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Reduction of epileptic seizures following electromyographic (EMG) biofeedback training : preliminary study
by Patti Jo Bodine

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Psychology
Montana State University
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Abstract:
Electromyographic (EMG) biofeedback training of the tibialis anterior muscle was provided to a 24-year-old female epileptic patient. It was hypothesized that broadband EMG conditioning would induce motor cortical activity that would have the effect of normalizing the electroencephalographic (EEG) patterns in such a way as to reduce seizures. EMG and seizure activity were monitored and recorded in an A-B-A design. Results indicated an apparent lack of significant EMG conditioning, and uncontrolled parameters precluded an adequate and unique assessment of the seizure data. An improved strategy for further research of the issue is presented.

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Date January 3, 1980

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by

PATTI JO BODINE

A thesis submitted in partial fulfillment
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ABSTRACT

Electromyographic (EMG) biofeedback training of the tibialis anterior muscle was provided to a 24-year-old female epileptic patient. It was hypothesized that broadband EMG conditioning would induce motor cortical activity that would have the effect of normalizing the electroencephalographic (EEG) patterns in such a way as to reduce seizures. EMG and seizure activity were monitored and recorded in an A-B-A design. Results indicated an apparent lack of significant EMG conditioning, and uncontrolled parameters precluded an adequate and unique assessment of the seizure data. An improved strategy for further research of the issue is presented.

INTRODUCTION

Biofeedback techniques are based on the principles of operant or instrumental conditioning, in which reinforcement or reward is given whenever the desired conditioned response is elicited by a conditioned stimulus or a certain signal. In the human biofeedback loop,

> "... certain responses are made when informational feedback is received ... and these responses are adjusted, corrected, and modified as feedback is continually received until it is determined that a final goal has been reached." (Davidson & Krippner, 1971, p. 7)

This involves the use of visual and auditory electronic signals that reveal to human beings certain information concerning aspects of their internal physiological processes. The information provided by the signals is associated with the internal response that is being manipulated and can be utilized by the individual directly to control the level of functioning of the specific internal event.

Epileptic seizure disorders represent an internal event in which biofeedback techniques have been clinically applied as a form of treatment. Epilepsy "is a condition in which individuals are predisposed to recurring seizures," with the term seizure defined as "the transient dysfunction of the central nervous system that is associated with the abnormal increased firing of neurons" (Crill, 1976, p. 326). Through biofeedback techniques, previous work has

examined the use of operant conditioning of certain electroencephalographic (EEG) patterns recorded from the sensorimotor area of the cerebral cortex as a means for the control of seizures.

Research involving the conditioning of certain EEG patterns to reduce seizures developed from neurophysiological studies in cats that indicated the occurrence of a 12-16 Hz EEG rhythm, termed the sensorimotor rhythm or SMR, that was correlated behaviorally with phasic motor inhibition (Sterman & Wywricka, 1967; Wywricka & Sterman, 1968) and resistance to drug-induced seizures (Sterman, LoPresti & Fairchild, 1969). The use of SMR feedback training in human epileptics is a relatively new area of research that has produced evidence of both success and failure. Significant seizure reduction in epileptic patients has been reported by Sterman and Friar (1972); Sterman, Macdonald and Stone (1974); Finley, Smith & Etherton (1975; and Lubar and Bahler (1976); while Kaplan (1975) reported no clinical improvement with the SMR training. Kuhlman determined the mu rhythm of 9-11 Hz to be the human analog of the feline SMR (1978a), and reported significant seizure reduction by training the 9-14 Hz frequency range (1978b).

Wyler, Lockard, Ward and Finch (1976) hypothesized that a "critical mass" of neurons discharging in synchrony was needed for the development of an epileptic seizure. They proposed a general desynchronization or alerting hypothesis as the most parsimonious explanation for observed seizure reduction with EEG training. This is based on observations in

which epileptic activity appeared to be diminished by desynchronized EEG activity. Recently, Sterman and Macdonald (1978) concluded that a "concept of EEG normalization" might provide an explanation for the therapeutic effects reported. This concept is based on the assumption that enhancement of normal EEG patterns may provide protection against abnormal discharges. Kuhlman (1978b) suggested that positive results obtained in studies utilizing feedback for a given band of EEG activity may have been due to such observed changes as: a) a reduction in the frequency of abnormal slow wave activity and the amount of abnormal epileptiform activity; and b) an increase of normal EEG synchrony and frequencies, all of which occurred outside the chosen frequency band. A review by Kuhlman and Kaplan (1979) stated,

> "There now appears to be a consensus that EEG normalization rather than selective enhancement of any specific frequency range of EEG activity is most clearly associated with reduced seizures." (p. 80)

The approach taken by the majority of studies associated with epileptic seizure reduction can be theoretically explained in terms of a "neural exercise" model, as opposed to a "voluntary control" model, as discussed by Kuhlman and Kaplan (1979). The neural exercise model predicts that a relatively permanent change in EEG patterns will occur as a function of practice. This model is founded on the assumption that the tonic EEG change will reduce epileptic EEG patterns associated with seizure occurrence and strengthen normal EEG activity. It

is also assumed that the EEG change will be sustained outside of the training environment and will be outside the limits of volitional control by the patient, in such a way that the patient will not be able to prevent or shorten a seizure by using a strategy or behavior acquired through training. According to Kuhlman and Kaplan (1979),

> "It appears that the most effective approach for training is becoming clear: 'normalizing' the EEG by suppressing epileptiform discharges and by enhancing 'normal' EEG activity." (p. 87)

The EEG analyses indicate, however, that despite favorable documented results, there is no single EEG rhythm or unique change in the EEG associated with seizure reduction in all patients. Coupled with this shortcoming is the recognition that EEG feedback training is considered to be most difficult and problematic due to the complexity of the human brain and the lack of understanding of even the most basic mechanisms involved in the generation of the EEG.

A consistent covariation between the activation of motor cortical cells and skeletal muscles during certain motor responses has been shown in the studies of Fetz (1969), Fetz and Finocchio (1971, 1975), and Fetz and Baker (1973), as discussed by Fetz (1976). Through the use of biofeedback conditioning techniques, monkeys were trained to contract specific muscles in isolation, and correlated activity of motor cortex cells was observed. The reverse experimental strategy was investigated by reinforcing activity of the cortical cell and observing the motor response. According to Fetz, these results provide evidence

of a functional relationship between the two elements. The strongest motor cortex cell-muscle correlations or reciprocal relationships found were those which involved the most intense coactivation of cells and muscle and those which appeared most consistently under different behavioral conditions. A useful finding showed that the strongest correlations or relationships could be changed by operantly reinforcing their dissociation. This indicates a degree of plasticity in the motor cortex cell-muscle correlations and suggests the relationship between the motor cortex and muscle activity to be a flexible one. Thus it appears that the system is not a rigid one and has the capacity to be shaped by conditioning.

At a conscious level, voluntary motor actions are composed in terms of goals, positions, and postures.

> "The motor cortex, with its direct and indirect connections to the spinal cord, must convert these and other 'orders' into command signals suitable for the motor neurons." (Henneman, 1974, p. 766).

It is known that neural influences converging onto a motor neuron arise from diverse areas, including muscle receptors, spinal interneurons, the reticular formation of the brainstem, the basal ganglia, and the cerebellum, as well as the cerebral cortex. However, within the nervous system,

> "... the highest level is the sensorimotor cortex [the motor cortex and the receiving area of the somatic sensory system considered together] which presides over the entire motor system." (Henneman, 1974, p. 605)

In spite of the fact that a simple neural model of motor control is not possible, the motor cortex is viewed as the primary control center for movement, particularly voluntary movement.

The review by Fetz (1976) suggests that muscle activity can exert an influence upon the neurons of the motor cortex, considered to be at the highest level of the motor system hierarchy. Neural activity induced in the cortex by muscle conditioning can perhaps act in the same way as does EEG conditioning of certain frequencies in the sensorimotor cortex. It is suggested that this action might serve to alter the overall EEG activity of the motor cortex in a direction towards generalized normalization. If normalization of the EEG activity does occur, it would be expected to cause a reduction in epileptic seizure activity. As is the case with the EEG conditioning techniques, this is based on the assumptions of the hypothetical neural exercise model, in which permanent and normalizing EEG changes are said to occur with training and to have the effect of reducing seizures.

In the present study it is hypothesized that muscle conditioning, as an alternative to previous methods of EEG conditioning, may produce EEG normalization with a predicted reduction in epileptic seizure activity. However, the EEG activity is not a measured variable in this study. Dependent variables include reported seizure activity and the measurement of electrical activity in the subject's tibialis anterior muscle, in which successful motor unit training has been reported

(Basmajian, 1972). Credence for the use of the tibialis anterior muscle is based on observations of trained motor units in the muscle which indicate that

> "... motor unit activity under conscious control can be easily maintained despite the distractions produced by voluntary movements elsewhere in the body." (Basmajian, 1967, p. 111)

The independent variable consists of auditory electromyographic (EMG) feedback provided to the subject, which is indicative of the increased electrical activity in the tibialis anterior muscle. Rationale for the use of feedback applied only for increased activity is explained in the procedures section of this paper.

METHOD

Subject History

The subject was a 24-year-old white female with a mosaic form of trisomy 21, complicated by epilepsy. The onset of epilepsy occurred at age 16 years with generalized seizures. The attacks have been characterized by an outcry, collapse with unconsciousness, an absence of involuntary movements, a duration of 30 seconds to three minutes, and after-effects of drowsiness and headache. Although the subject has had a gradual decrease in seizure activity, seizures have still continued with a frequency ranging from one to two per week to several per day. The subject, under the care of a physician, came as a referral for biofeedback therapy.

Epileptic seizures in an individual patient are classified on the basis of the clinical manifestations of the attacks and the EEG pattern. The symptoms of the subject have been diagnosed by a pediatrician as indicative of grand mal epilepsy, by a pediatrician and research geneticist as petit mal epilepsy, and by a neurologist as temporal lobe epilepsy with seizures characterized as akinetic. The differing positions taken by the three physicians indicate the confusing and complex nature of this particular clinical case.

The subject's medication regimen at the beginning of experimentation included 200 mg of dilantin (phenytoin sodium) twice daily, 250 mg of mysoline (primidone) three times daily, and 200 mg of tegretol

(carbamazepine) three times daily. According to Woodbury and Fingl (1975), phenytoin and primidone are effective agents for the treatment of all types of epilepsy except for petit mal seizures; and carbamazepine has been found to control approximately two-thirds of patients with temporal lobe epilepsy, occurring alone or combined with generalized grand mal seizures. By the attending physician's orders, the subject's medication regimen was altered once, during the treatment phase, with dilatin and tegretol dosages gradually phased out while mysoline levels remained constant.

In 1978, the subject was placed under the care of an organization for developmentally disabled adults. It is noteworthy that the supervisors of the subject felt the majority of her seizures to be purposeful falls to attract attention, and they have utilized behavior modification techniques with reported success. The seizures reduced by these techniques appeared to have been precipitated by sensory stimulation, one of many factors known to cause seizures. Specifically, the subject has been observed to have seizures associated with her use of the telephone. Behavior modification was utilized by requiring her to make a certain number of telephone calls per day until her seizure behavior in this instance was diminished. Although this particular seizure behavior was modified, the subject's overall seizure status was not significantly altered.

Apparatus

The instrument used for the purpose of monitoring and displaying the ongoing EMG activity generated by muscle action was the Autogen 1700. Output of the Autogen 1700 was transferred to the Autogen 5100 digital integrator, in order to provide a computation of the cumulative averaged value of the EMG amplitude over 30 second time intervals. These computations were averaged, by the experimenter, across each session to furnish the necessary information for data analysis.

The selected bandpass was 20-1000 Hz. According to the Instruction Manual for the Autogen 1700 (1975), this setting "is intended for special research applications where broadband EMG monitoring and recording are desired" (p. 19). Although the tibialis anterior muscle was specifically chosen for training, it was not known whether conditioning the specific muscle was as important as conditioning a broader range of muscle activity. It was felt that by using the 20-1000 Hz bandpass, adjacent muscle activity to that of the tibialis anterior muscle could perhaps be conditioned, and this would have the potential of influencing a greater amount of the motor cortex. Basically, the idea was to condition as much muscle activity and influence as much motor cortex neuronal activity as possible.

The form of feedback used consisted of a variable pulsated analog tone that varied both in pitch and pulsation rate in logarithmic proportion to the EMG activity level. As the activity level increased,

the pitch rose accordingly and the pulsation rate increased.

The selected threshold was used to set an upper or lower EMG microvolt limit at which audio feedback would be activated. This determined maximum or minimum absolute levels for EMG activity required to activate the feedback signal. The level utilized for training was selected according to the subject's responses on the first day of the initial treatment phase.

Procedure

An A-B-A single case design was utilized, with the A phase corresponding to baseline recording of the EMG activity in the subject's tibialis anterior muscle and the B phase representing EMG training of the same muscle. The A-B-A design, the prototype of experimental single case research, "allows for an analysis of the controlling effects of a treatment's introduction and subsequent removal" (Hersen & Barlow, 1976, p. 176).

Initially, the design for the present study was an A-B-A-B plan, but this had to be modified to the A-B-A design due to the medical complications suffered by the subject in response to her medication change. Although there are disadvantages associated with this, such as ending on a baseline rather than a treatment phase and allowing only one occasion to demonstrate the effects of the treatment variable,

> "The A-B-A design is a useful research tool when time factors or clinical aspects of a case interfere with the

> correct application of the more comprehensive A-B-A-B strategy." (Hersen & Barlow, 1976, p. 177)

The subject was familiarized with both the experimental procedure and the equipment prior to the actual experimentation. The experiment was conducted at a designated time three days per week, with four days or sessions constituting a completed phase of baseline recording or EMG training. The decision to use four sessions per phase was based on time considerations and the comment by Hersen and Barlow (1976), that a minimum of three separate observation points are required to establish a trend in the data. During the baseline sessions, the subject, who exhibited an inclination to lose attentiveness and/or fall asleep, was given a book to read in order to help her maintain a state of concentration and alertness. During the EMG training sessions, the subject was instructed to produce and maintain the feedback sound and to make the sound pulsate faster. At periodic intervals, approximately every 8-10 minutes, the experimenter interrupted the training procedure to insure that the subject was maintaining an alert state and following instructions.

The EMG training sessions began with alternating intervals of feedback given in response to muscle activity increases or decreases. After two sessions, the subject's response pattern showed a tendency for muscle relaxation. Once an interval of feedback was given for muscle activity decreases, the subject was unable to initiate any

substantial increases in muscle tension. It is stated in Hersen and Barlow (1976) that a situation in which a trend is shown in the desired direction of training "does not allow for an adequate assessment of the intervention" (p. 78). In view of this information, the experimental design was modified to provide feedback only for increased muscle activity, a condition that was the reverse of the subject's indicated trend.

Reports of seizure occurrence were provided by the subject and by the attendents at a workshop that the subject participated in on a daily basis. The subject verbally reported the occurrence of any seizures she experienced to the experimenter when she would arrive at the laboratory. The workshop seizures were recorded at the time of occurrence by the witnessing personnel, and this information was collected by the experimenter weekly. Reliability of the number of seizure occurrences might be limited due to human factors such as personal bias, forgetfulness, conscious distortion, or unawareness. A pre-determined criterion value of a 50 percent decrease in seizure activity was arbitrarily set by the experimenter in order to show the effectiveness of the treatment intervention.

RESULTS

The averaged values for the subject's EMG activity are plotted in Figure 1. In order to compare the mean values of the baseline and feedback phases, the Wilcoxon Rank Sum Test (Wilcoxon, 1949), a nonparametric measure independent of the assumption of serial dependency, was applied to these values. There was not sufficient evidence at any probability level to say that the mean values of the phases differed.

The number of seizures reported daily are plotted in Figure 2. Since the phases of experimentation were of unequal time intervals, the improvement criterion was calculated on a daily basis. In the initial baseline phase (12 days), six seizures were reported, yielding an average of 0.50 seizures per day. According to the criterion level, seizure activity was then required to be reduced to an average of 0.25 seizures per day. The feedback phase (10 days), with three total seizures or 0.33 seizures per day, did not meet this predetermined criterion level.

A trend reflecting improvement in the subject's rate of seizure occurrence was noted over the final four days of the initial baseline phase.

> "The major problem posed by this pattern, from a research standpoint, is that application of a treatment strategy while improvement is already taking place will not allow for an adequate assessment of the intervention." (Hersen & Barlow, 1976, p. 78)

Indications of a trend in a direction towards increased seizure

occurrence are seen on the final day of the feedback phase. This type of trend also makes assessment of the treatment difficult.

Figure 1: Mean EMG activity of each session.

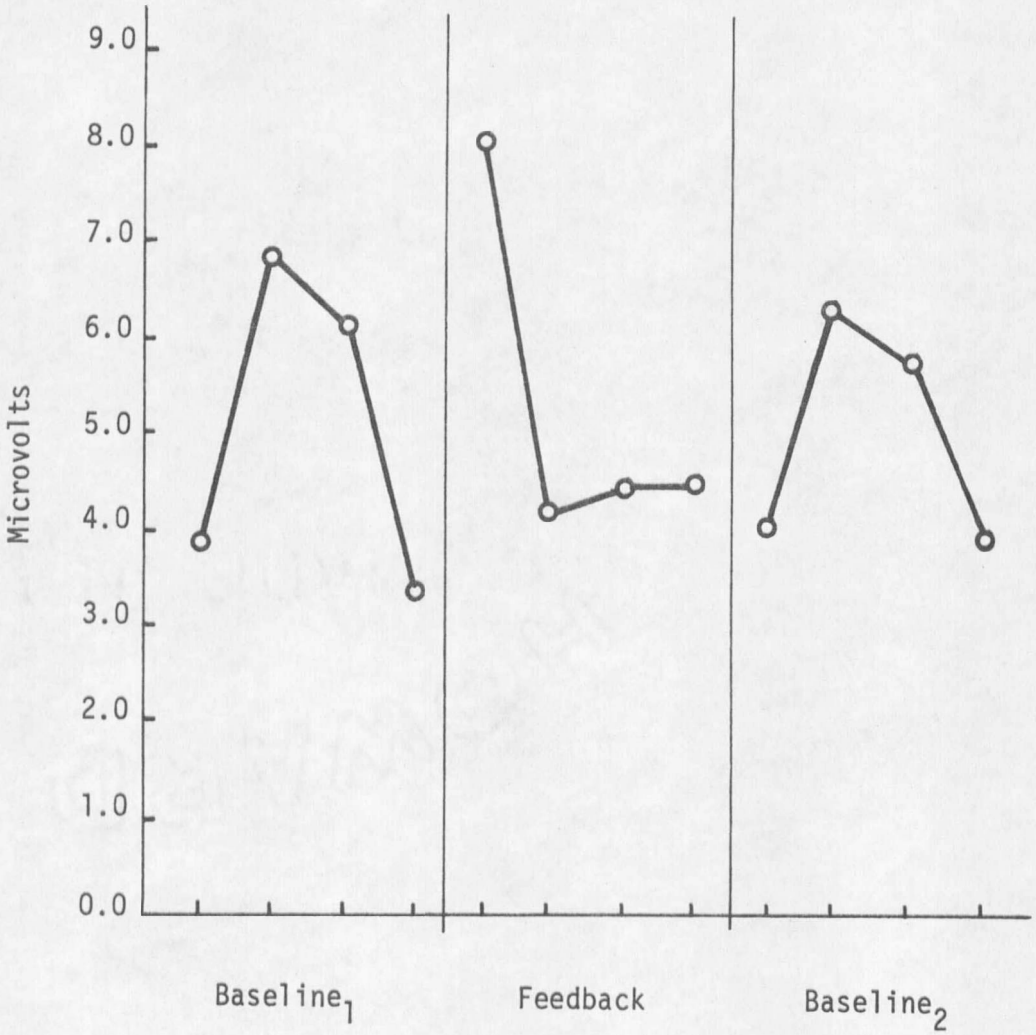
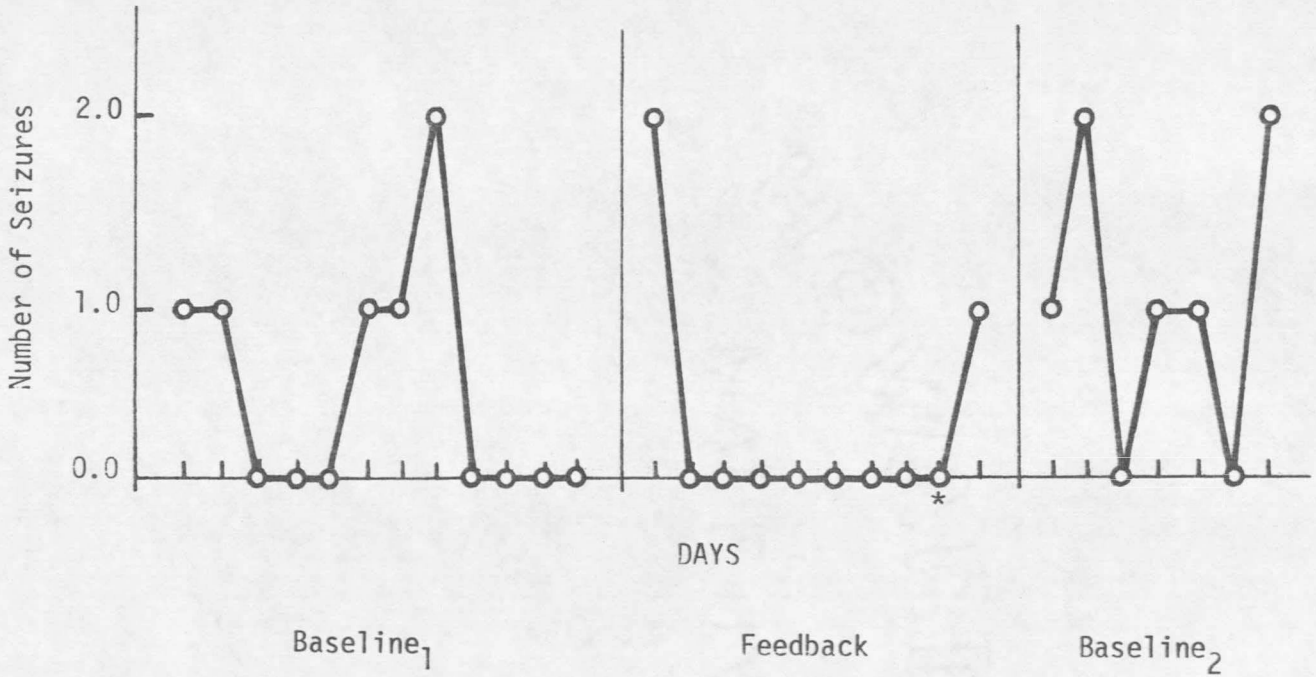

9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Microvolts
Baseline1
Feedback
Baseline2

Figure 2: Daily seizure activity during all phases.



* Medication change

DISCUSSION

The fact that the required decrease in seizure activity was not met signifies that success was not attained, as defined by this study. However, the actual seizure decrease of 33 percent suggests the possibility that some improvement might have occurred. Despite these seemingly contradictory results, the trends in the seizure data, along with the subject's change in medication, make any analysis of EMG training difficult at best. The apparent lack of EMG conditioning as well as the insufficient change in seizure activity seem to indicate that this was not an adequate test of the hypothesis.

At this point it should be noted that the number of seizure free days experienced by the subject was less in the feedback phase than in either of the baseline phases. Of special importance is the number of consecutive seizure free days. Although this was not a measured variable in the present study, it may act as a valuable measure to assess the efficacy of a treatment program. This type of data, concerning seizure free days, may provide more meaningful information, especially to the subject, than data concerning the average number of seizures per day.

An important factor in this study is the idiosyncratic history of the subject. According to Mostofsky and Balaschak (1977), little is known about the interactive effects or remedies of other behaviors

accompanying the seizure disorder problem; but such issues, especially involving mental and physical conditions, may be extremely important. The subject's handicap of mental retardation, one aspect of the trisomy 21 syndrome afflicting her, may contribute to the control of her epileptic seizures and also to the application of biofeedback training.

The change in medication, prescribed by the subject's attending physician, was initiated on the ninth day of the feedback phase. Although at the time, this change was made for the benefit of the subject, it did introduce an obvious confounding variable into the experiment. The change did not appear to produce any immediate effects upon the subject or the data, and it was not until after the second baseline was taken that the subject showed what appeared to be a sudden and serious adverse reaction to her medication change and was hospitalized. Whenever possible, constant medication regimens should be maintained throughout the course of experimentation to avoid confounding experimental results with the attendant limitations on the validity of the results and conclusions.

The selected target behavior in this study, reported seizure occurrence, constituted the criterion for improvement. Seizure activity was measured in two ways; via the subjective self-reports from the subject and seizure report records provided by the workshop attendents. Both of these measures have inherent problems associated with their use. According to Hersen and Barlow (1976), "The self-report system is the

one that is most subject to conscious distortion on the part of the patient or client" (p. 131). Subjects may respond in accordance with the experimenter's hypotheses or expectations, lie or fake reports, or react to their self-observations in such a way that the monitored behavior changes even without treatment. Self-report measures should be avoided if possible; but if used, they should be supplemented with data obtained by other measures. Human observors should have a specific and precise observational code on which to base their judgements and training to enhance their observational skills prior to the actual surveillance of the target behavior. Also, observors should be monitored occasionally to insure that they are making accurate judgements and not engaging in intentional or unintentional response errors or biases.

When monitoring a subject for a specific behavior, it would be best to have 24 hour surveillance, preferably with physiological measures to record the behavior. Aside from this, reliability (the extent that two independent observors will agree on the occurrence or nonoccurrence of a specified behavior or set of behaviors) could be strengthened by the experimenter supplying specific instructions regarding the methods for recording data concerning the target behavior and requiring precise descriptions of the observed behavior.

According to Mostofsky and Balaschak (1977), "Seizure behaviors are notorious for their cyclic exacerbations and remissions" (p. 745). This cyclic variation in seizure activity has the potential of

influencing the interpretation of the data. When using baselines recorded over a short period of time, the effects noted may be nothing more than mere coincidences. In order to dismiss the possibility of cyclic seizure patterns confounding the data, an extended and stable baseline should be obtained before beginning any treatment.

> "This kind of baseline pattern, which shows a constant rate of behavior, represents the most desirable trend, as it permits an unequivocal departure for analyzing the subsequent efficacy of a treatment intervention." (Hersen & Barlow, 1976, p. 76)

In the present study, the hypothesis that muscle conditioning may reduce seizure activity is based on the assumptions implicit in the neural exercise model. If it is possible to reduce seizures through muscle conditioning, it would also be necessary to demonstrate that a relationship exists between muscle activity and normalization of neuronal activity in the motor cortex. EEG changes indicating normalization must be correlated with conditioned EMG activity to substantiate the hypothesis.

Although the attempt to reduce seizure activity through EMG conditioning was not apparently successful, the present study can perhaps be used as a departure point for subsequent investigations. Problems and deficiencies identified in the present study should be rectified in any further examinations of this issue. These include extended baselines in order to identify any trends or cyclical patterns in the data; a criterion level for improvement that is associated with a time unit,

such that the desired effect is required to be maintained for a specified period of time; constant medication regimens throughout the duration of experimentation; enhanced reliability measures for reporting seizure activity; and concurrent EEG and EMG recordings to corroborate the hypothesis. Research employing a more precise and controlled strategy is necessary in order to provide for valid conclusions concerning this application of EMG feedback training.

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