PARTIAL REINFORCEMENT IN FRONTALIS ELECTROMYOGRAPHIC TRAINING

DISSERTATION

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This study investigated the role of reinforcement schedule and instructional set in frontalis EMG training. The experiment consisted of four groups participating in 30 minute sessions on three consecutive days. Group conditions were intermittent feedback (alternating 100 second trials), continuous feedback, motivated control and no-treatment control. Excepting the no-treatment controls, each subject was instructed that extra credit points were available contingent on the number of seconds in criterion. An individual criterion based on each subject's initial baseline microvolt level was utilized. Feedback subjects were able to view a display of seconds in criterion during each training trial. Motivated control groups were instructed to relax forehead muscles in order to maintain criterion responding and no-treatment controls were provided no information about the nature of the task. Following two training sessions, feedback groups received extinction trials during which the visual display did not advance.

Analyses of EMG data indicated that visual feedback resulted in higher microvolt levels than either control condition. Motivated controls achieved and maintained more time in criterion than all the others. Partial feedback resulted in
less criterion responding than continuous feedback during training but these groups were equal under extinction conditions. These results suggest that the intermittent schedule produced poorer acquisition but greater resistance to extinction than a continuous feedback/reinforcement schedule and that instructions paired with reinforcement produced superior criterion performance than feedback or control conditions.
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PARTIAL REINFORCEMENT IN FRONTALIS ELECTROMYOGRAPHIC TRAINING

Partial reinforcement extinction effect (PREE) refers to an increased resistance to extinction produced by partial reinforcement schedules during training. Empirical evidence for the partial reinforcement extinction effect in operant conditioning paradigms with animal subjects is plentiful (Hilgard and Bower, 1975). Jenkins and Stanley (1950) made three discrete generalizations based on a survey of the early animal literature:

1) Response acquisition occurs more rapidly with a 100% reinforcement schedule than with partial reinforcement;

2) Although both continuous and partial reinforcement groups show stable post-acquisition performance, the partial reinforcement subjects are usually at a lower level than continuous or 100% reinforcement subjects at the end of acquisition;

3) The partially reinforced groups show a definite advantage in maintaining response strength with no reinforcement or a greater resistance to extinction.

A more recent review of the animal literature by Robbins (1971) has further defined and contradicted some of the early evidence about PREE. The major finding of this review concerns the failure of many investigators to find the partial reinforcement acquisition effect (PRAE) denoted by Jenkins and Stanley (1950) and Lewis (1960). It has been demonstrated
that partially reinforced subjects initially perform slower or at a lower level than continuously reinforced subjects, although ultimately their performance equals or exceeds the continuous group (Goodrich, 1959; Haggard, 1959; McCoy and Marx, 1965; Wagner, 1961). The lack of PRAE has been interpreted in terms of number of acquisition trials and size of reinforcement (McCain, 1970a).

Although acquisition under partial schedules has been redefined in terms of several parameters, the PREE continues to compile a great deal of empirical evidence (Mackintosh, 1974; Sutherland and Mackintosh, 1981). Before investigating methodological and theoretical aspects of the PREE, the experimental data of this phenomenon in human learning will be considered.

The PREE has been demonstrated with human subjects under a variety of experimental paradigms (Morley, 1979). While several different concepts for the study of PREEs with humans are available (Gormezano and Moore, 1969; Longnecker, Kraushopf and Bitterman, 1958), the clearest measure of extinction comes from experiments employing simulated gambling procedures where extinction is defined as a voluntary cessation of gambling (Lewis and Duncan, 1959). Halpern and Poon (1971) used ninety undergraduate volunteers to investigate PREE in short acquisition (32 trials) and long acquisition (60 trials) training. Three groups within each training schedule were further divided by a continuous, small (50%
of trials), or a large (75% of trials) reinforcement schedule. Subjects were initially supplied with 52 nickels (short acquisition) or 80 nickels (long acquisition). Subjects were asked to bet five cents on which one of two lights would go on in each trial. A wrong bet yielded no reinforcement and a correct bet yielded 10 cents. Extinction sessions were identical to training procedures with the exception that the subjects' choice was manipulated to always be incorrect. A subject was considered to be extinguished after seven consecutive no-bet trials and the experiment was terminated. In both long and short acquisition conditions, mean number of trials to extinction was lower under continuous reinforcement than under partial reinforcement. Also, the lower reinforcement percentage led to more resistance to extinction under both conditions of acquisition. Finally, the number of subjects who did not extinguish was significantly larger with partial reinforcement than with continuous reinforcement.

A similar procedure was used to evaluate the effects of various sequences of schedules of reinforcement on acquisition and extinction by Cotler and Nygaard (1969). Eighty volunteer undergraduate students were randomly assigned to one of four groups: 1) twenty partial reinforcement trials followed by forty continuous reinforcement trials, (PCC); 2) twenty continuous trials followed by twenty partial trials, followed by twenty continuous trials (CPC); 3) forty continuous trials
followed by twenty partial trials (CCP); and 4) sixty continuously reinforced trials (CCC). The experimental task required subjects to decide whether a light would come on or not in each trial. Subjects were instructed to press a telegraph key if they thought the light would not come on. After the last block of acquisition trials, each subject was then given one hundred extinction trials during which time the light never came on. Although results yielded no significant differences between the three partial groups for acquisition or extinction, all partial groups were slower during acquisition and more resistant to extinction than the continuously reinforced group.

Several studies have attempted to investigate the importance of sequential shifts from partial to continuous (P-C), or continuous to partial (C-P) reinforcement trials (Jenkins, 1962; Perry and Moore, 1965; Shigley and Guffey, 1978; Sutherland, Mackintosh and Wolfe, 1965; Theios and McGinnis, 1967). Extinction results have not been uniform when comparing sequences of reinforcement. Greater resistance to extinction has been found with P-C groups than C-P groups but opposite results of equal magnitude have been obtained. However, results of previous studies have consistently demonstrated that partial reinforcement presented either before or after a continuously reinforced sequence of responses resulted in greater resistance to extinction than continuous reinforcement alone (Nation and Boyajian, 1980).
Although the majority of research concerned with PREE and response maintenance have been performed in laboratory settings, several attempts have been made to demonstrate the effect in settings outside of the laboratory (Kazdin, 1973a, b; Lovas, Koegel, Simmons, and Stevens-Long, 1973; Walker and Buckley, 1972). These studies have found significant maintenance of specific behaviors outside the laboratory but only when extra-therapy settings are programmed by training parents, peers, or other therapists. Koegel and Rincover (1977) studied target behaviors in autistic children trained under partial and continuous reinforcement schedules with independent raters who assessed performance in extra-therapy extinction trials. Results showed that the thinner the schedule of reinforcement used in the treatment setting, the greater the maintenance of treatment gains in extra-therapy extinction trials. These findings suggest that it may be possible during treatment to plan for behavior changes that are maintained indefinitely after treatment is terminated. The practical implication of this principle for maintaining behavior is obvious: Administer the reinforcing stimulus in conditioning according to a partial schedule, and the behavior will be maintained for long periods in the absence of external support from primary reward (Jenkins and Stanley, 1950).

Before considering the experimental data on the PREE in human biofeedback learning, it is necessary to briefly
examine the methodological criteria used to evaluate PREE experiments. One major problem inherent in all partial reinforcement experiments concerns the decision as to whether treatment groups should be matched on the basis of total number of training trials or the number of reinforced trials. The very nature of partial reinforcement implies that the two options are mutually exclusive. Although both procedures have been used, matching on the basis of total training trials appears to be more prevalent. This strategy is supported by research on small trials PREE (SMPREE) in which groups matched on as few as ten total acquisition trials have demonstrated increased resistance to extinction under partial reinforcement schedules (Poon and Halpern, 1971).

A second methodological consideration is the degree to which subjects are trained during acquisition. It is easiest to evaluate extinction data if groups can be equated on the basis of their performance level at the end of training. This may be done by training groups to the same criterion, but, since individuals learn at different rates, this approach may lead to unequal numbers of training or reinforced trials. A second strategy used to equate acquisition performance levels is by statistical correction in which performance at the end of training is used as a covariate in the analysis of extinction data (Winer, 1971). Lord (1969) gives some examples of how this type of adjustment may result in highly misleading interpretations. Since, as discussed earlier,
parameters of reinforcement schedules affect acquisition levels, it is not advisable to covary out effects which may be attributed to manipulations of the independent variable. At present unequal acquisition levels are most commonly controlled by use of a response which is quickly learned and allowing enough learning trials for performance to stabilize before extinction procedures are employed (Robbins, 1971).

Tests of extinction are commonly run when there is evidence of stable acquisition performance and consist of relatively large numbers of unreinforced trials. Also, extinction tests should be separated from training by a period "Sufficient in length to prevent carry-over of transient performance effects" (Berlyne, 1969). The length of this waiting period, however, is seldom consistent across experiments and extinction trials are often run immediately following training. Those studies which have examined the effects of delayed extinction have found the PREE to be eliminated or greatly reduced after sufficient delay (Aikon and Gibson, 1965; Johnson, Harrell and Pachman, 1979). These findings may indicate that the PREE is a transient phenomenon, implying that partial reinforcement schedules may not produce as resilient an effect as is commonly assumed.

Human biofeedback learning is commonly regarded as an operant phenomenon (Miller, 1969; Schwartz, 1972). In order to strengthen response maintenance when feedback is withdrawn, investigators have used partial reinforcement
schedules during biofeedback training sessions. Thus, Budzynski and Stoyva (1969) write of EMG training that "several silent trials were interspersed in order to increase the resistance to extinction of the relaxation response". Weiss and Engel (1971) used a similar procedure in a study of operant control of heart rate. Although partial reinforcement regimens were used in these studies, no extinction trials were run to test the validity of the partial reinforcement manipulation.

A more systemic manipulation of reinforcement schedules, which included as assessment of extinction trials, was performed by Brener, Kleinman and Goesling (1969) in a study of operant heart rate conditioning. Median resting heart rate was used as a criterion and one group received feedback each time their heart rate exceeded criterion while a second group received feedback on 50% of successful trials. A control group was given instructions as to the nature of the task but received no feedback. All subjects underwent bidirectional heart rate conditioning, and resting baseline periods were interspersed between training sessions. Extinction trials of one minute in duration were scheduled immediately after training trials. No significant differences between the two experimental groups were found in acquisition or extinction trials. However, it is not possible to evaluate the partial reinforcement effects in this study because of several methodological flaws. Subjects received a maximum of twelve short (fifty interbeat intervals per trial) feedback
trials spread over two sessions. Under these conditions it is unlikely that subjects reached stable, asymptotic performance during training. In addition, extinction performance was not tested under sufficient conditions to demonstrate PREE phenomena. Duration of extinction trials were extremely short and there was no delay between training and extinction conditions.

In a similar study of bidirectional heart rate training, Lang and Twentyman (1976) compared the relative effects of feedback provided on either 50% or 25% of training trials. Two groups under these partial schedules received contingent monetary reward while two partially reinforced groups did not. The data indicated that more frequent feedback and the presence of monetary reward produced larger changes during training and transfer trials. In terms of providing support for a PREE, the experiment presents the same methodological problems as the Brener et al (1969) study. However, results from Lang and Twentyman (1976) during acquisition seem to support the first generalized proposition of Jenkins and Stanley (1950) mentioned earlier (pg 1).

In addition to heart rate biofeedback, two studies have systematically varied the amount of available feedback in frontalis electromyographic (EMG) training. Hankin (1979) provided continuous, intermittent (feedback present on alternating trials), and aperiodic (randomly assigned feedback on 50% of all trials) auditory feedback over six training
sessions to facilitate reduction of frontalis muscle tension. All sessions were scheduled on consecutive days and a seventh session with no feedback for 45 minutes was used to evaluate extinction effects. The results did not support the hypothesis that EMG feedback was differentially effective in promoting acquisition or retention of muscle tension reduction ability. Ely (1977) evaluated the electromyographic reduction response in four groups of subjects over three sessions followed immediately by a ten minute extinction period. Each training session consisted of seventeen minutes or nine minutes with either continuous or intermittent (alternate trials) auditory feedback. The seventeen minute intermittent and nine minute continuous groups exhibited the best acquisition and did not significantly differ from each other. Extinction data showed greater resistance to extinction by the continuous groups than intermittently reinforced groups. However, the scheduling of the transfer trial immediately after feedback trials renders the data open to Berlyne's (1969) criticism that such measures may represent a transient "carry-over" performance effect rather than a stable learned response.

Although there appears to be no other direct tests of the PRBE with biofeedback, several authors have considered studies in which analogue and binary feedback have been compared as independent variables (Lang and Twentyman, 1974; Morley, 1979). Gatchel (1974) found greater heart rate increases using analogue feedback during training. Although
this data lends partial support to the PRAE hypothesis, extinction data are unclear for several reasons: 1) subjects in each group received different amounts of reinforcement and training trials; 2) transfer trials were scheduled immediately following training; and 3) instructions were different for training and extinction trials. Perhaps more important than methodological flaws involved in the analogue/binary comparisons, is a basic assumption concerning the nature of feedback. The assumption is that binary feedback provides less information than analogue feedback and that one can equate binary and analogue feedback with partial and continuous reinforcement respectively. The validity of this assumption will be discussed below.

A better understanding of the role of information as a reinforcing stimulus can be obtained by clarifying the nature of reinforcing events. There appears to be two distinct dimensions of reinforcers, one corresponding to biological/motivational gain and a second concerning information about the correctness of a response (Black, 1974). Mowrer (1967) has suggested that reinforcing stimuli might be viewed within similar dimensions, and has labeled these dimensions as "payoff" and "information." The fact that human biofeedback experiments typically use informational stimuli, whereas animal experiments utilize stimuli with high payoff value, may be a major reason why stimulus withdrawal has different effects in these situations (Annet, 1969).
Contingent monetary reward, in addition to informational feedback, has been employed in studies of learned heart rate control performance (Stephens, et al 1975; Schwartz, 1972; Weiss and Engel, 1971). Although the procedures involving investigation of a number of independent variables and employed different methodologies, all the studies concluded that it is possible for human subjects to develop some control over their heart rates when they are provided with feedback and reward. Lang and Twentyman (1976) investigated the effects of partial feedback (50%, 25%) with equal subgroups receiving either a monetary reward for successful heart rate performance or no supplementary incentive. Data from this study indicated that, regardless of schedule, heart rate control performance was generally superior under incentive conditions. Similarly, Lang (1977) had noted that subjects who received monetary feedback performed no better than instruction alone subjects, at least under conditions of heart rate slowing.

Siddle and Wood (1979) employed a between-subjects design to investigate the effects of auditory feedback and reinforcement (points which were exchangeable for money) on the lowering of frontalis EMG activity. The feedback and reinforcement manipulations were combined in a 2 x 2 factorial design and each subject underwent one baseline and two training sessions on three consecutive days. The results indicated that although analogue feedback did not
result in lowered EMG levels, trial period EMG level was significantly lower than baseline level under conditions of reinforcement. Moreover, the group exposed to reinforcement alone displayed EMG reductions of the same magnitude as the group who received both feedback and reinforcement. Clearly, the above studies demonstrate the importance of "high payoff" reinforcement in biofeedback, and in some cases the necessity of an informational stimulus is challenged.

Recently, Alexander (1977) has called into question the necessary contribution of the feedback stimulus in biofeedback training. His careful scrutiny of previous EMG biofeedback literature which has demonstrated a training effect reveals several difficulties.

First, prior to any training, subjects often reach EMG levels at the end of an initial baseline session which approach the lowest mean levels ultimately attained by trained subjects. This suggests that substantial decreases in EMG in the space of 20-30 minutes of adaption may be characteristic of normal subjects told simply to relax without feedback aid. Second, overwhelmingly the largest decrease in session mean EMG levels for subjects receiving contingent biofeedback occurs within the first training session (Budzynski and Stoyva, 1969; Alexander, 1975). Further, decreases in mean levels over sessions are small, and usually not significant by comparison. Whatever
"learning" is taking place is rapid indeed. Third, control subjects almost always manifest a decrease of similar magnitude from baseline through the first training session but then increase over subsequent sessions, often reaching final tension levels in excess of baseline.

In light of Alexander's experimental investigation of instructed control versus biofeedback groups, the above criticisms appear valid (Alexander, 1977). EMG reduction was measured under biofeedback conditions, and control subjects were motivated by instructions to perform maximally during relaxation without feedback. Both trained and untrained subjects produced significant EMG reductions but did not differ from each other. This result is supported by the Siddle and Wood (1979) data reported above, in a study which used contingent monetary reward to motivate control subjects and found no differences between rewarded feedback and rewarded control subjects.

The purpose of the present study was to compare effects of partial and continuous reinforcement in human EMG biofeedback training during acquisition and extinction. It was hypothesized that partial reinforcement will lead to greater resistance to extinction than continuous reinforcement. Also an instructed and rewarded motivated control group was tested, in addition to a no treatment control group, in order to investigate Alexander's hypothesis that an adequate instructional set
can exert the same influence as contingent biofeedback on EMG reduction.

Method

Subjects
Subjects were 40 volunteer undergraduates with no previous biofeedback experience from psychology classes at North Texas State University. All subjects received points to be applied to their class grade for participation. Twenty male and twenty female subjects were randomly assigned to one of four treatment conditions. This randomization procedure resulted in the following proportions of males/females in each group: Intermittent Biofeedback (5/5), Continuous Biofeedback (6/4), Motivated Control (5/5), Control (4/6). Mean age of the sample was 25 years old.

Apparatus
Electromyographic (EMG) data was measured via Beckman silver/silver chloride plated electrodes which were 9 mm in diameter. Double stick electrode collars were used to attach electrodes to the forehead and EKG-Sol paste was used as a conductant. A Micronta digital multimeter was used to measure skin resistance.

A Colbourn modular equipment rack was used to quantify muscle potentials in microvolts. The surface signal was directly inputted to a bioamplifier/coupler. Gain was set at one hundred percent of 10,000 x, and high and low cutoff filters were set at 1,000 Hz and 90 Hz, respectively. The
amplified signal was directly coupled to a cumulating/resetting integrator with a time constant of .1 volt seconds. This integrated signal was fed into a printer which produced a hard copy of microvolts measured to the second decimal every 100 seconds.

The threshold monitoring system consisted of an amplified signal directly coupled to a contour following integrator which averaged the signal at a time constant of 1,000 milli-seconds. The integrated signal was inputted to a bipolar comparator with a threshold adjustment dial accurate to the second decimal. Output from the comparator was relayed though a Lafayette Instruments power converter which triggered a Lafayette Instruments digital clock though a series of electromechanical relays. The clock's light emitting diode display recorded seconds up to 99.999 before resetting. Each digit was 1 inch high and .5 inch in diameter. During nonreinforced trials the clock display showed only 00.000 and manual timing was performed with a Hanhart stop watch accurate to .1 second.

Subjects sat in a semireclined chair facing away from the equipment rack which was approximately six feet behind the chair. The clock was positioned at eye level approximately 24 inches from each subject's eyes. Due to a loud noise made by the printer every 100 seconds, it was stored in a sound proof chamber in an adjacent room and subjects wore headphones which completely covered the ears. These headphones
were used only to insure elimination of printer noise and therefore produced no sound. Room temperature was maintained at 72° -75° Fahrenheit.

Procedure

Experimental procedures were similar to those described by Budzynski and Stoyva (1969). Each subject was placed in a quiet, dimly lit room and seated in a comfortable chair. The workings of the equipment as a passive recording device were explained.

Each subject participated in a 30 minute session on three consecutive days. The first two sessions consisted of an initial 10 minute baseline period followed by 20 minutes of training. Extinction sessions held on the third day were identical to training sessions with the exception that the clock never advanced for feedback groups.

Prior to electrode attachment each subject's forehead was briskly rubbed with a cotton ball dampened with isopropyl alcohol. A reference electrode was placed midway between the hairline and eyebrows above the bridge of the nose. Active electrodes were placed one inch from either side of the reference electrode so that all three electrodes were in a straight horizontal line across the forehead. Before recording began, impedance was measured for all possible electrode pairs. If electrical resistance within each electrode pair was less than 15,000 ohms with no difference between pairs greater than 5,000 ohms, electrode application was
judged acceptable.

Once recording criteria were met, subjects were instructed to sit quietly in the chair and remain still. After this instruction was presented, headphones were placed over the ears and baseline recording began. After six baseline trials were completed, each subject's average baseline level (in microvolts) was set by adjustment of the threshold monitoring dial. Then the experimenter read instructions to each subject. All subjects were informed that a standard number of points (5) would be added to their course grades based on the participatory time. At this point, the nature of the instructions varied according to experimental conditions.

Biofeedback groups were shown the clock and were familiarized with the display. These subjects were informed that once training began they could control the rate at which the clock advanced and that between 0-5 bonus points could be gained based on how much the clock ran. No further instructions about the nature of the task were provided.

Subjects in the motivated control group received instructions about the importance of relaxing during training trials. This group was further told that although no information regarding their performance could be provided during the experiment, between 0-5 bonus points would be awarded contingent upon the amount of EMG reduction during training trials.

No treatment control subjects were reread the instructions given to all groups prior to baseline periods. The exact
instructions read to each experimental group can be found in Appendices A, B and C.

Continuous visual feedback in the form of the clock was available throughout all training trials for each subject in the continuous biofeedback group. The intermittent feedback group received feedback on the initial 100 second trial and on alternating trials of each training session. Feedback in both groups was based on individual criterion performance. The clock advanced only when a subject was below the mean microvolt level of his/her baseline trials obtained in the first session. This criterion value remained constant for each subject across sessions. Motivated and no treatment control groups were not shown the clock.

For all subjects EMG data was collected for each trial of baseline and training during all three sessions. The number of seconds in criterion during each training trial was collected for all groups. These time values were obtained from the clock readings from each trial. However, since the clock did not advance during nonfeedback trials for the intermittent group or during extinction trials for either feedback group, this data was collected manually. The experimenter used a stop watch to record the number of seconds the threshold light on the bipolar comparator was illuminated during each trial. The threshold light was activated when EMG levels were below the present baseline values and therefore this measure is essentially equivalent to clock readings.
Three hundred trials were conducted prior to experimentation to assess agreement between manual and mechanical time measures. Time measures were obtained for motivated and no treatment control groups by placing the clock behind the subject and recording the number of seconds in criterion for each trial.

At the end of the third session, all subjects rated on a seven point scale how interesting they found the experiment and the extent to which they were motivated to perform well. These scales can be found in Appendix D.

**Results**

Upon initial inspection of EMG data it was discovered that one subject in the intermittent biofeedback group had an unusually high mean microvolt level of 13.90 v. Since this value was 4.15 standard deviations (S.D. = 2.65) above the intermittent biofeedback group mean (3.92 v) this subject was judged to be unrepresentative of that group and was eliminated from further data analyses. Exclusion of this data did not change the pattern of results or conclusions. A summary of group means and standard deviations before and after exclusion of this data is presented in Appendix E.

In all data analyses a Greenhouse-Geisser coefficient was used to adjust degrees of freedom for violations of symmetry of covariance matrices when appropriate (Winer, 1971). Alpha levels for significant differences are .05 unless reported otherwise.
A 4 x 3 (groups x baselines) analyses of variance with one repeated measure on EMG data revealed no significant group (p>.31, F = 1.61, df = 3,35), baseline (p>.14, F = 2.43, df = 2,57), or interaction (p>.27, F = 1.34, df = 6,57) effects. Based on the results of this analysis no corrections were made for baseline levels which are analyzed below as the initial block of trials in each session.

A 4 x 3 x 3 (groups x sessions x blocks of 6 trials) analysis of variance with one repeated measure was performed on EMG data. This analysis yielded a significant main effect for experimental groups (p<.05, F = 3.30, df = 3,34) and for blocks of trials (p<.01, F = 7.17, df = 2,58). A Newman-Keuls post hoc test showed a significant difference between biofeedback and control groups while neither pair of groups differed significantly from each other. For trials a significant difference was observed between baseline and all other trials. A summary table of this analysis can be found in Appendix F, and a graph of cell means is provided in Figure 1.

Agreement between manual and mechanical recordings for number of seconds in criterion was computed by dividing the smaller by the larger total for each of 300 practice trials. The mean agreement for all trials was .9781 with individual trial agreements ranging from .8824 to 1.00. A 4 x 3 x 2 (groups x sessions x trials) analysis of variance with one repeated measure (number of seconds in criterion) showed a significant interaction of experimental group and
session (p<.02, F=3.09, df = 6,52) as well as a significant main effect for session (p<.01, F = 8.00, df = 2,52). A Newman-Keuls test showed that all groups except for the continuous biofeedback group significantly increased time in criterion from session 1 to session 2. All groups showed significant decreases from session 2 to session 3 (extinction) with exception of the intermittent biofeedback group. In session 1 the motivated control and continuous biofeedback groups had more time in criterion than the no treatment control group, and the intermittent biofeedback group was lower than all groups. No differences existed between no treatment control and continuous biofeedback groups in session 2, with the motivated control group higher and the intermittent group lower than all other groups. Extinction data from session 3 revealed no differences between biofeedback groups with motivated controls higher and no treatment controls lower than all other groups. A summary table of this analysis can be found in Appendix G, and a graph of the cell means is provided in Figure 2.

A 4 X 2 (groups X scale) analysis of variance with one repeated measure was performed on rating scales. No significant effects were found for groups (p>.17, F = 1.74, df = 3,35), scales (p>.17, F = 1.88, df = 1,35), or the interaction (p>.40, F = .99, df = 3,35). A table of cell means can be found in Appendix H.
Figure 1. Mean microvolt levels versus trials.
Figure 2. Mean numbers of seconds in criterion versus sessions.
Discussion

The principal hypothesis of this study was that subjects who were reinforced with a partial schedule would show greater resistance to extinction than continuously reinforced subjects. This hypothesis received partial support. In terms of microvolt levels, both feedback groups were higher than either nonfeedback group throughout all sessions. However, time in criterion data show some evidence of PRAE and PREE with feedback groups. An acquisition effect between feedback groups shows that the intermittent feedback group displayed less time in criterion than the continuous feedback group for the first two training sessions. This difference at the end of training makes extinction data difficult to interpret and points to a possible need for a greater number of training trials. Despite this training deficit, the intermittent feedback group was the only group to maintain performance in extinction trials. In fact, it was only during the extinction session that performance in both feedback groups was equal.

The relatively poor performance of feedback groups in comparison to no-treatment controls and motivated controls as well as the slow acquisition of the intermittent feedback group may be the result of several factors. Firstly, the use of visual feedback may have impeded the performance of both biofeedback groups. Alexander (1975) postulates that keeping the eyes open may have some detrimental effects during frontalis training. Electrodes placed on the forehead
over the frontalis muscle pick up EMG output from other muscles, particularly those in the region of the eyes. These include not only the periorbital muscles, e.g., the procerus and corrugator, but those muscles controlling movement of the eyelids, e.g., the orbicularis oculi muscles, and also the eyes or globes themselves, e.g., the rectus and oblique muscles. Electrical activity arising from these muscles may militate against successful feedback assisted tension reduction during frontalis training. Although both feedback groups showed significant changes from baseline EMG levels, further performance gains may have been limited by eye movement.

The influence of eye movement on frontalis EMG may also explain the slow acquisition of the intermittent feedback group. Although Budzynski and Stoyva (1969) report large changes in EMG frontalis feedback training in a single 20 minute session, auditory feedback was used. Eye muscle artifact may have rendered this apparently easy learning task more difficult. Increased task difficulty leads to less reinforcement and fewer opportunities to establish adaptive discriminative stimuli (McCain, 1970) which produces lowered response acquisition rates. In light of the above, auditory feedback may eliminate the need for many acquisition trials to achieve similar performance between partial and continuous reinforcement schedules.

In the present study eye movement artifact confounds
interpretation across groups, since both feedback groups had their eyes open to observe the clock and control groups could have open or closed eyes for variable amounts of time throughout training. In fact it was observed that control subjects closed their eyes during most of each session. This confound limits interpretation of group differences to comparisons within feedback or control groups, and eliminates any comparisons between these two sets of conditions.

Although the eyes closed or open variable may hinder comparisons between feedback and other groups, interpretations of data between intermittent and continuous feedback groups remain valid. The intermittent feedback group, which received a partial schedule of reinforcement, maintained performance during extinction while continuous biofeedback/reinforcement counterparts displayed a marked performance decrement in the absence of reinforcement. Future research using auditory feedback or some manipulation of eye positioning is in order to replicate or expand these findings.

EMG performance of the motivated control group was superior to both feedback groups throughout training. Motivated controls had more time in criterion than all other experimental groups in each session with the exception of the first training session when motivated controls and continuous feedback subjects outperformed other groups. In light of the discussion above pertaining to possible artifact in feedback conditions, comparisons between motivated controls and feedback groups
are tentative. Although motivated controls did exhibit superior performance than feedback groups, a more conservative interpretation of this effect than a similar finding by Alexander (1977) is in order. Based on a study of auditory EMG feedback, Alexander (1977) concluded that "an adequate instructional set can exert the same influence for normal subjects under typical laboratory conditions in the absence of the contingent feedback stimulus". On the surface this study appears to support Alexander's (1977) conclusion. However, since in the present experiment, the uninstructed controls also outperformed biofeedback groups, it can only be safely concluded that an adequate instructional set paired with delayed reinforcement can indeed produce significant reduction in frontalis EMG for normal subjects under laboratory conditions. When visual feedback is used, motivated controls show superior performance to contingent feedback groups.

The observation that prior research demonstrating the superiority of biofeedback to no treatment control groups payed insufficient attention to the response patterns of control subjects (Alexander, 1975; White and Alexander, 1980) is supported by the present study. While no treatment controls manifested increased time in criterion similar in magnitude to other groups through the first two sessions, they displayed the largest decrease from session 2 to session 3. This response pattern of poor performance on later trials after initial success is characteristic of no treatment
controls. It is therefore not surprising that previous research which employed statistical comparisons between experimental and control groups at the final session have found significant differences. This finding significantly illustrates that prior research using this type of analysis (Budzynski and Stoyva, 1969; Budzynski, et al 1973) to document EMG training effects may be flawed. It is possible that these training effects were due to stable (or small decrementation of) performance of biofeedback groups as compared to controls, and not to increased experimental group performance as postulated.

Nearly all experimentation in human biofeedback learning has used EMG microvolt data as the single dependent measure to evaluate training outcome. While this measure is necessary to validate physiological change, the methodological complexities of recording, amplification and integration of this electrical signal often render this variable difficult to interpret by researchers and clinicians as well as their subjects/patients. Even when standard methodological criteria are used to collect EMG microvolt data it is at best an averaged measure of performance. The present study employed a time in criterion measure in addition to microvolt data. This measurement system has several advantages over traditional single variable recording procedures. Since an individual criterion was established for each subject, no feedback was provided unless the subject emitted the desired response.
In effect this enabled subjects to discriminate response acquisition, e.g., clock running/stopped, in addition to response maintenance, e.g., continual clock advancement.

More importantly the time measurement system was more sensitive to small changes in performance. This is evidenced by data analyses in which the time variable revealed more experimental effects than EMG data. Since both measures were analyzed in units ranging from 0 to 1,000 (EMG = .01-10.00 v, Time = .1-100.00 seconds), the differences between these measures is not likely to be a statistical artifact created by dependent measures of different ranges. Instead these differences are probably due to the nature in which these variables were collected. Firstly, EMG data was collected during each entire 100 second trial, but time in criterion was measured only when a subject was below initial levels. Therefore time data measured performance in terms of achieving criterion as opposed to the overall performance level reflected in microvolt measurement. Secondly, EMG data was an average microvolt level whereas time data was a cumulative total of seconds in criterion. It is conceivable that by using an averaged score as raw data, much of the variability had been removed from EMG measurements prior to data analysis. The differences between the measures discussed above are complimentary in that they enable evaluation of the total magnitude of change as well as the frequency of the criterion response produced by training.
Percent time in criterion is a relevant measure for evaluating performance in nonfeedback trials. It has excellent clinical applications because it provides both clinician and patient a commonly understood means of evaluating treatment gains as well as generalization potential. Future research is in order to validate the use of a time measuring system and to evaluate the utility of shifting criterion performance based on such a measure.

In summary, the present study offered a brief overview of partial reinforcement extinction effects with special consideration given to human biofeedback learning, and examined the effects of intermittent and continuous visual feedback in comparison to motivated and no treatment control groups in lowering frontalis EMG. While both feedback groups displayed significantly higher EMG levels than controls throughout training, a PRAE and FREE was found between feedback groups when time in criterion was evaluated. The motivated control group exhibited superior performance than all other groups, and no treatment controls showed a characteristic response pattern across sessions. These results offer some support to Alexander's (1975) surmise that an adequate instructional set can produce substantial performance gains in a frontalis EMG task. The influence of eye movement as a possible confounding variable and the advantages of measuring criterion performance in seconds are discussed. In addition, questions have been raised as to the role of feedback in frontalis
EMG training and generalization. Subsequent research in this area should decide these questions.
APPENDIX A

INSTRUCTIONS FOR BIOFEEDBACK GROUPS

PRE-BASELINE

I am going to monitor several of your physiological functions for three half-hour sessions on three consecutive days. For each session you will receive one research participation point for each half-hour of participation including the time it takes to set up the equipment. Each session will consist of an initial 10 minute baseline measure followed by another 20 minutes of monitoring. The total points available for participation are five with added bonus points which will be explained later.

POST-BASELINE

During this session you are to try to make the counter run. Up to five bonus points will be awarded based on your final counter readings so the more counter runs the more credit points you can gain. After this session I will record your counter readings and at your final session your total counter points will be tallied and your bonus credit points awarded. It is therefore very important that you complete your three sessions on consecutive days and do your best to run the counter during each session in order to get your maximum bonus points.
APPENDIX B

MOTIVATED CONTROL GROUP INSTRUCTIONS

PRE-BASELINE

I am going to monitor several of your physiological functions for three half-hour sessions on three consecutive days. For each session you will receive one research participation point for each half-hour of participation including the time it takes to set up equipment. Each session will consist of an initial 10 minute baseline measure followed by another 20 minutes of monitoring. The total points available for participation are five with added bonus points which will be explained later.

POST-BASELINE

During this session you are to try to relax as much as possible. The experimenter's major interest is the ability of this procedure to measure specific muscle tension. Your cooperation in attempting to relax your forehead muscles is crucial in our evaluation of effectiveness of this measuring system. Although no information about your performance will be available during each session, up to five bonus points will be awarded depending on how much you relax your forehead muscles. These bonus points as well as a discussion of your performance will be available at the end of the third session.
APPENDIX C

UNIFORMED CONTROL GROUP INSTRUCTIONS

PRE AND POST BASELINE

I am going to monitor several of your physiological functions for three half-hour sessions on three consecutive days. For each session you will receive one research participation point for each half-hour of participation including the time it takes to set up equipment. Each session will consist of an initial 10 minute baseline measure followed by another 20 minutes of monitoring. The total points available for participation are five with added bonus points if you complete all scheduled sessions on three consecutive days.
### APPENDIX D
### RATING SCALES

**NAME:** ____________________________

**HOW INTERESTING WAS THIS STUDY?**

<table>
<thead>
<tr>
<th>NOT INTERESTING AT ALL</th>
<th>MODERATELY INTERESTING</th>
<th>VERY INTERESTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
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**HOW MOTIVATED WERE YOU TO PERFORM WELL IN THIS STUDY?**

<table>
<thead>
<tr>
<th>NOT MOTIVATED AT ALL</th>
<th>MODERATELY MOTIVATED</th>
<th>VERY MOTIVATED</th>
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<tbody>
<tr>
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<td>6</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
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</table>
APPENDIX E

TABLE 1

GROUP MEANS AND STANDARD DEVIATIONS FOR EMG DATA WITH N=40 AND N=39

<table>
<thead>
<tr>
<th>N=40</th>
<th></th>
<th>CBF</th>
<th>IBF</th>
<th>MC</th>
<th>CONT.</th>
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</thead>
<tbody>
<tr>
<td>MEAN</td>
<td></td>
<td>3.06</td>
<td>3.92</td>
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<td>2.48</td>
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<tr>
<td>S.D.</td>
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<td>1.45</td>
<td>2.65</td>
<td>.82</td>
<td>.84</td>
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<table>
<thead>
<tr>
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<th></th>
<th>CBF</th>
<th>IBF</th>
<th>MC</th>
<th>CONT.</th>
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</thead>
<tbody>
<tr>
<td>MEAN</td>
<td></td>
<td>3.06</td>
<td>3.32</td>
<td>2.26</td>
<td>2.48</td>
</tr>
<tr>
<td>S.D.</td>
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<td>1.45</td>
<td>1.52</td>
<td>.82</td>
<td>.84</td>
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</table>
### APPENDIX F

#### TABLE 2

**SUMMARY TABLE FOR EMG DATA**

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>DF</th>
<th>MS</th>
<th>F</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Group</td>
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<td>Session</td>
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<td>SG</td>
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<td>1.12</td>
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<td>.4869</td>
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<td>9.47</td>
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<tr>
<td>ST</td>
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### APPENDIX G

#### TABLE 3

**SUMMARY TABLE FOR TIME DATA**

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<th>P</th>
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<tr>
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<td>1.68</td>
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</tbody>
</table>
### APPENDIX H

**TABLE 4**

GROUP MEANS AND STANDARD DEVIATIONS FOR RATING SCALES

<table>
<thead>
<tr>
<th>HOW INTERESTING WAS THIS STUDY?</th>
<th>LBF</th>
<th>IBF</th>
<th>MC</th>
<th>CONT.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUP</strong></td>
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<td></td>
<td></td>
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<td>1.77</td>
<td>1.71</td>
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</table>

<table>
<thead>
<tr>
<th>HOW MOTIVATED WERE YOU TO PERFORM WELL IN THIS STUDY?</th>
<th>LBF</th>
<th>IBF</th>
<th>MC</th>
<th>CONT.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUP</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>1.11</td>
<td>1.23</td>
<td>1.61</td>
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