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AN INSTRUMENT FOR PRODUCING DEEP MUSCLE RELAXATION BY MEANS OF ANALOG INFORMATION FEEDBACK[1]

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An instrument that assists subjects in attaining deep muscle relaxation by means of analog information feedback is described. Subjects hear a tone with a pitch proportional to the electromyographic activity in a given muscle group. Results showed that subjects receiving this type of analog feedback reached deeper levels of muscle relaxation than those receiving either no feedback or irrelevant feedback. The basic method employed—electronic detection, immediate information feedback, and systematic shaping of responses—would seem potentially applicable to a variety of physiological events, and might be useful both in behavior therapy and in certain psychosomatic disorders.

This paper describes the operation of an instrument that assists subjects in reaching deep levels of muscle relaxation by means of analog information feedback. The new device, which permits measurement of muscle action potential levels on a trial-by-trial basis, directly incorporates two major principles of operant conditioning: immediate knowledge of results and the gradual "shaping" of responses.

Such a shaping of the muscle relaxation response is of interest because it suggests that operant conditioning techniques may be successfully applied to certain events within the skin of the organism as well as to externally visible responses. Perhaps such application to private events may develop into a major new point of departure for operant techniques; if human subjects can be taught greater control over their internal environment, then the practical applications are considerable.

Although the basic technique outlined is potentially applicable to a variety of physiological responses, we decided for practical reasons to focus the beginning investigations on muscle activity. The latter has been extensively employed in several therapies of substantially independent origins: progressive relaxation, autogenic training, and the behavior therapy technique known as systematic desensitization. At the core of each of these three approaches is a strong emphasis on deep muscle relaxation, which is said to be useful in diminishing anxiety, in producing drowsy sleep-like states, and in treating certain stress-related psychosomatic disorders.

In behavior therapy, which has rapidly developed into a major therapeutic approach, deep muscle relaxation is employed extensively. Thus, in the desensitization technique developed by Wolpe (1958), the variant of behavior therapy most commonly employed with adult patients, deep muscle relaxation is utilized because it is said to be incompatible with the presence of anxiety.

The major recommendation of behavior therapy is that it seems to work, at least for certain disorders. Practitioners report successes in the order of 80 to 90% with neurotic patients (Wolpe and Lazarus, 1966). Systematic desensitization, however, is not without its problems. Particularly important are some issues, and difficulties, relating to Wolpe's central assumption about muscle relaxation. Even granting the validity of Wolpe's basic assumption about the incompatibility of anxiety and deep muscle relaxation, supported by the earlier work of Jacobson (1938), and the autogenic training literature (Schultz and Luthe, 1959), certain problems remain. Two questions, in particular, are likely to be significant: (1) How does the therapist actually know whether muscle relaxation is present or not? The usual way is for the patient to signal that

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he is relaxed. However, the demand characteristics of the behavior therapy situation are such that the patient is likely to indicate a condition of relaxation even in its absence. (2) What happens if the patient experiences difficulty in learning deep muscle relaxation? A common problem is that the patient is not able to tell whether a particular muscle is tense or relaxed. At the same time, it is difficult for the therapist to judge accurately whether the patient's muscles are tense or not. Consequently, the learning of muscle relaxation may be slow or may not occur at all.

INSTRUMENTATION

In view of the central importance of deep muscle relaxation in behavior therapy, and in light of the difficulties sometimes attendant on the induction of deep muscle relaxation, we proposed to develop an instrument with the following characteristics: (1) There would be continuous tracking of levels of muscle action potential. (2) The patient would receive precise and immediate analog information feedback from a given muscle. (3) The information feedback would be in the form of a tone with a pitch varying with the level of muscle activity. (4) The gain of the feedback loop would be adjustable to permit gradual shaping of the deep relaxation response. (5) The system would permit continuous quantification of performance as measured by levels of muscle action potential from trial to trial. Such a system would make possible an objective nonverbal indicator of relaxation. Also, the use of analog information feedback might serve to accelerate and intensify the process of relaxation.

In designing the system, we decided to use analog rather than digital feedback. The basic reason for this choice was that an analog signal provides more information. With a digital (on-off) signal, such as that previously employed in the feedback control of levels of muscle action potential (Hardyck, Petrinovich, and Ellsworth, 1967); and in the feedback control of the alpha rhythm (Stoyva and Kamiya, 1968), it is possible for the subject to be very close to some specified criterion level without being aware of it. However, with an analog information feedback system, the pitch of the tone would alter as the subject approached the criterion level. Therefore, the subject would be able to repeat whatever he was doing to make the quality of the tone change in the desired direction. Such an analog feedback system should be particularly useful in those instances where the response to be mastered is a very subtle one.

The essential function of the system shown in Fig. 1 is to provide the subject with a con-

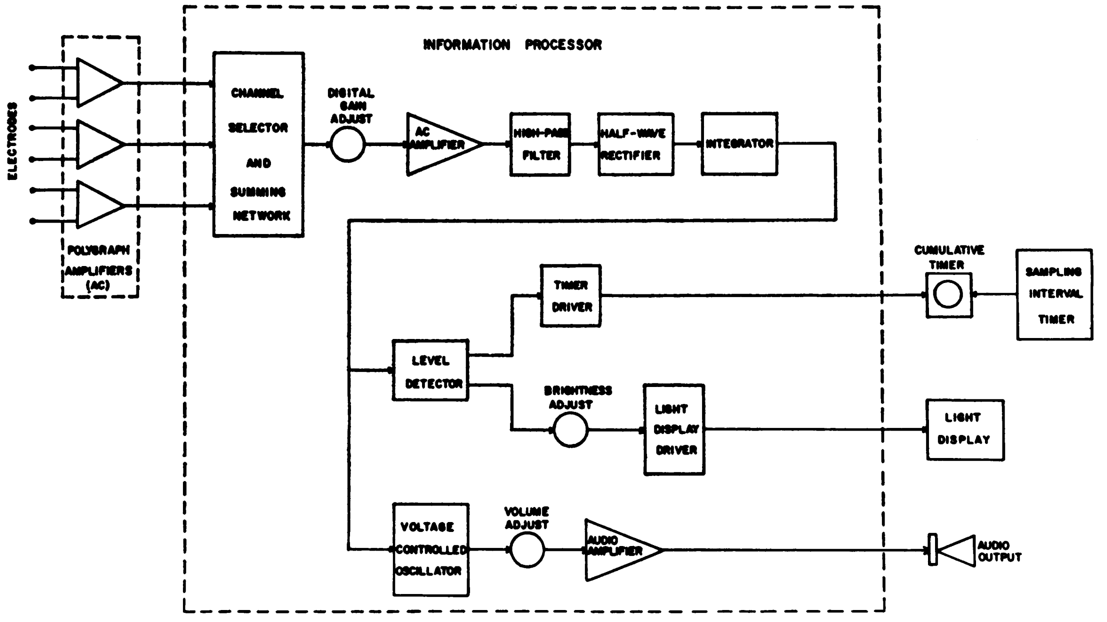

Fig. 1. Functional diagram of analog information feedback system for producing deep muscle relaxation.

stant volume tone that varies in pitch as electromyographic (EMG) activity changes. That is, the pitch of the tone tracks the level of muscle activity; for example, as EMG activity decreases the pitch becomes lower, as activity increases the pitch becomes higher. It was decided to present the feedback information within the pitch rather than the volume continuum because the range of volume excursions that could be expected would hardly be conducive to relaxation. Consequently, a voltage controlled oscillator was designed to convert the integrated muscle action potential into an audio signal varying in frequency. The subject thus receives constant analog information with respect to his level of EMG activity.

As shown in Fig. 1 functional diagram, Grass amplifiers are used to boost the muscle action potentials picked up with surface electrodes in bipolar configurations.

External to the Grass units is the information processor. The channel selector allows the signals from electrode sites 1, 2, or 3 to be processed individually, or any combination of the three may be summed and processed. The gain of the feedback loop is varied by a 10-turn precision potentiometer equipped with a digital microdial readout. Later, conversion curves are utilized in order to transform the minute-by-minute microdial readings into absolute levels of muscle action potential in microvolts. The high-pass filter rejects frequencies below 30 Hertz (12 db down at 20 Hertz) thus eliminating lower frequency artifacts such as caused by movement and cortical EEG rhythms (in the facial region). The Grass amplifiers provide high frequency roll-off (approximately 3 db down at 100 Hertz).

The signal is next rectified and then integrated with a simple RC integrator that effectively tracks the average value of the signal. At this point, the resulting fluctuating dc voltage is converted to an audio tone, the frequency of which is proportional to the dc level. The integrator output is also sensed by a level detector that energizes a red light (visible only to the experimenter in the present study) when the dc signal rises above a certain level and allows a timer to run whenever the dc level is below this level. The timer thus accumulates the time spent in the low frequency (low levels of muscle action potential) end of the audio range. A second timer sets the length of the trials, 1 min in the present study. The gain is adjusted so that the subject can "score" from 45 to 55 sec per minute trial. Gain setting and timer accumulation readings are taken after each 1-min trial. A precise quantification of the subject's progress can thus be obtained.

A key feature of the instrument is the shaping procedure incorporated into the system. Readings are taken each minute, and the gain of the feedback loop is gradually increased as the subject progresses, making the task more difficult in the sense that the subject must progressively decrease his level of muscle action potential in order to keep the tone at the lower frequencies. The subject's behavior is thus being shaped in the sense that the gain is carefully adjusted each minute so as to maintain performance at the low tone level approximately 85% of the time. This latter figure was found in the pilot studies to be a criterion that would not produce frustration and yet would allow learning to occur.

As a final step in data collection, the subject's microdial gain settings for each successive trial are converted into absolute levels of muscle action potential in microvolts by means of conversion curves (derived by introducing 50-Hertz calibration signals of known voltage into the system). The resulting absolute levels of muscle action potential readily lend themselves to graphic representation as may be seen in Fig. 2.

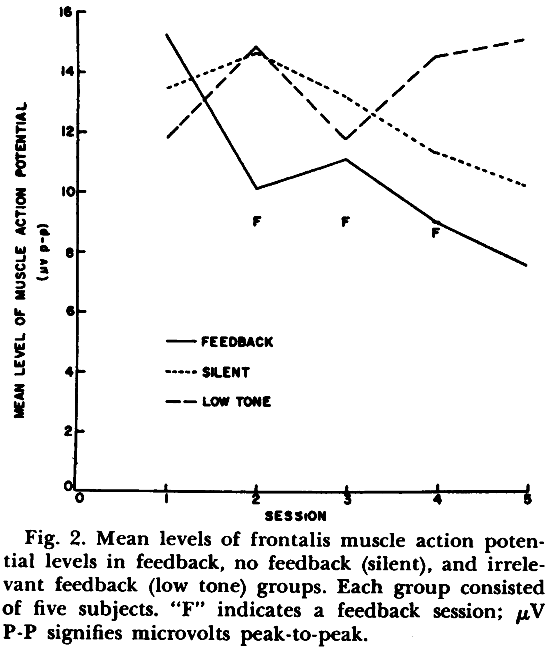

Fig. 2. Mean levels of frontalis muscle action potential levels in feedback, no feedback (silent), and irrelevant feedback (low tone) groups. Each group consisted of five subjects. "F" indicates a feedback session; μV P-P signifies microvolts peak-to-peak.

METHOD

The primary purpose of this article is to describe an analog information feedback instrument incorporating the operant conditioning principles of immediate knowledge of results and the systematic shaping of responses. However, in order to indicate the feasibility and potential usefulness of the feedback device, data are reported for 15 subjects, each of whom was told to lie quietly with his eyes closed and to concentrate on deeply relaxing his frontalis (forehead) muscle.

One reason for choosing the frontalis was that this muscle is said to be difficult to relax deeply (Balshan, 1962). If, however, subjects could learn to achieve a high degree of control over this hard-to-relax muscle, then the feedback procedure should presumably be readily applicable to other less-difficult muscle groups.

Electrodes were placed 1 in. above each eyebrow and spaced 4 in. apart on the subject's forehead. Resistances were 10,000 ohms or less. All recordings were taken at approximately the same time of day, late afternoon or early evening, and the successive sessions, which each consisted of 20 one-minute trials, were separated by at least one day and not more than three days.

Instructions to the Subjects

The experimental group was told that the pitch of the tone would vary with the level of muscle tension in the forehead. They were told to relax as deeply as possible and to keep the tone low in pitch.

The constant low tone, irrelevant feedback group was told to relax deeply, especially the forehead muscle, and were also told that the monotonous tone would help them to relax.

The silent group was told to relax as deeply as possible, especially the forehead muscle.

Subjects were paid $1.50 for each session, and were also instructed that a bonus would be given scaled according to rank in the group of 15; the lower the muscle action potential levels, the larger the bonus.

Subjects lay on a bed in a dimly lighted, electrically shielded room. The 20 trials in a given session were automatically sequenced, and no subject-experimenter interaction took place either during or between trials.

Each of the 15 subjects was randomly assigned to one of three groups; the experimental group, which received correct feedback; the first control group, which received no feedback, and the second control group, which received irrelevant feedback.

All subjects were initially recorded from the frontalis on two separate occasions without any feedback. The mean level of muscle action potential for the second session was then used as the baseline because it was assumed that subjects would be better adapted to the laboratory situation by their second day in the experimental setting.

After the baseline session (designated Session 1 in Fig. 2), each subject was recorded for four additional sessions. The five experimental subjects received information feedback on Sessions 2, 3, and 4. For this group, in Sessions 3 and 4, several silent trials were regularly interspersed (trials 11, 14, 16, 19, 20) in order to increase the resistance to extinction of the relaxation response. In the first control group, the five subjects received no feedback in any of the sessions. In the second control group, the five subjects received irrelevant feedback, a steady low tone of the same pitch as that which the feedback group heard 85% of the time. Also, as with the experimental group, these subjects had several silent trials that were regularly interspersed (trials 11, 14, 16, 19, 20) in Sessions 3 and 4. Session 5, the last day, was silent for all 15 subjects and was used to compare post-training levels of muscle action potential resulting from the three earlier treatment conditions.

Although other studies involving information feedback training (Engel and Hansen, 1966; Lang, Sroufe, and Hastings, 1967) have employed yoked controls, pilot observations in the present experiment, in which the aim was to produce relaxation, showed that a tone, rapidly fluctuating in pitch for no apparent reason, was irritating to many subjects and was likely to produce arousal rather than relaxation. Such pilot observations indicated that a more demanding control, in terms of helping the placebo-control group to rival the performance of the experimental group, was to present this control group with a steady low tone. Some pilot subjects had already spontaneously made suggestions along these lines, claiming that simply hearing a steady low tone would induce relaxation. This idea later proved to be quite plausible to the control subjects; they readily accepted the notion that a monotonous sound would help them to achieve relaxation.

RESULTS

Figure 2 shows that there were clear differences among the three groups with respect to mean levels of muscle action potential in Session 5 ($p < 0.009$; Kruskal-Wallis analysis of variance by ranks). Although the feedback group started with somewhat higher mean values of muscle action potential in session 1, the superiority of this group was apparent even on the first day of feedback (Session 2). This superiority in attaining low levels of muscle action potential continued throughout the remaining sessions.

Perhaps the most striking difference in the three groups was the *per cent* decline in muscle action potential levels. When baseline values were compared with post-training values (Session 1 *versus* Session 5), the feedback group showed a mean decrease of 50%, the no feedback group a mean decrease of 24%, and the irrelevant feedback group a mean increase of 28%.

Although, as Fig. 2 shows, the irrelevant feedback group had the poorest mean performance, the most salient characteristic of this group was its great variability—range of 6.1 to 28.4 μV in Session 5. For the feedback group, the range for Session 5 was 5.3 to 10.8 μV, indicating that correct feedback more reliably produced low levels of muscle action potential than did irrelevant feedback.

Further support for the statement that correct feedback more reliably produces deep relaxation than does irrelevant feedback, was demonstrated by comparing one of the subjects from the low tone group under both irrelevant feedback and correct feedback conditions. This subject, who had been one of the two poorest performers in the irrelevant feedback group, was provided with correct feedback training over four additional sessions (Sessions 6, 7, 8, and 9 in Fig. 3). For this subject, levels of muscle action potential had been high throughout the five regular sessions. But as may be seen in Fig. 3, the mean level dropped sharply on the first day of feedback training, and by the third day of correct feedback (Session 8 in Fig. 3), the mean level was down to 10.2 μV—less than 50% of the level for Session 5, and 60% of the level for Session 1, the baseline day.

An additional observation of interest, especially to electroencephalographers, was that cortical rhythms could be quite clearly distinguished in the forehead EMG after deep relaxation had been achieved. This phenomenon, although previously noted by Davis (1959), is difficult to observe under ordinary conditions because the dense, high-frequency muscle action potentials from the frontalis mask the cortical rhythms. After feedback training, however, most of the EMG activity drops out of the tracing. Then bursts of cortical frontalis rhythms, in particular *alpha* (8 to 12 Hertz) and *theta* (5 to 7 Hertz), are likely to become quite apparent.

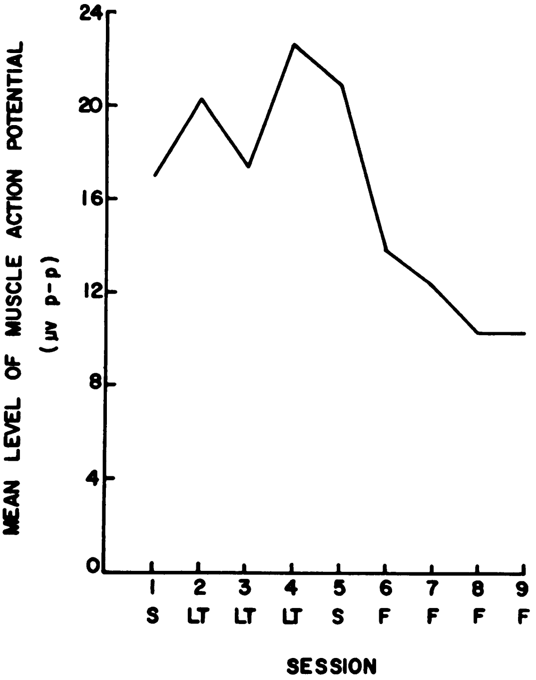

Fig. 3. Mean levels of frontalis muscle action potential in same subject under irrelevant feedback condition and, later, under correct feedback condition. Subject was one of the two poorest performers in the low tone group. "S" indicates a silent session (Days 1 and 5), "LT" a steady low tone session (Days 2, 3, and 4), and "F" a feedback session (Days 6, 7, 8, and 9). The ordinate, μV P-P, indicates microvolts peak-to-peak.

DISCUSSION

The present results are especially striking in view of a recent report by Jacobson (1967) on the effects of training in progressive relaxation. In this study, the patient was able to reduce muscle action potential levels in the jaw muscle by about 50% after one month of daily practice. Our own data for the frontalis, where it is ordinarily more difficult to achieve voluntary deep relaxation than with the much-used masseter, show that, with analog information feedback, subjects were able to reduce muscle potential levels to 50% of baseline line values after only three 30-min feedback sessions.

Although this experiment was not a direct test of the Jacobson procedure, the feedback technique should permit a precise comparison with the more traditional methods of relaxation training. Subjective reports from feedback subjects have indicated that, in most cases, deep relaxation of the frontalis muscle is followed by a generalization of the relaxation to other muscle groups. If this observation is later supported by more objective measures, it may be possible to train subjects in overall deep relaxation through feedback from one muscle group, rather than training on all muscle groups as in Jacobson's method.

The practical implication of these results would seem apparent. Systematic desensitization therapy, progressive relaxation, and autogenic training, in many independent studies have attested to the beneficial effects of profound muscle relaxation in alleviating a number of anxiety and stress-related disorders (Wolpe, 1958; Jacobson, 1938; Schultz and Luthe, 1959). A method for reliably accelerating and perhaps deepening the process of muscle relaxation could have widespread application. The analog feedback method should be particularly useful in producing relaxation in those patients who have proved resistant to conventional muscle relaxation training. This seemed to be the result in our pilot work with six anxiety patients who reportedly had been unable to acquire deep muscle relaxation after training with the modified Jacobson progressive relaxation procedure used by behavior therapists. Subsequent training with analog feedback appeared to enable all six to reach deeper levels of relaxation, whereupon systematic desensitization was begun by the therapist.

Another important application of the feedback system now being explored is its use as a monitor of degree of relaxation during systematic desensitization. Thus, the therapist can be reasonably certain that the patient is deeply relaxed before proceeding with each successive phase of the desensitization. It is also possible to set an upper limit on the amount of EMG activity permitted. Beyond this point the anxiety-evoking scene is terminated. With the establishment of this criterion it is not necessary to elicit any verbal report from the patient. A further advantage of this technique is that the criterion can be set low enough so that the patient experiences little or no anxiety during the entire session.

Certain psychosomatic disorders would seem promising candidates for a feedback approach; for example, tension headache, said to be associated with and perhaps caused by sustained contraction of the head musculature (Wolff, 1963; Ostfeld, 1962).

An additional merit of the analog information feedback system presented here is that it could presumably be adapted for use with a variety of physiological responses; the basic principles involved would be the same—precise detection of the response, information feedback, and systematic shaping. In light of Miller's (1969) work on the instrumental conditioning of a variety of autonomic responses in animals, the possibilities of using information feedback in teaching control of certain autonomic responses in humans would seem well worth exploring. Pertinent in this context is a recent statement (Brener and Hothersall, 1966) that an important determinant of where a particular response falls on the voluntary-involuntary continuum is the availability of sensory feedback from the response in question. A system such as the one described here should, in many instances, be able to supply the required feedback.

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