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Muscle Relaxation Training: A Comparison of EMG Biofeedback with Verbal Instruction

Michael D. Dennis
Eastern Illinois University

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MUSCLE RELAXATION TRAINING: A COMPARISON OF EMG BIOFEEDBACK WITH VERBAL INSTRUCTION

(TITLE)

BY

MICHAEL D. DENNIS

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A B S T R A C T

Early work in identifying and measuring the electrical impulses of muscle action potentials was done by Jacobson (1930), who also explored methods of reducing muscular tension referred to as progressive relaxation training. Further development of electronic technology brought about the use of EMG biofeedback techniques to systematically condition deep muscle relaxation (Green, Walters, Green and Murphy, 1969). Other EMG biofeedback applications were in the areas of tension headache treatment (Budzynski, Stoyva, and Adler, 1970) and muscle rehabilitation (Brooker, Rubow and Coleman, 1969). The conditioning of miniscule motor responses called single motor units was accomplished by Bdsmajidn (1963) using a feedback system. Verbal instruction means of training for muscle relaxation were developed parallel to the biofeedback approach by Wolpe (1958) in the treatment of anxiety disorders through reciprocal inhibition. A hypothesis was formulated that stated EMG biofeedback would be superior to verbal instruction methods of relaxation training. Fifteen college students were randomly assigned to two experimental groups, biofeedback and relaxation instruction, and a non-treatment control group. Six 20-minute sessions were held. The first two served as baseline for all Ss as measurements were taken from surface electrodes affixed to the frontalis muscle area of the

forehead. For the next three sessions biofeedback Ss received continuous auditory feedback of the muscle activity and relaxation instruction Ss received a prerecorded relaxation message. Post-training measurements were then taken for all groups. The data failed to support the experimental hypothesis. A non-orthogonal set of nine contrasts was employed and showed that relaxation instruction Ss reached significantly lower levels of relaxation ($p < .001$) when baseline mean microvolt figures were compared to those at end of training and post-training. The two expimental groups varied significantly only at end of training where relaxation Ss achieved deeper relaxation than did biofeedback Ss. Problems encountered during the study, including a random bias in the assignment of Ss to experimental and control groups, were reviewed. It was suggested that EMG biofeedback and verbal instruction procedures could be joined together to form an efficient relaxation training program, thus drawing on the strengths of both methods. The importance of rigorous scientific investigation, when looking towards the clinical applications of EMG biofeedback, was stressed.

ABSTRACT

The effectiveness of two muscle relaxation modalities, EMG biofeedback and verbal relaxation instruction, were compared. Fifteen college students were assigned to two experimental groups and a non-treatment control condition. Measurements of frontalis muscle activity were taken prior to, during and following three 20-minute training sessions. Results based on a set of non-orthogonal contrasts indicated significant relaxation effects for relaxation instruction when pre-training levels were compared to training completion and post-training levels. Experimental groups differed only at training completion where relaxation instruction was superior to EMG biofeedback. The necessity of careful scientific research of biofeedback techniques to be used in clinical applications was discussed. It was concluded that the two relaxation procedures should be combined to maximize treatment when developing a program for conditioning muscle relaxation.

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A special citation is noted for the long hours and efforts of Mrs. Rosalie Holycross. Mrs. Holycross was responsible for scheduling appointments, directing subjects, giving instruction on scrubbing foreheads, and generally bolstering the author throughout the entire project.

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MUSCLE RELAXATION TRAINING: A COMPARISON OF VERBAL INSTRUCTION WITH EMG FEEDBACK

Michael D. Dennis

Eastern Illinois University

Training of muscle relaxation using biofeedback techniques evolved from pioneer work in the measurement of electrical muscle activity performed by Jacobson (1930). Electromyograph (EMG) recordings were made from Ss lying relaxed with their eyes closed. Surface electrodes were placed over the right bicept and at a relatively indifferent point on the right arm. In one important investigation muscle action potentials were compared under three conditions, that of (a) instructions to relax; (b) instructions to visually imagine the right forearm bending without making actual movement, and (c) instructions to make a slight contraction of the forearm. Jacobson found that recordings of action potentials during imagery of muscle contraction were identical in type with recordings of actual muscle contraction, only the microvolt level was considerably smaller for the imagery condition. Furthermore, no such potentials were recorded when Ss were instructed to relax. Jacobson concluded that the electromyogram is an accurate measure of both muscle activity thought of as tension and the absence of muscle activity thought of as relaxation. He considered the finding to be consistant with two of his previous studies (Jacobson, 1925, 1929).

Lippold (1952) supported Jacobson by demonstrating a high correlation between muscle activity and EMG measurements. EMG's were recorded from a standardized location on the calf muscle group taken from the right leg of 30 Ss. Length of the muscle contractions were measured with a dynamometer, which restricted analysis to those muscle forces involved in rotation of the foot about the ankle joint. EMG was recorded via an amplified cathode-ray oscillograph from surface electrodes equally spaced along the midline calf. Thus, mechanically integrated EMG could be correlated with contractions of 4.5 to 45 kg. intensity. Calculations from EMG readings and simultaneous muscle contraction pressure were made for each Ss. Lippold reported a strong positive interdependence ranging from .93 to .99 across Ss.

The advent of automated techniques in the voluntary control of various physiological functions was brought about by two developments: first, the accelerated growth of electronic instrumentation that allows the accurate measurement of previously unmeasurable physiological events, and second, the technology of operant conditioning of autonomic nervous system responses. The term biofeedback was coined to describe this technology; it is conceptualized as the placement of a person in a closed feedback-loop where physiological information is continuously made known to the individual. Such immediate knowledge of progress will direct, adjust and shape the psysiological response until learned control has been accomplished.

Research pertinent to EMG biofeedback issues will be catergorized into four areas: muscle relaxation, single-motor unit training, muscle rehabilitation and tension headache.

Muscle Relaxation

One of the first biofeedback studies incorporating a control factor was in relaxation training (Budzynski and Stoyva, 1969). Electrodes were attached to the frontalis muscle on the forehead from which mean microvolt readings were taken. Control Ss received no feedback while experimental Ss received auditory feedback that was dependent upon frontalis muscle relaxation for one group and irrelevant for the other group. Findings established that the relevent feedback group reached significantly deeper levels of muscle relaxation than the irrelevant feedback group or the control group. They suggested that the basic method utilizing electronic detection, immediate information feedback and systematic shaping of responses would be useful in behavior therapy treatment.

Green, Walters, Green, and Murphy (1967) asked 21 Ss to relax dorsal forearm muscle groups in an operant self-conditioning paradigm. EMG feedback was provided visually in the form of a meter driven by pen-motor voltage of a polygraph channel, in turn driven by rectified voltage from a high gain EMG circuit. Polygraph gain was continuously adjusted by the experimenter to increase the meter sensitivity as lower levels of EMG activity were reached, as detected by surface electrodes. Seven out of 21 Ss were able to achieve intermittent neuromuscular silence within 20 minutes or more. Results for all Ss were not reported, nor were specific results of individual Ss. No alternative relaxation groups were used as controls, and no comparative conclusions could reasonably be drawn from the study.

Jacobs and Felton (1969) compared the effects of EMG feedback in reducing contraction of the upper trapezius muscle in normal Ss and Ss with neck injuries. They obtained 14 men and women, 21 to 57 years of age with neck injuries, from an urban orthopedic hospital. Fourteen other men and women without neck injury were selected from non-medical hospital staff to participate in the study. Four Ss from each of these groups were randomly assigned to control conditions. Ten injured and ten non-injured experimental Ss were given ten massed trials of raising the arm associated with the trapezius muscle, lowering the arm and attempting to relax the trapezius for 15 seconds. At this point an EMG measure from surface electrodes was taken and the procedure was repeated. Directly following this non-feedback relaxation phase, these 20 Ss, still sitting upright on a box, were given one practice and then 10 similar relaxation trials with the addition of EMG feedback via visual oscilloscope. In this phase Ss were instructed to use a summation EMG line on the oscilloscope and a second stationary momentary line to facilitate relaxation. The task was to keep the summation line as far left as possible and to minimize splaying of the momentary line on the oscilloscope. Data indicated more facilitation of relaxation via feedback than via simple relaxation instructions. Though it was not calculated, the data implied a strong apparent interaction of feedback and injury in that injured Ss were as effective at relaxing the trapezius with feedback as were non-injured Ss, but were less able to relax without feedback. The controls indicated that EMG feedback was equally effective when the prior non-feedback relaxation phase was absent. However, no controls were used to compare a second ten relaxation trial period without feedback to the ten trial period with feedback. In the feedback condition used by Jacobs and Felton (1969) Ss could have used either the cumulative EMG or the momentary EMG indicator or both; thus relative effectiveness of this variable was not examined. The use of the discrepancy measure rather than absolute values also makes the results more difficult to evaluate. Though this study is far from conclusive, it does yield a noteworthy initial suggestion that EMG feedback may be more helpful for people with muscle injuries in controlling those muscle states than for non-injured individuals.

Three methods of muscle relaxation were compared by Cleaves (1970) in an attempt to verify the superiority of EMG feedback within a single training session. Four groups were used: auditory feedback, visual feedback, verbal training, combination of autogenic and progressive relaxation instruction, and control. Measurements of change in tension at the frontalis were compared over three phases: during training, after training and one week following training. The major findings were: (1) the two feedback groups demonstrated greater reduction than the control group through all phases; (2) there was no significant difference in tension reduction between the auditory feedback and verbal training groups during any phase, and, (3) there was no significant difference in tension reduction between the feedback groups during any phases.

Single Motor Unit Training

An early report on operant conditioning of muscular responses using feedback was furnished by Hefferline, Keenan and Harford (1959). Twelve _S_s were equally divided into four groups. Surface electrodes were affixed to thumb and edge of the left hand. _S_s were to make a muscle twitch in the left thumb in escape or avoidance of an aversive 60 hertz hum. Different tasks were given each group: (1) listen to muscle through earphones with superimposed noise for study of its effect upon body tension; (2) discover and make a specific but small, invisible response;

(3) similar to #2 except that the response should be a tiny twitch of the left thumb; (4) like #3 but with visual feedback. Two 30 minute conditioning periods and a 10 minute extinction period were run followed by 10 minutes of music. All groups showed a positively accelerated learning curve with group four _Ss_ learning at the quickest rate, apparently due to the continuous visual feedback. The authors compared the results to animal learning in that the response choosen was so small as to preclude previous strengthening from environmental discriminative stimuli.

Control of even smaller responses has been achieved by the isolation and conditioning of a single motor unit (SMU). Basmajian (1963) stated that a motor unit included a spinal anterior horn cell, its axon, and all the muscle fibers on which the terminal branches of the axon end. Use of the indwelling electrode techniques allows identification of SMU firing by individual shape as long as electrode placement remains constant. Basmajian provided 16 normal persons from 20-55 years of age with continuous auditory (loudspeaker) and visual (oscilloscope) feedback from one indwelling bipolar electrode in the right abductor pollicis bevis (which enervates the thumb). After ten minutes of observing their augmented auditory and visual EMG correlates of various thumb movements and postures, _Ss_ were instructed to learn to maintain slight (covert) contractions detectable only through augmentation. They were then instructed to control individual units which they were able to identify (not necessarily recruit), because of their observably differential potentials, particularly on the oscilloscope. Within 30 minutes, all Ss had achieved notably better control. Almost all had learned to relax the whole muscle on command and to recruit the activity of a SMU; after 30 minutes Ss attempted to repress activity of the first SMU and to recruit another one, only one S required more than 15 minutes for this. Over half could similarly recruit a third SMU and a few could recruit a fourth and fifth. Most successful Ss were subsequently trained to increase and decrease SMU frequencies, and 10 of 11 of these Ss were able to produce various rhythms of frequency. Three Ss could recall SMUs without feedback. The author stated that other tests revealed that aural feedback was more effective than visual display but did not elaborate these tests. Though no non-feedback control conditions were employed, it would seem that the covert nature of the responses being controlled would necessitate augmented control.

In a summary of such SMU training studies, Basmajian (1967) contended that no variable such as age, sex, dexterity, or athletic prowess have been shown to be related to differential levels of skill achieved by different Ss. Complexity of control appears most directly related to adequacy of the provision of meaningful feedback.

Lloyd and Leibrecht (1971) trained 17 male volunteers from

18-24 years of age for control of SMUs from indwelling bipolar electrodes. Binary feedback (i.e. correct or incorrect activation of SMUs), was signaled by a white or amber light respectively. The comfortably seated Ss were instructed to activate a SMU at a steady frequency for as long as possible during each trial by activating the white (correct) light within five seconds of a trial period. If an incorrect or no response occurred within the allotted five seconds, the amber incorrect light was activated to signal termination of the trial and initiation of the 15 second intertrial interval during which Ss were instructed to relax. Ss could not view the oscilloscope screen used by the experimenters to mediate binary feedback. Ss were trained to a criterion of five successive trials in which continuous activation of an SMU occurred for a minimum of five seconds. Sessions took about 15 minutes and consisted of 100 trials. With a 45 minute inter-session interval, there was a maximum of five sessions in one day with the same electrodes. All Ss were retested 15 days later in an identical procedure except that a new set of electrodes were placed in relatively the same position as the original set. In the initial phase 13 of the 17 Ss reached criterion. Two curves, percent correct responses and mean correct response time, were plotted over 10-trial blocks for all groups. It appeared that Ss tended to eventually select and activate the easiest controlled SMU as trials progressed. The authors concluded that skill level achieved may have increased to the levels obtained in continuous feedback studies if more training and careful shaping procedures had been provided.

A subsequent study by Leibrecht, Lloyd, and Pounder (1972) directly compared the binary feedback procedure just described to an identical procedure except for the addition of continuous auditory feedback. Initially, 17 normal male volunteer Ss, without previous participation in a similar experiment, participated in a binary feedback study identical to that described by Lloyd and Leibrecht (1971), except for the addition of continuous auditory EMG feedback through a speaker. The same procedure, with the exception of the elimination of auditory EMG feedback, was repeated 14 days later. Again, a new set of electrodes were implanted in the same relative position as the original set. The two studies (Lloyd and Leibrecht, 1971; Leibrecht, Lloyd, and Pounder, 1972) were designed similarly in terms of paradigm, apparatus, and S variables of I.Q., age, and educational level. In the latter study, comparisons of performance with the previous study was facilitated by referral to the first study Ss as group I and of the later study Ss as group II. While group I initially required a mean of 256.7 trials to reach criterion, the mean for group II was 42.1. Furthermore, while four Ss failed to achieve criterion in group one, all Ss in group II achieved criterion within 228 trials. This improvement from the addition of continuous auditory feedback was significant ($p < .001$). The addition of continuous auditory feedback appeared to have clearly increased the rate of acquisition of SMU control in these studies. The authors argued that the superiority of continuous auditory feedback over binary display was due to the increased duration of trial and error (search) for selection of the most easily controlled SMU. This was because most of the differences between group I and II occurred prior to the first appearance of the criterion SMU.

Muscle Rehabilitation

Marinacci and Horande (1960) suggested that the most important goal of neuromuscular retraining is to increase the frequency of neuromuscular potentials, which in turn facilitates overuse of the muscle fibers and their hypertrophy. The two factors of increased frequency and overuse are mainly responsible for increases in voltage and voluntary neuromuscular power. During retraining the patient was allowed to hear sounds from a loud speaker produced by contracting one of his normal muscles into which an active electrode is inserted. Slight exertion against counter-pressure from the E produced a repetitive knocking sound from the loud speaker. When no normal muscle was present, E would demonstrate the technique on himself. Next, the needle electrode was inserted into the paralyzed muscle and the patient instructed to exert voluntary effort to identify latent function via the loud speaker. It was found that feedback of muscle activity from the speaker guided him to exert the proper degree of voluntary effort. Thus, it facilitated the transmission of neuromuscular impulses.

Brooker, Rubow and Coleman (1969) described a case study of a 36 year old woman with paralysis of the facial muscles on the left side resulting for a severed nerve. A major peripheral bundle of the left spinal accessory was surgically divided. Treatment began after two years of failure to gain controlled return of function.

A training procedure was developed that required the patient to track EMG-generated signals from the left side of the face. These signals were derived from surface electrodes and fed through an oscillograph to a modular EMG integrator coupler. They were then channeled through further complex equipment which ultimately produced analog representations of target and tracking EMG on an oscilloscope screen. The tracking electrodes from the left side of the face were recorded from several different points at different times to establish control over different areas, particularly to train independence of eye closure from movement of the lower half of the face. Another tracking program was later developed to develop symmetry of voluntary facial movements, including those occurring during speech. The patient practiced at home for four months with bi-monthly monitoring sessions. After a subsequent unspecified duration the authors stated that her face was essentially symmetrical at rest while a minimal but acceptable asymmetry was present during speech and other facial movements.

Harrison and Connolly (1971) investigated the ability of normal and spastic Ss to learn to recognize, isolate and produce on command fine degrees of neuromuscular activity. A basic feature of spasticity is the hyperactivity of the spinal motorneurons, the simplest explanation of which is that their threshold has been lowered by lesions of the upper motorneuron system. Surface silverchloride electrodes were used to record activity from the front flexor muscle-groups of the arm. Simultaneous visual feedback in the form of an oscilloscope display of muscle firings was presented to the 4 normal and 4 spastic Ss. Motor activity recruited was at a fine level, but not as discrete as single motor unit firing due to the use of surface electrode recording as opposed to needle electrode recording. The level of control ultimately attained by the spastic group was as fine as that achieved by the normal Ss under the conditions studied. However, the spastic Ss took appreciably longer to attain such control. Harrison et al. (1971) indicated that further work would be necessary to elucidate whether spastics are able to overcome hyperactivity in all motor units and thus achieve conscious control over dysfunctional muscle groups.

Tension Headache

An application of feedback-induced muscle relaxation to tension headache was reported by Budzynski, Stoyva and Adler (1970). Data was collected from 5 individual cases studies of the treatment of tension headache, a condition associated with sustained contraction of the scalp and neck muscles. Each patient received two or three 30 minute feedback training sessions as described earlier (Budzynski and Stoyva, 1969) per week for the duration of treatment which varied from 4 to 8 weeks depending on individual progress. Patients were encouraged to practice relaxation training at home at least once a day. They were required to keep a daily record of their headaches that included a frequency count and a rating of headache intensity on a 0 to 5 scale. The authors found a significant decrease both in headache activity and EMG levels between the baseline values and an average value for the third and fourth weeks. Patients also related subjective change characterized by a heightened awareness of maladaptive rising tension, an increasing ability to reduce such tension and a decreasing tendency to overreact to stress. Budzynski et. al. concluded that the biofeedback training technique would seem potentially applicable to a variety of physiological events in addition to muscle tention.

Wickramaseka (1972) studied the effects of using contingent and non-contingent EMG feedback on five female Ss diagnosed by neurologists as chronic tension headache sufferers. Each S underwent psychological testing, a physical examination prior to treatment and was required to maintain a chart of the frequency and intensity of headaches. At the end of a three week baseline period Ss were orientated to the EMG feedback training procedure. The procedure involved auditory information feedback presented to Ss via headphones. Feedback was associated with frontalis muscle activity measured by three surface electrodes attached to the forehead of each S. The feedback tone varied proportionately in pitch to the amount of muscle activity. During weeks 3 through 6 Ss received "false" auditory feedback for 30 minute sessions which in actuality was tape recordings of previous EMG feedback sessions and thus, non-contingent upon the Ss responses. This was followed by 12 weeks of EMG feedback training using contingent auditory feedback. Wickramaseka suggested that the significant decreases in headache activity levels between baseline and contingent feedback periods were probably not a function of placebo effects. Similar reductions were not shown between baseline and non-contingent feedback periods. Wickramaseka's training was a promising method of reducing both the frequency and intensity of tension headaches.

Both tension headaches and migrain headaches were treated using a technique called autogenic feedback training by Sargent, Green and Walters (1973). Autogenic feedback training combines biofeedback techniques with autogenic training, a therapetic method involving simultaneous management of mental and somatic functions brought about by passive concentration upon phrases of preselected words. A biofeedback technique was used whereby Ss were trained to increase the differential temperature between the midforehead and the index finger of the right hand, thus increasing blood flow to the hands. This strategy of combining temperature training with autogenic suggestion was originally developed for the treatment of migraines. However, since tension headaches result from chronic muscle contraction and thus an increase in blood flow to that affected muscle, it was hypothesized that tension headaches could also be ameliorated by regulation of blood flow. Of the 28 Ss in the pilot study, 20 were positive migrain sufferers, 2 had questionable migrain attacks and 6 had tension headaches. All Ss practiced daily with a temperature biofeedback trainer for the purpose of increasing hand temperature. They also recorded severity of headaches between practice sessions, type of medication and dosage. Of the migrain patients, 63% were evaluated as improved while 33% of the tension headache patients showed improvement. Sargent et. al. concluded from their data that tension headaches may require a different kind of biofeedback training such as the technique used by Budzynski, Stoyva and Adler (1970).

Budzynski, Stoyva, Adler and Mullaney (1973) reported a controlled outcome follow-up to their pilot study (Budzynski et. al. 1970). After a two-week baseline period during which two no-feedback sessions were used to assess pretraining EMG levels, 18 tension headache patients were randomly assigned to three groups of six each. Group A patients received EMG biofeedback training in the form of auditory clicks presented through headphones; Group B patients received "false" non-contingent feedback which was tape recorded from Group A; and Group C served as controls receiving no feedback. In addition, all Ss were asked to keep track of their headaches on a daily chart. EMG levels were again assessed at the end of the three-month follow-up. Group A showed a significantly lower EMG levels ($p < 0.05$) than did Group B for the last two weeks of training. Group A also apparently retained the learning of lowered muscle activity as mean Group A levels were significantly lower ($p < .01$) than mean Group B levels for the three-month follow-up. Averaged headache rating scores pointed to significantly lower ratings for Group A compared to Group B. The authors concluded that training in relaxation of the forehead muscles with EMG feedback to be useful in eliminating muscle contraction or tension headaches. They also reported that preliminary evidence indicates that use of two supplementary methods, a portable EMG feedback unit and cassette tape recordings of relaxation instructions, are valuable in conjunction with EMG feedback training of tension headache patients.

Progressive Relaxation Training

The use of verbal instructions in the training of muscle relaxation began with the early efforts of Jacobson (1930). Using EMG recordings as an objective basis for evaluation of progress he developed a training method for the reduction of muscle tension. In reporting his findings, Jacobson (1938) noted that the complete absence of all muscle contractions was the direct physiological opposite of tension. It followed that muscle relaxation would be a logical treatment for the overly tense or anxious person.

Wolpe (1958) modified Jacobson's training program because of the prohibitive amount of time it required. Training time was reduced from up to 200 sessions to six 20-minute sessions with two 15-minute daily home practice sessions intersperced between training sessions. Muscle relaxation was used in counter-conditioning treatment of anxious patients. Wolpe demonstrated that when an anxiety response was paired with a conditioned relaxation response the responses were reciprocally inhibited, thereby eliminating the anxiety.

An overview of progressive relaxation training was reported by Bernstein and Brokovec (1973). They described training in progressive relaxation as the systematic tensing and relaxing of various muscle groups accomplished through verbal instructions from the therapist. _S_s learned to discriminate between the resulting sensations of tension and relaxation. By attending to sensations of relaxation _S_s almost entirely eliminate muscle contractions and experience a feeling of deep muscle relaxation.

Paul (1969) studied the comparative effects of progressive relaxation, hypnotic suggestions and a control group that was told to sit quietly and relax. Sixty female college students were exposed to two half-hour experimental sessions held seven days apart. Dependent measures included pre- and post-assessment of self-reported anxiety and measures of physiological arousal (muscle tension, heart rate, skin conductance, and respiration rate) sampled during five periods in the sessions. The results indicated significantly reduced discomfort and arousal within each session and, more importantly, significant differences among the three groups on all but the skin conductance measure. During both first and second sessions the progressive relaxation procedures resulted in greater relaxation on all measures than did control procedures, and also produced greater heart rate and muscle tension decreases than did hypnotic induction. Paul concluded that progressive relaxation was superior to hypnotically induced or self-induced relaxation.

The literature revealed that muscle relaxation has been achieved through the use of EMG biofeedback techniques as well as through training procedures incorporating verbal instruction.

This project was designed to compare the effectiveness of the two relaxation training techniques.

It was hypothesized that EMG biofeedback would be relatively more effective than verbal instructions at producing muscle relaxation, both during the training period and after the training period.

METHOD

Subjects

Students from the Danville Junior College in Danville, Illinois served as Ss. Ss were drawn from introductory Psychology classes and then randomly assigned to one of three groups, each group consisting of five persons. The ten female Ss and five male Ss ranged in age from 18 to 22 years.

Apparatus

Three silver/silverchloride surface electrodes were placed on the forehead. The electrodes were connected to a Feedback Myograph BFT 401 which measured electrical muscle activity at the frontalis and displayed this activity visually for E on a meter calibrated in microvolts. Design characteristics of the BFT System 401 met those suggested by Leaf and Gaarder (1971) as important for instrumentation in EMG research. Auditory feedback was presented to biofeedback subjects through headphones in the form of a continuous tone. Tones varied in pitch proportionally to the amount of neuromuscular activity; higher activity levels produced higher pitched tones while lower activity levels produced lower pitched tones.

Raw EMG signals were coupled to a BFT 215 Time Period Integrator where the amplitude of each pulse was integrated and averaged over a one-minute time interval. Mean microvolt levels were recorded on a digital readout window as percentage of a criterion signal, arbitrarily set at 20 microvolts, measured during the sampling interval; percentages were then converted directly to microvolts.

Procedure

The experimental procedure used closely approximated that of Budzynski and Stoyva (1969). Electrodes were attached to the *S*s approximately one inch above each eyebrow and spaced approximately four inches apart on the forehead. The frontalis muscle was chosen because it has been used frequently in EMG biofeedback research and it is considered to be a difficult muscle to relax deeply (Budzynski and Stoyva, 1969). Intuitively *S*s who achieve voluntary control over this muscle with a high difficulty factor then should easily gain control of less difficult muscle groups. Also, for most individuals frontalis relaxation generalizes to muscles of the upper trunk, shoulders, neck and head.

The experimental room was a dimly lit, carpeted office containing a reclining chair in which subjects were situated in a semi-recumbent position. Each session consisted of a ten minute period of inactivity for Ss to adapt to the laboratory situation followed by twenty one-minute trials. The interval between sessions was at least one day, but no more than seven days. Sessions were held in the evening on weekdays and during the afternoons on weekends.

All Ss were initially recorded from the frontalis on two separate occasions without any treatment condition. Scores for session 1 were disregarded and mean muscle action potentials for session 2 of pre-training served as the baseline level. It was assumed that Ss would habituate by the second day to the novel stimuli of the experimental setting.

After pre-training assessment, each Ss' EMG was recorded for another four sessions. The five biofeedback Ss received continuous auditory biofeedback of their muscle activity during sessions three, four and five. A shaping procedure was built into the feedback loop. As the S acquired ability to lower the feedback tone through lowered muscle activity, the gain of the feedback system was advanced, thus requiring a further reduction in EMG level to maintain a low tone. The relaxation response was shaped by increasing the difficulty of the task in three steps: sensitivity settings of low, medium, and high. To increase resistence to extinction of acquired muscle relaxation, five trials of no-feedback were intersperced randomly within sessions four and five (trials 11, 14, 16, 19 and 20).

For relaxation instruction the five Ss were given pre-recorded instructions in progressive relaxation techniques during sessions three, four and five. Each tape segment was 20 minutes in length. An additional two minute recorded orientation to progressive relaxation was presented prior to training for session 3. Control Ss did not receive either feedback or taped instructions for any of the sessions. The last day, session 6, was used to record post-training EMG levels for all groups. As in sessions one and two, Ss received neither auditory feedback nor pre-recorded instructions.

Instructions To Subjects

General instructions to all Ss were "You are participating in an experiment requiring that three harmless disks be attached to your forehead. Their only purpose is to gather information and they will not give off shock of any kind." Once electrode hook-up was completed and Ss were seated, they were instructed: "You should make yourself as comfortable as possible in the recliner by adjusting it to the best position for you. Remember to relax as deeply as possible, especially your forehead muscle." Additionally, those in the biofeedback group were told "the tone you will hear will vary in pitch with the level of muscle tension in your forehead. Keep the pitch of the tone as low as possible." Further directions for the relaxation instruction group were incorporated in the tape recording itself.

RESULTS

FIGURE 1 shows there were clear differences from the onset between the two treatment groups and the control group which continue over sessions five and six. However, a Mixed-design Analysis of Variance demonstrated that when overall data were evaluated no significant difference existed between groups (A), or in the interaction of groups with sessions (B), see Table 1. The within factor, sessions, appeared as the only component that attained statistical distinction ($p < .001$) and the absence of control S data for session three and four exaggerates inter-session variance.

To examine differences between means in the analysis of variance design, a non-orthogonal set of nine contrasts was employed. From Table 2 it can be seen that the biofeedback and relaxation instruction groups differ significantly from the control group for session 2 (pre-training, $p < .001$), session 5 ($p < .05$), and session 6 (post training, $p < .001$). Other contrasts of interest are relaxation instruction at pre-training with relaxation instruction at session 5 and at session 6. Relaxation instruction was the only condition that declined substantively in mean microvolt levels, from 9.53 in pretraining to 5.74 for session 5 ($p < .001$) and 7.45 for post-training ($p < .05$).

Biofeedback and control groups did register decreases for sessions 5 and 6 compared to pretraining, but not to a significant extent. Relaxation instruction also contrasted favorably with biofeedback. Percentages of decreases in muscle activity are displayed in Table 5. It was noted that for all three groups there was a reduction in mean microvolt values for all sessions that followed baseline. Percentages of change varied from a 3.3% decrease in session 3 to the 39.8% decrease in session 5, each case involving the relaxation instruction condition. At post-training biofeedback decreased 15.2% from pre-training, relaxation instruction decreased 21.8% and control group 12.0%.

A separate two-factor Repeated Measurements Analysis of Variance was applied to biofeedback training sessions 3, 4 and 5 to examine for trial (A) effects and session (B) effects (See TABLE 3). There were no significant findings for biofeedback training. It should be pointedout that the greatest amount of variability appeared in the subject(s) factor. Ss ranged from 5.52 to 14.57 microvolts in session 3 and from 4.55 to 17.15 microvolts in session 5, see Table 2.

DISCUSSION

The present results are confounded by a chance occurrance of random bias in the assignment of Ss to groups. A significant difference in the baseline rate of muscle activity existed between the non-treatment control group and the experimental groups prior to training. Thus, caution must be used in drawing conclusions and generalizing from these data.

Relaxation instruction was seen as clearly superior to biofeedback at end of training and no less effective than biofeedback at post-training. Such results reject the experimental hypothesis that predicted EMG biofeedback to be qualitatively better than verbal instruction at inducing muscle relaxation. In view of the unexpected rejection of the hypothesis, a series of attendant problems encountered in controlling for extraneous variables will be discussed in turn.

The first problem was in the application of surface electrodes and the resultant higher than desirable skin resistances. It was found that the forehead area of female Ss is smaller and more rounded than the forehead area of male Ss, making it harder to affix the round, disk shaped electrodes firmly to their foreheads. Males,having broader, flatter foreheads make attachment much easier and produced resistances below 10,000 ohms in each case. To compound the problem females use cosmetic preparations on their faces including the forehead. Even with the regular use of an abrasive soap (Multi-Scrub^{TM}) before each session, there were instances that skin resistance could not be lowered to the appropriate level. When electrode cream was rubbed into the skin to reduce resistance, the electrodes would not adhere to the skin. After the electrode cream technique failed, an alternative method was attempted of repeating the entire hook-up process. This worked for some females, but not for all; in fact, one S went through the process three times without lowering resistance to a sufficient degree. Several Ss complained of irritation and dryness of skin due to frequent use of the abrasive soap.

A second problem is the unequal time between sessions for Ss. Mean days between sessions were 4.00 for control Ss, 3.12 for biofeedback and 2.48 for relaxation instruction Ss. Group differences appear to be related to the number of cancellations of scheduled appointments by Ss within the groups. The increase in time between sessions after each cancellation may have affected the performance of those Ss.

A third problem is that experimental procedures in biofeedback research are sensitive to distractions such as noise, extreme weather conditions, etc. Such distractions can produce conditioned emotional responses that include heightened anxiety and muscle tension that could bias data obtained at those times.

To counter the above mentioned uncontrolled variables in future research projects, the following recommendations are made. The exclusive use of male Ss would be the easiest manner to insure uniformly low electrode resistances. An alternative would be to briskly rub the forehead with an abrasive pad before connecting electrodes. This might be best accomplished with consenting, paid Ss who would not be concerned with the reddening effect of removing epidermal forehead skin. Another method of reducing the consequences of extraneous variables would be to increase the number of Ss. Cleaves (1970) used a population of 75 Ss, although it was on a one session basis. A sound-proof room should be used to eliminate all external noise.

The apparent superiority of relaxation instruction must be qualified by the following factors. First of all, the data for session 3, 4 and 5 of relaxation instruction were collected from trials 11 through 20. Since progressive relaxation required tensing in addition to relaxation, especially facial muscles, it was felt that trials involving periods of tensing (1-10) should not be contrasted directly with trials of pure relaxation as in biofeedback training. Secondly, the relatively low relaxation effect for the biofeedback group could be attributed to an inefficient shaping of response procedure. The present study incorporated a manually-operated, three-stage (high, medium and low) system of shaping. It might be argued that the lowering trend for sessions 3 and 4 of biofeedback training would have been continued or improved upon if a system of shaping described by Budzynski and Stoyva (1969) had been available. Their system used an automated procedure that adjusted the gain of the feedback loop after each one minute trial designed to maintain Ss' performance at criterion level 85% of the time. Wickramaskera (1972) reported significant results using a three-stage system, but his control condition was non-contingent biofeedback which Budzynski et.al. found to be vastly inferior to a non-feedback control group.

Thirdly, Ss were all young college students free from complaints of excessive anxiety or muscle tension. Pre-training levels for relaxation instruction and biofeedback groups were close to post-training levels for Budzynski and Stoyva's (1970) feedback group composed of adult Ss, indicating that biofeedback and relaxation instruction Ss began comparatively not tense.

Rather than thinking in terms of one treatment modality being more effective than another, each treatment might be considered beneficial in achieving the ultimate objective of lowered muscle activity. Since each modality has its own advantages, integrating the two treatments into one program would prove to be more effective than using either treatment alone. Wickramasekera (1972) indicates that Ss receiving both verbal instructions and contingent biofeedback increased in suggestability over those receiving verbal instructions alone. Such increase in suggestability, as effected by both relaxation methods, has important implications to clinicians who use verbal influence techniques such as psychotherapy. Relaxation training might preceed other therapeutic interventions, thus increasing the control exerted upon client behavior by verbal stimuli.

In the therapeutic application of muscle relaxation the ability to transfer training effects to real life situations is crucial. Budzynski et. al. (1973) feel that clinical treatment with biofeedback methods can be reinforced by home practice with relaxation instructions recorded on 30-minute cassette tapes. Relaxation responses conditioned in the clinic thereby can be carried over and strengthened in the natural environment of the patient, providing improvement in the patient's daily life where it is most needed.

EMG biofeedback emerges as an important technique demanding widespread exploration. It offers practical applications to a host of presenting problems and dysfunctions in the field of psychology, as well as in associated fields such as biological science (Basmajian, 1972). There is urgent need to scientifically and systematically approach this new technology by requiring careful research and investigation (Lader and Mathews, 1971; Miller, 1973). Exploratory studies should be undertaken using rigorous controls to avoid the possibility of drawing spurious conclusions, i.e. those arising from the phenomena of spontaneous recovery or placebo effects.

Treatments that demonstrate promising findings should be repeated, preferably at a different laboratory, to insure that the results were not due to a Type I statistical error. Only through the combined exertions of the research scientist and the clinical technician can biofeedback realize its full therapeutic value.

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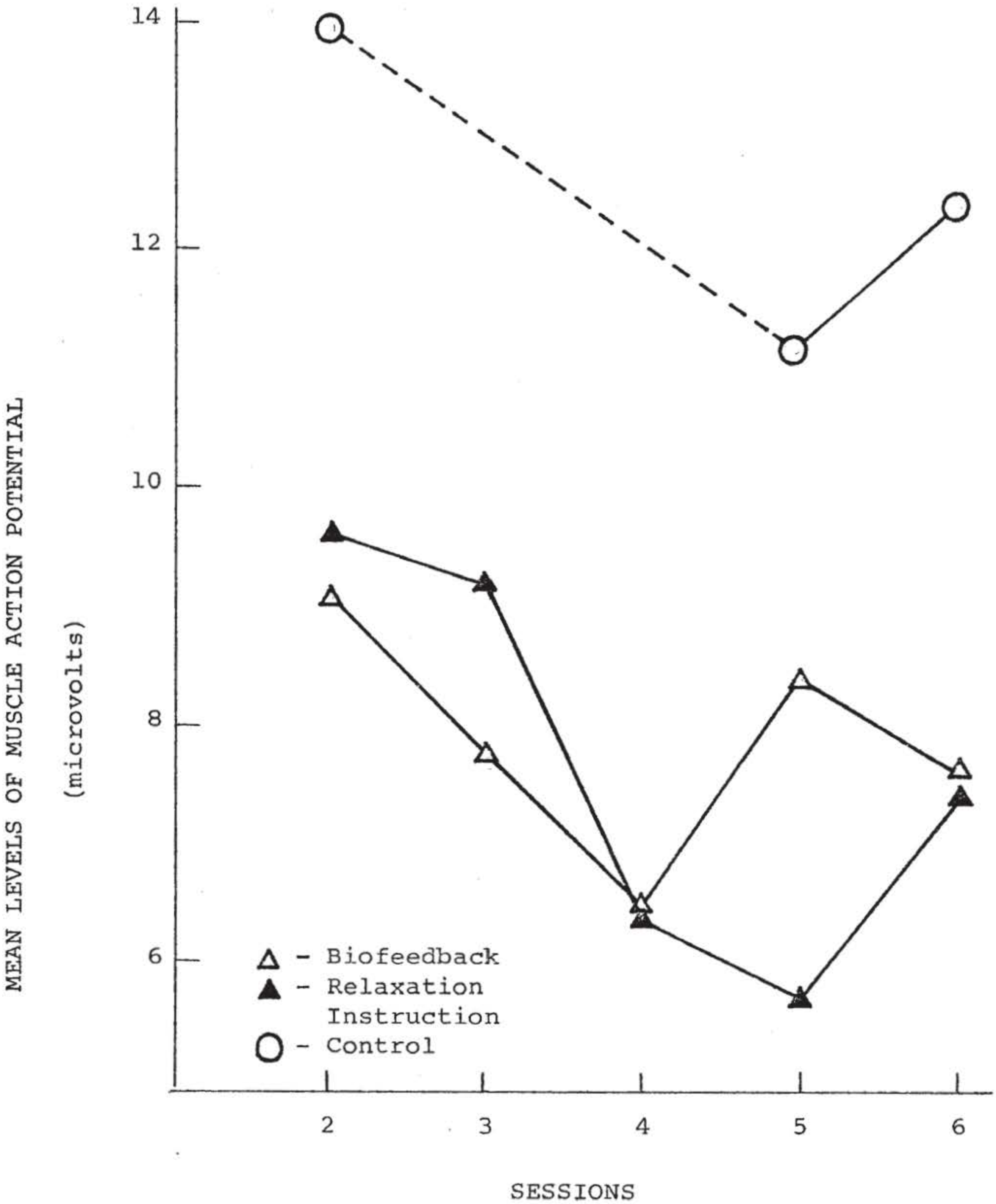

FIG. 1. Comparison of mean microvolt levels obtained by Biofeedback, Relaxation Instruction and Control groups over sessions.

TABLE 1

Analysis of Variance of Mean Microvolt Levels
For Experimental And Control Groups

Source	df	ss	ms	f
TOTAL	64	1049.59	16.40	
Between Subjects (S)	14	808.85	57.78	1.23
Groups (A)	2	247.03	123.51	2.63
S/A	12	561.82	46.81	
Within S	50	231.74	4.63	
Sessions (B)	4	117.21	29.30	13.19*
A x B	8	30.08	3.76	1.69
SB/A	38	84.45	2.22	

NOTE -- A technique to estimate missing data (Winer, 1962) was used to compute the correction factor in the A x B interaction.

*$p < .001$

TABLE 2

Non-Orthogonal Set of Contrasts

CONTRAST	MS	F
BF - pre-training with session 5	1.05	.47
BF - pre-training with post-training	4.73	2.13
RI - pre-training with session 5	35.99	16.21***
RI - pre-training with post-training	10.90	4.95*
BF and RI with Control at pre-training	70.25	31.46***
BF and RI with Control at session 5	12.12	5.46*
BF and RI with Control at post-training	69.52	31.32***
BF with RI at session 5	17.58	7.92**
BF with RI at post-training	.19	.09

*$p < .05$
**$p < .01$
***$p < .001$

TABLE 3

Analysis of Variance of Mean Microvolt Levels
For Biofeedback Group

Source	df	ss	ms	f
TOTAL	299	4197.61		
Trials (A)	19	38.81	2.04	1.27
Sessions (B)	2	166.63	83.31	.72
Subjects (S)	4	2494.12	673.53	
A x B	38	1.22		.90
A x S	76	122.81	1.60	
B x S	8	922.95	115.37	
A x B x S	152	206.86	1.36	

TABLE 4

Mean Levels of Muscle Activity in Microvolts

Condition	Ss	Sessions				
		B_2	B_3	B_4	B_5	B_6
A_1 Biofeedback	S_1	6.79	5.52	5.26	4.55	6.81
	S_2	11.75	6.27	7.41	10.02	6.95
	S_3	5.97	6.57	5.97	5.47	5.65
	S_4	7.85	5.47	6.29	4.77	6.52
	S_5	12.84	14.57	7.97	17.15	12.39
A_2 Relaxation Instruction	S_1	10.39	8.32	3.44	5.96	8.12
	S_2	6.08	6.88	6.46	6.66	8.86
	S_3	12.55	9.20	10.48	5.80	8.51
	S_4	8.10	8.10	5.00	4.80	4.46
	S_5	10.55	13.56	6.92	5.48	7.28
A_3 Control	S_1	16.29			15.02	17.28
	S_2	15.78			10.76	10.50
	S_3	14.23			8.17	10.27
	S_4	17.68			18.05	18.66
	S_5	5.41			3.97	3.90

TABLE 5

Percentage of Decrease
In Mean Microvolt Levels From Session B_2

	Sessions				
Condition	B_2	B_3	B_4	B_5	B_6
A_1 Biofeedback	9.04	7.68 -14.0%	6.58 -27.2%	8.39 -7.2%	7.66 -15.3%
A_2 Relaxation Instruction	9.53	9.22 -3.3%	6.46 -32.2%	5.74 -39.8%	7.45 -21.8%
	13.89			11.19 -19.4%	12.22 -12.0%