1969) and Haynes, Moseley & McGowan (1975); (2) the subject is instructed to let the feedback be a guide to how relaxed he or she is at any given moment and to feel free to experiment with different approaches to relaxation including visualization, pleasant thoughts and different emotions, as used by Kinsman, O'Bannion, Robinson & Staudenmayer (1975) and Raskin, Johnson & Rondestvedt (1973). Neither type of instructions appears to fit entirely within either the Progressive Relaxation or Autogenic Training framework. Reiking & Kohl (1975) combined EMG feedback and Jacobson-Wolpe type
instructions but found no differences in effectiveness for reducing EMG activity between that group's results and a straightforward EMG feedback group or those of an EMG feedback plus money reinforcement for decreased EMG activity group. A more systematic examination of Progressive Relaxation and Autogenic Training approaches to relaxation training in EMG BFT might produce useful clinical applications.

With regard to the type of feedback signal available to the individual, Alexander, French & Goodman (1975) reported that an eyes closed audio feedback condition produced significantly greater decreases in frontalis EMG activity than either eyes open audio feedback, visual feedback or no feedback conditions. Green, Walters, Green & Murphy (1969) used visual feedback and found significant reductions in forearm EMG activity. The literature on the voluntary control of single motor units uniformly points to the superiority of audio feedback for a variety of muscle sites (Basmajian, 1963; Gray, 1971; Harrison & Mortensen, 1962; Wagman, Pierce & Burger, 1965). When visual feedback was also available subjects tended to identify the single motor unit visually on the oscilloscope and then rely on the auditory feedback to maintain control (Gray, 1971).

Schandler & Grings (1975) have designed an apparatus to give subjects tactile feedback of their EMG activity. Tactile EMG feedback appears to add a new dimension to the study of cognitive processes which might be involved in EMG BFT because the sensory information produced by tactile feedback appears to be more directly related to motor behavior than either audio or visual feedback due to the extensive interconnections between the sensory cortex and the motor cortex.
There is also the possibility of an interaction between the type of instructions given to a subject and the type of feedback available. This possibility has yet to be examined. The delineation of such an interaction might produce valuable information concerning the learning processes and cognitive mechanisms involved in EMG BFT as well as useful clinical applications.

Statement of the Problem Investigated

In teaching muscle relaxation via BFT the clinician is faced with the problem of offering optimal learning strategies to the client. As reviewed above, little systematic research has been conducted in this area. The present study evaluated two disparate learning strategies to EMG BFT within the context of an interaction between the type of instructional set given to the subject and the type of feedback signal available to the subject during training.

One strategy, as suggested by Brown (1974), was that the feedback signal is interpreted as an abstract symbol by the subject rather than as simple sensory information. Brown also suggested that much cognitive activity is required in BFT. The approach which Autogenic Training suggests for producing muscle relaxation appears to emphasize the same type of learning strategy which Brown suggests, considerable cognitive activity to mediate the learning process.

The other strategy, as suggested by Basmajian & Simmond (1967) and Leibrecht et al. (1973), was that the feedback signal simply augments or reinforces the normally available proprioceptive cues during training. The approach which Progressive Relaxation suggests appears
to emphasize the same type of learning strategy which Basmajian & Simmard and Leibrecht et al. suggest: paying attention to proprioceptive cues during training with little or no emphasis on symbolic cognitive activity to mediate the learning process.

The feedback mode or type of signal available to the subject was hypothesized to be of considerable importance to the two learning strategies. Consequently feedback modes were selected which appeared to fit within the framework of each strategy. An audio feedback signal appeared to be a rather abstract symbol and was therefore paired with Autogenic Training type instructions (AT). A tactile feedback signal appeared to be more directly related to motor behavior and perhaps therefore less likely to be interpreted symbolically. Therefore a tactile feedback signal was paired with Progressive Relaxation type instructions (PR).

It appeared possible that either the feedback mode or instructions alone might account for any differences between the two learning strategies described above. To examine this possibility the interaction between the two instruction sets, AT and PR, and the two feedback modes, audio and tactile, was evaluated.

To determine if the two sets of instructions to be used in the BFT study were indeed perceived as different and as being representative of the two learning strategies, a pilot study was conducted. The instructions were presented to groups of subjects not otherwise involved in the BFT study. The subjects rated the instructions on several questions designed to differentiate the major components of the two instruction sets.
In addition to the above mentioned reasons for comparing audio and tactile feedback audio feedback was chosen because the Autogenic Training and Progressive Relaxation instructions specified that subjects would have their eyes closed during training.

The frontalis muscle was chosen for this study because that muscle has figured prominently in studies of tension headache, chronic anxiety, and maladaptive stress responses. The frontalis muscle has also been used extensively in previous EMG BFT studies. Finally, it is a "public" muscle and therefore easily accessible to skin electrode placements without undue subject discomfort.

The two sets of instructions could have had a differential initial effect on relaxation such that one set of instructions, per se, could have been perceived as more relaxing than the other. To test this possibility two baselines were taken with the instruction set presented to the subject between them. A separate statistical analysis was conducted on these baseline data.

Although it was expected that the subjects would follow the instructions, each subject was briefly interviewed after each training session to determine to some extent what the subject was indeed doing during the BFT. The interviews were structured in such a way as to be minimally disruptive of the learning process. No formal analysis of the interviews was planned.

Since the major emphasis of the study was to examine the two learning strategies, a statistical analysis was used which would enable illumination of possible differences in the response curves for each of the treatment conditions. Overall group performances, subject performance
over several separate training sessions, and subject performances within the training sessions were evaluated by means of a split-split plot factorial analysis of variance.

Several specific hypotheses were developed regarding anticipated results. It was anticipated that the pilot study would demonstrate that the AT and PR instructions were indeed perceived as different and as representative of their respective learning strategies. The two sets of instructions were not anticipated to have differential initial effects on subject EMG levels, and the postinstruction baseline was expected to be somewhat lower, but not significantly lower, than the preinstruction baseline.

With regard to the anticipated results of the biofeedback training, EMG levels accompanying the two instruction sets were not expected to be significantly different due to the well proven effectiveness of both approaches to muscle relaxation.

The type of feedback, auditory or tactile, was expected to have a significant effect on EMG levels since Fehmi, Ancoli & Selzer (1972) found that subjects gained control of their frontal lobe alpha activity faster with tactile feedback than with audio feedback. The underlying mechanisms of subject control of brain wave activity and of subject control of muscle activity, though not as yet clearly differentiated, are quite likely to be different. Thus any direct comparisons between brain wave BFT and EMG BFT appear somewhat tenuous. It appeared possible, however, that the nature of the feedback signal could be a pervasive phenomenon such that Fehmietal's result with alpha activity BFT would be replicated with EMG BFT.
The major hypothesis to be tested was whether or not the four treatment conditions would produce different types of performance curves. The PR and tactile feedback condition was expected to produce relatively steady decrements in EMG activity across a period of time. This expectation was based on two assumptions. During slowly increasing muscle activity motor units are gradually recruited (Goldstein, 1972); a similar process was assumed to operate during slowly reducing muscle activity. The second assumption was that little symbolic cognitive activity involvement would produce little or no time delay in executing the desired response. Thus a decreasing, linear performance curve was anticipated.

The AT and audio feedback condition was expected to produce little change in EMG activity during the first part of a period of time primarily because subjects were expected to be involved more in conceptualizing the response than in actually executing it. Decreases were expected to occur near the end of a period of time since once the response was conceptualized it would be executed with little difficulty. Thus a gradually at first but then sharply decreasing performance curve was anticipated.

The two remaining conditions, AT with tactile feedback and PR with audio feedback, were anticipated to produce response curves which would be composites of the other two conditions. Figure 1 represents the anticipated response curves of the four treatment conditions over a period of time.

The interaction between the two instruction sets and the two feedback modes was not expected to be significant because all of the groups
Figure 1. Hypothesized EMG activity response curves for each of the treatment groups (Autogenic Training instructions (AT) with audio feedback (A), AT with tactile feedback (T), Progressive Relaxation instructions (PR) with A, PR with T) over a period of time.
were expected to have fairly equivalent significant reductions in EMG activity across the several training sessions and across the time periods within the training sessions.

The hypothesis that the treatment groups would produce different response curves was expected to be seen in the interactions of the four treatment conditions with two major time dimensions. The response curves were expected to be different over the several training sessions of the experiment. This effect was also expected to be seen within the training sessions, that is, across the several time periods within each training session. Thus the types of response curves presented in Figure 1 and described above were expected to occur in the instruction set X feedback mode X training session interaction graph, in the instruction set X feedback mode X time period interaction graph, and in the instruction set X feedback mode X training session X time period interaction graph.

The amount of variation in EMG levels within each of the time periods was considered to be of interest in determining the appropriate dimension of time for the analysis of the learning process of EMG BFT. An additional analysis of variance incorporating the variance in EMG levels within each time period was conducted to examine this question.
METHOD

Subjects

Subjects were 48 male undergraduates, age 18 - 26, enrolled in Psychology courses at Louisiana State University who volunteered to participate in the study.

Apparatus

An Autogen 1500b Feedback Myograph (Autogenic Systems, Inc., Berkeley, California, 94710) was used to transduce the electrical activity of the frontalis muscle into an audio signal. The audio signal which was used was a click-rate signal, the rate of which was logarithmically proportional to the level of EMG activity displayed on the EMG Activity Meter of the 1500b. The 1500b produced an integral averaged measurement of EMG activity within a bandpass of 100 - 200 Hz. Three scales of the Activity Meter were used during the study: 1.0 to 20.0 microvolts (uV), 0.5 to 10.0 uV, 0.1 to 2.0 uV. The experimenter switched from one scale to another when the resolution of a particular scale was more appropriate to the subject's EMG activity level. The scale was only changed between training sessions and therefore did not affect EMG data collection.

The Log EMG Output Function of the 1500b served as input to a device which produced tactile feedback (N. T. Welford & W. J. Murphy, Medical Electronics, University of Texas Medical Branch, Galveston, Texas, 77550; see Appendix 1 for wiring diagram). The tactile feedback
was delivered to the subject via a 2-inch speaker which was encased in a rounded wooden case which was comfortable and easy to hold in the hand. The pulse rate of the tactile feedback signal was logarithmically proportional to the level of EMG activity displayed on the EMG Activity Meter of the 1500b.

EMG data acquisition was accomplished by an Autogen 5100 Digital Integrator (Autogenic System, Inc.) which was connected to the 1500b and which was set to display visually the integral averaged EMG activity in microvolts for 1-minute periods, with the automatic cycling mechanism engaged at a setting of 0.1 seconds "rest period" between each 1-minute data acquisition period.

A cassette tape recorder was used to present an audio tape of instructions to each subject.

A set of headphones (Nova 14, catalogue number 33-1013, Radio Shack, Fort Worth, Texas, 76102) was used to present the audio feedback signal and the tape recorded instructions to each subject. The headphones were modified so that the two speakers could receive independent input. This was done so that the subjects in the auditory feedback conditions could hear the feedback signal and the instructions at the same time with as little distortion as possible.

A chaise longue lawn chair and a small head rest pillow were used for the subjects to recline upon during the training sessions of the study.

A large wool mitten was used to dampen possible sounds from the tactile feedback device for the subjects in the tactile feedback conditions during the training sessions.
Procedure

Prior to the start of the biofeedback training study a pilot study was conducted. The tape recorded instructions, described below, to be presented to the subjects in the BFT study, were played to groups of male undergraduates enrolled in undergraduate Psychology courses at Louisiana State University who were not otherwise involved with the BFT study. Each group had 30 subjects and each group heard only one set of instructions. After hearing the instructions each subject rated the instructions. The Instruction Response Form (see Appendix 2) which was used had the subjects rate on a scale of one to seven the importance of the biofeedback signal, of thoughts and feelings, of remaining motionless, of learning how a tense and then relaxed muscle feels, and of paying close attention to muscle sensations to the instructions which they heard. Subjects also rated how active or passive and how interested or disinterested in results the instructions told them to be.

Students in good general health and without known muscle disorders were given the opportunity to participate. The investigation was described at recruitment as a study of subjects' ability to relax their forehead muscle with the aid of biofeedback. The experimenter said that he was interested in comparing different kinds of feedback and approaches to relaxation and that he was interested in how the individuals made use of the feedback signal. He stated that all of the procedures had been shown to be effective and that he would be interested in seeing if one procedure would be better than the others. He stated that the time required for participation would be about two hours and that almost all subjects in previous biofeedback studies had enjoyed their participation.
He also stated that any subject in the study who wished to terminate his participation would be free to do so at any time. Subjects were then asked to sign an appointment sheet and include their phone numbers. Each subject was contacted by phone by the experimenter at least one day prior to his appointment, reminded of his planned participation, and screened as to his health.

Subjects were assigned to treatment conditions on a rotating basis from the appointment sheet so that each group filled up gradually. To each of the following treatment conditions 12 subjects were assigned: Progressive Relaxation type instructions (PR) with audio feedback, PR with tactile feedback, Autogenic Training type instructions (AT) with audio feedback, AT with tactile feedback.

Each subject was individually greeted upon arriving at the experimental site, asked to read and sign a consent form, and then asked to recline upon the chaise longue. The experimenter then told the subject that he would attach three electrodes to the subject's forehead and that the electrode gel in the electrode would feel cool at first but that it would warm up quickly. The subject was also assured that the instruments were battery powered and that he would be completely free from possible shocks from the equipment. Silver/silver chloride skin electrodes were then attached to the subject's forehead with adhesive discs in accord with Lippold's (1967) standard placements for the frontalis muscle. Spectra 360 Electrode Gel (Parker Laboratories, Inc., Irvington, New Jersey, 07111) was used as the conducting medium for the electrodes.

The subject was then asked to make himself as comfortable as
possible and asked the following questions: "What do you think biofeedback will be like?" "On a scale of zero (very tense) to ten (very relaxed) how do you feel right now?" The experimenter recorded the subject's responses on an interview form.

The experimenter then informed the subject that there would be a 3-minute baseline, that he would then hear a set of tape recorded instructions and that a second 3-minute baseline would follow. The subject was then told that the training sessions would follow the last baseline. The headphones were then placed on the subject so that the instructions would be introduced into the right ear and the subject was asked not to move around. The first baseline was then conducted.

The subjects in the PR condition heard a tape recording of the experimenter reading the following:

Learning to relax your forehead muscle is very much like learning any other motor skill such as riding a bike, playing tennis or even walking. You are already somewhat aware of how your muscles are when they are tense or when they are relaxed. The biofeedback signal is simply a very precise measure of how tense or of how relaxed your muscle is. This becomes very important as your muscle relaxes because you can't feel when your muscle is completely relaxed. So the biofeedback signal can let you know a lot more about your muscle than you could tell without the signal. A specific way to learn to relax your forehead muscle is to pay attention to the feedback signal and learn how you can make it change. Increasing your muscle tension and then relaxing is an excellent way to see how the signal will
will change. You also get to see what happens when your muscle relaxes. Your thoughts and feelings during this are not really very important so don't be overly concerned with them. You will have several training sessions with the feedback signal and what I would like for you to do is to get your muscle as relaxed as you can. I will ask you to close your eyes at the start of each session and to keep them closed until the session is over. Then I'll ask you to flex your forehead muscle and keep it tense so you can see how that feels. Next you'll relax your muscle gradually and keep on relaxing it using the feedback signal as a guide. From time to time during the sessions I will modify the feedback slightly so that you will be getting just the right amount of feedback. Each time I modify the signal I'll let you know. After each session you'll have a brief break and I'll ask you how it went. Do you have any questions?

The subjects in the AT condition heard a tape recording of the experimenter reading the following instructions:

Thoughts and feelings significantly affect what our bodies do and it is possible to literally tell our bodies what we want them to do. So in learning to relax your forehead muscle you can simply tell it to be relaxed. There is, however, a specific way to do this. If you concentrate too hard your muscle will become tense because of all of the mental effort you are making, so you need to have a passive, effortless concentration where you are not really, really concerned with what you want to
happen; more like you are only mildly interested in what is going on. The other thing to do is to have a mental contact with your muscle by saying to yourself, "My forehead is cool" every now and then or you can visualize a neon sign that comes on now and then that says, "My forehead is cool." We use "cool" because that is how your forehead will feel when that muscle is relaxed. The biofeedback signal is simply a very precise measure of how tense or of how relaxed your muscle is. Every now and then you can sneak a peek\(^1\) at the signal and know how relaxed you are becoming. If you wish, you can use the signal in your mental contact with your forehead by thinking that the signal is cooling your forehead and that as it slows down your forehead gets even cooler. Try to stay fairly still though because it is more difficult to relax if you are moving around a lot. You will have several training sessions with the feedback signal and what I would like for you to do is to get your muscle as relaxed as you can. I will ask you to close your eyes at the start of each session and to keep them closed until the session is over. I'll ask you to establish mental contact with your forehead muscle. After that you'll relax your muscle during the rest of the session with occasional mental contact and passive concentration. From time to time during the sessions I will modify the feedback slightly so that you will be getting just the right amount of feedback. Each time I modify the signal I'll let you

\(^1\)The phase "sneek a peek" was used figuratively; the subjects did not open their eyes during the training sessions.
know. After each session you'll have a brief break and I'll ask you how it went. Do you have any questions?

Following the tape recorded instructions the experimenter answered any questions by referring to the proper aspect of the foregoing instructions. He then informed the subject that the second baseline would be taken and that the subject should not move around.

After the second baseline the experimenter turned on the audio feedback signal, which was introduced into the subject's left ear, for the subjects in the audio feedback condition. The subjects in the tactile feedback condition were given the tactile feedback device and told to place it in their left hand with a finger placed on the diaphragm of the speaker. The woolen mitten was then placed over the subject's left hand. Each subject was then asked to close his eyes.

The subjects in the PR condition heard a tape recording of the experimenter reading the following instructions at the start of each training session:

"Please flex your forehead muscle and keep it tight for the next minute. Be sure to notice the feedback signal."

(1-minute pause)

"Over the next two minutes very gradually let the tension go out of your muscle. Be sure to notice the changes in the feedback signal."

(2-minute pause)

"Now during the rest of this session continue to relax your muscle using the feedback signal as a guide."

(12-minute pause)
"This session has ended, please open your eyes."
The subjects in the AT condition heard a tape recording of the experimenter reading the following instructions at the start of each training session:

"During the next minute please create a mental image of your forehead for yourself by focusing your concentration on your forehead."

(1-minute pause)

"Gradually let your concentration become more and more passive and unconcerned for the next two minutes. Replace your own mental image with the phrase 'My forehead is cool.'"

(2-minute pause)

"Now during the rest of this session continue to relax your muscle using passive concentration and the mental contact phrase 'My forehead is cool.' You can also use the feedback signal if you wish."

(12-minute pause)

"This session has ended, please open your eyes."

During each pause in the above sets of instructions, the subjects heard a very low volume white noise in their right ears.

Data on EMG activity levels during the two baselines and the five training sessions were recorded onto a data sheet by the experimenter from the visual display of the 5100 Digital Integrator. Each data point was the average amplitude of EMG activity in microvolts (uV) of a 1-minute period of time. During each baseline three
such data points were collected and during each training session 15 such data points were collected.

After each of the five training sessions the subject was briefly interviewed. The experimenter recorded the subject's responses, onto the subject's interview form, to the following questions:

Following the first session, "How did that seem to you?", "Have you ever done anything that even remotely reminds you of this? How so?", "What were you doing mentally while you were relaxing your muscle?", "On a scale of zero (very tense) to ten (very relaxed), how do you feel right now?"; 
Following the second session, "How did that seem to you?", "Now that you've had more experience with biofeedback does it remind you of anything? How so?", "Last session you said you were doing ______. How about during this last session?", "On a scale of zero (very tense) to ten (very relaxed), how do you feel right now?";

After the third session, "How did that seem to you?", "During the first session you said you were doing _____ and during the second ______. What about this last one?", "On a scale of zero (very tense) to ten (very relaxed), how do you feel right now?";

"What kinds of thoughts did you have during the session?", "On a scale of zero (very tense) to ten (very tense), how do you feel right now?";

After the fifth session, "How did that seem to you?", "What were you doing mentally during the session?", "On a scale
of zero (very tense) to ten (very relaxed), how do you feel right now?"

Throughout the experimental sessions the experimenter maintained a pleasant, relaxed, matter of fact, mildly optimistic demeanor. He did avoid, however, extensive conversations with the subjects until the BFT sessions were completed. At the end of the experimental session each subject was debriefed as completely as possible and at the end of the study the results of the study were made available to any interested subjects.

Data analysis

To test for perceived differences on the two sets of instructions in the pilot study, t-tests were performed on the mean ratings of the two groups for each item of the Instruction Response Form.

A 2 X 2 repeated measures factorial design was used to evaluate differences in EMG activity between the preinstruction and postinstruction baselines which may have been associated with the subjects having different instruction sets. The units in this analysis were the means of three 1-minute data periods. There were 24 such experimental units associated with each of the PR--preinstruction, PR--postinstruction, AT--preinstruction, AT--postinstruction baselines.

A factorial arrangement of main effect treatments, instruction set and feedback mode, with training sessions as a repeated measure and 3-minute time periods within training sessions as a repeated-repeated measure was used to analyze for changes in EMG activity during the biofeedback training portion of the study. The initial 3-minute time
period within each training session was dropped from the analysis because the subjects of the PR conditions were flexing their muscles and including this data would have only obscured any possible differences between the instruction conditions. The experimental units in this analysis were the mean EMG activity of three 1-minute data periods; there were four such units in each training session.

A second analysis of the changes in EMG activity during the BFT segment of the study was conducted to determine the effect of the variation in EMG levels within each of the 3-minute time periods. The same design as described immediately above was used but the additional source of variation was added. The units in this analysis were the average amplitude of EMG activity in uVs for each 1-minute data period.

Results were accepted as significant if they exceeded the .05 significance level.
RESULTS

Results of the pilot study on subject ratings of the instruction sets are reported first. Changes in EMG levels during the baselines are discussed second and changes in EMG activity during the biofeedback segment of the study are then reviewed. Subject interview responses are then presented.

**Pilot Study on Instruction Sets.** Subjects who heard the AT instructions rated thoughts and feelings \((t = 4.60, p < .01)\) and remaining motionless \((t = 3.10, p < .01)\) as being more important than did subjects who heard the PR instructions. The AT instructions were also rated as telling the subjects to be more passive \((t = 2.38, p < .05)\) than the PR instructions. Subjects who heard the PR instructions rated paying close attention to muscle sensations as more important \((t = 2.38, p < .05)\) than subjects who heard the AT instructions. The biofeedback signal, being interested or disinterested in results, and how their muscle would feel when tense and when relaxed were not rated as being significantly more important to one set of instructions than to the other. Table 1 contains the mean rating of each group and the statistical significance of each comparison for each of the Instruction Response Form items.

**EMG Level Changes: Baselines.** Statistical analysis of changes in EMG levels during the baselines indicated that the postinstruction baseline mean was significantly lower than the preinstruction baseline.
Table 1
PILOT SUBJECT MEAN RATINGS OF AUTOGENIC TRAINING AND PROGRESSIVE RELAXATION INSTRUCTIONS

<table>
<thead>
<tr>
<th>Item</th>
<th>AT mean</th>
<th>PR mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>. . . the biofeedback signal will be</td>
<td>5.7</td>
<td>6.1</td>
</tr>
<tr>
<td>. . . my thoughts and feelings will be</td>
<td>5.4</td>
<td>3.1**</td>
</tr>
<tr>
<td>. . . remaining relatively motionless will be</td>
<td>6.1</td>
<td>4.8**</td>
</tr>
<tr>
<td>. . . learning how my muscle feels when tense and when relaxed is</td>
<td>5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>. . . paying close attention to my muscle sensations will be</td>
<td>4.4</td>
<td>5.4*</td>
</tr>
<tr>
<td>active - passive</td>
<td>5.9</td>
<td>4.9*</td>
</tr>
<tr>
<td>disinterested in results - interested in results</td>
<td>4.7</td>
<td>5.2</td>
</tr>
</tbody>
</table>

* p < .05
** p < .01
for both instruction conditions \((F = 9.49, p < .01)\), the former represents an 11% decrease from the latter. The instruction condition did not significantly affect EMG levels nor was there a significant interaction between the pre-post and instruction conditions. Table 2 is a summary of these findings.

**EMG Level Changes: Biofeedback Training.** The two instruction sets, AT and PR, were not accompanied by significantly different EMG activity levels. The EMG uV levels associated with auditory feedback were on the average 25% lower across training sessions and across time periods than the EMG uV levels associated with tactile feedback. This difference was statistically significant \((F = 5.68, p < .05)\). The interaction between the two instruction conditions and the two feedback modes was not statistically significant.

To gain a better understanding of the distribution of changes in EMG activity associated with the treatment conditions, percent change scores based on each individual subject's own mean baseline, were calculated for each training session. There were 240 training sessions; 84 had decreases of 40% or greater; 92 had decreases of 20 to 39%; 34 had decreases of 0 to 19%; 30 training sessions had increases in EMG activity levels. Although the distribution of frequency of occurrence of the percent change categories among the four treatment groups appeared to indicate an interaction between feedback mode and instruction set in aiding decreases in EMG activity, chi square tests showed no significant deviation in frequencies within a percent change category across treatment groups. Table 4 contains the distribution of
### TABLE 2
STATISTICAL ANALYSIS OF CHANGES IN EMG ACTIVITY BETWEEN
THE PRE AND POSTINSTRUCTION BASELINES

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction set</td>
<td>1</td>
<td>2.46</td>
<td>2.46</td>
<td>1.01</td>
<td>ns</td>
</tr>
<tr>
<td>Individuals within instruction set</td>
<td>46</td>
<td>112.42</td>
<td>2.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>3.51</td>
<td>3.51</td>
<td>9.49</td>
<td>.01</td>
</tr>
<tr>
<td>Instruction set x Time</td>
<td>1</td>
<td>.17</td>
<td>.17</td>
<td>.46</td>
<td>ns</td>
</tr>
<tr>
<td>Individual x Time within instructions</td>
<td>46</td>
<td>16.92</td>
<td>.37</td>
<td>2.85</td>
<td>.01</td>
</tr>
<tr>
<td>Residual</td>
<td>192</td>
<td>24.44</td>
<td>.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>287</td>
<td>159.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 3
STATISTICAL ANALYSIS OF EMG CHANGES DURING BIOFEEDBACK TRAINING

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instruction set (Set)</td>
<td>1</td>
<td>1.07</td>
<td>1.07</td>
<td>.17</td>
<td>ns</td>
</tr>
<tr>
<td>Feedback Mode (FM)</td>
<td>1</td>
<td>34.91</td>
<td>34.91</td>
<td>5.68</td>
<td>.05</td>
</tr>
<tr>
<td>Set X FM</td>
<td>1</td>
<td>8.74</td>
<td>8.74</td>
<td>1.42</td>
<td>ns</td>
</tr>
<tr>
<td>Error A</td>
<td>44</td>
<td>270.55</td>
<td>6.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training Session (S)</td>
<td>4</td>
<td>16.22</td>
<td>4.05</td>
<td>9.64</td>
<td>.0001</td>
</tr>
<tr>
<td>Set X S</td>
<td>4</td>
<td>.51</td>
<td>.13</td>
<td>.31</td>
<td>ns</td>
</tr>
<tr>
<td>FM X S</td>
<td>4</td>
<td>2.37</td>
<td>.59</td>
<td>1.40</td>
<td>ns</td>
</tr>
<tr>
<td>Set X FM X S</td>
<td>4</td>
<td>1.93</td>
<td>.48</td>
<td>1.14</td>
<td>ns</td>
</tr>
<tr>
<td>Error B</td>
<td>176</td>
<td>74.53</td>
<td>.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Period (TP)</td>
<td>3</td>
<td>3.12</td>
<td>1.04</td>
<td>17.33</td>
<td>.0001</td>
</tr>
<tr>
<td>Set X TP</td>
<td>3</td>
<td>.33</td>
<td>.11</td>
<td>1.83</td>
<td>ns</td>
</tr>
<tr>
<td>FM X TP</td>
<td>3</td>
<td>.13</td>
<td>.04</td>
<td>.67</td>
<td>ns</td>
</tr>
<tr>
<td>Set X FM X TP</td>
<td>3</td>
<td>.03</td>
<td>.01</td>
<td>.17</td>
<td>ns</td>
</tr>
<tr>
<td>S X TP</td>
<td>12</td>
<td>1.45</td>
<td>.12</td>
<td>2.00</td>
<td>.05</td>
</tr>
<tr>
<td>Set X S X TP</td>
<td>12</td>
<td>1.13</td>
<td>.09</td>
<td>1.33</td>
<td>ns</td>
</tr>
<tr>
<td>FM X S X TP</td>
<td>12</td>
<td>.39</td>
<td>.03</td>
<td>.50</td>
<td>ns</td>
</tr>
<tr>
<td>Set X FM X S X TP</td>
<td>12</td>
<td>.54</td>
<td>.05</td>
<td>.83</td>
<td>ns</td>
</tr>
<tr>
<td>Error C</td>
<td>528</td>
<td>33.96</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual</td>
<td>132</td>
<td>15.13</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>959</td>
<td>467.04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent Change Category</td>
<td>Treatment Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PR - A</td>
<td>PR - T</td>
<td>AT - A</td>
<td>AT - T</td>
<td></td>
</tr>
<tr>
<td>40% decrease</td>
<td>32 (10)*</td>
<td>19 (7)</td>
<td>23 (6)</td>
<td>10 (5)</td>
<td></td>
</tr>
<tr>
<td>20 to 39% decrease</td>
<td>20 (10)</td>
<td>20 (9)</td>
<td>24 (9)</td>
<td>28 (11)</td>
<td></td>
</tr>
<tr>
<td>0 to 19% decrease</td>
<td>3 (3)</td>
<td>13 (7)</td>
<td>6 (2)</td>
<td>13 (8)</td>
<td></td>
</tr>
<tr>
<td>increase</td>
<td>5 (2)</td>
<td>8 (4)</td>
<td>7 (3)</td>
<td>9 (6)</td>
<td></td>
</tr>
</tbody>
</table>

* Parentheses contain number of subjects having at least one such training session.
training sessions and the number of subjects accounting for the sessions of each percent change category in each treatment condition.

EMG uV activity levels significantly decreased across training sessions \(F = 9.64, p < .0001\), 33% from the postinSTRUCTION baseline mean. The first two training sessions produced the greatest decreases in activity but the decreases had leveled off by the fourth training session. EMG uV activity levels also significantly decreased across time periods within training sessions \(F = 17.33, p < .0001\), 29% from the postinSTRUCTION baseline mean. The greatest decreases in activity also came in the first few time periods but the decreases had essentially leveled off by the third time period.

The interaction of training sessions and time periods was significant \(F = 2.00, p < .05\). The response curve for the first training session represents a fairly linear decrease in EMG activity. The curve for the second training session is also fairly linear, but there is an increase in EMG activity during the last time period of the session. The remaining curves also have the increase in EMG activity during the last time period but the slopes of these curves are considerably flatter. Still each training session's performance curve is generally lower than that of the preceding session. Figure 2 illustrates these findings.

No other effects were found to be statistically significant and Table 3 is a summary of these findings.

An additional analysis was conducted using the design in Table 3 but incorporating as an additional source of variation the variation in uV activity levels within each 3-minute time period. This analysis
Figure 2. Mean EMG activity levels of 3-minute time periods within each of the five training sessions of the EMG biofeedback training segment of the study.
Figure 3. Mean EMG activity of the treatment groups (Autogenic Training instructions (AT) with audio feedback (A), AT with tactile feedback (T), Progressive Relaxation instructions (PR) with A, PR with T) for each of the five training sessions of the EMG biofeedback training segment of the study.
confirmed the significance of the feedback mode, training session and time period main effects of Table 3. The additional source of variation caused the training session X time period effect to be nonsignificant; no additional effects were significant in this analysis. The average variance in EMG activity associated with a 3-minute time period was .09 uVs.

**Subject Interview Responses.** The behavior of the subjects in the PR condition seemed to indicate that they were following the instructions since they all flexed and then relaxed their forehead muscle during the initial 3-minute time period of each training session. Compliance with the instructions of the AT condition was generally demonstrated by the subjects' self-reports following the training sessions. During the remaining 12 minutes of each 15-minute training session, the PR subjects tended, however, to adopt strategies not unlike those of the AT subjects. In both conditions the subjects appeared to use the detailed instructions as jumping off points from which they developed idiosyncratic strategies.

Within the 84 training sessions in which subjects achieved a 40% or greater decrease in EMG activity, subject self-reports were roughly lumped into six somewhat distinct categories. In seven of these 84 training sessions subjects reported feeling drowsy, or that they were falling asleep. In eight sessions subjects reported relaxing all of their muscles, and in eight other sessions subjects reported thinking of the feedback signal. Subjects reported that in ten sessions they were not thinking at all or having a blank mind. Daydreaming, a flow of
thoughts or mental drifting was reported in 16 sessions. In the remaining 35 training sessions the subjects reported utilizing combinations of the above five categories, using the instructions, feeling numb, concentrating on their respiration, and thinking things which appeared to be unrelated to any systematic cognitive strategy for producing decreased activity in their muscle.

Of the 92 training sessions in which 20 to 39% decreases in EMG activity occurred, subjects reported feeling drowsy or falling asleep in one session, thinking of the feedback signal in five sessions, not thinking or having a blank mind in eight sessions, and daydreaming, drifting or a flow of thoughts in 15 sessions. In the remaining 63 training sessions subjects reported combinations of the above categories, more use of the instructions in general, and again apparently unrelated thought processes.

Subject reports in the sessions in which EMG activity decreased 0 to 19% and in those in which it increased are generally flavored by increased self-consciousness, concern over performance, and reports of more conscious effort in trying to produce relaxation.
DISCUSSION

The two sets of instructions were rated as being different in the appropriate directions, but they were not entirely without overlap. It appears, therefore, that the two sets of instructions used in this study were fairly representative of the Progressive Relaxation and the Autogenic Training approaches to teaching muscle relaxation.

A tempting conclusion which could be drawn from the analysis of EMG changes during the baselines would be that informing an individual what will be expected of him and giving him some idea about how he may go about achieving those results facilitates decreasing the activity of the frontalis muscle. It is possible however that the reduction in EMG levels was due primarily to adaptation to the experimental situation. Future research on this question should include a "no instruction" condition to test the possibility of adaptation.

The two sets of instructions were not associated with significantly different levels of EMG activity thus confirming the hypothesis that both types of instructions would be effective aids to relaxing the frontalis muscle.

The significantly lower level of EMG activity accompanying the audio feedback conditions was opposite the anticipated result. Fehmi, et al. (1972) finding that tactile feedback aided subjects more than audio feedback in learning to control frontal lobe alpha rhythm may be specific to alpha rhythm BFT. Tactile feedback may not, therefore, be better than audio feedback for all types of BFT. There are at least two
possible explanations for the obtained results. The differences found in this study may have been based on the subjects' inability to perceive meaningful changes in the tactile signal used in this study. It is also possible that the tactile feedback produced arousal, since it feels somewhat sensuous at some frequencies, and this arousing nature may act as an impediment to very deep levels of relaxation. The findings that the tactile mode was associated with consistently higher levels of EMG activity throughout the study and the lack of interactions involving the feedback mode factor tends to support both of these explanations.

As expected, subjects were able to reduce their EMG activity levels across the training sessions and across the time periods within the training sessions. The performance curves of the training session x time period interaction appear to represent fairly systematic changes in EMG activity indicating that the subjects were able to acquire some skill in voluntarily reducing their muscle tension levels. When combined with the above finding the nonsignificant interaction of the instruction sets and feedback modes indicates that the treatment conditions were effective aids to the subjects in relaxing their frontalis muscle. Only four of the 48 subjects appeared not to learn to relax their frontalis muscle.

The second analysis of variance which incorporated the variation in EMG activity within the 3-minute time periods of the training sessions indicated that the training session x time period interaction was not statistically significant. The response curves represented in Figure 2 are of a type well known to the psychology of learning literature. This second statistical analysis obscured the skill acquisition
effect associated with the EMG BFT. This analysis appears to be at too fine a level for exploring the learning processes of EMG BFT.

The major hypothesis tested in the study, that the four treatment conditions would produce different types of performance curves, was not supported by the results. None of the interactions in which the effect was expected to be seen were found to be statistically significant.

The response curves of the instruction set X feedback X training session interaction, shown in Figure 3, are strikingly similar and the powerful effect of which type of feedback was available can be clearly seen. Within the audio feedback condition the two response curves for the AT and PR instructions are almost identical.

Within the context of the present study, the hypothesized differences in learning strategy represented by the Autogenic Training and Progressive Relaxation instructions may have been only slight variations in semantics since, as reported above, the subjects in the treatment conditions tended to use similar strategies for reducing their EMG levels. The underlying mechanisms which mediated the reductions in EMG activity for the subjects in the experiment may have been similar in spite of the considerable differences in the reports which the subjects gave of their cognitive activity. Such a commonality is suggested by the strategies reported by the subjects who reduced their EMG activity by 40% or more. Those strategies appeared to involve a suspension of logical, time-ordered, goal-oriented thought processes. Such thought processes have been associated with a receptive, appositional, intuitive-holistic mode of consciousness generally attributed to the activity of the right hemisphere (Bogen, 1973; Delkman, 1973; Ornstein, 1972): The
subjects' reports of their adopted learning strategies suggest hypotheses which have not been fully developed or explored in the current biofeedback literature.

If the cognitive processes involved in mediating the changes in EMG activity levels during biofeedback training are assumed to be based primarily on the activity of the right hemisphere, then the theoretical disparity between the positions of Brown (1974) and of Basmajian & Simard (1967) and Leibrecht, et al. (1973) regarding subject use of the feedback signal could be resolved. A single underlying mechanism could be proposed involving cortical and subcortical structures. Such a mechanism could also mediate the effects obtained by Progressive Relaxation and Autogenic Training.

Ornstein (1972) has stated that the "evidence seems to indicate that the left hemisphere is more anatomically specialized for the discrete, focal information-processing underlying logic, and that the right hemisphere is more diffusely organized, which is advantageous for orientation in space and for other situations which require simultaneous processing of many inputs" (p. 79-80). BFT is a process which appears to require simultaneity in processing.

On the anatomical side, Luria (1973) has stated that, "the right hemisphere is directly concerned with the analysis of direct information received by the subject from his own body and which it can easily be understood, is much more closely connected with direct sensation than with verbally logical codes" (p. 165). Levy-Agresti & Sperry (1968) have suggested that the two modes of information processing may be quite incompatible. Budzynski (1976) has suggested that
Perhaps the decrease in critical, analytical, logical linear-functioning that occurs with a lowering arousal level is the gradual, functional disabling of the major hemisphere. We might also speculate that the minor hemisphere is not as quickly disabled as is the major hemisphere with decreasing arousal. Thus at the point where the major hemisphere ceases to process effectively incoming (or outgoing) information, the minor hemisphere can still do so in its own holistic manner (p. 381).

If the right hemisphere is assumed to process analogue information better than digital (language coded) information and the reverse assumed for the left hemisphere, then Brown's contention that the mind can respond directly to an abstract, analogue signal is quite correct. The contention that the feedback signal augments normal proprioceptive activity by Basmajian & Simard and Leibrecht, et al., is also correct if the individual does not interfere with this process by attempting to verbally code the feedback signal and "make sense" of it. Attempting to verbally code the feedback signal is seen to add several time consuming steps in the information processing circuit as follows: input of analogue feedback signal $\rightarrow$ translation of analogue signal into digital (language) signal $\rightarrow$ processing of digital signal $\rightarrow$ translation of digital signal into analogue signal $\rightarrow$ processing of analogue signal $\rightarrow$ output of behavior $\rightarrow$ input of analogue signal, etc. The deleterious effect of delayed feedback is well documented and the delay may not be of any considerable duration to disrupt the learning process involved in BFT.

A distinction should be made at this point between the process of learning the response and the process of executing the response at the subject's command. The above discussion is concerned with the acquisition of an entire neuropsychological program. Once the program and its
information processing circuits have been debugged and are stable, then the entire program can be verbally coded and executed en masse when cued. The effectiveness of cue-controlled relaxation has been clearly demonstrated by Russell, Miller & June (1975) and others. It is contended that the introduction of verbal coding into the response acquisition process at too early a stage would be disadvantageous. The parameters of when and of what type of verbal coding can be introduced into EMG BFT are at present uninvestigated.

In Progressive Relaxation left hemispheric activity is discouraged and in light of Luria's comment the right hemisphere would appear to be extensively involved in the process of relaxation via Progressive Relaxation. Autogenic Training also appears to involve right hemisphere activity but via the mechanism of a repetitive phrase and encouraged suspension of active, goal-oriented cognitive activity. The proposed mechanism underlying the effects of Autogenic Training and Progressive Relaxation involves two components. One is shifting the individual into a pattern of cognitive processes predominantly right hemispheric in nature, which both appear to do to some extent. The second component involves volition, consciousness and subcortical structures.

Green, et al.'s (1974) statement that subjects appear to be able to self-program themselves in learning voluntary control of a physiological process is accounted for by Sperry's (1976) statement that,

Conscious phenomena, thus conceptualized as dynamic emergent properties of high order cerebral processes, are not merely products of neural complexity but are also designed to produce operational subjective effects. . . . Conscious cerebral processes, as dynamic entities in brain activity, contain entitative systemic properties that exert controlling influence over many aspects of the component physiochemical elements of which they
are built. As with any part-whole relationship, a mutual interaction prevails in which the conscious mental effects are determined by the neural events, including their molecular and atomistic components, while these latter in turn are reciprocally controlled by the higher holistic or systemic properties of the conscious cerebral process in which they are embedded (p. 464).

Benson, Beary & Carol (1974) have reviewed many cognitive strategies for achieving relaxation and most of them involve predominantly right hemispheric activity. They have also suggested that a common neurological process, activation of the anterior hypothalamus, produces the relaxation in most of the procedures.

Thus the underlying mechanism which is proposed to mediate EMG BFT as well as the effects of Autogenic Training and Progressive Relaxation involves the person making a conscious, or perhaps even an unconscious, choice to relax. Shifting out of a logical, analytical cognitive mode and into a synthetic, gestalt mode of consciousness appears to be the next stage of the process. These two stages enable the formation of a neuropsychological system involving predominantly the right hemisphere and the subcortical structures which Benson, et al. have identified. Such a system would function on its own until interrupted or modified. One of the properties of systems in general is equifinality—the property that a system can arrive at the same final state from many different starting points and through many different processes. The question of differential effectiveness of classes of learning strategies in aiding relaxation becomes somewhat of a moot point for the neuropsychological system described above. Future research into the mechanisms involved in EMG BFT and relaxation might most profitably focus on determining the extent of left and right hemispheric involvement.
With regard to the optimal strategy to present to the client or subject engaged in EMG BFT, it is suggested that having the person program himself to relax the appropriate muscle and then having the person shift into right hemispheric activity, or perhaps simply block left hemispheric activity, would produce the best results.
REFERENCES


Coursey, R. D. Electromyograph feedback as a relaxation technique. *Journal of Consulting and Clinical Psychology*, 1975, **43**(6), 825-834.


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APPENDICES
APPENDIX 1

Voltage to Impulse Converter
APPENDIX 2

INSTRUCTION RESPONSE FORM

ANSWER THE FOLLOWING QUESTIONS BY PLACING A CHECK MARK (✓) ON THE HORIZONTAL LINES AT THE POINT WHICH BEST INDICATES YOUR ANSWER:

In following these instructions, the biofeedback signal will be

not important

very important

In following these instructions to relax my muscle, my thoughts and feelings will be

not important

very important

In following these instructions remaining relatively motionless will be

not important

very important

According to the instructions, learning how my muscle feels when it is tense and when it is relaxed is

not important

very important

According to the instructions, paying close attention to my muscle sensations will be

not important

very important

These instructions tell me to be

active passive

disinterested interested

in results in results
Kip Errett Patterson was born in Cincinnati, Ohio on September 15, 1949. He spent the first nine years of his life in Circleville, Ohio. He then lived in South Euclid, Ohio and Bucyrus, Ohio. In June of 1967 he graduated from Chatham Township High School, Chatham Township, New Jersey. After four years of coursework he received a Bachelor of Science degree from Louisiana State University in Baton Rouge, Louisiana in Psychology in May of 1971. He was accepted into the graduate program in Clinical Psychology and received his Master's degree in May of 1974. He is now a candidate for the Doctor of Philosophy degree at the Spring 1977 commencement.
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Major Field: Psychology

Title of Thesis: The Interaction of Instructional Set and Feedback Mode in the Acquisition of a Reduced Muscle Activity Response via Biofeedback Training

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

March 15, 1977