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Effects of fixed interval and continuous biofeedback reinforcement on EMG frontalis muscle activity: a thesis...

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Effects of fixed interval and continuous biofeedback reinforcement on EMG frontalis muscle activity

A Thesis
Presented to the Graduate Faculty
of the University of the Pacific

In Partial Fulfillment
of the Requirements for the
Degree of Master of Arts

by
Kathleen I. Twinem
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This thesis, written and submitted by

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is approved for recommendation to the Committee on Graduate Studies, University of the Pacific.

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ABSTRACT

The effects of continuous vs. intermittent reinforcement using electromyographic (EMG) feedback as the reinforcer were compared in reducing frontalis muscle activity. Fourteen subjects were chosen from a group of 30 students who had expressed an interest in learning how to relax. Those students having the highest pre-experimental baseline scores were chosen. They were matched according to both those scores and sex and then randomly assigned to either a continuous biofeedback reinforcement group or a 30 sec. fixed interval biofeedback reinforcement group. The experiment consisted of nine sessions (three acquisition, two treatment, and four extinction) with integrated EMG activity from the frontalis muscle and time spent below criterion recorded as dependent variables. While results from the first variable were inconclusive as to the efficacy of using intermittent reinforcement over continuous reinforcement, time spent below criterion supported the hypothesis of the study that intermittent reinforcement does increase the durability of the response.
EFFECTS OF FIXED INTERVAL AND CONTINUOUS BIOFEEDBACK REINFORCEMENT ON EMG FRONTALIS ACTIVITY

Biofeedback is the use of modern instrumentation to give a person better moment-to-moment information about a specific physiological process that is under the control of the nervous system but not clearly or accurately perceived. The initial development of the biofeedback technique was the result of work done by two separate groups of researchers. The first group, headed by Neal Miller, was interested in demonstrating that operant control of visceral and glandular processes, such as heart rate, was possible in humans using amplified bodily feedback as contingent reinforcement (1969). In animal experiments rewards and punishments are an important type of feedback. For the person who is trying to achieve something, information that a response is succeeding or failing acts as the reward or punishment. Miller and his associates (see Miller, 1969) showed that curarized rats could modify their heart rate and other autonomically mediated behavior by means of contingent reinforcement. The second group of researchers, Joseph Kamiya (1969) and Barbara Brown (1971), were interested in seeing whether humans could learn to discriminate higher nervous system activity and their associated subjective states. They supplied subjects with external feedback for specific electroencephalographic (EEG) changes and found that subjects could develop control over this activity.

Currently, the electromyograph (EMG) is perhaps the most useful of all biofeedback instruments. The EMG measures the amount of electrical discharge in the muscle fibers and therefore quantifies muscle contraction and relaxation.
This electrical discharge is translated into auditory and visual displays. These displays enable a person to begin to notice and bring about changes in muscle tension which he was previously unable to do.

Applications

Research using EMG feedback has been carried out on numerous activities. In the treatment of fecal incontinence, Engel (1974) used instantaneous feedback of sphincter responses with six patients. Verbal praise was used to help the subjects determine which polygraph readings were appropriate. Eventually they were able to control their sphincter muscles and remain continent. Follow-ups, lasting from six months to five years, showed a continuation of voluntary control. Four patients remained completely continent, while the other two were greatly improved.

In a clinical case study Furman (1973) found that biofeedback was highly successful among patients suffering from functional diarrhea. Five patients learned to control their bowel activity after a short period of biofeedback training. Follow-up has shown that all five have maintained normal bowel activity.

Neuromuscular re-education, in which subjects learn the use of various muscle groups, is another field in which biofeedback appears promising. Andrews (cited in Blanchard & Young, 1974) reported on a series of 20 patients suffering from hemiplegia who had shown no return of function in one year since the onset of hemiplegia and who had shown no progress in traditional neuromuscular rehabilitation procedures. Following the EMG training, 17 of the patients were successful in developing strong, voluntary well-modulated action in the muscle. Johnson and Garton (1973) reported similar results with several patients suffering from hemiplegia who each wore a leg brace.
Using EMG feedback Hardyck and Petrinovich (1969) were able to eliminate subvocalization from a group of college students who subvocalized while reading. A control group who did not receive feedback training showed no change in the same experiment. Aarons (1971) found similar results in reduction of subvocalization using EMG feedback and also found gains in comprehension in a controlled study comparing subjects high or low in level of subvocal speech.

EMG feedback has also been shown to be effective in the reduction of pain. Nouwen and Solinger (1979) used EMG feedback in the treatment of 18 patients suffering from chronic lower back pain. Compared to seven controls, the 18 feedback patients showed a significant reduction in muscle tension during training and subsequently in pain. During the follow-up it was found that the EMG levels had returned to the original readings but the pain scores and reports showed further improvement.

Biofeedback techniques have also been used to facilitate deep muscle relaxation and lowered arousal levels. Budzynski and Stoyva (1970, 1973) trained tension headache sufferers to decrease activity in the frontalis muscle using EMG feedback information about muscle tension provided to subjects and home practice. Subjects reported a decrease in headache activity as well as a decrease in overall arousal levels. Raskin, Johnson, and Rondestvedt (1973) used EMG frontalis feedback with patients suffering from chronic anxiety. Although their results failed to support the efficacy of this technique for reducing anxiety, other related symptoms, such as insomnia and tension headaches, did show major improvements. Moeller and Love (1973) studied the effects of frontalis muscle relaxation on blood pressure levels in hypertensive patients. They found significant decreases, both clinically and statistically, in diastolic blood pressure.
levels which corresponded to the lower muscle tension levels of the frontalis. Wickramasekera (1972), using only biofeedback training on the frontalis, found that patients were able to reduce the frequency and intensity of tension headaches when supplied with contingent EMG auditory feedback. Sargent, Walters, and Green (1973) report similar results in their studies with tension headache sufferers. Lendell Braud (1978) found that using either biofeedback training on the frontalis or progressive relaxation resulted in significant reductions of muscle tension in children diagnosed as hyperactive. In addition, significant reductions were also seen in the areas of hyperactivity, distractability, irritability, explosiveness, aggressivity, and emotionality. It also appears that EMG frontalis biofeedback training is effective in reducing responses to stress. McGowan, Haynes, and Wilson (1979) found that subjects were able to reduce resting levels of frontal EMG and frontal EMG response to stress.

While biofeedback techniques show a great deal of promise in the field of psychosomatic medicine, the question of durability and maintenance of treatment effects arises. For biofeedback to be beneficial it must be demonstrated that individuals can continue to show control over internal behaviors across time and settings. Budzynski et al. (1973) found that after a three month follow-up, treatment effects (the learned response was relaxation) did generalize to the patients' home surroundings. In this study home practice was also a part of the training along with the EMG training on the frontalis muscle. Elder and Rutz (1973) found that conditioned reductions of diastolic blood pressure persisted for one week, however, they presented no results that indicated these reductions were related to any improvement in the subjects'
hypertension. Kondo and Canter (1977) incorporated a 12 month follow-up into their study of patients suffering from tension headaches and found that four of the five subjects contacted from the original true feedback group reported continued reduction of headaches. In general, only clinical case studies have presented follow up results; in more experimentally oriented studies, follow-up data are typically lacking. Consequently, the available literature is still inconclusive as to the lasting effects of biofeedback techniques.

The Present Experiment

In trying to increase the durability of the biofeedback response researchers have looked at several different options. One involves the combining of more than one technique. Using biofeedback in conjunction with progressive relaxation, home practice, autogenic suggestion or biofeedback training on several sites are just a few of the possibilities. A second option would be the use of partial reinforcement. In operant conditioning research, schedules of reinforcement have been shown to affect the durability of the conditioned response (Williams, 1973; Jenkins & Stanley 1950). Generally speaking, intermittent schedules produce greater resistance to extinction than continuous reinforcement. Surprisingly, few researchers have investigated the possibility of promoting durability of biofeedback effects using intermittent reinforcement. In measuring electrodermal control of spontaneous skin potential response (SPR), Shapiro and Watanabe (1973) found that regulated patterns of spontaneous autonomic activity developed during training and maintained through extinction periods. Few researchers, if any, have systematically varied the amount of reinforcement.

The present study was concerned with the maintenance of biofeedback
effects and compared continuous and intermittent biofeedback reinforcement on EMG frontalis activity. The design of the study allowed for between as well as within subject comparisons. It was expected that the use of intermittent schedules would increase the durability of EMG changes relative to continuous reinforcement after formal biofeedback training had been discontinued. The study included an extinction phase to see if this was the case.

Method

Subjects

Four large psychology classes were visited by the experimenter to obtain subjects. During these visits male and female students interested in learning how to relax were asked to leave their name with the professor. The students were informed of the amount of time required from them (e.g. the number and length of the training sessions) and that the experiment was concerned with how people learn to relax using a technique called biofeedback. The students who had left their name were contacted, and a meeting was arranged for further explanation of the experiment. The meeting re-emphasized the amount of time required from students who would be participating in the study. Those still interested were asked to leave a list of the hours that they would be available for the experiment. The prospective subjects were then shown the equipment and given a brief explanation as to its use. Approximately 30 students were scheduled for three sessions each of baseline EMG measures. Twenty-two students completed the sessions and the 14 with the highest readings were selected to be subjects for the study.

Design

The dependent variables were (a) total time in seconds spent below
criterion per session and (b) integrated EMG microvolt readings. The experiment was divided into three sections: acquisition, treatment, and extinction with each section analyzed separately. The between-subject variable (A) for both dependent measures consisted of the two types of reinforcement schedules, (a) CRF and (b) FI 30". The with-in subject variable (B) for both dependent measures consisted of nine repeated measurements taken during the course of the study, one at the end of each session. Three measurements occurred during acquisition, two during treatment, and four during extinction. The second with-in subject variable (C) for the EMG microvolt data only consisted of five separate measures taken during each session. Fourteen subjects (3 males and 11 females) were randomly assigned to one of the two experimental groups (variable A) yielding seven subjects per experimental condition.

**Apparatus**

Sessions were conducted in an 8' x 12' (1.83 m x 3.66 m) air conditioned laboratory. Subjects were seated at the outset of each session in a reclining chair. Rubbing alcohol and cotton balls were used to clean each subject's forehead. Three silver-silver chloride electrodes prepared with Biofeedback Technology, Inc. (BFT) #28 electrode cream were attached to the forehead by means of a velcro headband. A BFT electromyograph (EMG) and a time/period integrator were used to obtain periodic EMG microvolt readings. The experiment was run automatically using appropriate timing and logic devices. Electromechanical devices were also used to determine if a correct response was made and whether or not to reinforce that response. Automatic counters (by Testan and Colburn Electronics) were used to determine the number of excursions below criterion and the amount of time spent below criterion for each session.
Procedure

Baseline. Three separate 10 min. baseline sessions were held for each prospective subject to determine normal frontalis activity. Baseline sessions were scheduled on three consecutive days and lasted for 15 min., 10 min. for measures and 5 min. for preparation and clean up. At the beginning of each session the prospective subject was instructed to remain quiet and move as little as possible while trying to relax. During these sessions 20 separate measurements were made at 30 sec. intervals using EMG electrodes attached to the frontalis muscle. A mean reading for each session was determined from these observations. The 14 subjects with the highest readings were then used for the study. Each subject's overall mean EMG was computed from the three baseline sessions and was used as his initial criterion for receiving the feedback stimulus.

Acquisition. Subjects received three sessions of biofeedback training on the frontalis muscle using continuous auditory feedback stimulus (Alexander, 1973). Instructions for tone training were given to each subject as follows:

The purpose of this study is to find out if people can learn to control the amount of activity or tension in the forehead area. You will try to learn to control the amount of activity in this region. In order to help you learn, we will supply you with information concerning the amount of activity in the forehead region. Each time the activity is below a specified criterion you will hear a tone. If there is too much activity, there will be silence. Your job is to find out what turns the tone on and keeps it on because this means there is very little activity in the forehead region and that you are doing a good job. Decreasing the amount of activity will demonstrate your control over the amount of activity in the forehead region. Try to eliminate those things that turn the tone off. Do not try too hard or this will defeat your goal of control over that region. Again try to keep the tone on and do not let your mind wander. This session will last for 30 min. Try not to go to sleep. Are there any questions?

Repeated EMG readings were taken during the entire session at five min.
intervals, with each measure taken for 30 sec. Previous experience of the experimenter had shown that following the final cessation of a feedback stimulus, i.e. at the end of the session, EMG readings tend to increase briefly.

Following each training session new criterion values were determined for each subject. The mean for the five measures taken during a given session was that subject's criterion for his next training session. If a subject was able to remain below threshold 50 out of 60 sec. for five consecutive min. his criterion was lowered by 1.2 microvolts. This shaping procedure was used to enable the subjects to learn to control frontalis muscle activity.

During training all subjects received reinforcement (tone) each time and for as long as they made a correct response. A correct response was defined as decreasing frontalis muscle tension below the subject's preestablished criterion, as noted above. An increase above criterion level terminated reinforcement until the next correct response was made. The first dependent variable, EMG readings, was measured using the following procedure. Five 30 sec. measures were taken at 5, 10, 15, 20 and 25 minutes into each session. The second dependent variable, total time spent below criterion, was also recorded for each session.

Treatment. Upon completion of the training phase subjects were matched according to their baseline measures and sex. They were then randomly assigned to one of the two groups, CRF or FI 30". Subjects received two treatment sessions under these conditions.

Subjects assigned to the CRF group received biofeedback training as described in the training phase with the same set of instructions. Subjects assigned to the FI 30" group received reinforcement on a fixed-interval 30"
schedule. Subjects assigned to the intermittent reinforcement group were informed of the change in contingencies as follows:

As before, you will be trying to control the amount of activity in the forehead region. Each time that you are able to keep the amount of activity below a specified criterion for a total of 30 sec., three sets of 10 consecutive sec., you will hear a tone for three sec. Your job is to try and control the activity so that you will hear as many of the 50 possible tones as you can. When you hear the tone, you will know that you have kept the activity in the forehead region down to a minimum for at least 30 sec. and that you are doing a good job. Remember the techniques you used in the previous sessions and try to use them. Do not try too hard or this will defeat your goal of control over the forehead region. Do not let your mind wander and try not to fall asleep. This session will last for 30 min. Are there any questions?

Repeated EMG readings were taken during the entire session at 5 min. intervals, with each measure lasting 30 sec. Subjects in both groups had one set criterion value for the entire treatment phase, their own overall mean EMG reading from the last training session.

Subjects in the CRF group received reinforcement (tone) each time, and for as long as, they made a correct response (as described in the training phase). Subjects in the FI 30" group received three sec. of reinforcement each time they remained below criterion for three consecutive intervals of 10 sec. Five 30 sec. EMG readings were taken at 5, 10, 15, 20, and 25 min. into each session. The total time spent below criterion was also recorded for each session.

Extinction. Each subject received four sessions of no feedback following the treatment phase, two sessions per week for two weeks. These sessions were scheduled one week after the last treatment session. Dependent measures were recorded as before. All subjects were given the following instructions:

As before, you will by trying to control the amount of activity in the forehead region. This time, however, there will be no tone to tell you how you are doing. Try to use whatever techniques you found
successful in the previous sessions. Do not try too hard or this will defeat your goal of control over the activity in the forehead region. Do not let your mind wander and try not to fall asleep. This session will last for 30 min. Are there any questions?

Results

The results of the study are shown in Figures 1 - 7. The two dependent variables were analyzed separately using a split-plot (SPF) ANOVA (Kirk, 1968). The experiment was divided into three sections, acquisition, treatment, and extinction. Each section is described separately.

EMG Scores

The acquisition phase was analyzed using a SPF 2.5 ANOVA with treatment as the between subject variable and within session scores as the within subject variable. The across session scores were averaged over the three sessions as a result of equipment failure. Analysis revealed that there were no significant differences between groups over the acquisition phase. Within session analysis showed significant decreases in EMG scores $F(4,48) = 2.64, p<.05$, from the start to the finish of each session (see Figure 1). That is, subjects from both groups demonstrated improved ability to decrease frontalis muscle activity from the beginning to the end of each session. There were no significant interactions.

A SPF 2.2 5 analysis of the treatment phase revealed essentially the same results as the acquisition phase (the between subject variable being CRF vs. FI 30", the first within subject variable being across session scores, and the second within subject variable being within session scores). There were no significant differences between groups, that is, after using separate schedules of reinforcement, both groups remained essentially the same (see Figure 2). No significant differences were found across the two sessions showing that no change occurred from one session to the next (see Figure 2). As with the
AVERAGED EMG SCORES WITHIN SESSIONS FOR TRAINING PHASE

WITHIN SESSION

FIG. 1 Mean levels of frontalis EMG activity within session for the training phase in microvolts
FIG. 2 Mean levels of frontalis EMG activity across sessions in microvolts
acquisition phase, significant differences were found within sessions, $F(4,48) = 10.2, p < .01$ (see Figure 3). None of the interactions were significant.

Analysis of the extinction phase using a $SPF$ 2.4 5 (the between and within subject variables being the same as mentioned in the preceding paragraph) again showed no differences between groups nor across sessions (see Figure 2). Significant differences were found in two areas. Within session changes were significant, $F(4,48) = 3.56, p < .01$ (see Figure 4). An interaction of all 3 variables; between groups, across sessions and within sessions was significant, $F(12,144) = 2.81, p < .01$. The latter indicates that EMG scores were dependent on which group a subject was in, which extinction session the score occurred in, and at which time during the session it occurred. No other interactions were significant.

Because of the significant three-way interaction, a test of simple main effects was performed. This analysis revealed three significant differences. For the CRF group there was a significant increase in EMG scores over the five within session measures during the second extinction session, $F(4,192) = 2.51, p < .05$ (see Figure 5) and a significant decrease over the five within session measures during the fourth extinction session, $F(4,192) = 3.0, p < .05$ (see Figure 5). For the $FI_{30}$ group there was a significant decrease in EMG scores during the second extinction session across the five within measures, $F(4,192) = 2.51, p < .05$ (see Figure 6). Two significant interactions were also found in the test of simple main effects. During the second extinction session there was a significant interaction between the two groups across the five within session measures, $F(4,192) = 4.95, p < .01$. This interaction was alluded to previously with the significance of the simple main effects for the CRF group and the $FI_{30}$ group during session two. The final significant interaction occurred in the CRF group. The significant simple main effect of the second extinction session for
FIG. 3 Mean levels of frontalis EMG activity within session for the treatment phase in microvolts
AVERAGED EMG SCORES WITHIN SESSIONS FOR EXTINCTION PHASE

FIG. 4 Mean levels of frontalis EMG activity within session for the extinction phase in microvolts
FIG. 5 Mean levels of frontalis EMG activity within session during extinction for the CRF group in microvolts.
FIG. 6 Mean levels of frontalis EMG activity within session during extinction for the FI 30" group in microvolts
the CRF group is related to this interaction, which occurred across all four sessions and the five within session measures, $F(12,144) = 2.55, p < 0.01$ (see Figure 5).

**Duration Below Threshold**

The acquisition phase was analyzed using a SPF 2.3 ANOVA with treatment as the between subject variable and across session scores as the within subject variable. Analysis showed that there was no significant difference between treatment groups nor across training sessions. In other words both groups remained basically the same at the end of training (see Figure 7).

During the treatment phase the results remained unchanged. There were no differences between groups nor across session, using a SPF 2.2 analysis. Again the two groups were not diverging from one another in ability to perform the response (see Figure 7).

Analysis of the extinction phase using a SPF 2.4 revealed a significant difference between groups, $F(1,12) = 6.91, p < 0.05$ indicating that the FI 30'' group was able to maintain performance of the response more effectively than the CRF group (see Figure 7). No differences were found across the four extinction sessions. There were no interactions.

**Discussion**

The results of this study suggest that using an intermittent schedule of reinforcement enhances the durability of a biofeedback learned response. Though the results of lowered EMG levels are inconclusive, time spent below threshold during extinction was greater following intermittent reinforcement.

As expected, there were no differences between groups in EMG levels during the acquisition phase. The purpose of this phase was to train the subjects in the use of an electromyograph. It was a learning phase. Both groups showed
FIG. 7 Mean time in seconds spent below threshold across sessions.
improvement from the start of a session to its finish, when both groups were under the same contingencies. Jenkins and Stanley (1950) in their survey of the available literature on partial reinforcement found that response strength is built up somewhat more rapidly under a schedule of 100% reinforcement (in this case continuous tone feedback) than under a partial regime.

It was expected that changes between the two groups would begin to appear during the treatment phase. The second group was given a new task, and it was expected that initially they would show less control over the relaxation response. As with the acquisition phase, within session changes showed learning taking place from start to finish of each session.

During the extinction phase there was the expectation of a significant difference between the groups. However, statistically there was none. Two circumstances could be related to the lack of significant change. All subjects were participating in final exams during the last week of extinction and seemed to be under greater stress. No measures were taken to validate this hypothesis. However, in comparing means from session one and session nine, one finds that for both groups the session nine means were the greater of the two (session one CRF = 8.9, FI 30" = 9.2; session nine CRF = 15.4, FI 30" = 10). This could be indicative of the greater stress that the students were experiencing at that time. A second possibility was that the treatment phase was not long enough to allow learning to take place. Tests for extinction are generally administered when there is evidence that responding is stable under acquisition conditions and are run for relatively lengthy periods on large number of trials (Morely, 1979). It is not clear from the data that the subjects achieved acquisition of the defined response, decreasing frontalis muscle tension below criterion. There was also no
confirmation that the subjects' responding had stabilized before extinction procedures were instituted. The literature indicates that the frontalis muscle is one of the hardest muscles to control (Balshan, 1962). Several of the subjects never seemed to have learned the response of turning on the tone as shown by the inconsistent scores from session one to nine. In future research, one way to increase the likelihood of subjects learning the response is to require that they decrease their EMG level by a reasonable percentage before introducing intermittent reinforcement rather than specifying an arbitrary number of sessions in advance. Morely (1979) suggests either training groups to the same criterion or using a statistical correction in which performance at the termination of training is entered as a covariate in the subsequent analysis of extinction responding. Either procedure would allow for the necessary equating of the two groups in order to study extinction legitimately.

The variable of time spent below threshold indicates that intermittent reinforcement does increase the durability of the response. As with the EMG variable, there were no changes expected or presented in the training or treatment phases. During the extinction phase the FI 30's group spent considerably more time below threshold than did the CRF group. These results indicate that subjects receiving intermittent reinforcement as a part of their training maintained frontalis activity below their criterion for a longer period of time in the absence of external support from reward than did the group receiving continuous reinforcement.

As of this time very little research has been done on schedules of reinforcement as a means of weaning subjects from biofeedback and producing greater retention of learning. Matthew Janicki (Note 1) compared a fixed ratio
schedule with continuous reinforcement to decrease heart rate using biofeedback techniques. His hypothesis that there would be greater retention of the learned response for the fixed ratio group was not confirmed. His recommendations for future research were (a) have a sufficient number of sessions for subjects to adequately master the desired response, (b) wean subjects from reinforcement only at subject specific increments, and (c) use a clinical population that has a vested interest in reducing the effects of the response in question. This last recommendation would be inappropriate for studying the partial reinforcement effect.

Few, if any conclusions can be drawn from the evidence with respect to the partial reinforcement effect phenomena in human biofeedback learning. This is due mainly to the paucity of data that is methodologically sound. It is therefore, difficult to determine if partial reinforcement does increase durability of responding in this area. The lack of concrete conclusions as to the efficacy of the biofeedback technique is also the result of too few rigorously designed studies (Miller, 1978). Studies in biofeedback do indicate some positive effect. The ultimate value of biofeedback training may be that it allows the individual to pinpoint sources of stress and the motivational bases for the symptoms rather than dealing directly with symptoms. This could easily lead to the discovery of measures to alleviate them. Generalizing this format of pinpointing undo stress could be generalized to society and perhaps effect public health.
Footnotes

1 There appear to be two distinct properties of reinforcers; one corresponding to biological/motivational gain and a second having connotations of information about the correctness of a response (see Morley, 1979). The feedback used in biofeedback experiments usually falls into the information category.

2 As a result of equipment failure, two subjects' scores in the CRF group were calculated and the mean for that group in session one is an approximation based on those calculations.
Reference Note

References


