PERFORMANCE MOTIVATION IN ELECTROMYOGRAPHIC BIOFEEDBACK

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CHAPTER I

INTRODUCTION

Biofeedback phenomena were initially conceptualized as an example of a conditioning process. In this paradigm the feedback stimulus was seen as a necessary and sufficient condition for gaining control over the associated physiological process. Numerous studies, where a treatment group given feedback is compared to a non-feedback control group, have tended to generally support this position. Recently, however, several authors have emphasized various cognitive factors which may also have mediating influences on the conditioning process in biofeedback.

Meichenbaum (1976) states that biofeedback therapists have failed to appreciate that a client's problem represents a set of complex responses, including affective, cognitive and physiological components. There is considerable research supporting the role of cognitive factors in this complex and interrelated set of responses. Three studies (Wolf, 1950; Graham, Kabler, and Graham, 1962; Sternbach, 1964) indicate that a subject's meaning system can have direct and significant effects on his physiological reactions. Another group of studies (Platonov, 1959; Barber, 1964; Zimbardo, 1969; May and Johnson, 1973) indicate that changing a client's style of self instruction can have direct physiological effects.

Further support for this position comes from research on physiological stress reactions. Mason (1971), citing supporting research, suggests that the primary mediator underlying physiological stress reactions is psychological in nature. Support for the occurrence of this process in humans comes from observations of patients dying from diseases or injury (Symington, Currie, Curran, and Davidson; 1955). They found that patients who remained unconscious during the fatal period did not show any adrenal cortical changes, while patients who were conscious did display these changes.

Lazarus (1975) presents a more specific theory concerning the relationship between cognitive and physiological processes. His theory maintains that the quality and intensity of an emotional response (with its associated somatic component) depends on the cognitive appraisal of the significance of the given transaction with the environment. Cognitive processes, then, are seen as mediating between the environment and the internal somatic processes. In relating this theory to biofeedback training, he maintains that the interpersonal features of biofeedback research are primary sources of the mediating psychological processes responsible for successful training.

Cognitive influences, then, do appear to be linked to physiological processes, and most likely are an important element in successful biofeedback training. Identification of the most important cognitive dimensions involved in successful biofeedback training would allow the design of more effective training procedures. However, little research has been done in this area.

Performance Motivation as a Possible Source of Training Effects in EMG Feedback

One cognitive variable that has been investigated is performance motivation. Alexander, White, and Wallace (1977) question whether the feedback stimulus is a necessary component of EMG feedback training. They maintain that differences between treatment and control groups may not be due to the presence or absence of the feedback, but rather to differences in motivation. The authors note that the public excitement generated by biofeedback phenomena has provided for a high level of sustained interest, favorable attitudes, and motivation on the part of contingent feedback subjects. They also note that it is difficult to maintain equally high levels of positive motivation and interest in control subjects. To control for these differences a design was used in their study which provided for greater motivation and goal directedness in control subjects.

As in most studies in this area, treatment subjects were given contingent EMG feedback and were compared to a control group not given feedback. However, following this phase, control subjects were also given contingent feedback. This was to allow subjects to compare their control experience to an actual feedback situation. The authors explain the logic of this approach as follows:

> During the initial interview, it was further impressed upon control subjects that their earnest and purposeful attempt to relax the relevant muscles just as much as they possibly could was absolutely crucial both in scientific evaluation of the effectiveness of the biofeedback and in their own evaluation of how much more effective EMG biofeedback might prove to be in comparison with their ability to relax their muscles prior to feedback training. The intention of these instructions to control subjects was to engage their interest and motivation to perform by actually involving them in the logic of the experimental enterprise. It was felt that such involvement

> would motivate maximal performance far more than nominal sums of money or simple encouragement to relax. In this manner subjects actually felt they were in a position to evaluate biofeedback effectiveness for themselves because their control experience would be followed by bona fide training (p. 554).

Using this design, results indicated no significant differences between treatment and control groups on measures of EMG level. These results would suggest that motivation, rather than the feedback stimulus, was the essential mediator of EMG training effects. However, several methodological flaws in the study negate the validity of these results.

Criticism of the Alexander et al. Study

The above study has three major weaknesses. The first problem involves the number of subjects used in the experiment. Second, there are unrecognized experimental demand characteristics made on the treatment group. Finally, an inefficient training procedure was used in the feedback group.

This study used only five subjects in the experimental group and six subjects in the control group. Since the power of a statistical test to detect a significant difference falls sharply as N is reduced below eight per group, the design is weighted against finding any significant between-group differences. In that support of their research hypothesis depends upon a finding of a non-significant interaction between the two groups, and considering that a rather subtle experimental variable is being investigated, the design employed provides a very weak test of their hypothesis.

The very strong positive demand characteristics put on the control group would be expected to produce motivation and goal directedness, as desired. However, there was also a negative demand put on the EMG training group. This probably occurred when, during the initial interview, the experimenters emphasized that EMG biofeedback is still in the experimental stage. Other research (Andrews, 1975; Brown, 1977) has suggested that the EMG feedback process is sensitive to negative suggestions, and that these effects are most prominent in the early stages of training. The use of a very short total training time (29.6 minutes), divided up into short blocks (4.2 minutes) would be expected to emphasize the effects of the negative demands. Related to this problem, their study has no provisions to deal with experimenter bias. Again, considering the subtle nature of the effect being investigated, a design whereby experimenters were kept blind to the conditions involved would seem appropriate.

Finally, an inefficient training method was used. Subjects in the feedback condition were only given 29.6 minutes of feedback which was further divided into 4.2 minute blocks spread over these different sessions. Coursey (1975) has indicated that an average of five twenty-one minute sessions (105 minutes total time) are required for normal subjects to reach basal levels. Subjects were given approximately half of what should be considered the minimum training time. Furthermore, research (Caronite, 1972; Kinsman, O'Banion, Robinson, and Standenmayer, 1975; Pope, 1976) has indicated that continuous feedback is more effective than discrete feedback. In that the short blocks employed represent a more discrete type of feedback, the efficacy of training was further reduced.

Alexander, White and Wallace, suggest that the lack of performance motivation in control groups may be responsible for the differences between EMG feedback and control groups found in earlier studies.

While they have devised an approach to induce appropriate motivation in a control group, the foregoing criticisms have indicated that they have used a methodologically inadequate experimental design to test their hypothesis.

The Present Study

The present study provides a methodologically adequate test of the performance motivation hypothesis. Given the number of studies which support the role of the feedback stimulus in EMG training, it is predicted that, when both groups are adequately motivated, the feedback group will achieve lower EMG levels.

Specifically, this study compared an EMG feedback group to a no feedback control group. Both groups were given instructions to induce a motivated and goal-oriented state. To aid motivation in the control group these subjects were given EMG feedback following the control period to allow them to personally compare self-relaxation and feedback experiences.

A sufficient number of subjects were used in order to avoid the statistical problem noted in the earlier section. Appropriate training procedures, using sessions of a reasonable length, and sufficient total training time, was used. Finally, to avoid experimenter bias, experimenters were kept blind as to the subjects' condition.

EMG level during training was the major dependent variable. For an additional physiological measure, EMG baselines taken at the first of each training session were compared. Psychological dependent measures included the STAI A-State scale, and two single item scales to assess subjective physical and mental relaxation. All psychological measures were administered before and after each session.

CHAPTER II

METHOD

Subjects

Twenty-two volunteer subjects, who received extra credit for their participation, were selected from undergraduate psychology classes. There were five males and six females in both the treatment group and the control group.

Instruments

The State Anxiety scale of the State-Trait Anxiety Inventory (STAI) (Spielburger, Gorsuch, and Lushane, 1970) was used. This scale is concerned with how the subject feels "right now." It has items intended to evaluate feelings of tension, nervousness, worry and apprehension.

The scale has twenty items. Scores on each item range from one to four, with one corresponding to a response of "not at all" and four corresponding to a response of "very much so." The overall score for the scale is obtained by summing responses to the individual items (for some items referring to positive feelings, e.g., I feel calm, the scoring is reversed). Various studies using this scale have produced internal reliability coefficients ranging from 0.83 to 0.92.

In addition, subjects were asked to rate their subjective mental and physical tension before and after each training session. For each of these two dimensions, subjects marked a Likert-type scale ranging from one to seven. On this scale one represented the most physically or mentally relaxed state the subject has ever experienced, while seven represented the most tense physical or mental state the subject has ever experienced.

Apparatus

EMG measures were recorded from an Autogen 5100 Digital Integrator connected to an Autogen 1700 Feedback Myograph. Electrodes were connected to the frontalis muscle. Standard placements (Venables and Martin, 1967), with electrodes placed two inches from the center of the forehead and one inch above the eyebrows, were used. The ground electrode was attached midway between the active electrodes.

Subjects in the EMG feedback group received auditory feedback of ongoing muscular tension level through headphones routed to the Autogen 1700 unit. The feedback was presented in the form of clicks which were logarithmically proportional to the EMG activity of the frontalis muscle.

Instructions for each group was presented by a cassette recording routed through a switchbox. Following presentation of instructions a switch was thrown to the training position. Then, depending upon the position of another coded switch, the subject heard either a tone recorded on the tape or contingent feedback from the Autogen 1700 unit.

Procedure

Adaptation Session

In this session all subjects were treated identically. It was explained that this session has the purpose of allowing the subject to become accustomed to the experimental setting. Subjects were seated in a comfortable reclining chair. Following attachment of the EMG electrodes, subjects were asked to rest quietly, with their eyes closed, and with both arms and legs uncrossed. While subjects were sitting quietly multiple frontalis EMG baselines were taken. These baselines were averaged and later used as the covariate in some of the statistical analysis.

Training Sessions (Sessions 1-8)

There were eight one-half hour training sessions for all subjects. At the start of each session subjects filled out all psychological measures. They were then moved to the training area and seated in a comfortable, reclining chair. EMG electrodes were attached, and subjects were asked to rest quietly with their eyes closed and with arms and legs uncrossed. Baseline frontalis EMG data was then recorded. After the baseline period, headphones were placed on the subjects' head and tape recorded instructions appropriate to the condition were played.

In the EMG feedback condition the following instructions were played:

> This study is a test of muscle biofeedback. During these sessions you are to concentrate on relaxing your forehead as much as you can with the help of biofeedback. The speed of the clicks you will hear is proportional to the level of muscle tension in your forehead. The clicks go faster as your forehead muscles become more tense, and go slower as your forehead muscles become more relaxed. Try to make the clicks go as slowly as possible. Please remain as still as possible during these sessions, which last 20 minutes. Remember, your earnest and purposeful attempt to relax your forehead with the help of biofeedback is absolutely crucial in the scientific evaluation of muscle biofeedback. Just concentrate on relaxing your forehead muscle as much as you possibly can.

Input to the headphones was then switched from the tape recorder to the Autogen 1700 Feedback Myograph. Subjects in this condition then received 17.5 minutes of contingent EMG feedback.

In the control condition (for sessions 1-6) the following instructions were played:

> Muscle biofeedback is still in the experimental stage. This experiment will actually allow you to compare biofeedback training to your ability to relax on your own. For these first six sessions you are to concentrate on relaxing your forehead muscle as much as you can on your own. The last two sessions you will be given muscle biofeedback, so that you can compare the effectiveness of these two approaches. During this first stage of the experiment, you will hear a constant tone whose only purpose is to block any distracting noises. Please remain as still as possible during these sessions, which last 20 minutes. Remember, your earnest and purposeful attempt to relax your forehead on your own is absolutely crucial both on the scientific evaluation of muscle biofeedback and in your own personal evaluation of muscle biofeedback. Just concentrate on relaxing your forehead muscle as much as you possibly can.

Following the above instructions, subjects heard a quiet tone through the headphones for the next twenty minutes. For sessions seven and eight subjects in the control condition received the EMG feedback instructions and received contingent frontalis EMG feedback. Following training, subjects in both conditions again filled out all psychological measures.

For recording purposes the 17.5 minute training session was divided into seven 2.5 minute trials. However, subjects in the feedback group heard continuous feedback for the entire 17.5 minute period. Frontalis EMG levels were recorded from the Autogen 5100 Digital Integrator. It was set to produce a reading which reflects the average amplitude (over the 2.5 minute trial) of the EMG level in micro-volts.

All training and data collection were performed within a double blind design where both subject and experimenter were unaware of the treatment received. Specifically, experimenters did not know which of the two conditions a subject was in. Subjects were not aware of the nature of the differing conditions used. Subjects were also informed that the experimenters were blind to some aspects of the experiment, and were asked not to question the experimenter. This was done to avoid the possibility of a subject's question cueing the experimenter to the treatment being received.

Subjects in each of the two conditions were assigned a code letter, either A or B, according to the treatment condition they were in. The two conditions were combined into one list, which consisted only of the subjects' names paired with the appropriate letter code. This list was the only information the active experimenters have access to.

The experimenters utilized identical procedures for all subjects. First, electrodes were attached and baseline readings taken. The instructions for the two conditions were on separate tape cassettes, which were appropriately coded either A or B. The experimenter then selected the cassette matching the subjects code and placed it in the tape recorder. At this time he or she also set the coded switch on the switch box to either position A or B, as appropriate. The other switch was placed in the instructions position. The tape recorder was started. After allowing time for complete playback of the instructions, the instruction switch was moved to the training position. Depending upon the position of the coded switch, subjects either heard the tone (control condition) or the contingent feedback (EMG feedback condition). Data collection procedures for the remainder of the session were identical for all subjects.

Hypothesis

In comparison to the control group it is hypothesized:

Ho_1: That the feedback group will achieve lower EMG levels, both within and across sessions (sessions 1-6), on EMG training measures.

Ho_2: That the feedback group will have lower EMG levels as training progresses (sessions 1-6) on EMG baseline measures.

Ho_3: That the feedback group will achieve greater reduction in baseline to trial one EMG levels in sessions one through six.

Ho_4: That the feedback group will produce greater reductions in state anxiety (sessions 1-6) on pre-post change scores from the STAI A-State scale.

Ho_5: That the feedback group will produce greater reductions on pre-post change scores of subjective mental relaxation (sessions 1-6).

Ho_6: That the feedback group will produce greater reductions on pre-post change scores of subjective physical relaxation (sessions 1-6).

Ho_7: That the feedback group will achieve lower EMG levels in sessions seven and eight, on EMG training measures.

Design

The independent variable used in this study is treatment condition. Specifically, one-half of the subjects received contingent EMG feedback and instructions creating a positive expectancy for this condition, while the other one-half attempted to self-relax and were given instructions expected to produce motivation and goal directedness. There were two independent within subjects variables used in this study: sessions (six) and trials (seven).

The dependent measures used in this study were frontalis EMG during training, baseline frontalis EMG, baseline-trial one EMG, pre-post change scores from the STAI A-State scale, pre-post change scores from the subjective mental relaxation measure, and finally, pre-post change scores from the subjective physical relaxation measure.

The first hypothesis was tested by a three-way split plot factorial analysis of covariance (Kirk, 1968). Groups (2) is the between subjects variable, while sessions (6) and trials (7) are within subjects variables. The baseline taken during the adaptation session was used as the covariate. The second hypothesis was tested by a two-way (2 groups x 6 sessions) analysis of covariance. The third hypothesis was tested by a three-way (2 groups x 6 sessions x baseline-trial 1) analysis of variance. The fourth, fifth, and sixth hypothesis were tested by two-way (2 groups x 6 sessions) analysis of variance. The seventh hypothesis was tested by a three-way (2 groups x 2 sessions x 7 trials) analysis of covariance.

CHAPTER III

RESULTS

A covariate was used for all analysis involving EMG data. The covariate was taken during the habituation session, as noted previously. Specifically, during this session a series of two minute baselines were taken. The first two of these readings were dropped. The next three were averaged together and used as the covariate. The average covariate for the control group was 2.178 (SD = 0.892), while the average for the treatment group was 2.176 (SD = 0.863). Given the obvious equivalence of the two groups on this pre-experimental baseline, a *t*-test was not performed.

EMG Training Data

The EMG training data for the first six sessions were analyzed using a three way split-plot factorial analysis of covariance. The variables were groups (EMG feedback versus control), sessions (6), and trials within sessions (7). Results from this analysis are summarized in Table I. The covariate was significant, $F(1,19) = 11.14$, $p = 0.003$, indicating that this factor was accounting for a significant amount of the variance (proportion of variance = 0.33; Hays, 1973), and that the analysis of covariance was an appropriate design.

The main effect for groups was significant, $F(1,19) = 11.93$, $p = 0.003$, indicating that the treatment and control groups differed significantly

TABLE I

ANALYSIS OF COVARIANCE SUMMARY TABLE FOR EFFECTS OF EMG TRAINING (FEEDBACK VERSUS CONTROL) ON EMG LEVEL

Source	SS	d.f.	M.S.	*F*	*p*
Between Subjects (Ss)					
Group (G)	129.87	1	129.87	11.93	.003
Covariate	121.24	1	121.24	11.14	.003
Error	206.80	19	10.88		
Within Ss					
Sessions (S)	11.04	5	2.21	1.20	N.S.
G x S	16.84	5	3.37	1.83	.114
Error	184.32	100	1.84		
Trials (T)	3.43	6	.57	1.87	.091
G x T	1.29	6	.21	.70	N.S.
Error	36.63	120	.31		
S x T	3.92	30	.13	1.08	N.S.
G x S x T	3.15	30	.11	.87	N.S.
Error	72.85	600	.12		

overall. Examination of the data indicates that the control group had consistently higher EMG levels on all sessions and trials within sessions. The control group mean was 1.95 microvolts, while the treatment group mean was 1.19 microvolts. Variances for the two groups, based on average trial variance, was 1.23 for the control group and 0.25 for the treatment group. The variances for the two groups differ significantly, $F(41,41) = 4.93$, $p < 0.01$, indicating that EMG levels for the treatment group are substantially less variable.

All other sources of variation in this analysis were not significant. However, two trends were noted. Examination of the trials variable, $F(6,120) = 1.87$, $p = 0.091$, indicated that, across both groups, EMG levels tended to drop most rapidly between trials one to three, remaining relatively more stable across trials three to seven. The group by session interaction, $F(5,100) = 1.83$, $p = 0.114$, although a weak trend, suggests that the groups may be performing differentially over sessions. Given that a major focus of this study involves this interaction, one supplemental analysis was run. To completely control for all variations in baselines, an analysis of covariance using the same design, with the addition of multiple covariates was used. The covariates were the subjects' baselines at the beginning of each session. For the group by session interaction this analysis yielded an $F(5,99)$ of 1.00, $p = 0.086$, indicating a slightly stronger trend. Examination of session means (see Figure 1), indicates that treatment group levels dropped from session one to two, remaining fairly stable throughout the remainder of training. In contrast the control group performed more eratically, with EMG levels increasing from sessions one to three, decreasing between three and five, and increasing between five and six.

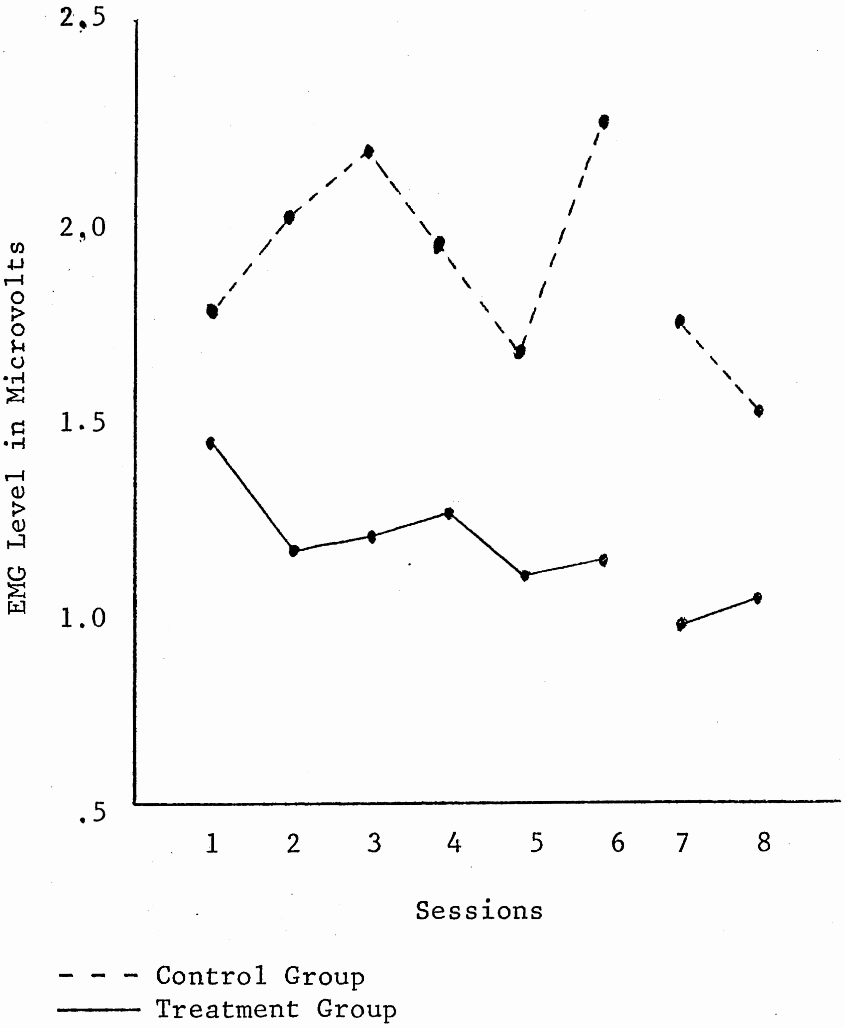

Figure 1. Session Means for EMG Training Measure

Summarizing the EMG training data for sessions one through six, the treatment group receiving EMG feedback maintained an overall EMG level that was significantly lower than the control group. Across sessions the control group's mean EMG levels tended to fluctuate more than the treatment group's mean EMG levels. Finally, the treatment group was substantially less variable than the control group.

EMG Baseline Data

The EMG baseline data for sessions one through six was analyzed by a two way analysis of covariance. The variables were groups (2) and sessions (6). The covariate used in this analysis was significant, $\underline{F}(1,19) = 10.15$, $\underline{p} = 0.005$, supporting the use of the analysis of covariance design. The proportion of variance accounted for was 0.30. The main effect for groups, $\underline{F}(1,19) = 1.94$, $\underline{p} = 0.18$, and the session by group interaction, $\underline{F}(5,100) = 0.91$, $\underline{p} =$ NS, were not significant. The main effect for sessions, $\underline{F}(5,100) = 2.56$, $\underline{p} = 0.032$, was significant. Examination of the data indicates that, across groups, EMG baseline levels increased slightly from session one to three, decreased from session three to five, and increased again between sessions five and six (see Figure 2). Baseline EMG measures, then, did not differentiate between the two groups in sessions one through six.

Baseline-Trial One Data

A two (groups) by six (sessions) by two (baseline-trial 1) analysis of variance was used to compare the two groups' abilities to reduce EMG levels from baseline readings. The group by baseline-trial 1 interaction was significant, $\underline{F}(1,20) = 4.82$, $\underline{p} = 0.04$. Simple main effects

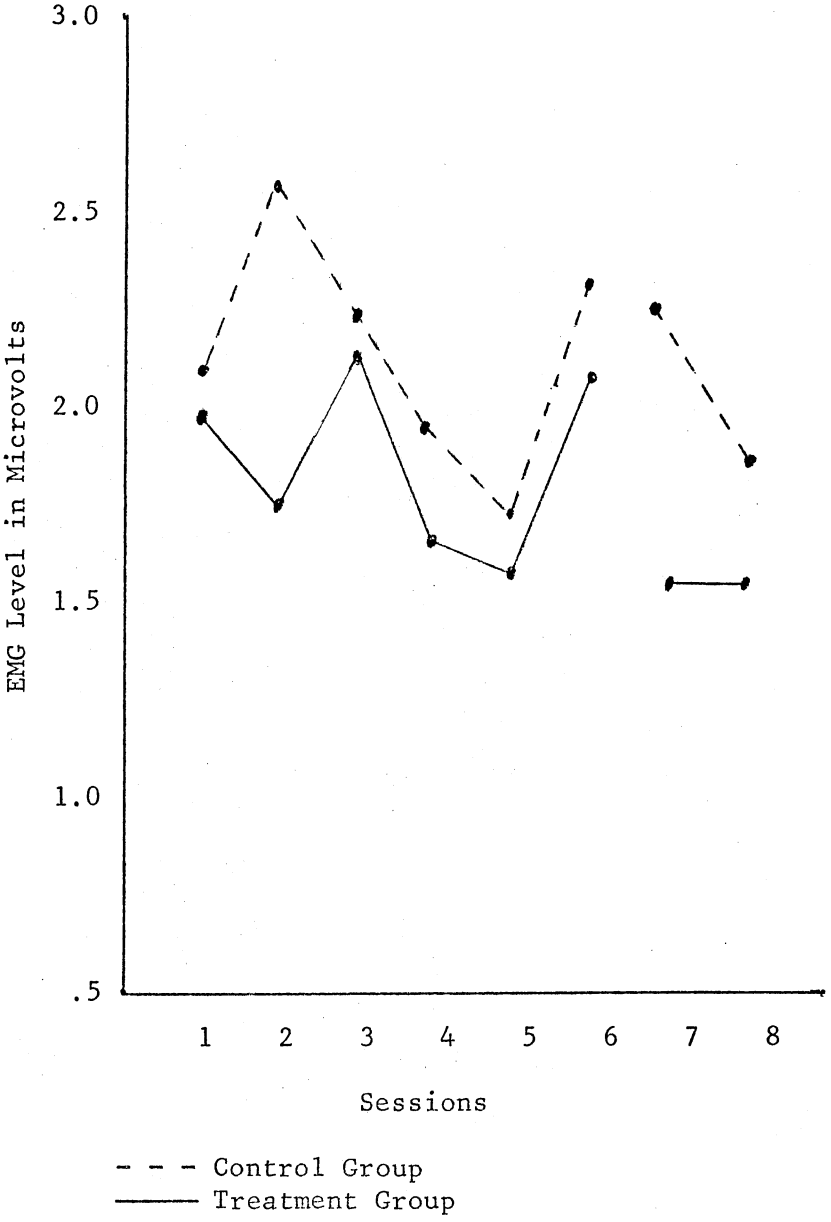

Figure 2. Session Means for EMG Baseline Measure

tests indicate that the control group did not produce a significant decrease, 2.16 - 2.03 = 0.13, $p > 0.05$, ($HSD_{0.05} = 0.408$). The treatment group did produce a significant drop, 1.87 - 1.36 = 0.511, $p < 0.05$. Additionally, a trend was noted in the group be session by baseline-trial 1 interaction, $F(5,100) = 1.95$, $p = 0.092$. Examination of the data (see Figure 3) suggests that the control group was able to achieve some reductions in EMG level in sessions one, two, three, and five. On sessions four and six, the control group did not show a reduction on this measure, but actually produced increases. In contrast, the treatment group produced reductions in all sessions.

Sessions Seven and Eight EMG Data

EMG data for the last two sessions (seven and eight) was analyzed by using a three way analysis of covariance. Variables were groups (2), sessions (2), and trials within sessions (7). Due to the loss of one subject in the latter part of the study, N = 10 for each group in this analysis. As in previous analysis, the covariate was significant, $F(1,17) = 16.19$, $p = 0.001$, and the proportion of variance accounted for was 0.44. Of all other sources of variation, only the main effects for groups, $F(1,17) = 7.62$, $p = 0.013$, was significant. The mean for the control group was 1.61 microvolts (SD = 0.88), while the mean for the treatment group was 1.01 microvolts (SD = 0.52). In these last two sessions, when both treatment and control groups were receiving feedback, the treatment group maintained an EMG level which was substantially lower than the control groups EMG level (see Figure 1).

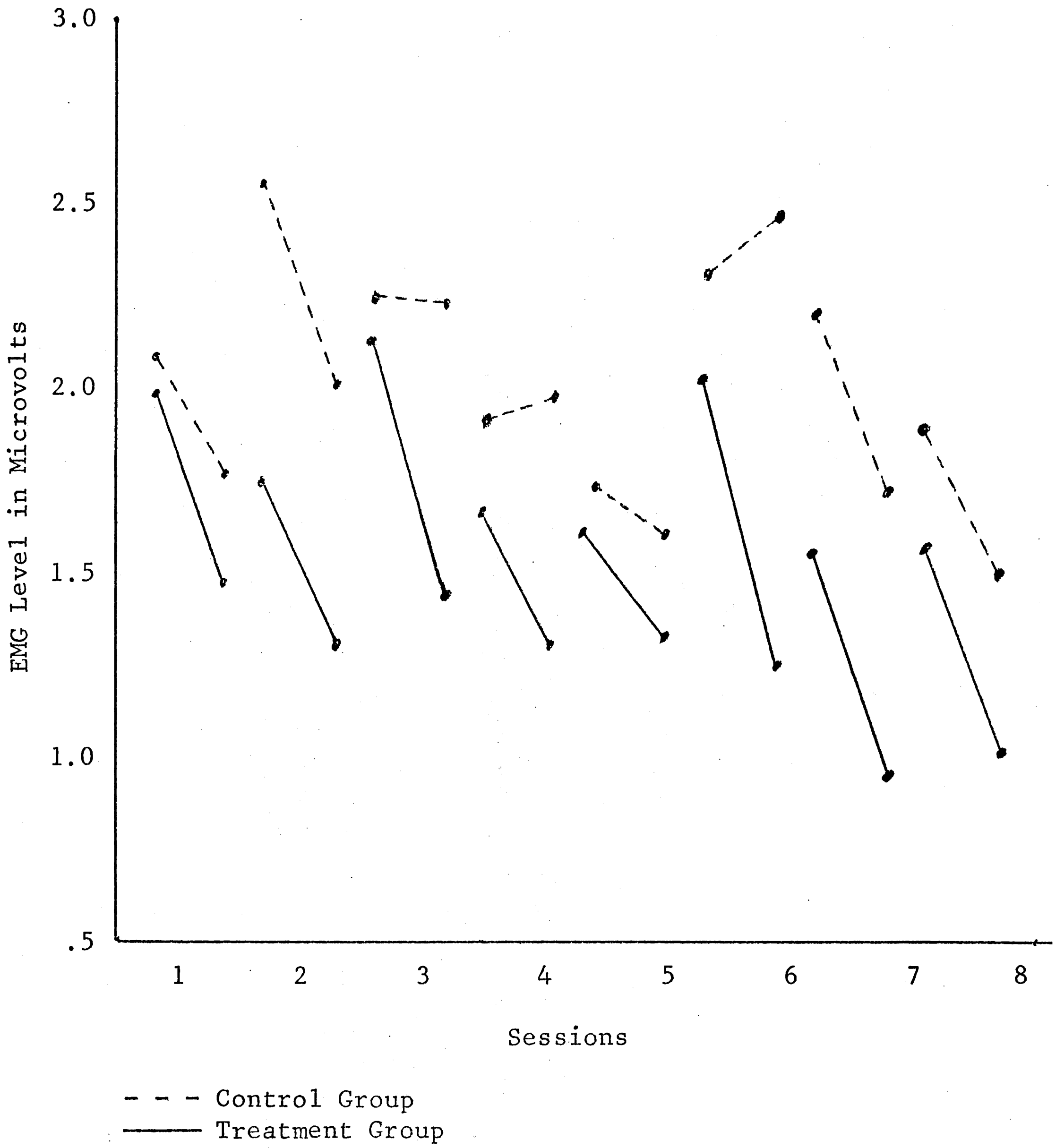

Figure 3. Baseline-Trial One Means for EMG Measure

Psychological Measures

All psychological measures were analyzed using a two way (two groups by six sessions) analysis of variance. There were no significant results from the analysis of the pre-post change scores from the STAI A-state scale, the subjective mental relaxation measure, or the subjective physical relaxation measure. The mean (across sessions) pre-post change score on the STAI A-state scale for the treatment group was 4.9, while it was 6.8 for the control group. Means for the subjective mental relaxation measure change score were 0.92 for the treatment group and 0.88 for the control group. Finally, means for the subjective physical relaxation measure change score were 0.71 for the treatment group and 0.65 for the treatment group.

Double Blind Detection Rate

The possibility that experimenters may have detected the meaning of the group codes was tested by the use of the binomial test (Siegal, 1956). Following the conclusion of the study, experimenters were asked to guess the treatment groups code, resulting in five correct guesses. The probability of this hit rate occurring by chance was 0.45, indicating a non-significant detection rate.

CHAPTER IV

DISCUSSION

The major focus of this study was the effect of motivation on ability to lower EMG levels. More specifically, it was hypothesized that a motivated group receiving feedback would achieve lower EMG levels than a motivated group not receiving feedback. Results of the data analysis indicate that the feedback group did in fact produce lower EMG levels during training. The feedback group rapidly reached a low EMG level which was consistently maintained throughout the remainder of training, while the control group performed less consistently and was unable to substantially lower EMG levels.

Another important difference between the two groups on training measures involves variability. The treatment group's average trial variance was significantly lower than the same measure for the control group. In addition, examination of trial and session means suggests that the control group was also less stable on these measures. The precise information on muscle tension level provided by feedback allowed the treatment subjects to gain much more precise control of their muscle tension level.

Although EMG baselines did not produce a consistent trend and did not differentiate between the two groups at a statistically significant level, examination of the data for sessions one through six produces some interesting observations. If the 2.2 microvolt level obtained for both groups in the habituation session is taken as a measure of resting EMG level before treatment intervention, it can be seen that the control group fluctuates around this mean in a fairly even fashion ($\bar{X} = 2.16$). In contrast, the treatment group, while varying in a manner similar to the control group, was fluctuating around a slightly lower mean ($\bar{X} = 1.87$). While this difference is clearly not significant ($p = 0.18$), it is interesting to note that the treatment group maintained a consistently lower EMG level. It should also be noted that the absence of a trend for the treatment group on this measure is not unexpected. Since the baseline measure was taken when the subject first entered the session, it is the best available measure of the individual's resting EMG level throughout the day. The study did not provide any features designed to promote generalization of training to the subject's daily environment, therefore the lack of significant reductions is not surprising.

Analysis of the reduction in EMG level between session baselines and training trial one additionally illuminates the relationship between the two groups. Across sessions, the treatment group produced significant reductions on this measure, while the control group did not. Examination of individual sessions shows that the control group produced the largest decreases on this measure in sessions one and two, achieving less substantial decreases and even some increases in sessions three through six. The treatment group produced substantial reductions starting from baselines near the pre-treatment level, while the control group's greatest decrease occurred when starting from the highest baseline found in the study. The increased consistency of results produced by EMG feedback seen in the training data is also suggested by visual inspection of this data.

In sessions seven and eight, the treatment group continued to receive feedback, reaching the lowest EMG levels of the eight sessions. The control group, which was now also receiving feedback, achieved an EMG level is session seven which was slightly above the lowest level previously achieved by this group. In session eight the control group reached the lowest level that they obtained in the study. It is interesting to observe that the control group's session eight data appeared to be very similar to the treatment group's performance in session one.

The lack of treatment effects on psychological measures is not unexpected. This study was not designed to produce any cognitive sets which would promote generalization of training effects. Subjects were not asked to relax in general but were asked only to relax their forehead muscle. This lack of generalization in the absence of cognitive support is consistent with Mason's and Lazarus' emphasis on the importance of cognitive components in the biofeedback process. This finding underscores the importance of including techniques designed to associate a relaxed mental state with a reduced EMG level when clinical applications are involved.

The results of this study contrast markedly with Alexander et al.'s work. While they found that a motivated state alone was sufficient for production of reduced EMG levels, the present study indicates that EMG feedback allows more rapid and consistent achievement of reduced levels in comparison to the control group. Possible sources of these different findings include those noted in the introduction: low N, inappropriate demand characteristics, or an inefficient training paradigm. An additional inadequacy may have involved their method of reducing data before analysis.

The present study has dealt adequately with the problems initially noted. There were eleven subjects in each group for all major analysis, and ten subjects per group for some supplemental analysis. Instructions were designed to produce a positive set in both groups. The possibility of experimenter demand characteristics biasing the results requires more detailed consideration. Of the eight experimenters involved in this study two became aware of the meaning of the codes for each group. For one experimenter, this knowledge constituted only a correct guess made in session four from an examination of the data. For the other experimenter a statement made in session six indicated which group the subject was in. The remainder of the experimenters did not make guesses about the nature of the coded groups. When asked to make a guess following completion of the study, an analysis of their answers indicated a non-significant detection rate. It can be concluded that the experimenters' influences were not a significant variable in the study. Both groups, then, were subject to equal and appropriate demand characteristics. The EMG training approach used was appropriate, as evidenced by the rapid and consistent EMG reductions achieved by the feedback group. These results support the previous contention that Alexander et al.'s instructional set and training paradigm were blocking the performance of the feedback group.

Results from this study indicate that Alexander et al.'s research also used an inappropriate method of summarizing data. In that design the median of the five EMG scores for each four minute block was used as the data for further analysis. Medians were employed instead of means by the authors because of their reduced sensitivity to movement artifacts. However, this approach also lacks sensitivity to variation in EMG levels produced by other sources. In the present study the continuous average integral EMG level was monitored, and averages of this information over trials was the data source for further analysis. In this approach movement artifacts contributed only slightly to the total score because of their short duration, while sensitivity to other sources of variation was maintained. This method produced results suggesting that an important indication of the non-feedback group's inability to control EMG level was a markedly larger variability. The approach used by the earlier authors in a sense disguised this difficulty of the non-feedback group, and may have produced the appearance of more EMG control than was actually present in this group.

The results of this study, then, clearly do not support Alexander et al.'s (1977) conclusion that

> . . . the most important role of the contingent feedback stimulus in these studies may have been simply to provide a motivational set which served to keep the subjects oriented toward a specific goal (relaxation of designated muscles) and to maintain their motivation to perform (p. 557).

While performance motivation appears to be a necessary condition for achievement of reduced EMG levels, the results of this study would indicate that it is not a sufficient condition.

The findings of this study are consistent with a more general review of the literature. The present results would suggest that the cognitive aspects of the training paradigm, while important, are not the essential mediator of the biofeedback training effect. Andrews (1975) and Brown (1976) have indicated that any suggestions to the subject regarding the feedback process have the greatest impact early in training, and that EMG levels can still be reduced given sufficient training. Edwards (1979) has indicated that the addition of relaxation instructions to training procedures facilitates rapid lowering of EMG levels. These studies would suggest that both negative and positive sets have an impact early in the EMG learning process. However, while negative sets can hamper learning and positive sets can aid learning, the learning is not dependent upon these sets. There does appear to be an essential difference between negative and positive sets, in that some studies have indicated that positive sets have aided the continued maintenance of lowered levels.

One difficulty in this issue is separation of positive cognitive set, for example, relaxation instructions, from the subject's motivational state. Edwards (1979) instructions emphasized attempting to achieve a relaxed state and may have included a motivational element. The present study's instructions clearly emphasized high motivation. Both approaches produced rapid and consistent lowering of EMG levels. In addition, the relaxation instruction treatment group in Edwards' 1979 study produced sessions effects which were absent in the motivation only treatment group in this study. If the relaxation treatment group (Edwards, 1979) did include a motivational element, these results would suggest that feedback and motivation to utilize that feedback are necessary for achievement of reduced EMG levels and that the addition of the relaxed set provides generalization outside the specific training session. Various other studies (Alexander, 1975; Deegood and Chisholm, 1977; Shedivy and Kleinman, 1977; Alexander, White, and Wallace, 1977), indicating that EMG feedback on a specific muscle alone does not tend to generalize to other situations or to facilitate training on other muscle groups, are consistent with this conceptualization.

Integrating the above findings, a fairly clear understanding of the relationship between EMG feedback and cognitive variables emerges. EMG feedback appears to be a sturdy, reliable process, which can be initially hampered by negative suggestions, but which will eventually produce lowered EMG levels in the monitored muscle given sufficient training time and sufficient subject motivation. However, EMG feedback by itself does not easily generalize outside the specific training session. The addition of positive cognitive sets (such as the notion of a relaxed state) facilitates generalization of EMG learning across sessions, and should be considered an integral part of any program using clinical applications.

The remainder of this discussion will be concerned with several diverse issues related to this study, including suggested changes in methodology, a comment on the statistical design used in this study, and some suggestions for future research. Two suggested changes in methodology will be discussed. The first involves extraneous noise which could not be eliminated from the experimental environment. The room used for the experiment was situated near a hallway where conversations could be occasionally overheard through the closed door. Several subjects commented on this noise. Since Lloyd and Shurley (1976) have indicated that greater EMG control can be achieved in reduced stimulus conditions, this noise may have slightly biased the results in favor of the treatment group. This could have occurred because the control group was using a much weaker feedback stimulus (their own somatic sensations) which could be more easily overridden by external distractions. In contrast, the treatment group had a clear feedback stimulus which was easier to pay attention to. While the effects of this extraenous variable were probably negligible, it is suggested that future studies in this area use a more isolated and soundproof setting.

Two suggestions are offered to increase the security of the double-blind design. First, individual data sheets should be used for each training session for each subject. When training is completed for a subject's session, the data sheet should be dropped into a box, making the information inaccessible to the researcher. This would stop an experimenter from comparing data for several subjects, thereby preventing him from developing a "feel" for the data. In addition, the necessity of not discussing the experiment with the researcher should be presented to the subject at the beginning of each session. This issue was clearly presented to subjects at the beginning of the study, but it appears that some subjects need a continual reminder.

The methods of analysis used in this study represent a useful way of understanding what is occurring in this type of data, and it is recommended that future research in this area use this procedure. Specifically, the separation of baseline, baseline to training trial one, and training data allows differential analysis of these qualitatively different types of data. Because numerous studies in this area have indicated that EMG measures covary significantly with baseline measures, analysis of covariance appears to be the most appropriate statistical design for EMG research. It is recommended that only a pre-training baseline be used as the covariate for major analysis. While the use of multiple covariates (the baselines at the beginning of each session) provides maximal control of this variable, these baselines could be affected by previous training, thereby confounding the covariate and training data F tests.

Two possible designs for further research in this area will be noted. The first design, involving a replication and extension of this study, would use three groups. A motivated EMG group, a motivated control group, and a motivated EMG group presented with suggestions promoting relaxation and generalization outside the training setting would be compared. In this study the new hypothesis would be that session effects on baseline and training measures would be significant only in the group which promoted this type of generalization. A second possible study would involve a two by two design, with all four groups receiving feedback. The independent variables would involve differing instructional sets. One variable would be instructions expected to produce either a motivated or an amotivated state while the second variable would be the presence or absence of instructions promoting relaxation and generalization to other settings. This approach would allow assessment of the differential contribution of performance motivation and generalized relaxation instructions to the EMG biofeedback process.

In conclusion, results of this study indicate that performance motivation alone is not a sufficient condition for reduction of EMG levels. The information provided by the feedback stimulus is definitely necessary for reduction of EMG levels. Examination of the results of this study in conjunction with previous research suggests that motivation is a necessary condition for successful reduction of EMG levels, but this study did not provide a direct test of this hypothesis. Finally, this study represents an addition to the body of literature supporting the basic efficacy of the electromyographic biofeedback process.

CHAPTER V

ELECTROMYOGRAPHIC BIOFEEDBACK: A REVIEW OF THE LITERATURE

Over the past nine years the field of EMG biofeedback has progressed from the basic, early studies suggesting the validity of this process to widespread clinical applications and various investigations of specific components of the EMG feedback technique. This review will be concerned with research in both clinical and methodological areas. In reviewing both of these areas, one is confronted with the wide variance in EMG feedback procedures employed. Given these sometimes large procedural differences, this review will still attempt to generalize research results from related groups of studies.

Two studies in 1969 initiated research into electromyographic biofeedback. Budzynski and Stoyva (1969) were the first researchers to describe the EMG feedback process. After describing necessary equipment and a procedure involving immediate analog feedback of EMG information, they report on a study using 15 subjects. When comparing an EMG feedback group to non-feedback and irrelevant feedback groups, the EMG group was found to achieve deeper levels of muscular relaxation.

During this same time period, Green, Walters, Green, and Murphy (1969) reported that 7 of 21 subjects were able to achieve zero firing or single motor unit firing in the large forearm muscle bundles in less than 20 minutes. This study, although it did not employ an experimental design, was the first to suggest that EMG feedback could provide precise control of single motor units in some individuals.

The remainder of this review is divided into two major sections. The first section is concerned with clinical applications of EMG feedback, while the second section covers methodological issues in EMG feedback.

Clinical Applications of EMG Biofeedback

Approximately one-half of the studies in this review are concerned with various clinical applications of EMG feedback. Areas covered will be treatment of headaches, anxiety, hypertension, stuttering, muscular spasms, hyperactivity, and alcoholism. Finally, some miscellaneous, less well researched, clinical applications will be noted.

The earliest clinical application of EMG feedback was in the treatment of headaches. Eleven studies in this area will be reviewed. Budzynski, Stoyva, and Adler (1970), using five tension-headache subjects, found that EMG feedback produced lowered frontalis EMG and reduced headache activity. Wickramasekera (1972) used five subjects with headache symptoms which had failed to respond to other treatment procedures. EMG feedback produced reduced headache frequency and intensity when compared to a treatment utilizing non-contingent feedback. Budzynski, Stoyva, Adler, and Mullaney (1973) were the first to use an experimental design to evaluate the efficacy of EMG treatment for headaches. Using 18 tension headache subjects, an EMG biofeedback group was compared to false feedback and no feedback control groups. Results showed that the EMG group produced significant reductions in headache activity and that the control groups did not produce significant reduction in headache activity.

Haynes, Griffen, Mooney, and Parise (1975) compared an EMG group to a relaxation training group and a control group. Utilizing twenty-one tension headache subjects, results indicated that both the relaxation and EMG groups produced significant decreases in headache activity, that they were both significantly different for the control group, and that they were not significantly different from each other. The effectiveness of the two experimental procedures was maintained at follow up. Cox, Freundlich, and Myer (1975) using twenty-seven tension headache subjects, compared EMG, progressive relaxation, and placebo groups. Results were similar to the above study in that the EMG and progressive relaxation groups proved superior to the placebo group on reduction of EMG levels and on all measures of headache activity. These results were maintained at a four month follow up.

Hutchins and Reinking (1976), using eighteen tension headache subjects, compared an EMG group, a Jacobson-Wolpe relaxation training group and a combined EMG-relaxation training group. Results showed that the EMG and EMG-relaxation groups had an earlier impact, and that they produced greater reductions in headache activity. In a similar study, with twenty-four tension headache subjects, Chesney and Shelton (1976) compared EMG, verbal relaxation, EMG plus relaxation, and control groups. Phillips (1977) compared EMG feedback to pseudofeedback in the treatment of fifteen subjects with tension or mixed tension-migraine headaches. The biofeedback treatment produced greater decrements in resting EMG levels, headache intensity, and medication usage. However, the biofeedback treatment produced only a very slight decrement in headache frequency. In addition it was noted that the mixed tension-migraine subjects did not respond as well to biofeedback. Bild (1976), using 19 subjects with vascular headaches (migraine), compared cephalic vasomotor feedback, EMG feedback, and a waiting list control group. On measures of headache frequency, vasomotor feedback was superior to EMG feedback, and both treatments were superior to the control group. There were no significant differences on measures of headache intensity. Vasomotor feedback was the only condition to produce reduced medication intake.

Two final studies utilizing tension headache subjects question the long term effectiveness of EMG treatment. Epstein, Hersen, and Hemphill (1974), in a single case study, found that EMG feedback failed to produce reduction in headache activity past the initial training period. The addition of antitension exercises did produce sustained decreases in headache activity. Epstein and Abel (1977) treated six tension headache subjects with EMG feedback. Results showed no maintained control of EMG levels. However, half of the subjects did report favorable changes in headache activity.

Summarizing this area, EMG feedback reduced headache symptoms in ten of the eleven studies reviewed. In two studies relaxation training was as effective as EMG feedback, and two other studies suggest that combined EMG-verbal relaxation approaches are most effective. Results of two studies suggest that EMG feedback is not the treatment of choice for migraine headaches, and that vasomotor feedback is more effective in this situation.

Ten studies focus on the effectiveness of EMG feedback in the treatment of anxiety. Five of these studies used anxious college students as subjects. Silverson (1974), using female subjects, found no significant differences between the EMG treatment and control groups on measures of EMG level, heart rate, and anxiety. Olshan (1975), using thirty subjects, compared an EMG-autogenic instructions-home practice group, a home practice group, and a control group. Results showed that the first group produced reductions in anxiety, while the latter two groups did not produce any reduction. Teague (1976), using twenty subjects, compared an EMG-systematic desensitization treatment with a control group. Results showed a trend toward reduction of anxiety in the treatment group which was not significant at the 0.05 level. Romano (1977), using forty students, compared an EMG-systematic desensitization group, an EMG group, an automated systematic desensitization group, and a control group. The EMG groups were superior to the automated group on two of three measures of anxiety reduction. The three treatment groups did not differ from the control group on the third measure of anxiety. Le Boeuf (1977), using an EMG biofeedback treatment, compared sixteen anxious introverted and sixteen anxious extroverted female subjects. Results showed that while both groups reduced EMG levels, only the introverted group reported a significant decrease in anxiety.

The remaining five studies utilize subjects with more severe anxiety problems, and who are in most cases psychiatric patients. Raskin, Johnson, and Rondestvedt (1973), using ten chronically anxious patients, trained all subjects until they reached a specified low EMG level criteria. Results showed that four of the ten subjects achieved reduced anxiety levels. Townsend, House and Addario (1975), using thirty chronically anxious subjects, compared an EMG group with a group psychotherapy control. The EMG group produced significant decreases in

EMG levels and on three measures of anxiety, while the control group had no significant reductions. Canter, Kondo, and Knott (1975), using forty-eight anxious neurotic subjects, compared EMG feedback and progressive relaxation. Results indicate that both treatments produced reduced EMG levels, and that the EMG group produced greater relief of anxiety sumptoms. Miller, Murphy, Miller, and Smouse (1976), using twenty-one dental phobic subjects, compared EMG feedback, progressive relaxation, and a self-relaxation control group. When compared to the control group, both treatment groups produced significant reduction in EMG levels, state anxiety, and dental anxiety. Finally, Reaves and Mealiea (1975) treated three flight phobics with a combined EMG-systematic desensitization procedure. Treatment was successful in all three cases.

In the treatment of anxiety, EMG feedback appears to be an effective approach, although not necessarily superior to verbal relaxation techniques. In the one study that showed no differences between the EMG and control groups (Siverson, 1973), both groups showed an overall decrease in anxiety. Experimental demand characteristics, such as expectancy of benefit from treatment, may have influenced these results.

Three studies investigating heart rate or blood pressure reduction have involved EMG treatments. Cuthbert (1976), using normal subjects, compared heart rate feedback and EMG feedback to a reduce heart rate instructions only group. Results showed no differences between the groups. Surwit and Shapiro (1976), using twenty-four borderline hypertensive subjects, compared feedback for heart rate and systolic blood pressure, feedback for EMG level, and a verbal relaxation procedure. There were no differences between the groups, and in no case were reductions below baseline levels observed. Fray (1975) compared autogenic training, EMG feedback, and a no-treatment control for effectiveness in reducing diastolic blood pressure. Subjects were thirty hypertensive males. Both treatment groups produced significantly lower blood pressure when compared to the control group. Since two of the above three studies produced negative findings, it would appear that EMG feedback is not a preferred treatment choice for hypertensive symptomology.

Five studies used EMG feedback to treat stuttering. Alexander (1975), using thirteen subjects with stuttering problems, provided EMG feedback from the muscle determined to be most tense at the moment of stuttering. Results showed that reductions occurred in frequency and duration of nonfluent behavior. Lanyon, Barrington, and Newman (1976), using EMG masseter feedback, gave two subjects feedback with an oscilloscope and gave six subjects feedback with a voltmeter. In the latter six subjects training produced virtual elimination of stuttering during feedback, and some generalization to non-feedback periods. Wilson (1977) used systematic desensitization initially until reduction in stuttering behavior reached a plateau. EMG feedback was then introduced to see if further gains could be achieved. Results for the ten subjects indicated that the systematic desensitization procedure produced significant reductions in stuttering, however, the addition of EMG feedback did not produce further significant reductions. Legewie, Cleary, and Rackensperger (1975) in reporting on a single case study of stuttering, noted that EMG feedback produced remission of stuttering even in difficult speech situations. However, generalization outside the training period did not occur. Guitar (1975) reports on four case studies. Analysis of the first three cases suggested that reductions in stuttering were associated with EMG training at specific muscle sites (four different sites were used). This information was used in planning a treatment approach for the fourth subject, where EMG training resulted in the elimination of stuttering in two monitored situations. Stuttering was markedly reduced in all situations at a nine-month follow up.

In four of these five studies EMG feedback produced reductions in stuttering. In the fifth study, EMG feedback was unable to produce further reductions following a systematic desensitization program. Although EMG approaches may not be superior to systematic desensitization, it does appear to be an effective treatment, especially when feedback is given on the specific muscle involved. The generalization of stuttering reduction outside of training may be a problem for EMG treatment in this area, but research results on this issue are inconclusive.

The next five studies are concerned with the reduction of muscle spasms and tremors. Harrison and Connolly (1971) provided EMG feedback from the forearm flexor to four normal and four spastic (diplegic) subjects. No significant difference in degree of achieved control was found between the two groups although spastic subjects took longer to achieve control. Cleeland (1973) combined EMG feedback with contingent cutaneous shock in the treatment of ten subjects with either torticollis or retrocollis. Results indicate reduced spasm frequency in eight subjects, and these conditions proved to be of therapeutic benefit in six cases. Swaan, VanWieringen, and Fokkema (1974) used EMG feedback to suppress activity in specific spastic muscles blocking progress in physical therapy. The authors found EMG feedback to be superior to traditional physical therapy interventions. Goldberg (1976) treated five spastic cerebral-palsied children with EMG feedback. The EMG feedback produced greater control in a no-feedback post training test, however, no permanent improvement resulted. Finally, Le Boeuf (1976), in a single subject case study, treated a severe tension tremor with EMG feedback. Feedback was first used alone and then combined with imagery of stressful situations. The author reported marked decrease in tremor symptoms and anxiety, with improvement retained at six month follow up. In these applications EMG feedback appears to be a very effective approach. In the one study which reported a lack of long term effects, a progressive degenerative neural disease was involved, therefore permanent gains could not be expected.

Four experimental and one case study have involved the use of EMG feedback in the treatment of hyperactivity. Braud (1975) compared EMG, progressive relaxation, and control groups, with five hyperactive children in each group. Results showed that both treatments significantly reduced both EMG levels and behavioral problems. While the EMG treatment produced significantly greater EMG level reduction than the progressive relaxation group, the two treatments did not differ on amount of behavioral improvement. Braud, Lupin, and Braud (1975) report on a single subject case study where a six-year-old hyperactive male was treated with eleven sessions of EMG feedback. Muscular tension and activity decreased both within and across sessions. A seven month follow up indicated continued retention of behavioral control. Anderson (1976) assigned nine hyperactive males to each of four groups. The four groups were EMG training, relaxation training, combined EMG-relaxation training, and a no-treatment control group. Results showed significant differences between groups on EMG levels, but no differences on behavioral measures of hyperactivity. Johnson (1977), using 30 hyperactive children, compared a counseling-EMG group, an EMG group, and a placebo control group. Results showed that both treatment groups reduced inappropriate classroom behavior and EMG levels, with the combined counseling-EMG group producing greater reductions on the behavioral measures. Jeffrey (1976) compared hyperactive and normal children on ability to relax. All subjects were given EMG feedback training. Results indicate that hyperkinetic subjects can be trained to relax in a clinical setting and suggest that these children may be able to exert greater control over their behavior than other researchers have suggested. Three of the above four experimental studies and the case study support the effectiveness of EMG feedback in this area. Since one study has indicated that counseling may be an important component of the treatment, it is possible that the study producing negative findings may not have provided sufficient experimenter involvement.

Three studies involved alcoholic subjects. Eno (1975), using ten subjects in each group, compared EMG verbal relaxation, combined EMG-verbal relaxation, and control groups. Results indicated that the combined treatment produced the lowest EMG levels and the greatest reduction in state anxiety, while the EMG only group also lowered EMG levels significantly. Parent (1975) reports that 19 of 20 alcoholics were able to achieve lowered EMG levels. Steffen (1974), using four chronic alcohol abusers as subjects, compared an EMG group with an attention placebo control group. Results indicated that the EMG group achieved lower EMG levels during training, and that this group maintained lower blood alcohol levels in a post training test which allowed free access to alcohol.

These three studies indicate that EMG feedback is a useful approach for achieving relaxed states in alcoholic subjects. However, only one study involving only four subjects actually used alcohol consumption as a dependent measure. Research investigating the effects of EMG feedback on alcohol addiction, while indicating some potential, must be considered inconclusive at this time.

EMG feedback has been used as a treatment for numerous other clinical problems either by itself or in combination with other approaches. Successful applications include treatment of Raynaud's disease (Stephenson, 1976), duodenal ulcers (Beaty, 1976), phantom limb pain (Sherman, 1976), epileptic seizure control (Johnson and Meyer, 1974), blepharospasm (Stephenson, 1976), increased relaxation during childbirth (Gregg, 1976) and improvement of facial expressions in blind subjects (Webb, 1974). Two studies (Freedman, 1975; Coursey, Frankel, and Gaarder, 1976) report improvements in insomnia with EMG feedback treatment, however, one of these studies suggests that the sleep gains may be so small when the time for daily relaxation practice is subtracted that the practical utility of the method may be questionable. A final miscellaneous clinical study (Lamontague, Hand, Annable, and Gaynon, 1975) reports that EMG feedback did not affect cannabis use among college drug users.

Summarizing this section, EMG biofeedback appears to be most effective in treating conditions in which a major component of the problem is muscular tension. This is clearly the case for tension headaches and muscle spasms. It is probably also true for anxiety, stuttering, and hyperactivity. In areas where muscular tension is not directly involved, such as hypertension and drug addictions, EMG feedback does not appear to be an effective treatment choice.

Methodological Issues in EMG Biofeedback

In contrast to the clinically oriented studies reviewed in the first section, the other large group of EMG biofeedback studies are more concerned with aspects of the feedback process itself and are less concerned with specific clinical populations. Four areas will be considered. The efficacy of EMG feedback in lowering EMG levels in comparison to other approaches will be reviewed. The second section is concerned with the most effective procedures for using EMG feedback. Third, the issue of generalization will be reviewed. And finally, cognitive influences in the EMG biofeedback process will be discussed.

Eight studies compare EMG feedback to other approaches. Delman and Johnson (1976), using 30 normal subjects, compared EMG feedback, progressive muscle relaxation, and a self-relaxation control group. Total training time was four hours. Results show that, for EMG levels, the EMG group dropped sharply, controls did not change, and the progressive muscle relaxation group actually increased. Sime (1976) compared three groups; EMG, progressive muscle relaxation, and a control group. There were ten subjects in each group and total training time was 1.5 hours. Results showed that both treatment groups produced significantly greater reduction than the control group. Delman (1976) compared three independent groups, which were EMG, progressive muscle relaxation, and self-relaxation control. Results show that EMG feedback produced the lowest EMG levels, the control group was intermediate, and the progressive muscle relaxation group was highest. Mohr (1976) compared progressive relaxation, autogenic suggestion and a self-relaxation group. Half of each of these groups received EMG feedback so that six groups were involved. Each of the seventy-two subjects received two one-hour sessions. Results showed no significant differences between groups on EMG measures.

Haynes, Moseley and McGowan (1975) in a one session design with 101 subjects, compared EMG, passive relaxation, active relaxation, false feedback, and a no-treatment control. Results showed that EMG feedback and passive relaxation produced the only significant reduction in EMG levels, and that these two treatments did not differ significantly. Coursey (1975) used 30 subjects, each of which received two hours of total training time. Subjects were divided into three groups which were EMG, self-relaxation, and a group given some instructions on how to relax. Results showed that the EMG group significantly lowered EMG levels to below that of the other two groups. Reinking and Kohl (1975) using 50 subjects, compared a Jacobson-Wolpe relaxation procedure, EMG feedback, EMG combined with the relaxation procedure, EMG combined with a monetary reward, and no-treatment control. Total training time was three hours, distributed over twelve sessions. Results indicate that all EMG groups were superior in speed of learning and depth of relaxation (lower EMG level) to both the control group and the Jacobson-Wolpe procedure. The EMG groups did not differ significantly among themselves. Finally, Splitter (1977) compared a progressive relaxation group, an EMG group, a skin conductance feedback group, and a combined EMG-skin conductance group. Thirty-five subjects were used, and results indicated no significant differences between any groups on EMG levels.

Overall, six of these eight studies support the efficacy of EMG feedback in lowering EMG levels. In only two other instances, once with a progressive relaxation group and once with a passive relaxation technique, were other treatments effective in lowering EMG levels. The two studies reporting negative findings did not find other treatments more effective than EMG feedback, but rather produced no significant results at all. The possibility exists that they were simply using an ineffective training paradigm.

The next section is concerned with the most effective training paradigm to use when employing EMG feedback. Pope (1976) compared binary, digital, and continuous feedback. Binary feedback gave the subjects the least information (above or below criterion level) while continuous feedback provided the most information. Forty-six subjects were given training during one session only. Results indicated no significant differences between these feedback modalities. Kinsman, O'Banion, Robinson, and Standunmayer (1975) compared continuous auditory feedback with discrete verbal feedback. Sixty-four subjects were each given three twenty-one minute training sessions. Results indicate that while the discrete verbal feedback produced some reductions in EMG levels, the continuous feedback was much more effective, both within and across sessions. Rubow (1974) gave subjects visual feedback in the form of a pursuit tracking task, where a computer generated a target spot and a moveable spot representing the subject's EMG level. Computer modifications to the feedback signal allowed investigation of several feedback parameters, with the most important results as follows.

Amplitude coding was found superior to frequency coding, continuous smoothing was superior to intermittent smoothing, and the addition of auditory feedback to the visual signal proved superior to the visual signal only. Caronite (1972), using 160 subjects, compared nine forms of feedback in a single session design. The subjects' goal was not reduction of EMG to the lowest possible level, but rather maintenance of the EMG level within a specific, middle voltage range. Results indicated that performance was best under conditions of continuous, quantitative feedback.

Schandler and Grings (1976) compared visual, tactile, and auditory EMG feedback. One hundred subjects were trained in a single-session design. Results indicate that while all treatment produced significant reductions in EMG level, tactile feedback produced significantly greater reductions. Alexander, French, and Goodman (1975), using twenty-eight subjects each given seven training sessions, compared auditory feedback with eyes closed, auditory feedback with eyes open, visual feedback, and a no-feedback control. Results indicate that only the eyes closed auditory feedback group produced significant reductions in EMG levels. Cleaves (1971) compared auditory feedback, visual feedback, verbal relaxation, and a control group. Seventy-six subjects were used in a single session design. Both feedback groups produced significant reductions in EMG levels, and did not vary significantly.

Kondo, Canter, and Bean (1977), using twenty-four subjects compared the effect of short (two sessions per day), medium (one session per day), and long (one session per week) intervals between training sessions. Subjects in all conditions were given ten sessions of training. Results indicated that the short and medium intervals produced significantly greater reductions than did the long interval group. Lloyd and

Shurley (1976), using forty subjects, investigated control of single motor units. In comparing isolated and non-isolated conditions, results indicated that subjects were able to exert greater control in the reduced stimulus condition. Finally, Coursey (1975) refers to a pilot study done by himself which suggests that twenty-one minutes was the most effective length for a biofeedback training session, and that normal subjects seem to take an average of five sessions to reach a basal EMG level.

Taken together, these studies have several implications for EMG feedback training. First, it appears that continuous, quantitative feedback is superior to any type of end of period or qualitative feedback. Second, tactile feedback may be superior to auditory and visual feedback, however, both of these modalities also produce significant reductions in EMG levels in most instances. In addition, eyes closed auditory feedback is superior to eyes open auditory or visual feedback. Third, training should be scheduled so that subjects receive a minimum of two sessions per week. Fourth, the training environment should be free of any extraneous distractions. Finally, pilot work has suggested that subjects need approximately five 21-minute sessions to reach basal EMG levels.

Five studies have investigated the issue of generalizations in EMG feedback. Grahm (1975) did not find significant training effects in his one session design, so that the issue of generalization could not be tested. Degood and Chisholm (1977), using eight subjects, with each subject receiving two forty-minute training sessions, found that EMG feedback produced more generalized arousal changes (heart rate, respiration rate, EEG, and EMG) than did parietal EEG feedback.

Alexander (1975), gave three sessions of frantalis EMG training to twenty-eight subjects while also monitoring EMG readings from the forearm and lower leg. Results indicate that there was no evidence of generalization from the frontalis training to the other muscles. Shedivy and Kleinman (1977) exposed each of eight subjects to five sessions. Each session consisted of a baseline period, an increase frontalis period, and a decrease frontalis period. Results indicated that the frontalis muscle varied significantly and in a direction appropriate to the training condition. However, sternomastoid EMG did not vary significantly during either training period. Semispinalis/splenius EMG did not change during "increase frontalis" training, but increased significantly during "decrease frontalis" training. Finally, Alexander, White and Wallace (1977) used a transfer of training paradigm to test EMG generalization. Twenty-two subjects were used. One group of subjects received forearm feedback training followed by frontalis training. A second group received training in the reverse order. Two control groups relaxed first on their own followed by either forearm or frontalis training. Generalization would be indicated when previous feedback training on one muscle produced increased training on another muscle in the second phase of the experiment. Results indicated that this did not occur. Taken together, these studies suggest that EMG feedback produces more generalized effects than EEG feedback, but that EMG feedback does not generalize or facilitate training on other muscle groups. However, in some of these studies, very short training periods were used. The possibility exists that lack of generalization may be due to insufficient training time and is not inherent in the EMG feedback process, but current research does not support the notion of a broad generalized response to EMG feedback.

This last section deals with cognitive influences in EMG biofeedback learning. Farnes (1974) compared an EMG feedback group which had control of the presentation and duration of the feedback stimulus to a group which did not have this control. Forty-two subjects were used. A non-parametric test indicated significantly greater reductions of EMG levels in the first group. However, a parametric analysis indicated only a trend in the same direction, due to considerable within groups variance. Hartman (1977), using sixty subjects, compared an EMG feedback group, a group told to count silently while trying to relax, and a combined EMG-silent counting group. Silent counting, similar to many meditation procedures, might serve to block any anxiety producing cognitions, thereby facilitating relaxation. Contrary to expectations, results indicated that the EMG only group produced significantly greater reductions in EMG levels. Gaston (1977) used the same design as in the previous study, again using sixty subjects. Results from this study indicated that all three groups did not vary significantly. Edwards (1979), using thirty-two subjects, compared one EMG feedback group in which no mention of relaxation or reduction of muscle tension was made and another EMG feedback group in which relaxation instructions were used. Results indicated that the relaxation instruction group produced a more rapid drop in EMG levels which was more consistently maintained for the remainder of training. These studies, taken together, suggest that cognitive manipulations may influence the EMG feedback process. However, the extent of these influences is unclear.

The next three studies, involving suggestibility, clarify this issue somewhat. Wickramasekera (1973), using twelve subjects, compared verbal relaxation instructions plus EMG feedback and verbal relaxation instructions plus false feedback. The dependent variable was suggestibility, and results indicated that the true feedback group did produce greater increases in suggestibility. Andrews (1975), using thirty subjects, compared one trial where subjects were told that they were receiving accurate feedback and another trial where subjects were told that the feedback was accurate only 50% of the time. True feedback was actually given on both trials. Results indicated that there were significant differences on the high and low expectancy trials in the expected direction, and that these effects were strongest on the first trial. Borwn (1977) compared EMG feedback groups given either positive, negative, or neutral instructions. Forty-eight subjects, all of whom had EMG baselines within a specific range to reduce initial variance, were used. While results indicated no overall group differences, there were significant differences between the negative and neutral instructional groups during the first training trial. These studies, then, indicate that the EMG feedback process facilitates a suggestible state. In regard to suggestions involving the feedback process itself, it appears that negative suggestions have an impact early in training process, with this effect being reduced as training progresses.

In the final study in this section, Alexander, White, and Wallace (1977) investigated motivational influences in the EMG feedback process. Using a design they claimed provided high motivation for control subjects, they compared an EMG feedback group with a control group. Results indicated no significant differences between the groups. Although these results are in conflict with numerous other studies supporting the efficacy of EMG feedback, the implication is that EMG feedback provides primarily a motivational element, and that the information on muscle tension carried by the feedback stimulus is of little value. However, very short training periods were used in this study. This may have reduced the efficacy of the EMG feedback.

Summarizing this section, the EMG biofeedback process is clearly pre-potent in achieving reducing EMG levels in the muscle generating the feedback stimulus. However, the ability of this reduction to generalize to other muscle groups is questionable. Parameters for achieving effective EMG biofeedback training have been established, and future studies in this area should use procedures consistent with these established parameters. Finally, cognitive influences do affect the EMG feedback process. Suggestions of negative effects appear to have an impact in the early phase of training. Motivational influences may be important, but research on this variable is inconclusive at this time.

Conclusion

Electromyographic biofeedback is in widespread clinical use. Research data supports the effectiveness of this approach for most of the common current applications. Additionally, research on methodological issues has determined many of the important parameters for effective biofeedback instrumentation, training environments, and training schedules.

However, research on cognitive parameters involved in EMG training is lacking. Greater understanding of this aspect of the EMG process could be expected to result in more effective application of existing

EMG biofeedback technology. In light of the recent emphasis of the importance of these factors in biofeedback (Lazarus, 1975; Meichenbaum, 1976) further research in this area is needed.

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APPENDIX A

ANOVA SUMMARIES FOR EMG DATA

TABLE II

ANALYSIS OF COVARIANCE SUMMARY TABLE FOR EMG BASELINE MEASURES

Source	SS	d.f.	M.S.	*F*	*p*
Between Subjects (Ss)					
Group (G)	2.72	1	2.72	1.94	.18
Covariate	14.28	1	14.28	10.15	.005
Error	26.72	19	1.41		
Within Ss					
Sessions (S)	6.13	5	1.23	2.56	.032
G x S	2.18	5	0.44	0.91	N.S.
Error	47.91	100	0.48		

TABLE III

ANALYSIS OF VARIANCE SUMMARY TABLE FOR BASELINE-TRIAL ONE MEASURES

Source	SS	d.f.	M.S.	*F*	*p*
Between Subjects (Ss)					
Group (G)	14.97	1	14.97	3.84	.064
Error	77.96	20	3.90		
Within Ss					
Sessions (S)	8.10	5	1.62	2.36	.046
G x S	3.06	5	0.61	0.89	N.S.
Error	68.74	100	0.69		
Drop (D)	6.85	1	6.85	14.11	.001
G x D	2.34	1	2.34	4.82	.040
Error	9.71	20	0.49		
S x D	0.86	5	0.17	0.74	N.S.
G x S x D	2.27	5	0.45	1.95	.092
Error	23.21	100	0.23		

TABLE IV

ANALYSIS OF COVARIANCE SUMMARY TABLE FOR SESSION SEVEN AND EIGHT EMG MEASURES

Source	SS	d.f.	M.S.	*F*	*p*
Between Subjects (Ss)					
Group	23.24	1	23.24	7.62	.013
Covariate	49.36	1	49.36	16.19	.001
Error	51.84	17	3.05		
Within Ss					
Sessions (S)	0.26	1	0.26	0.34	N.S.
G x S	1.72	1	1.73	2.28	.149
Error	13.64	18	.76		
Trials (T)	1.04	6	0.17		
G x T	0.10	6	0.02	1.47	N.S.
Error	12.80	108	0.12	0.14	N.S.
S x T	0.27	6	0.05	1.50	0.186
G x S x T	0.15	6	0.03	0.85	N.S.
Error	3.27	108	0.03		

APPENDIX B

SELF-RATING SCALES FOR PHYSICAL AND MENTAL RELAXATION

How does your whole body and muscles feel right now physically, where 1 represents the most relaxed you have ever felt and 7 represents the most tense you have ever felt?

1 2 3 4 5 6 7

How do you feel right now mentally, where 1 represents the most calm and pleasant you have ever felt and 7 represents the most tense and anxious you have ever felt?

1 2 3 4 5 6 7

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