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OPERANT CONTROL OF E.E.G. ALPHA IN HUMANS
AFTER EXTENDED BASELINE ASSESSMENT:
A TEST OF THE DISINHIBITION
HYPOTHESIS

by Gary K. Mills

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CURRICULUM STUDIORUM

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INTRODUCTION

Since the "Industrial Revolution" man has made remarkable strides in harnessing a vast technology for controlling his external world. More recently, attention has turned to aspects of his internal world, such as states of consciousness, which have, by and large, been beyond his control. This renewed interest in conscious states prompted a re-examination of the claims made by Eastern mystics of voluntary alterations in psychophysiological states. Using an advanced technology, Kamiya was the first to demonstrate that man, when given feedback, could gain control over "involuntary" physiologic functions, such as frequency related neural events. This finding sparked a "revolution" of feedback research in which autonomic, as well as central neural activity, were brought under "voluntary" control.

The need for a theory to unify these somewhat disjointed findings gave rise to relatively few operant conditioning models, because the issue of mediation was never adequately resolved. In a careful review of the literature, Lynch and Paskewitz concluded that operant control of central nervous system activity through feedback is questionable. They proposed that such "control" really represents a spontaneously occurring baseline shift resulting from an orienting reaction habituation phenomenon. This was termed the "Disinhibition Hypothesis".

Since the disinhibition hypothesis represents a construct which generates testable hypotheses, and since it represents a devastating interpretation of a growing body of scientific literature which supports the view that operant control is possible, the present investigation is designed to test certain aspects of this hypothesis.

Specifically, a careful examination of feedback increases in electroencephalographic alpha rhythm activity is attempted after the orienting reaction has had opportunity to habituate during an extended baseline period. Furthermore, a yoked control group which receives false feedback is employed to further test the notion of voluntary control. Finally, the issue of voluntary control is confronted directly during a post-feedback retention phase in which subjects attempt to control alpha density without aid of feedback.

Chapter one contains a development of the problem through a review of relevant research findings, ending with a statement of hypotheses. Chapter two provides the details of subject selection, screening, experimental apparatus and procedures and appropriate statistical analyses to test the hypotheses. The third and final chapter contains a presentation and discussion of the results of the present experiment.

CHAPTER I

REVIEW OF THE LITERATURE

In this chapter evidence is first reviewed which suggests that man is capable of learning voluntary control over physiological functions traditionally considered beyond conscious control. Since oriental "mystics" have made some of the earliest claims in this direction, section two examines the psychophysiology of altered states of consciousness as manifest during Zen, Yoga and Transcendental Meditation. In section three, studies of operant-autonomic conditioning in infrahuman subjects are reviewed which lend support to the idea of voluntary or operant control of autonomic or involuntary physiological functions. Section four considers the research on operant conditioning of involuntary physiological activity in humans with particular emphasis on biofeedback or operant neural conditioning of the alpha rhythm. Clinical implications of alpha control are suggested from a few available studies. In section five, the major hypotheses which attempt to explain observed increases in alpha density resulting from biofeedback training are reviewed. The last section provides conclusions based on the literature reviewed and a statement of hypotheses for empirical test.

1. Historical Perspective

In their overview of biofeedback research, Davidson and Krippner¹ following Miller's² outline, trace the philosophy which has lead Western scientists into the fallacious belief that instrumental or operant conditioning is successful only with somatic (skeletal) responses which are mediated by the cerebro-spinal nervous system while classical (pavlovian) conditioning is possible only for visceral responses mediated by the autonomic nervous system. The origins of this attitude began as early as Plato's time with the doctrine which compartmentalized rational and emotional processes into cerebral and thoracico-abdominal regions of the body respectively; the head region possessing "superior" rational functions such as thinking which are voluntary, with the rest of the body governing "inferior" visceral functions such as emotions which are involuntary. Miller³ reports the work of Bichat,⁴ a nineteenth century neuro-anatomist, as contributing early scientific evidence in support

1 R. Davidson and S. Krippner, 'Biofeedback Research: The Data and Their Implications,' Paper Presented at the Second International Invitational Conference on Humanistic Psychology, Wurzburg, Germany, 1971, p. 30.

2 Neal Miller, 'Learning of Visceral Glandular Responses,' Science, Vol. 163, Jan. 1969, pp.434-445.

3 Ibid.

4 X. Bichat, 'Recherches Physiologiques sur la Vie et le Mort,' Brosson, Gabon, Paris, 1800.

of the "superior-inferior" dichotomy. Bichat made a sharp distinction between the anterior cerebrospinal system governing voluntary skeletal behaviour and the more posterior dual chain of ganglia descending along the spinal cord governing visceral responses which he termed "vegetative". This "inferior" nervous system was given the name "autonomic" and was believed by Cannon⁵ to be incapable of finely differentiated responses as is the cerebrospinal system, since its nerves of innervation tend to fire in a simultaneous manner.

Pavlov⁶ and Skinner⁷ both borrowed heavily from this earlier neurophysiological tradition in developing their respective classical and operant models of conditioning or learning. Until recently, students of the learning process generally considered classical conditioning to be effective for lower forms of learning such as that which takes place in the involuntary or autonomic nervous system. Higher forms of learning involving voluntary or skeletal activity were believed to require the more flexible procedure of operant conditioning. Davidson and Krippner⁸ highlight these two types of conditioning and their

5 W.B. Cannon, "The Wisdom of the Body," New York, Norton, 1932.

6 I.P. Pavlov, "Conditioned Reflexes," (Trans. by G. Anrep), London, Oxford University Press, 1927.

7 B.F. Skinner, "The Behavior of Organisms," New York, Appleton-Century, 1938.

8 R. Davidson and S. Krippner, op. cit., 1971, p. 4.

limitations in the following way:

In classical or Pavlovian conditioning (which is thought to be involuntary), a conditioned stimulus (a signal of some kind) is presented along with an innate unconditioned stimulus (such as food) that normally elicits a certain innate unconditioned response (such as salivation). After a time, the conditioned stimulus elicits the same response as the unconditioned stimulus. In instrumental (or operant) conditioning a reinforcement, or reward, is given whenever the desired conditioned response is elicited by a conditioned stimulus (such as a certain signal). The possibilities of learning are limited in classical conditioning, as the stimulus and response must have a natural, direct relationship to begin with. In instrumental learning, on the other hand, the reinforcement strengthens any immediately preceding response, therefore, a given response can be reinforced by a variety of rewards and a given reward can reinforce a variety of responses.

As a result of this long history of thinking, Western scientists were justifiably skeptical of evidence such as that offered by Eastern mystics that inferior, autonomically mediated, visceral functions could be brought under voluntary control. Likewise, the possibility of applying operant procedures to learning in the autonomic nervous system was considered to be inappropriate even though little concrete evidence existed to support this contention.^{9,10}

In opposition to this traditional thinking about what can be learned in the autonomic nervous system is a

9 B.F. Skinner, op. cit., 1938, p. 87.

10 O.H. Mowrer, "On the Dual Nature of Learning--A Reinterpretation of "Conditioning" and "Problem Solving", Harvard Educational Review, Vol. 17, 1947, pp. 102-148.

recently expanding body of evidence which suggests that voluntary control is possible via operant conditioning. Furthermore, using the same operant paradigm organisms have achieved voluntary control over low frequency electroencephalographic (EEG) activity in the alpha bandwidth. While this latter activity is not truly autonomic in the visceral sense, it is nevertheless beyond usual awareness and therefore out of the realm of conscious control (i.e., involuntary). This evidence is reviewed in the following sections.

2. Psychophysiology of Altered States of Consciousness

Since Eastern mystics from Tibet, Japan, India and China were likely the first to claim voluntary (operant) control over autonomic functions, their data is reviewed first. In this section physiological self-control and related altered states of consciousness, as achieved through various forms of meditation (self-induced), such as Zen, Yoga and Transcendental Meditation (T.M.), are distinct from drug-induced altered states of consciousness. Also, the term "consciousness" will be used interchangeably with "awareness", both are considered to signify an intergration of sensory and psychological factors.

For thousands of years Eastern mystics have practiced the art of Yoga and Zen meditation without much ado from the scientific community. More recently, an interest in understanding the remarkable claims of bodily self-control has prompted an

examination of brain mechanisms and consciousness in general and has led to the publication of studies exploring the physiological intricacies of self-control as practiced by Zen and Yoga meditators. Unfortunately, many of these studies were published in Japanese or Indian journals. The few that were translated or published in English journals will be examined in this section.

The practice of Yoga, whose origins go back as far as 700 B.C., is carried out by Easterners as part of a religious ceremony in which an equilibrium or union of the soul with God is attempted by means of various meditative techniques.¹¹ One such technique or branch of Yoga known as Hatha Yoga teaches its disciples specific postural respiratory controls to reduce external stimuli and increase depth of meditation.

Wenger and Bagchi¹² ventured a trip to India for purposes of testing numerous claims made that Yogis can, in the course of meditation, voluntarily control autonomic functions. Forty-three male and two female practitioners of Yoga cooperated in having their heart rate, blood pressure (diastolic and systolic), respiration, finger temperature and pulse volume recorded during

11 M. Eliade, "Yoga: Immortality and Freedom", Boston, Houghton-Mifflin, 1958, p. 346.

12 M. Wenger and B.K. Bagchi, "Studies of Autonomic Functions in Practitioners of Yoga in India," Behavioral Science, Vol. 6, 1961, pp. 312-323.

meditation. After an analysis of this data the authors concluded that although certain autonomic functions showed change during meditation, it was probably due to intervening voluntary mechanisms rather than through direct control (i.e., hyperventilating causing metabolic-autonomic changes, as in "Bhastrika" and "Pranayama", two types of Yoga). They further concluded that although direct control of autonomic functions is probably rare among Yogis, subsequent research is nevertheless needed to explain all the physiological changes which accompany meditation.

In a similar study, Das and Gastaut¹³ recorded EEG, EKG (electrocardiogram) and EMG (electromyogram) from seven experienced practitioners of Yoga during their meditation. They reported that no muscular electrical activity whatsoever appeared during their hours of physical immobility while changes in their cardiac rhythms were obvious. These changes were described as accelerating during profound meditation and especially during "ecstasy" and slowing down after the end of the ecstatic period. It was also noted that changes in heart rate very closely paralleled those of the EEG. Cortical electrical activity during meditation showed an accelerated alpha rhythm with decreased amplitude and the appearance of faster (15-30 Hz)

13 N. Das and H. Gastaut, "Variations de l'activite electrique du cerveau, du coeur et des muscles squelettiques au cours de la meditation et ed l'extase Yogique," Electroencephalography and Clinical Neurophysiology, Vol. 6, 1955, pp. 211-219.

components. Beta rhythms appeared in rolandic areas along with generalized low amplitude fast activity emerging periodically throughout meditation. During "Samadhi" (peak experience) the fast activity showed increases in amplitude. Alpha was a particularly prevalent rhythm both before and after, but not during this "ecstatic" period of meditation. Das, et. al., conclude that Yoga meditation represents a state of intense concentration of attention unlike that achieved by Western methods. Furthermore, that during meditation Yogis are far from being lethargic, anesthetic or in a coma, but rather their state represents intense cortical stimulation. It should be noted that these electrocortical findings were never replicated in later studies.

In 1961, Anand, Chhina and Singh¹⁴ examined four practitioners of Raj Yoga only with regard to their EEGs during meditation. Cortical electrical activity was recorded before as well as during meditation. Two yogis were exposed to noxious external stimuli, such as photic, auditory, vibratory and thermal stimuli, while two others experienced the cold pressor test (4 degrees centigrade) to the hands for 45-55 minutes during meditation. Results showed that all Yogis had prominent

14 B.K. Anand, G. Chhina and B. Singh, "Some Aspects of Electroencephalographic Studies in Yogis," Electroencephalography and Clinical Neurophysiology, Vol. 13, 1961, pp. 452-456.

alpha activity in their normal resting records and had persistent alpha during Samadhi with increased amplitude. It was found that before meditation, the external noxious stimuli blocked all alpha activity. Conversely, during meditation none of these produced alpha blockage. Apparently, practitioners of Raj Yoga enter a unique psychophysiological state during meditation which they term Samadhi. During this time well-modulated alpha activity persists and they report a state of consciousness in which they are oblivious to their external, as well as their internal environments. Anand, et. al.¹⁵ rely on traditional reticulo-cortical mechanisms in explaining the altered state of consciousness of Yoga meditators during Samadhi:

It is, therefore suggested that the brain activity of Yogis during the stage of Samadhi has for its basis a type of consciousness which probably depends upon mutual influences between the cephalic reticular activating system and the cortex, which does not depend upon the activation of the reticular activating system through external and internal efferents.¹⁶

These results confirm the findings of Bagchi and Wenger¹⁷ who report persistent, well-modulated alpha activity during Yoga meditation and conflict with Das and Gastaut's findings of

15 B.K. Anand, G. Chhina and B. Singh, op. cit., 1961, p. 454.

16 Ibid.,

17 B.K. Bagchi and M. Wenger, "Electro-physiological Correlates of some Yoga Exercises," Electroencephalography and Clinical Neurophysiology, Vol. 7, 1957, Suppl. #7, pp. 132-149.

low amplitude fast cortical activity during the same type of meditation.

Zen Buddhism is similar to Yoga in that both practice meditation to achieve an altered state of consciousness (Satori in Zen and Samadhi in Yoga), the by-product of which is usually some measure of transient autonomic stability. In Zen meditation (Zazen), the practitioner sits passively and stares (eyes open) at an object about four feet in front of him to achieve Satori or insight about the nature of reality. In Yoga meditation, one may meditate with eyes closed maintaining a certain posture and breathing in a prescribed way, as in Pranayama. Yoga is practiced primarily in India, while Zen is predominantly a Japanese religion.

In Japan, Kasamatsu, Okuma, Takenaka, Koga, Ikeda and Sugiyama¹⁸ studied the cortical activity of Zen and Yoga practitioners with hopes of shedding some light on the comparative EEGs of both. Two expert Zen and Yoga masters were matched on resting EEGs with two control (non-expert) subjects. With progress in meditation, both Yoga and Zen Master's alpha rhythms increased in amplitude as its percent-time occurrence increased. This occurred for both regardless of the "eyes open"

18 A. Kasamatsu, T. Okuma, S. Takenaka, E. Koga, K. Ikeda and H. Sugiyama, "The EEG of "Zen" and "Yoga" Practitioners," Electroencephalography and Clinical Neurophysiology, Suppl. #9, 1957, pp. 51-52.

condition in marked contrast to the flattened, irregular alpha production of the controls. Furthermore, they found that auditory stimulation in the way of ringing bells and clapping hands did not block alpha to any significant extent. In contrast, five years later Kasamatsu, Hirai and Ando¹⁹ reported that habituation to auditory stimulation by practitioners during Zen meditation is rarely seen. They concluded that the psychophysiological state achieved during Zazen cannot be affected by external or internal stimuli beyond an immediate, transient response to it.

In 1966 Kasamatsu and Hirai²⁰ continued in their efforts to describe the psychophysiology of Zen meditation but this study dealt with the electroencephalographic aspects of Zen meditation in greater detail. Forty-eight Zen Masters aged 24-72 years of age cooperated in having EEG recordings taken before, during and after meditation. Four stages of cortical activity were determined during meditation:

Stage I: A slight change which is characterized by the appearance of alpha waves in spite of opened eyes.

19 A. Kasamatsu, T. Hirai and N. Ando, "E.E.G. Responses to Click Stimulation in Zen Meditation," Proceedings of the Japanese E.E.G. Society, 1962, pp. 77-78 (Translation).

20 A. Kasamatsu and T. Hirai, "An Electroencephalographic Study on the Zen Meditation (Zazen)," Folia Psychiatrica et Neurological Japonica, Vol. 20, 1966, pp. 315-336 (Translation).

- Stage II: The increase in amplitude of persistent alpha waves.
Stage III: The decrease of alpha frequency.
Stage IV: The appearance of the rhythmical theta train, which is the final change of EEG during Zen meditation but does not always occur.²¹

The authors also found that the more years spent in Zen training, the more EEG changes observed during meditation. A comparison was also made between EEG changes of subjects in a hypnotic trance with subjects in Zen meditation. During the hypnotic state very few alpha rhythms were seen and the activation pattern was more prominent than the EEG in Zen. Also, the four stages above were not observed in the trance state. These findings are consistent with the data of Kleitman^{22,23} which suggest no definite psychophysiological changes occur during the hypnotic trance. Another finding of interest was that deep meditation (Stage IV) differs from sleep or drowsiness in the reaction of the theta and alpha rhythm to click stimulation (i.e., in sleep or drowsiness click stimulation replaces theta with alpha whereas, in Zen meditation, clicks block theta momentarily to beta and then it returns again). Thus, the subjectively induced Zen state has both neurophysiological and psychological

21 A. Kasamatsu and T. Hirai, op. cit., p. 324.

22 N. Kleitman, "Sleep and Wakefulness," Chicago, University of Chicago Press, 1963.

23 H. Jana, "Effects of Hypnosis on Circulation and Respiration," Indian Journal of Medical Research, Vol. 55, 1967.

effects of a unique variety. After repeatedly attempting to habituate the alpha blocking response with clicks, the authors concluded that virtually no habituation of the alpha blocking response occurs during Zen meditation.

Neurophysiologically, the lack of habituation of alpha blocking was explained in terms of an equilibrium of tonic and phasic activation of the cortex to afferent information. Diencephalic and mesencephalic reticular activating mechanisms were thought to be somehow influenced by the Zen meditation to achieve an equilibrium or optimal preparedness for oncoming stimuli represented by rhythmic electrocortical activity. Psychologically, the meditation was described as producing an "awakening consciousness" which is unique in that objects are perceived and responded to without disturbance; that concentration without tension is achieved and that visual input is somehow perceived more clearly during Zen than in ordinary states of consciousness.

Electroencephalographically, alpha and theta rhythms observed during Zen meditation may be representative of a unique altered state of consciousness in which EEG activity is quantitatively the same yet functionally quite different than mere "drowsiness" usually attributed to these EEG states.

Kasamatsu and Shimazono²⁴ report electrocortical slow waves as a result of nitrogen gas inhalation. This occurs just before consciousness is lost and is accompanied by changes (elevated) in mood and increased relaxation. Other changes in autonomic variables during Zen led Kasamatsu and Hirai²⁵ to postulate decreases in systemic metabolic rates which effect the brain's chemistry and thus its electrocortical pattern. Specifically, decreases in oxygen consumption are believed to be responsible for cortical slow waves. Wallace,²⁶ citing earlier data,^{27,28} disagrees with this since drastic reductions in oxygen consumption are necessary before observable EEG changes occur.

Hirai²⁹ made further investigations into the EEG patterns of Japanese Zen Buddhists during their meditation. Fourteen

24 A. Kasamatsu and Y. Shimazono, "Clinical Concept and Neurophysiological Basis of Disturbance of Consciousness"; Folia Psychiatrica et Neurologica Japonica, Vol. 11, 1957, pp. 969-999.

25 A. Kasamatsu and T. Hirai, op. cit., 335.

26 Robert Wallace, "The Physiological Effects of Transcendental Meditation"; Ph.D. thesis, University of California at Los Angeles, 1970, p. 79.

27 R. Meyers, Archives of Neurology, Vol. 3, 1960, pp. 529-552

28 R. Mangold, E. Sokoloff, J. Conner, J. Kleinerman, P. Therman and S. Kety, Journal of Clinical Investigation, Vol. 34, 1955, pp. 1092-1100.

29 T. Hirai, "Electroencephalographic Study on the Zen Meditation (Zazen)--EEG Changes During the Concentrated Relaxation," Folia Psychiatrica et Neurologica Japonica, Vol. 62, 1960, pp. 76-105 (Translation).

experienced priests agreed to cooperate with the research. Hirai reported a persistent alpha rhythm which appeared immediately after subjects began meditating, regardless of eyes being open. The amplitude of alpha progressively increased while theta rhythms began to appear in the parietal area of the brain. As the EEG slowed, the priest's respiration also decreased while their pulse rate increased. It was found that Galvanic Skin Response (GSR) was evoked much easier with click stimulation during meditation than not. Consistent with other data³⁰ on Zen, the well-modulated alpha frequency was seen to persist after meditation ended suggesting a prolonged meditative effect on the brain's activity. As meditation progressed the frequency of alpha increased in amplitude and decreased in frequency up to the theta bandwidth. This occurred in both occipital and parietal leads. The authors concluded, in agreement with most Zen researchers of the Japanese school, that a general slowing of the EEG accompanies Zazen, indicating a reduction in general cortical excitation level. The observed decreases in GSR and respiratory activity which accompanied the EEG slow waves are consistent with a parasympathetic state in the autonomic nervous system. The increase in pulse-rate was ambiguously explained as

30 A. Kasamatsu and T. Hirai, op. cit.

the result of a "release phenomenon of the brain stem autonomic function"³¹ Presumably, the author is referring to the regulators of visceral activity located in the brain stem.

The above studies lend support to the findings reported earlier by Hirai, Izawa and Koga,³² particularly with regard to the general lessening of cortical excitation and slowing of the EEG frequency during Zen meditation. Respiration was also shown to decrease while pulse rate increased.

It appears that during Zen and Yoga meditation, as practiced by experienced disciples, definite electrocortical patterns emerge. Less clear are the exact autonomic correlates of these meditations even though Yogis have been observed in some instances to exert control over cardiac and other seemingly involuntary functions³³. Taken as a whole, visceral activity during meditation is often altered in the direction of parasympathetic dominance. Those mystics who claim to be able to exert control over involuntary functions, in some instances, can do this but more generally meditation appears to produce a deeply relaxed state as a by-product. More often than not, these mystics are reticent about revealing their methods of self-control, thus making an interpretation about mediating psychophysiological variables difficult.

31 T. Hirai, op. cit., p.102.

32 T. Hirai, S. Izawa and E. Koga, 'EEG and Zen Buddhism,' Electroencephalography and Clinical Neurophysiology, Suppl. 18, 1959, pp. 52-53.

33 BK. Bagchi and M. Wenger, op. cit., p. 148.

It seems clear that disciples undergo a process of learning to achieve their altered states. Since this learning involves voluntary control procedures, they are presumably operant in nature. As Bagchi³⁴ points out, control over visceral activity is most probably attained via mediating somatic or voluntary mechanisms such as breathing patterns which alter thoracic pressure. A simple example of voluntary autonomic control is the Valsalva maneuver. By attempting to forcibly exhale with the nose and mouth closed, intrathoracic pressure increases, causing slowing of the pulse, decreased return of blood to the heart, and increased venous pressure. This possibility of mediation throws into question the validity of direct control over autonomic activity. Thus, operant control of non-mediated physiological functions would appear to be unproven in meditators.

A third type of meditation which makes no claims regarding direct physiologic self-control is gaining momentum in North America and is known as Transcendental Meditation (TM). TM, as taught by Maharishi Mahesh Yogi, its founder, is claimed to yield immediate beneficial psychological effects without involving concentration or any type of voluntary control.

Although it is difficult to discern the exact historical roots of TM suffice it to say that Maharishi Mahesh Yogi developed

34 BK. Bagchi and M. Wenger, op. cit.

the technique of TM probably during his studies in India under Swami Brahmananda Shankaracharyas. The Maharishi describes his technique, which is practiced twice a day for about 20 minutes, as "(...)turning the attention inwards towards subtler levels of thought until the mind transcends the experience of the subtlest state of the thought and arrives at the source of the thought".³⁵

Wallace³⁶ who made a detailed physiological study of TM selected 20 male and female meditators whose practice ranged between six months and three years. Oxygen consumption, cardiac output, arterial blood gas concentrations, arterial blood pressure, heart rate, skin resistance and EEG were recorded before, during and after meditation and with eyes open and closed.

An overview of Wallace's results indicate striking differences physiologically between pre-post and meditative states of consciousness. EEG activity showed predominantly alpha waves in central and frontal regions with occasional trains of theta appearing frontally. The intensity of voltage showed increases for eight to nine Hz activity while 11 to 12 Hz

35 Maharishi Mahesh Yogi, The Science of Being and Art of Living, Stuttgart, Normendruck, 1966, pp. ii-335.

36 Robert Wallace, op. cit.

activity steadily declined. EEGs were also characterized by lack of habituation of alpha blocking by visual or auditory stimuli similar to Zen. Unfortunately, the EEG data were given in "arbitrary" units of intensity (amplitude) and only a few "typical" subjects were presented. Specifics regarding habituation rates or procedures were not reported. Heart rate was marked by a mean decrease of five beats per minute during the meditative periods as compared to the pre-meditation period. Increases in skin resistance (kilohms) were dramatic during meditation, up to 500% after 10 minutes of meditation. Cardiac output, heart rate and arterial blood pressure all were shown to decrease during meditation. Biochemically, slight declines in arterial pH and pCO_2 occurred while small increases in pO_2 occurred. Lactic acid concentrations in arterial blood were shown to decrease with the onset of meditation and continue at low levels in two subjects. Oxygen consumption and CO_2 elimination both decreased significantly by 40 cc/min., respectively. Respiration in five subjects showed significant decreases during meditation by a mean of three per minute. These findings were also supported in a later study by Wallace, Benson and Wilson³⁷ in which TM was shown to produce a unique quality of rest characterized by a decline in overall metabolism believed

37 R. Wallace, H. Benson and A. Wilson, "A Wakeful Hypometabolic Physiologic State," American Journal of Physiology, Vol. 221, 1971, pp. 795-799.

to be greater than that achieved during sleep. Further studies by Orme-Johnson³⁸ on autonomic stability and Allison³⁹ on respiratory activity during TM lends credence to Wallace's original findings. In general, Wallace considered his physiological results to represent a fourth major state of consciousness unlike waking, sleeping or dreaming in that a unique hypometabolic state was achieved.

Parenthetically, it should be noted that although not making direct claims about physiological self-control, the Wallace data has been duplicated and widely distributed (internationally) by Maharishi and his followers. At an introductory lecture on TM (designed to enlist new members), the present writer was astounded by the misrepresentation of the physiological data. The speaker was observed to repeatedly imply that TM would enable everyone to produce the "hypometabolic state" reported by Wallace. Perhaps the TM people are capitalizing on their premature conclusions based on experimental data (a charge of \$25 for students and \$75 for workers is levied for teaching the technique).

In summary, Yogic claims of self-control of involuntary autonomic functions may have some basis in reality. Although

38 D. Orme-Johnson, "Autonomic Stability and Transcendental Meditation," Paper Presented at Stanford Research Institute, Menlo Park, 1971.

39 J. Allison, "Respiratory Changes During Transcendental Meditation," Lancet, Vol. 1, 1970, p. 7651.

the evidence is not definitive, it should stimulate explorations into the question of what types of learning and voluntary control can occur in the autonomic nervous system. Similarly, the mechanisms by which meditators achieve their "autonomic feats" are unclear although it is likely an operant process in which greater and greater alterations in physiological activity are shaped.

Zen meditators, although usually not claiming autonomic self-control, nevertheless manifest by-product biological rhythms which are both remarkable and stable. Perhaps by studying their techniques more closely, insight can be gained regarding the learning mechanisms which facilitate the obvious electrocortical changes which were observed to take place.

These findings provide a starting point from which to re-examine the traditional view within neurophysiology and conditioning regarding what can be learned in the autonomic nervous system via operant conditioning. The next section will review animal studies which have recently added further support to the idea that control of visceral functions is possible using an operant conditioning paradigm.

3. Operant Autonomic Conditioning in Infrahuman Subjects

More definitive empirical evidence, that learning is possible in autonomically mediated responses, was presented by Neal Miller and his associates at Rockefeller University. Miller and Carmona,⁴⁰ as the first in a series of experiments, endeavored to increase and decrease the autonomically mediated activity of salivation in two groups of dogs using an operant conditioning procedure. Their paradigm involved rewarding thirsty dogs with small amounts of water for either increasing or decreasing salivation. After extensive training (45 minutes per day for 40 days), both groups of dogs showed statistically significant changes in the desired direction from baseline salivation rates.

Since the commonly measured autonomic functions of heart rate, GSR, and vasomotor activity are known to be affected by skeletal activity, it becomes imperative to rule out the criticism of mediated learning (i.e., what is really learned is a certain posture or muscular state which secondarily alters autonomic responses in the desired direction).

The problem of skeletal mediation was solved when Jay Trowill,⁴¹ a colleague of Miller's, after great persistence, succeeded

40 N. Miller and A. Carmona, "Modification of a Visceral Response, Salivation in Thirsty Dogs, by Instrumental Training with Water Reward," Journal of Comparative and Physiological Psychology, Vol. 63, 1967, pp. 1-6.

41 J. Trowill, "Instrumental Conditioning of the Heart Rate in the Curarized Rat," Journal of Comparative and Physiological Psychology, Vol. 63, 1967, pp. 7-11.

in demonstrating that rats could be trained to increase or decrease their heart rates after injection of d-tubocurarine chloride. Otherwise known as curare, this drug acts to inhibit acetylcholine in peripheral myoneural junctions, thus acting as an effective anesthetic to the skeletal muscles. Under curare and artificially respired (curare also acts on the diaphragm), the rats were totally incapable of voluntary muscle control. Stimulation to the rat's medial forebrain bundle (pleasure center) for heart-rate changes in the desired direction proved successful, and thus provided the basic methodology for subsequent experiments.

Miller and DiCara⁴² improved on Trowill's technique by gradually shaping heart rate responses in rats over time. They found that rats rewarded for increasingly faster heart rates changed from an initial rate of 422 to 510 beats/min. Conversely, rewards for decreasing heart rate showed a decline from 400 to 316 beats/min. Both these heart rate changes were significant beyond the 0.01 level of probability.

It might be mentioned at this point that under conditions of curarization, animals learned the desired autonomic controls quicker and more efficiently than animals not curarized. Enhanced learning under these conditions may be due to a narrowing of afferent sensory bombardment to the central nervous system,

42 N. Miller and L. DiCara, "Instrumental Learning of Heart Rate Changes in Curarized Rats: Shaping and Specificity to Discriminative Stimulus," Journal of Comparative and Physiological Psychology, Vol. 63, 1967, pp. 12-19.

thus allowing higher centers to concentrate on only the task at hand. This process might be analogous to the suggested reticulo-cortical inhibition which initiates EEG slow waves in meditators.

In Miller's laboratory the operant-curarization methodology begot a variety of other studies, in which many autonomic responses were brought under control, such as urine formation by the kidneys,⁴³ differential intestinal contractions⁴⁴ and vasoconstriction-vasodilation⁴⁵ to name a few. Parenthetically, it is noted that at one point DiCara and Miller⁴⁶ were successful in training two groups of six rats to differentially increase or decrease blood flow to the pinna of one ear while the other ear remained stable, a truly remarkable demonstration of operant specificity in the autonomic nervous system.

43 N. Miller and L. DiCara, "Instrumental Learning of Urine Formation by Rats, Changes in Renal Blood Flow," American Journal of Physiology, Vol. 215, 1968, pp. 677-683.

44 ----- and A. Banuazizi, "Instrumental Learning of Curarized Rats of a Specific Visceral Response, Intestinal or Cardiac," Journal of Comparative and Physiological Psychology, Vol. 65, 1968, pp. 1-7.

45 L. DiCara and N. Miller, "Instrumental Learning of Peripheral Vasomotor Responses by the Curarized Rat," Communications in Behavioural Biology, Part A, Vol. 1, 1968, pp. 209-212.

46 Ibid .

Benson, et. al.⁴⁷ were successful in their attempts to increase mean arterial blood pressure in squirrel monkeys to hypertensive levels and then reversing the schedule so that blood pressure returned to control values using an operant avoidance conditioning procedure.

Although not strictly autonomic in the visceral sense, electrocortical activity, which is normally beyond conscious control, has yielded to the powerful effects of instrumental conditioning in a variety of animal studies. Under Miller's direction Carmona attempted to teach cats to produce high or low voltage activity in their EEG. First he used unrestrained, non-curarized cats and achieved success; the cats rewarded for high voltage activity showed motionless, staring behaviours while those rewarded for low voltage activity seemed more aroused, moving about restlessly, sniffing, etc. To rule out somatic mediation, cats were curarized, again using subcortical stimulation (Hypothalamus) as reinforcement, and rewarded for either high or low voltage EEGs. Results showed that the curarized animals could learn control of the voltage characteristics of their EEG and furthermore could make voltage changes in the opposite direction (differential) when the reinforcement contingencies were reversed. Thus, mediating skeletal responses were ruled

47 H. Benson, J.A. Herd, W.H. Morse and Roger Kelleher, "Behavioral Induction of Arterial Hypertension and its Reversal", American Journal of Physiology, Vol. 217, 1969, pp. 30-34.

out as a contaminating variable. In the future, Miller⁴⁸ hopes to modify the activity of the vagal nucleus using his operant paradigm in hopes of controlling a more central nervous system determinant of visceral activity. Such an approach would require much basic research to first determine what electrical characteristics the vagal nucleus possesses during a given visceral state.

Very recently, (Society for Psychophysiological Research, Boston, 1972) Miller has admitted an inability to replicate these earlier findings. The exact roots of this failure are at present unclear.

Abraham Black, from McMaster University, has also been successful in producing operant changes in electrocortical states. Using flaxedilized (curare-like drug) dogs and stimulating the septal area of the limbic system (pleasure center) as a reward, Black⁴⁹ was successful in training his animals to emit theta activity (4-7 Hz), as well as non-theta differentially from the hippocampus. The functional significance of hippocampal theta, as determined in his conditioning experiments, is considered by Black to be the initiation of a "(...)manipulative phasic skeletal movement, such as running(...); they do not reflect processes

48 N. Miller, op. cit., p. 442.

49 A. Black, 'The Direct Control of Neural Processes by Reward and Punishment,' American Scientist, Vol. 59, 1971, pp. 236-245.

leading to consummatory or reflex responses, (...) nor do they occur when the animal is holding still, whether with muscles tense or relaxed."

Wyrwicka and Sternman⁵⁰ reported success in operantly conditioning a 12-20 Hz synchronous spindle over the motor cortex they termed the "sensorimotor rhythm" (SMR). Food deprived cats rewarded for SMR activity increased such activity and concurrently showed signs of reduced motor activity in the form of a definite stereotyped posture. This is reminiscent of Black's finding with hippocampal theta. Operant abolition of the SMR resulted in moving about and searching activity, the opposite behavioural correlate of augmented SMR activity.

A series of other investigators reported success in operant neural conditioning which include alterations in certain components of the sensory evoked potential,⁵¹ Amygdala spindling,⁵² and synchronization-desynchronization.⁵³

50 W. Wyrwick and M.B. Sternman, "Instrumental Conditioning of Sensorimotor Cortex EEG Spindles in the Waking Cat", Physiology and Behavior, Vol. 3, 1967, pp. 703-707.

51 S.S. Fox and Z. Rudell, "Operant Controlled Neural Event: Formal and Systematic Approach to Electrical Coding of Behavior in Brain," Science, Vol. 162, 1968, pp. 1299-1303.

52 J.M. Delgado, V.S. Johnston, J.L. Wallace and R. Bradley, "Operant Conditioning of Amygdala Spindling in the Free Chimp", Brain Research, Vol. 22, 1970, pp. 347-362.

53 M.H. Chase and R.M. Harper, "Somatomotor and Visceromotor Correlates of Operantly Conditioned 12-14 c/sec. Sensorimotor Cortical Activity," Electroencephalography and Clinical Neurophysiology, Vol. 31, 1971, pp. 85-92.

In summary, there is ample support for the notion of operant autonomic conditioning in infrahumans. Mediating skeletal mechanisms for such control were ruled out by the use of drugs such as curare and flaxedil which act to inhibit myoneural junction activity. Highly specific vascular control was demonstrated which invites criticism of the traditional view that the viscera tend to discharge as a whole, thus being incapable of finely differentiated responses.

Although not truly autonomic, involuntary central neural activity ranging from desynchronization to components of the sensory evoked potential responded in the predicted direction following reinforcement. Behavioural correlates of central neural synchronization induced operantly included cessation of ongoing motor activity and stereotyped "frozen" posture, both in the direction of reduced motor activity. Although visceral conditioning studies are useful, a challenging possibility for major control may exist in the alteration of central neural activity. This would first involve the unravelling of relationships between types of neural activity and other psychophysiological functions. For example, central nervous system activity of a particular frequency and amplitude configuration in a certain cerebral location may effect specific functional states in the viscera. Similarly, it may be possible to begin the task of understanding electrocortical correlates of psychophysiological and behavioural states (an area of limited knowledge)

by observing activity in these systems following operant control of critical rhythms such as alpha, theta, gamma, mu and so forth. This seems plausible since specific behavioural correlates were determined for instrumentally induced EEG patterns as the SMR.

Before complex psychophysiological relationships can be explored in humans using the above procedures, evidence must be reviewed regarding the feasibility of using instrumental techniques for altering human central neural activity. This evidence is reviewed in the next section.

4. Operant Control of Neural Events in Human Subjects

Joe Kamiya⁵⁴ was the first to report that human subjects without any training in Yoga, Zen or TM, could learn to discriminate between different frequency brain waves (e.g., 8-13 Hz occipital alpha rhythm) between 75% and 80% of the time after only three hours of training. After attaching EEG electrodes Kamiya⁵⁵ describes his early training procedure as follows:

Our experimental question was, if we set up the proper discrimination procedure, could we get individuals to say "A" when the alpha rhythm was present and to say "B" when the rhythm was absent? The S was told that from time to time

54 Joe Kamiya, 'Conditioned Discrimination of the EEG Alpha Rhythm in Human,' Paper Read at the Western Psychological Association, San Francisco, 1962.

55 -----, 'Operant Control of the EEG Alpha Rhythm and Some of its Reported Effects on Consciousness,' In C.Tart (Ed) Altered States of Consciousness, New York, John Wiley, 1969, pp.507-17.

he would hear a bell ring once; when he heard it, he was to make a guess as to whether at that time he was in brain wave state A or brain wave state B. And as soon as he made his response we told him if he was correct. You will recognize this as a pretty straight forward discrimination learning problem.

Subjects were unable to articulate exactly how they were able to make the discrimination between A or B other than they felt it was correct. In another experiment, Kamiya⁵⁶ found that subjects who were able to make the discrimination between A and B or alpha-on and alpha-off were also able to enter that state at will, even without the aid of feedback. This remarkable finding led to the conclusion that in the process of learning to discriminate between the two EEG states the subject acquired the skills necessary for their control. Independent and parallel findings have been reported by Bundzen⁵⁷ on autoregulation of biological states in the Soviet Union.

Kamiya's augmented sensory feedback model of operant conditioning deserves closer analysis. It is a difficult model to analyse since no clear-cut reinforcements are employed. In animal studies, the organism is usually first motivated to action by procedures such as food deprivation or stimulation of sub-cortical pleasure centers. Thus, food or further stimulations becomes desirable and therefore meet the requirements of a reinforcement. By analogy, EEG biofeedback involves more indirect, subtle reinforcements such as 1) harnessing the

56 Joe Kamiya, op. cit., p. 508.

57 P.V. Bundzen, "Autoregulation of Functional State of the Brain", Federation Proceedings (Trans.), Vol.25, 1966, pp.551-554

"Hawthorne Effect"⁵⁸ where subjects are motivated to please the experimenter; 2) possibly reinforcement comes from having succeeded in the task at hand; 3) or perhaps experiencing the alpha-related psychophysiological state as reinforcing itself. In either case, reinforcement of some kind is believed to be present in the biofeedback setting and follows the correct response of increased alpha in an operant fashion.

Thus, Kamiya's original studies have provided the link between animal and human studies by offering an operant methodology which may enable humans to learn EEG control as did Miller and Carmona's⁵⁹ rats.

While this section is concerned mainly with operant conditioning of neural events in humans, it is of interest to note that Kamiya's biofeedback model was employed successfully in teaching humans control over a variety of visceral functions. Since heart rate control has serious clinical implications, two representative studies are briefly reviewed.

Brener and Hothersall⁶⁰ used both low and high frequency tones to monitor five human subject's inter-heartbeat interval. As a result of this feedback, all subjects learned to lower

58 N. Wallen and R. Travers, "Analysis and Investigation of Teaching Methods," In N.L. Gage (Ed.), Handbook of Research on Teaching, Chicago, Rand McNally, 1963, p. 473.

59 N. Miller and A. Carmona, op. cit.

60 J. Brener and D. Hothersall, 'Heart Rate Control Under Conditions of Augmented Sensory Feedback,' Psychophysiology, Vol. 3, 1966, pp. 23-28.

their heart rates significantly after only eight practice trials. No explanation was attempted as to the dynamics of how auditory feedback enables control of that process. Unfortunately, neither pre-training baseline nor no-feedback control group was employed.

Shapiro, Tursky, Gershon and Stern,⁶¹ in an attempt to demonstrate the potential of feedback techniques in the treatment of essential hypertension developed an automatic instrument that gives a continuous approximation of systolic blood pressure on each successive heart beat. The authors felt this to be an improvement over arterial cannulation and cuff-type recordings of blood pressure. Without knowing which bodily process they would be controlling, 20 male college students were rewarded with a view of a "Playboy" nude (slide); half the subjects were rewarded for increases and the other half for decreases in their systolic blood pressure. Differences were reported significant beyond the 0.01 level for voluntary changes in blood pressure in one session. Again, no control group was employed. These findings, nevertheless, seem to lend support for generalizing the findings with animals to humans.

61 D. Shapiro, B. Tursky, E. Gershon and M. Stern, 'Effects of Feedback and Reinforcement on the Control of Human Systolic Blood Pressure', Science, Vol. 163, 1969, pp. 588-590.

In a very recent review of human cardiac self-control literature, Blanchard and Young⁶² differentiated between statistical and clinical significance of heart control. After an extensive examination of findings, they conclude that desired changes in blood pressure, heart rate acceleration, deceleration and variability have been clearly shown. However, the magnitude of these changes has been quite low, the duration of control brief, and generalization beyond the laboratory poor. Thus, autonomic conditioning studies in humans need improvement before their reported statistical significance can be considered significant for use in a clinical setting. Although a very promising area for clinical application it is clear that further work is necessary to replicate and verify the existing tentative findings before they are ready for the clinic. This same situation is true for operant conditioning of neural events.

Kamiya's early experiment led to a series of studies⁶³ in which an auditory tone or light is fed back whenever the subject is emitting occipital alpha rhythms. The procedure usually consisted of transducing the 8-13 Hz alpha rhythm into a tone for continuous feedback of EEG. In this way immediate

62 E.B. Blanchard and L. Young, "Self-Control of Cardiac Functioning: A Promise as Yet Unfulfilled," Psychological Bulletin, Vol. 79, 1973, pp. 145-163.

63 Joe Kamiya, op. cit., p. 514.

and continuous feedback was given whenever EEG alpha was present. Kamiya found that subjects could quickly learn to keep the tone off (suppress alpha) very easily. Conversely, subjects could also be trained, via feedback, to keep the tone on (producing alpha). When asked to describe how they did this for the tone-off condition, subjects reported imagining visual images and holding these images in their mind (concentration). If they were able to fixate on something, they seemed able to suppress alpha.. On the other hand, descriptions of general well-being and relaxation accompanied the tone-on or alpha production condition.

This relaxation accompanying alpha generation was further described as a very pleasant "general calming down of the mind". Kamiya goes on to speculate that people who are introspective, sensitive and comfortable in interpersonal relationships tend to be the best candidates for learning conscious control of cortical states.

Although non-meditators can be trained to enhance their alpha densities, Kamiya tentatively reports that subjects that have practiced meditations such as Zen or Yoga and are more introspective than not, do much better at learning to augment alpha rhythm activity. These people are characterized as feeling comfortable in using words such as "images", "dreams", "wants" and "feelings!"

Brown⁶⁴ using visual stimuli (different colored lights), instead of an auditory tone to monitor different cortical frequencies, reported in her preliminary findings that after only 60 minutes of practice, subjects were able to associate different feeling states with alpha, beta and theta frequencies. Two years later, Brown⁶⁵ continued in her efforts to determine the subjective feeling states associated with the production of the 8-13 Hz occipital alpha rhythm and reported the following findings. A highly significant degree of enhanced alpha activity was achieved after only one practice session when subjects were given visual feedback in the form of a blue light whenever alpha was present. Subjects were informed that they were to try to isolate the feeling state associated with the light coming on. The intensity of light represented the strength (amplitude) of the alpha activity while the time the light was on represented alpha presence. Immediately following each of the four practice sessions, the 23 subjects filled out a brief questionnaire which included questions such as "1) what did you experience during the practice session?, 2) did you use any special technique to control the light, and if so, can you describe it?" . With reference to the first question, three independent judges came up

64 B. Brown, "Awareness of EEG Subjective Activity Relationships Detected Within a Closed Feedback System," Paper Presented at Society for Psychophysiological Research, Oct., 1968.

65 -----, "Recognition of Aspects of Consciousness Through Association with EEG Alpha Activity Represented by a Light Signal," Psychophysiology, Vol. 6, 1970, pp. 442-452.

with three categories of responses for this question: 1) the subject remained aware of his environment, 2) he lost all awareness except of the light signal and 3) he experienced floating or drifting sensations. With regards to question number two, subjects a) felt relaxed by the experience, b) actively attempted to relax, and c) concentrated on mental imagery. So it appears that alpha production under conditions of augmented visual feedback is not only enhanced, but associated with subjective feelings of mainly pleasantness and a narrowing of perceptual awareness. In neither of Brown's studies did she employ any control group to ensure the observed changes were the result of the feedback procedure as opposed to other variables. Next, she acquired only 10-15 min. of baseline EEG before training which may have been too short for subjects to adapt themselves to the laboratory situation.

Thomas Mulholland is another worker in the feedback area who has contributed many significant findings^{66,67,68} with human subjects. Mulholland's work has emphasized the importance of visual influences in the generation of the alpha rhythm.

66 T.B. Mulholland and S. Runnals, "A Stimulus-Brain Feedback System for Evaluation of Alertness", Journal of Psychology, Vol. 54, 1962, pp. 69-83.

67 T.B. Mulholland, "Feedback Electroencephalography", Activitas Nervosa Superior, Vol. 10, 1968, pp. 410-438.

68 -----, "Problems and Prospects for Feedback Electroencephalography", Paper Presented at 2nd Winter Conference on Brain Research, Aspen, January, 1969.

He demonstrated that eye position (i.e., deviated up, down or laterally) can be a significant artifact when attempting to train human subjects in the self-control of brain waves. The work of Fenwick⁶⁹ shows the Mulholland effect to be limited in that 15 subjects produced alpha regardless of eye position. Mulholland emphasizes that being a special case of applied cybernetics in psychophysiology, feedback electroencephalography should be unified under the engineering theory of adaptive control. He went on to warn that unless there is such a theory, one runs the risk of seeing a flood of studies related by method but not conceptually or theoretically, pervade the journals and scientific literature.⁷⁰

Hart⁷¹ attempted to replicate and extend Kamiya's findings by assessing the importance of feedback in the autocontrol of EEG alpha. His study employed three groups of subjects which received either in-session feedback training and post-session information about their scores, only received in-session feedback training and a control group which had only post-session

69 P. Fenwick, 'The Effects of Eye-Movement on Alpha Rhythm,' Electroencephalography and Clinical Neurophysiology, Vol. 21, 1966, p 618.

70 T.B. Mulholland, op. cit., 1968, p. 143.

71 Joseph T. Hart, 'Autocontrol of EEG Alpha,' Paper Presented at the Society for Psychophysiological Research, San Diego, October, 1967.

data about their trial-by-trial alpha densities. Subjects in all groups were instructed to try to produce as much alpha as possible (this is the basic instructional procedure employed in most EEG feedback studies which report success). Results indicated that after 10 training trials the three groups did not differ significantly in the amount of alpha produced. Closer inspection of the data did indicate that three of the five control subjects showed alpha increases and both experimental groups significantly increased their alpha content. These findings suggest that post-session performance information is not crucial to the learning process in alpha control. Probably more provocative are the control group increases in alpha, since this suggests that factors other than contingent feedback of EEG are operating to enhance alpha.

Nowlis and Kamiya⁷² attempted to elucidate the mental activity associated with alpha presence and absence using auditory feedback. Twenty-six subjects received approximately one hour of feedback training to enhance and suppress alpha differentially. Before training two minute baselines of alpha content were determined. Results showed a significant tendency for alpha increases to occur during 'enhanced' conditions and alpha decreases during 'suppress' conditions when compared with baseline. Verbal self-report of mental activity during

72 D. Nowlis and J. Kamiya, "The control of Electroencephalographic Alpha Rhythms Through Auditory Feedback and the Associated Mental Activity," Psychophysiology, Vol. 6, 1970, pp. 476-484.

alpha reflected states of relaxation, "letting go" and pleasant affect. Reports of being alert, vigilant, tense, etc. were predominant during alpha suppression. These findings, although replicating earlier work showing that EEG control is possible, are limited since 1) no control groups were employed, 2) very short baseline assessment was used and 3) brief training periods (i.e., 1 hour and less) were provided.

Beatty⁷³ employed a matched yoked control group in his study on the relationship of initial alpha wave abundance to subsequent feedback control. Based on a 300 second pre-training baseline period, subjects were divided into low, medium and high alpha groups. Nine additional subjects served as yoked controls and received non-contingent feedback based on the pattern of reinforcement (tone) received by yoke-mates. Training consisted of auditory feedback contingent upon alpha presence given over approximately thirty-three minutes (16.6 minutes of alpha training). This period was divided into randomly alternating blocks of 200 seconds during which either alpha or beta was reinforced. Between the blocks, subjects were asked to get up and move about for at least one minute. Post-trial training totals of alpha and beta were also provided. Results indicated

73 Jackson Beatty, "Effects of Initial Alpha Wave Abundance and Operant Training Procedures on Occipital Alpha and Beta Wave Activity," Psychonomic Science, Vol. 23, 1971, pp. 197-199.

that baseline levels of alpha are related to the production during feedback,"But the lack of a significant interaction between alpha wave abundance, group, and trials(...)fails to support the view that initial alpha wave abundance is a major determinant of the relative efficiency of learning differential control"⁷⁴. Subjects could significantly increase alpha and beta activity, differentially supporting earlier findings, while yoked controls failed to demonstrate significant EEG changes. Although providing a necessary control feature to his experiment, Beatty's use of a five-minute baseline period may have been too short to allow his subjects to adapt or habituate to the novelty of the experimental situation, thus providing a stable baseline. Similarly, longer training periods may give time for the development of a more reliable curve of learning.

Subsequent work by Beatty and Kornfield⁷⁵ demonstrated that in fourteen subjects trained to enhance alpha and beta differentially, as before, heart rate and respiratory activity showed no significant concomitant changes. He concluded that conditioned changes in EEG activity are independent or not mediated by central nervous system mechanisms which control

74 Jackson Beatty, op. cit., p. 198.

75 Jackson Beatty and C. Kornfield, "Relative Independence of Conditioned EEG Changes from Cardiac and Respiratory Activity," Physiology and Behavior, Vol. 9, 1972, pp. 1-4.

breathing and cardiac functioning. This work which attempts to rule out autonomic correlation is consistent with the findings of Nowlis and Kamiya,⁷⁶ Hord and Barber,⁷⁷ and Schwartz, Shaw and Shapiro.⁷⁸

Hord and Barber⁷⁹ tested the effectiveness of two kinds of feedback on alpha control. In a repeated measures design, eleven subjects received a feedback tone representing alpha presence and no tone indicating alpha absence or beta. After training, the same subjects were to attempt differential control of alpha and beta as before except tone-on represented beta and tone-off alpha. Findings showed that 1) both methods of feedback were equally effective in producing significant changes in alpha and beta density; 2) baseline percent alpha (over an eight minute period) was positively correlated with biofeedback increases in alpha and 3) heart rate was not significantly related to alpha levels.

76 D. Nowlis and Joe Kamiya, op. cit.

77 David Hord and J. Barber, "Alpha Control: Effectiveness of Two Kinds of Feedback," Psychonomic Science, Vol. 25, 1971, pp. 151-154.

78 G. Schwartz, G. Shaw and D. Shapiro, "Specificity of Alpha and Heart Rate Control Through Feedback," Psychophysiology, (Abstract), Vol. 9, 1972, p. 269.

79 David Hord and J. Barber, op. cit.

Green, Green and Walters⁸⁰ in an attempt to provide "psychophysiological training for creativity" reported success with biofeedback procedures in increasing alpha densities as well as decreasing "unconscious" (biological signals the subject is not aware of) electromyographic (EMG) activity to zero and increasing temperature in the hands by 10 degrees farenheit. Some subjects were reported to have maintained control over all three simultaneously when given visual feedback in the form of a visual display of vertical bars of light which continuously ascend their columns as desired physiological states (increased alpha and skin temperature with decreased EMG activity) are maintained. Green, et. al. believe that the alpha-theta state is analogous to the psychological state during which creative thought and discovery can flourish. Thus, by training people to mimic this psychophysiological state creativity will be enhanced.

Sittenfeld⁸¹ was also interested in biofeedback control of theta wave activity. She tested a two-stage feedback training procedure involving EMG feedback first to induce a relaxed state presumably facilitating theta and then theta training in which

80 E. Green, A. Green and E. Walters, "Voluntary Control of Internal States: Psychological and Physiological," Journal of Transpersonal Psychology, Vol. 2, 1970, pp. 1-26.

81 Pola Sittenfeld, "The Control of the EEG Theta Rhythm," Paper Presented at the Biofeedback Research Society, Boston, 1972.

auditory feedback was employed. She found that subjects with high baseline EMG levels reach control over theta only after EMG (relaxation) training. Conversely, subjects with low baseline EMG do quite well when given theta feedback only. Simultaneous measurement of heart rate showed marked reductions in this as well as frontalis EMG with the onset of theta suggesting the induction of a low state of arousal.

To date, most EEG feedback studies have concerned themselves with the enhancement of the frequency component of EEG. A break in this trend is noted with Osborne and Fehmi's⁸² work with occipital EEG phase relation changes using biofeedback. Auditory EEG feedback was given to twenty subjects with instructions to keep the tone on representing phase agreement. Measurements were secured bilaterally from the occipital lobes. Two rhythms were considered in-phase when their crests and troughs coincided temporally. Control of phase relation activity between left and right occipital lobes was achieved, both for increasing and decreasing, when compared with baseline. Associated mental activity underlying this control consisted of concentrating attention on a stable mental image.

82 S. Osborne and L. Fehmi, "Autoregulation of Occipital EEG Phase Relations Using Biofeedback", Unpublished Manuscript.

Fehmi, Ancoli and Selzer⁸³ reported that mid-frontal lobe EEG alpha was successfully controlled by tactile as well as auditory feedback. Non-contingent tactile feedback groups did not show alpha increases, while both tactile and tone groups receiving contingent feedback did. No significant difference was evident between tactile and auditory groups in learning, although the former group showed significant alpha control by the second session while the latter group took until the fourth session.

The little explored area of amplitude control was investigated by Silverman and Sherwood.⁸⁴ They found that subjects were successful in controlling non-frequency dependent amplitude components of the EEG when given four auditory feedback sessions. It is interesting to note that in all cases, increases in amplitude was related to low frequency EEG components. Perhaps, amplitude training is a different route to the same location (i.e., alpha training).

In summary, it appears that ample evidence exists to confirm the idea that operant neural conditioning in the form of a biofeedback paradigm is effective in teaching human subjects

83 L. Fehmi, S. Ancoli and F. Selzer, "Tactile and Auditory Feedback in the Autoregulation of Frontal Lobe EEG", Paper Presented at the Biofeedback Research Society, Boston, 1972.

84 S. Silverman and M. Sherwood, "Operant Conditioning of the Amplitude Component of the EEG," Psychophysiology, (Abstract), Vol. 9, 1972, p. 269.

to alter EEG alpha activity in the direction of increased densities.

What remains quite nebulous are the mechanisms responsible for the observed increases or decreases in alpha wave production. Had many of the above reported studies employed tighter methodologies, these mechanisms would perhaps be easier to observe. Generally speaking, most of the research synthesized earlier first suffers from unduly short feedback training periods. Had they been longer, more stable "learning curves" may have appeared or possibly disappeared. Also, subjects would have had the chance for their learning to asymptote, thus providing data about maximum alpha possible. Second, many of these earlier studies employed very short baseline EEG assessments or none at all. Experimentally naive subjects who are brought to a laboratory, wired with electrodes and then told to relax are likely to be aroused. Since arousal alters EEG patterns, usually towards desynchrony, accurate assessment of baselines should provide longer periods of time during which the subject's true resting EEG (alpha density) can be assessed. Third, although more workers are beginning to employ yoked controls or non-contingent feedback groups with which to compare results, their numbers are still small. Fourth, the term alpha control is used quite popularly in the literature to describe the significant increases shown by subjects during feedback. This term is inappropriate since true control would be better measured by turning off the feedback and asking the subject to produce as much alpha as possible. Thus, more studies which

use a post-feedback retention phase are badly needed. Finally, very little attention has been given to controlling personality variables (e.g., individual differences) which may differentially effect biofeedback outcome.

In light of these shortcomings any definitive statement about mechanisms of alpha control is very difficult to make. Nevertheless, four different hypotheses have been advanced which attempt to unravel the mechanisms responsible for biofeedback increases in EEG alpha.

Although operant control of EEG activity in humans is perhaps in its infancy (slightly more than a decade old), it is surprising that more attempts at clinical application have not been reported. The possibilities of operant neural conditioning in such disorders as epilepsy, learning disorders, etc., would appear unlimited in a research sense. This writer found only a few such studies.

Dewan⁸⁵ as early as 1964 suggested a clinical application for EEG biofeedback. He showed that with short training, subjects could learn to send morse code with their EEG by means of long and short bursts of alpha activity. He developed a computer program which translated this activity into typed messages that could be read. The possibilities of such telecommunication

85 E. Dewan, "Communication by Electroencephalography", Air Force Cambridge Research Laboratories, Special Report No. 12, 1964, pp. 1-4.

in completely paralyzed individuals, such as stroke victims, are exciting indeed. Although suggested, no such application has been reported.

More recently, Gannon and Sternbach⁸⁶, in a case study, attempted to enhance EEG alpha as a treatment for pain in a head injury patient with chronic headaches. Using biofeedback they increased the subject's alpha density from 20% to 92% which partially enabled him to thwart the onset of pain but failed to alleviate the pain once it began.

Mills and Solyom⁸⁷ endeavored to explore the possibility of reciprocally inhibiting chronic and severe ruminative behaviour in five obsessive neurotics by having them produce an "alpha state" instead. Although, not all subjects learned to increase their alpha densities from baseline, they all reported no ruminations during the feedback sessions.

Poirier⁸⁸ provided evidence suggesting that subjects with problems of light evoked epileptic seizures could be treated with auditory feedback of EEG alpha. Subjects were taught to enhance alpha at the first signs of a seizure, thus

86 L. Gannon and R. Sternbach, 'Alpha Enhancement as a Treatment for Pain; A Case Study,' Behavior Therapy and Experimental Psychiatry, Vol. 2, 1971, pp. 209-213.

87 G.K. Mills and L. Solyom, 'Biofeedback of EEG Alpha in the Treatment of Obsessive Ruminations, An Exploration', In Press, Behavior Therapy and Experimental Psychiatry.

88 F. Poirier, 'Traitement de l'Epilepsie Par Retroaction Sonore,' Paper Presented at the Biofeedback Research Society, Boston, 1972.

driving the spreading abnormal electrocortical activity into the alpha range of normality. Work has also just begun on the possibility of unilateral alpha training to alter the visual evoked response in dyslexic children.⁸⁹

Although not definite or conclusive, these attempts at application are promising. As Black⁹⁰ suggests "(...) we should wait until more of this (research) information is available before we permit ourselves to be carried away by passionately expressed hopes and fears".

5. Mechanisms of Alpha Control

Although EEG biofeedback with human subjects is a little over a decade old, only a few testable hypotheses have emerged to explain the mechanisms which underlie alpha control. The only substantial hypotheses found equal four in number. They are reviewed under the headings, "Oculo-motor Hypothesis", "Meditation Hypothesis", "Anoxia Hypothesis" and "Disinhibition Hypothesis".

89 J. O'Malley and C. Conners, "Unilateral Alpha Training on VER in a Dyslexic Adolescent," Psychophysiology (Abstract), Vol. 9, 1972, p. 467.

90 A.H. Black, "The Operant Conditioning of Central Nervous System Electrical Activity," In G.H. Bower (Editor) , The Psychology of Learning and Motivation, New York, Academic Press, 1972, p. 56.

A. Oculo-motor Hypothesis:

This hypothesis was advanced by Mulholland⁹¹ to account more for periods of no-alpha rather than alpha. Basically, this hypothesis regards alpha increases and decreases to be the direct result of efferent oculomotor commands in which the subject advertently or inadvertently facilitates or inhibits alpha through control of oculo-motor activity. This is supported by the finding⁹² that alpha rhythm density is increased when eyes are maximally elevated. Once elevated, even strong visual stimulation does not disturb the resulting alpha even when eyes are open. In this vein, Kris⁹³ reported that lateral eye deviation of an angle greater than 30 degrees also facilitates alpha. Mulholland supports his hypothesis by a series of experiments.^{94,95}

91 T. Mulholland, op. cit. ,1968.

92 ----- and S. Runnals, "Cortical Activation by Alternate Visual and Auditory Stimuli," Cortex, Vol. 1, 1964, pp. 225-232.

93 E.C. Kris, "EEG and EOG Measurement While Learning to Position the Eyes," Electroencephalography and Clinical Neurophysiology, Vol. 24, 1968, p. 189.

94 T. Mulholland, "The Electroencephalogram as an Experimental Tool in the Study of Internal Attention Gradients", Transactions of the New York Academy of Sciences, Vol 6, pp. 664-669.

95 -----, "Variations in the Response-Duration Curve of Successive Cortical Activation by a Feedback Stimulus," Electroencephalography and Clinical Neurophysiology, Vol. 16, 1964, pp. 394-395.

in which he showed that visual tracking of stationary and moving targets under conditions of focused accommodation, with relaxed accommodation which is blur tracking and no tracking with relaxed accommodation, significantly effected alpha density. Thus, biofeedback increases in EEG alpha are interpreted to be the result of a refrain from oculo-motor activity which would normally block alpha. Subsequent work by Peper⁹⁶ using visual tracking procedures supported Mulholland's oculo-motor hypothesis. Briefly, his study involved having subjects track a moving target whose visibility was controlled by the presence of alpha. He showed that at no time could tracking be initiated and continued without subsequent alpha blocking. Thus, he concluded that efferent oculo-motor commands block alpha.

Recent work by Lippold⁹⁷ indirectly supports Mulholland's hypothesis. Lippold suggested that alpha waves are generated by the standing electrical potential across the eye rather than from cortical neurons. This potential is modulated by extra-ocular muscles (tremor) at about 10 Hz when the eye is blurred or when there is no sharply focused image on the retina.

96 Erik Peper, "Feedback Regulation of the Alpha Electroencephalogram Activity Through Control of the Internal Parameters", Kybernetik, Vol. 7, 1970, pp. 107-112.

97 O. Lippold, "Origin of the Alpha Rhythm," Nature, Vol. 226, 1970, pp. 616-618.

Contradictory evidence to the oculo-motor hypothesis was forthcoming by Chapman, Cavonius and Ernst⁹⁸. They found both alpha and Kappa rhythms to occur normally in a bilaterally enucleated subject. Also, in two one-eyed subjects whose eyeball and extraocular muscles were removed alpha was present in normal amounts. Fenwick⁹⁹ also reports that deviations of the eyeball into various positions is not significantly related to alpha activity.

B. Meditation Hypothesis

This hypothesis, although not well-formulated, was tentatively advanced by both Kamiya¹⁰⁰ and Brown¹⁰¹. They believed that since alpha is a prominent electrocortical rhythm during Zen¹⁰² and Yoga¹⁰³ meditation, it may form the basis for "altered states of consciousness". In other words, alpha

98 R. Chapman, C. Cavonius and J. Ernest, "Alpha and Kappa Electroencephalogram Activity in Eyeless Subjects", Science, Vol. 171, 1971, pp. 1159-1161.

99 P. Fenwick, op. cit.

100 J. Kamiya, op. cit., 1969.

101 B. Brown, op. cit., 1970.

102 A. Kasamatsu and T. Hirai, op. cit.

103 BK. Anand, G. Chhina and B. Singh, op. cit.

activity is related to a psychological state which is highly similar to that which occurs during meditation. Their hypothesis is rooted in the reports of mental activity reported by subjects during the high alpha state. Reports of a narrowing of perceptual awareness, relaxation and so forth would appear to be crude expressions or analogs of altered psychological states achieved through meditation. It would seem to follow from this hypothesis, that if alpha abundance is the basis for altered psychological states similar to meditation, then teaching people to produce copious amounts of alpha via EEG feedback should facilitate the occurrence of these states, or least enable novice meditators to achieve them faster.

C. Anoxia Hypothesis

This is a very recent hypothesis advanced by Watanabe, Shapiro and Schwartz¹⁰⁴ in 1971. Although it was formulated specifically to account for meditation-related increases in alpha activity, it is appropriate to consider it in terms of biofeedback changes in alpha. Having reviewed the existing physiological data on meditation they concluded that both the altered states of consciousness and increased alpha rhythm activity are due to a marked reduction in oxygen consumption.

104 T. Watanabe, D. Shapiro and G. Schwartz, "Meditation as an Anoxic State: A Critical Review and Theory," Psychophysiology, (Abstract), Vol. 9, 1972, p. 279.

They report that meditation related EEG changes resemble very closely those observed during the early stages of anoxia (oxygen deficiency) in both sequence and localization. Wallace's¹⁰⁵ findings of decreased blood pH and reduced oxygen consumption during TM appear consistent with the anoxia hypothesis. This hypothesis, although not formulated to account for feedback-related alpha increases, nevertheless provides a framework from which to study the role of oxygen and carbon dioxide exchange (respiratory activity) as possible mechanisms of mediation and control.

D. Disinhibition Hypothesis

The final and most important hypothesis to the present study is the disinhibition hypothesis of Lynch and Paskewitz.¹⁰⁶ Their position suggests that the alpha increases observed during feedback training are due to a process of "unfocusing of attention" to the environment rather than the feedback process. In their words,

"(...)alpha activity occurs in the feedback situation when an individual ceases to pay attention to any number of stimuli which normally block this activity". p. 215.

105 R. Wallace, op. cit.

106 James Lynch and D. Paskewitz, "On the Mechanisms of the Feedback Control of Human Brain Wave Activity", Journal of Nervous and Mental Diseases, Vol. 153, 1971, pp. 205-217.

Going further, they believe that an individual's ability to produce alpha is limited by innate or "constitutional factors" and therefore, observed increases in alpha during feedback training should never significantly exceed the alpha levels observed during "optimal baseline conditions". Thus, it becomes crucial to make very accurate determinations of pre-training baseline alpha levels. In an earlier study, Paskewitz, Lynch, Orne and Costello¹⁰⁷ found that a yoked control group who received non-contingent feedback produced operant learning curves of alpha activity as did their contingent feedback group. Also, during rest periods (no feedback) all subjects demonstrated learning shaped curves and the amount of alpha densities were always greater during rest than during the experimental feedback periods. These results highlight the importance of using proper control groups.

Based on Katkin and Murray's¹⁰⁸ criteria, Lynch and Paskewitz emphasize the importance of carefully determining alpha increases by accurately assessing baselines and employing appropriate controls so that alpha increases can be clearly related to the feedback procedure rather than other factors.

107 D. Paskewitz, J. Lynch, M. Orne and J. Costello, "The Feedback Control of Alpha Activity: Conditioning or Disinhibition," Psychophysiology (Abstract), Vol. 6, 1970, pp. 637-638.

108 E.S. Katkin and E. Murray, Instrumental Conditioning of Autonomically Mediated Behavior: Theoretical and Methodological Issues, Psychological Bulletin, Vol. 70, 1968, pp. 52-68.

This is known as the disinhibition hypothesis because they believe that when those factors present in the environment which normally act to inhibit alpha are reduced or abolished alpha density increases. For example, biofeedback increases in alpha activity are often considered in reference to the subject's initial baseline alpha density. If initially tense due to the novelty, or what Orne¹⁰⁹ calls the "demand characteristics" of the experimental situation, this baseline is likely to be low. This is consistent with orienting reflex literature,¹¹⁰ which shows that a novel situation will cause the organism to orient to environmental cues, the EEG component of which is alpha blocking. As a result, a short interval pre-feedback baseline may reflect a distorted picture of "resting" baseline alpha density. As the subject becomes more relaxed during the course of the experiment his alpha density may naturally increase. This is also consistent with orienting reflex literature. This increase would, in the feedback setting, be considered as due to the effects of training rather than a habituation or disinhibition phenomenon. Such an error can be reduced at the design level of the experiment by

109 M.T. Orne, "On the Social Psychology of the Psychological Experiment; With Particular Reference to Demand Characteristics and their Implication"; American Psychologist, Vol. 17, 1962, pp. 776-783.

110 E. Sokolov, "Neuronal Models and the Orienting Reflex"; In M.A. Brazier (Editor), The Central Nervous System and Behavior, New York, Josiah Macy Fdn., 1960, pp. 187-276.

carefully assessing alpha baselines.

By controlling visual effects during feedback, Paskewitz and Orne¹¹¹ demonstrated that "increases in alpha densities can take place only if inhibitory mechanisms are initially present to depress alpha". Observed alpha increases during feedback were interpreted as reflecting an increasing ability by the subject to ignore those influences present which act to reduce alpha from its optimal level. Cleeland, Booker and Hosokawa¹¹² provide further evidence which supports the disinhibition hypothesis. They found that subjects receiving contingent alpha feedback did no better than those who experienced non-contingent feedback, and in some cases the latter group produced greater densities of alpha. Contingent feedback subjects were also, unable to raise their alpha densities significantly above those observed during baseline. That alpha does not go above baseline was also reported by Walsh¹¹³.

The disinhibition hypothesis is perhaps the most devastating interpretation of feedback increases in alpha

111 D. Paskewitz and M. Orne, "Visual Effects During Alpha Feedback Training," Psychophysiology, Vol. 9, 1972, p. 269.

112 C. Cleeland, H. Booker and K. Hosokawa, "Alpha Enhancement: Due to Feedback or the Nature of the Task," Paper Presented at the Society for Psychophysiological Research, New Orleans, 1970.

113 D.H. Walsh, "Effects of Instructional Set, Reinforcement and Individual Differences in EEG Alpha Feedback Training", Paper Presented at the Biofeedback Research Society, Boston, 1972.

activity. Implicit within it is the idea that the feedback signal contingent upon alpha presence may not be as important as situational and rapport factors in maximizing alpha densities. Thus, groups of subjects trained under contingent and non-contingent feedback conditions would be expected to demonstrate similar changes in alpha. A serious implication of the disinhibition hypothesis is that alpha training through biofeedback may not be the most efficient way of producing alpha increments.

A second implication of this hypothesis is that attentional factors are the stimuli which normally serve to block or reduce alpha activity. In this context it would be expected that spontaneously occurring habituation (orienting reflex) to the novelty of the experimental situation could account for some of the alpha increases attributed to feedback. If this is true, one can expect subjects to show spontaneous alpha increases during baseline assessment if they are long enough in duration. Also, since Lynch and Paskewitz believe that the maximum alpha density a subject can produce is limited by "(...) the S's own natural ability to generate this activity",¹¹⁴ alpha produced during feedback may significantly increase but not beyond maximum baseline values.

Finally, if alpha increases are not due primarily to an orienting reflex habituation phenomenon but reflect a truly operant neural conditioning phenomenon, then control which represents

114 J. Lynch and D. Paskewitz, op. cit., p. 206.

an ability to produce alpha at will should be better in a contingent feedback group than in a non-contingent group. Therefore, if asked to produce alpha without aid of feedback after training, subjects should be able to do so.

The disinhibition hypothesis clearly questions the importance of a discriminative feedback signal contingent on alpha presence for producing observed increases in alpha density. What is less clear, yet implicit within this formulation, is the idea that voluntary control over alpha density is unlikely by these methods. If alpha density increases spontaneously as a baseline shift, and discriminative feedback is equally as effective as non-discriminative feedback, then voluntary control over these changes cannot be asserted.

Since the disinhibition hypothesis seriously questions the validity of a growing body of research which reports success in training human subjects to control brain wave activity via feedback, it is considered worthy of further investigation.

A chapter summary and final statement of hypotheses follows in the next section.

6. Summary and Statement of Hypotheses

Since Plato's time a dichotomy has existed within physiology between the "superior" (cerebrospinal) and "inferior" (autonomic) parts of the body. This division has also pervaded later thinking in psychology manifest in the notion that classical conditioning (requiring an UCS capable of evoking an UCR which is innate) is the best, if not the only kind of learning possible in the autonomic nervous system, while operant conditioning (where a reinforcement can strengthen any immediately preceding response) is appropriate for skeletal responses but ineffective with autonomic functions.

This tradition of dividing the body and the way it learns into voluntary and involuntary sectors seems inappropriate in light of recent evidence. A review of meditative findings and operant neural and visceral conditioning in both animals and humans suggests voluntary control by this type of operant conditioning (Biofeedback) can be exerted over many autonomic functions.

The exact mechanisms by which biofeedback control is effected over EEG alpha activity, in particular, are still unclear. Various hypotheses have been proposed to explain this phenomena. The disinhibition hypothesis is of special interest since it considers biofeedback increases in EEG alpha as a naturally occurring baseline shift resulting from habituation of the EEG component of the orienting reflex. It is believed, that when those factors, both internal and external, which

normally act to block or inhibit alpha activity disappear (disinhibition), spontaneous increases in alpha density occur. Such increases are thought to be limited by the individual's "constitutional" ability to produce alpha. Thus, learning of the proposed operant variety is thought not to be taking place and doubt is cast on earlier work reporting positive results. Although much discussion¹¹⁵ has emphasized the importance of controlling for spontaneous baseline shifts (i.e., the disinhibition hypothesis), no study has been found which attempted a direct test of this idea.

The basic question of the present experiment, following from the disinhibition hypothesis, is as follows:

Do changes in EEG alpha densities observed during biofeedback exceed baseline densities, reflect a feedback contingent phenomenon, and represent learning which transfers beyond the feedback situation?

When translated more specifically, this general question becomes:

- a. Do subjects who receive true (contingent) feedback perform better than subjects who receive false (non-contingent) feedback of alpha activity?
- b. If subjects who receive contingent feedback do not learn alpha control any better than those who receive non-contingent feedback, will both groups perform equally well at the task of increasing alpha density without aid of feedback following training?

115 James Lynch and D. Paskewitz, op. cit., p. 206.

An ambiguous area meriting further exploration is that of the density and temporal shape of spontaneous pre-feedback (baseline) EEG alpha densities. Interpreted in terms of a theoretical question relevant to both orienting reflex theory and the disinhibition hypothesis it becomes,

Assuming that experimental subjects are initially orienting to the novelty of the experimental situation, do patterns of EEG alpha activity conform with expectations suggested by orienting reflex theory (i.e., initial suppression of alpha, diminishing progressively as the novelty of the situation disappears)?

Putting this question in the context of the disinhibition hypothesis it is expected in this study that the following will take place:

- a. Increases in alpha density should occur during extended baseline periods even though no contingent feedback is provided. The course of these increases should approximate an asymptote.
- b. Once alpha densities reach an asymptote during baseline, this value can be used as an index of the maximum alpha capable under existing laboratory conditions, feedback or not.

And finally, the short periods of training usually employed during feedback experiments raises questions regarding the reliability of observed alpha increases. Specifically, if learning is taking place one would expect improvement with practice. Stated as a general hypothesis:

Improvements in performance, represented by increased alpha abundance, should occur after three separate training (practice) sessions such that greater alpha densities are manifest on the third than on the first day of training.

Restated in the statistically null form these observations become:

1. There is no significant difference in alpha density between overall contingent and non-contingent baselines.
2. There is no significant difference in alpha density by days between contingent and non-contingent baselines.
3. There is no significant difference in alpha density between days within baseline sessions for the contingent feedback group.
4. There is no significant difference in alpha density between days within baseline sessions for the non-contingent feedback group.
5. There is no significant difference in alpha density between trial blocks within baseline sessions for the non-contingent feedback group.
6. There is no significant difference between trial blocks within baseline sessions for the contingent feedback group.
7. There is no significant difference in overall alpha density between contingent and non-contingent feedback groups.
8. There is no significant difference in alpha density by day between contingent and non-contingent feedback.
9. There is no significant difference in alpha density by trial block between contingent and non-contingent feedback.
10. There is no significant difference in alpha density between days within the contingent feedback group.
11. There is no significant difference in alpha density between trial blocks within contingent feedback sessions.
12. There is no significant difference in alpha density between days within the non-contingent feedback group.
13. There is no significant difference in alpha density between trial blocks within non-contingent feedback sessions.
14. There is no significant difference between contingent and non-contingent feedback in alpha densities produced voluntarily without aid of feedback.

The last hypothesis is descriptive and is stated as follows:

15. Alpha densities produced over trial blocks by the contingent feedback group never exceed the highest trial value achieved during baseline.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter elaborates the experimental methods used to test the hypotheses proposed earlier. The details of subject selection, psychological screening and physiological instrumentation for EEG amplification and feedback are given in the first three sections. Section four describes the experimental design in terms of four phases: Instructional Set, Baseline Assessment, Feedback Contingency, and Retention. The exact procedures used for the conduct of all phases of the experiment are given in section five. Last, the necessary statistical analyses appropriate for hypothesis testing are considered.

1. The Subjects

Since the EEG is reactive to systemic chemical changes associated with different phases of the female's menstrual cycle¹, only males were used in the experiment. Twenty-four University of Ottawa students who fell within the ambivert range on the Eysenck Personality Inventory (EPI), Form A²

1 D. DeBarenne and F. Gibbs, "Variations in the Electroencephalogram During the Menstrual Cycle", American Journal of Obstetrics and Gynecology, Vol. 44, 1942, pp. 687-690.

2 H.J. Eysenck and S. Eysenck, Manual, Eysenck Personality Inventory, Educational Testing Service, 1968, pp. 5-27.

volunteered as subjects. They were selected at random from a larger list of 56 subjects who were interested in participating in "a psychology experiment". Subjects were screened out of the experiment if they were currently taking drugs (amphetamines, barbiturates, marijuana, etc.) or involved in meditative practices. Ages ranged from 18 to 34 years. Participants were paid only after completing all phases of the experiment.

2. Psychological Screening

Since it has been suggested³ that individual differences in personality can affect performance in an EEG biofeedback task, error variance due to personality was restricted by screening subjects on the basis of the EPI. Eysenck's introverted and extraverted dimensions of personality are considered to be related to general electrocortical states of inhibition and excitation. Introverts are thought to be in a generally higher state of arousal, sensation avoiding and more easily conditioned than extraverts who maintain essentially opposite characteristics. To avoid these extreme features of personality which could possibly effect the outcome of the present study, extreme introverts and extraverts were screened out. Only subjects

³ Joe Kamiya, "Operant Control of the EEG Alpha Rhythm and Some of its Reported Effects on Consciousness"; In C.T. Tart (Editor), Altered States of Consciousness, New York, John Wiley and Sons, 1969, pp. 507-517.

who scored in the range of 8 to 16 on the EPI were operationalized as ambiverts and included in this investigation.

As shown in Chapter I meditative practices can have significant consequences on electrocortical activity. Similarly, it has been speculated that subjects who are "introspective" and have practiced meditation of any variety are likely to do better in an EEG biofeedback task⁴. For these reasons only subjects with no history of meditation were included in the present study.

Thus, some measure of control is exerted over subject's psychological characteristics which could interact with the treatment effects of EEG feedback to confound results.

3. Physiological Instrumentation

Although EEG activity was the only physiological variable of immediate interest in the present experiment, corresponding measures of Galvanic Skin Response (GSR) and heart rate (HR) were recorded throughout all phases of the study.

EEG was recorded from the occiput bilaterally using a O_1-P_3 and O_2-P_4 electrode placement.⁵ Grass model E4s pure silver flat disc electrodes attached to a velcor headband

4 Joe Kamiya, op. cit.

5 H.H. Jasper, "The Ten-Twenty Electrode System of the International Federation," Electroencephalography and Clinical Neurophysiology, Vol. 10, 1958, pp. 371-375.

were placed on the scalp and interfaced with Beckman Ofner paste which served as an electrolyte. Scalp impedance was routinely reduced to at least three Kilohms between electrode pairs by alcohol cleansing and abraiding of the skin with a wooden swab. Grass model E34 ear electrodes were placed bilaterally on each lobe to serve as ground. All recordings were obtained using a bipolar configuration.

Figure A is a block diagram of the arrangement of physiological apparatus. EEG was first amplified by a single channel Mousseau SA 4 EEG amplifier set to pass signals between 2 and 50 Hz. The signal was then directed to a specially built non-reactive variable bandpass filter controlled audio tone generator for detecting the presence of alpha activity and providing a feedback tone. A 2.5 volt square wave lasting the duration of the alpha rhythm activated a custom made cycle timer controlled elapsed time meter with three clock banks. Raw EEG was secondarily filtered with a Krohn-Hite variable filter, Model 3550, set to 8 and 13 on high and low cut, respectively. Both A.C. and D.C. coupled GSR and HR were recorded and amplified on a Type RM-85 Nihon-Kohden 8-channel Multipurpose Polygraph. GSR was recorded from two chrome-plated finger electrodes placed on the index and third fingers of the right hand and transduced by a Nihon-Kohden model GSR-2 bridge box (wheatstone bridge). Voltage was set at 1 volt and each subject was balanced to zero before each recording session.

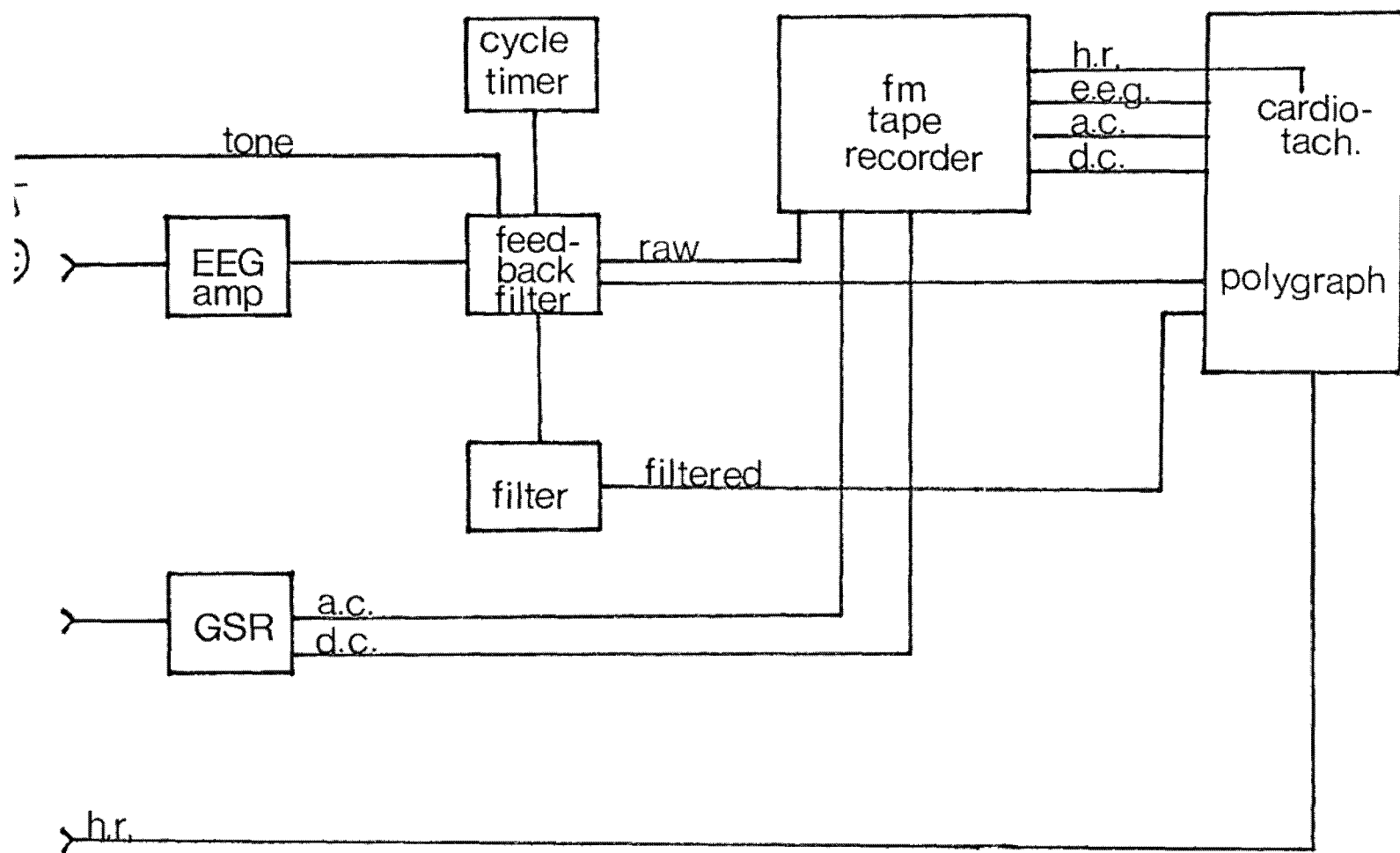


Figure A, Circuitry for the Transduction, Amplification and Recording of Physiological Data.

Polygraph settings for amplification on Biophysical Amplifier, Model RB-5, were 8.5 db with filters set at 2 and 15 Hz.

Cardiac activity measured from two stainless steel disc electrodes interfaced with Beckman Ofner paste to alcohol cleansed skin from the left and right wrists, was amplified by Biophysical Amplifier, Model RB-5, set at approximately 30 db with filtering of extraneous signals below and above 0.3 Hz and 30 Hz, respectively. This raw HR signal was used to trigger a Pulse Rate Tachometer, Model RT-5, which measures the duration of each R-R cycle in the PQRS complex and plots the output as a beat by beat histogram per minute.

Raw and filtered EEG, raw and beat by beat HR, and AC and DC GSR were displayed on a Nihon-Kohden Model VC-85, 8 channel oscilloscope, as well as being strip charted on the polygraph at a speed of 15 mm/sec. All raw physiological data was further recorded on analog Columbia tape using a four channel Thermionic T3000 recorder running at 1-7/8 inches/second.

A great deal of concern has recently been expressed by the Society for Psychophysiological Research (SPR) over the unrestricted manufacture and sale of biofeedback instruments to the public. These products were feared to be of inferior quality (i.e., EEG instruments which respond to muscle artifacts with a feedback tone) and sold by means of extravagant claims ranging from increasing sexual potency to eliminating phobias (Comments made at a meeting of the Society for Psychophysiological Research, during a general discussion, Boston, 1972).

Similar concern over the unrestricted sale of "(...) more than two dozen alpha brainwave biofeedback devices now on the market"⁶ has lead the U.S. Food and Drug Administration to consider taking regulatory action. If decisive in their efforts, the FDA would require all feedback devices to pass inspection standards appropriate for regulating medical devices.

To avoid this entanglement, the present study employed a specially designed and built EEG biofeedback system⁷. (See Appendix I and II for panel layout and specifications). This system consisted of a non-reactive bandpass filter controlled audio-tone generator and cycle timer controlled elapse time meters.

A. Non-Reactive Variable Bandpass Filter Controlled Audio-Tone Generator

This instrument was designed to receive an amplified EEG signal for filtering. High and low pass filter bandwidths, with roll off of 24 db/octave, are adjustable between 2 to 24 Hz with a frequency resolution of 0.2 Hz. With EEG amplification of 20 K the amplitude threshold can be adjusted to pass a signal selectable between 5 and 200 microvolts. Once a signal has been defined by threshold and frequency a 600 Hz, 100 milliwatt tone is produced with adjustable volume. An added feature in this generator is an audio delay ranging from

6 American Psychological Association, F.D.A. Weighs Action on Alpha Devices, APA Monitor, Vol. 4, May 1973, p. 6.

7 Designed in collaboration with and built by T.J. Mousseau, Mousseau Scientific Instruments, Ottawa, Canada.

0 to 1000 m.s. This allows some precision in controlling the temporal characteristics between the EEG signal and the tone feedback. An analog meter calibrated between 2 and 24 Hz. provides continuous monitoring of EEG frequency at an accuracy of 0.5 Hz. A BNC input handles the amplified EEG signal. An auxiliary BNC output makes available an amplitude histogram of the raw signal. A third BNC provides a 2.5 volt square wave-out whenever the defined signal is present. This output is the voltage source for activating separate time meters. This instrument receives its power supply from line voltage (see Appendix I). It is not claimed that this device is an improvement over existing machines, only that its response characteristics are known.

B. Cycle Timer Controlled Dual Channel Elapsed Time Meter

This instrument was designed to accompany the filter for on-line determination of EEG alpha in seconds. Basically, the cycle timer consists of three digital decade displays. Two of the displays have three decades reading a maximum of 999 seconds and are controlled by separate 10 division dials calibrated in minutes. The third display contains two decades and gives the total experimental elapsed time in minutes. Each of the three displays has separate reset to zero push buttons. The square wave out from the filter which represents alpha presence is fed to one of the three decade timers. Which timer is operating is controlled by their respective minute setting.

When in a rest period, selectable between one and ten minutes, the feedback tone is not operating and alpha is nevertheless being counted in seconds by the first clock display. At the end of the rest period the second clock is automatically activated to count alpha presence in seconds and simultaneously enables the feedback tone to be heard. The resolution of the elapsed time counters is 0.1 second. Pin jack input and output provide remote feedback and BNC outputs give a square wave from the cycle timer out and a positive going spike marking the beginning and end of work and rest periods. An added feature which gives versatility to the unit is an auxiliary BNC input which accepts voltage from an external timer such as a quasi-random function generator when the timers are each in the zero position. A panel switch when in "hold" position shorts the input so that the clocks stop timing. When switched to the "run" position the cycle timer resumes timing where it left off. A push-button switch allows resetting of the timing cycle back to a rest period when in the hold position. The total timing cycle always begins with a rest period and power is supplied from line voltage (see Appendix II).

4. Design

To test the disinhibition hypothesis, it was necessary to first provide a psycho-social context which is approximately the same throughout all phases of the experiment. This aim

was achieved by means of instructions which provided the proper mental set for all subjects. Next, it was extremely important to establish pre-training baselines of alpha density which were as free as possible from transient influences which would unreliably enhance or depress this activity. This was achieved by serial baseline EEG recordings taken before training and under constant environmental conditions. Third, to insure that increases in alpha abundance observed during EEG feedback are due to the nature of the feedback rather than from chance or naturally occurring phenomena, a non-contingent feedback control group was employed. In this arrangement, one group received auditory feedback that was alpha contingent and another group received taped feedback which was unrelated to alpha activity. And finally, as a further check on response acquisition, contingent and non-contingent subjects were given a post-training retention trial during which they attempted to produce as much alpha as possible without aid of feedback.

A. Instructional Set

All subjects received exactly the same instructions, regardless of contingency of feedback. Subjects were initially informed about the experiment in terms of "a brain wave conditioning study". At no time during the first solicitation for volunteers or baseline sessions was reference ever made to alpha waves or altered states of consciousness. Care was taken to

avoid terminology or conversations which would influence subject attitude, mental set or expectations of brain wave training. No subject appeared to have more than a casual knowledge of neurophysiology or concepts related to biofeedback. This is perhaps the most difficult variable to assess or control since biofeedback is gaining popularity among the lay public. After initial screening, each subject was told that the purpose of the study was to determine "(...) how well they could control their brain waves after three practice sessions". They were instructed to refrain from taking any drugs during their involvement as subjects and to report any changes in their normal sleep cycles or eating patterns. They were told that the experiment had three phases; a baseline phase where their task is to relax and listen to a periodic tone which is meant "(...) to keep them awake by promoting a steady level of arousal"; a training phase where their task is to relax and learn to control their brain waves; and a retention phase where their task is to relax and control their brain waves without aid of feedback.

The instructions, regardless of whether for baseline, training, or retention were designed to promote a task-oriented psycho-social context in which subjects are expected to operate. A second instructional feature has been on relaxation. All subjects are asked to relax within the the task-oriented context. All instructions were delivered by a Webcor Cassette Taperecorder. Phases one and two, which are most crucial for

testing the disinhibition hypothesis (alterations in EEG activity through learning or other factors?), both emphasize relaxation in a task-oriented context which focuses attention on a tone. Thus, they are quite similar in their emphasis.

B. Baseline Assessment

To insure a reliable assessment of baseline three separate, consecutive 30-minute recording sessions were made on each subject. Within each 30-minute session two minute subtotals of alpha density were calculated in seconds. This allowed the calculation of between session variability as well as two minute means. These two minute means were then collapsed into six minute trial blocks for analysis. As shown in Chapter I, virtually no EEG biofeedback studies include a reliability check (repeated measurement) on their baseline calculations, but rather determine what is considered "baseline alpha" from a rather short pre-training recording (e.g., 5-10 minutes).

In the context of the disinhibition hypothesis, lengthy and repeated baseline assessment under environmental conditions exactly like those in subsequent feedback trials should be sufficient for an individual's maximum resting alpha to emerge; a figure which theoretically, should not be significantly exceeded during feedback to be consistent with the disinhibition hypothesis.

In addition to the pre-training baselines, the feedback

trials, 1) began with a two-minute baseline, 2) staggered with five two-minute rest periods (baselines), and 3) were ended with another two-minute baseline.

C. Feedback Contingency

Subjects were randomly assigned to one of two groups in a single blind fashion. One group received contingent EEG feedback and the other group received non-contingent feedback. This procedure controls factors unrelated to the contingency of the feedback which may tend to enhance alpha density. Both conditions were identical in instructional set, environmental context and procedure with the single exception that non-contingent subjects received false feedback from a tape of the author's EEG while at rest. In fact, the environment was identical on all six days of recording for the non-contingent feedback group.

Earlier studies which have reported significant increases in alpha densities from baseline have usually employed remarkably short (one hour or less) training periods. As Lynch and Paskewitz⁸ suggest, such increases may represent an epiphenomenon of a larger process of habituation to the demand characteristics and novelty of the experimental situation. These increases, observed early in the feedback session may take a different shape if more training sessions are provided. In this spirit each subject underwent three separate feedback training sessions lasting 30 minutes each.

⁸ James Lynch and D. Paskewitz, "On the Mechanisms of the Feedback Control of Human Brain Wave Activity", The Journal of Nervous and Mental Disease, Vol. 153, 1971, pp. 205-217.

D. Post-Feedback Retention

Immediately after the last feedback trial all subjects were instructed to control their brain waves which were normally associated with the tone. They were told to engage in this task for six minutes. This phase of the experiment provides a check on how well alpha can be increased without aid of feedback, if at all. Minute by minute alpha densities were thus acquired and compared between contingent and non-contingent feedback groups. If learning has taken place then presumably, contingent feedback groups should produce greater alpha densities than non-contingent feedback groups.

5. Procedure

Broadly speaking, the experimental procedure was divided into three phases; the baseline phase, the feedback phase and the retention phase.

Following screening of meditators, drug users and females, the remaining subjects were instructed in the first baseline session as to the broad purpose of the experiment in the following way:

This is a brain wave conditioning experiment. It has three phases. Phase I involves determining how your body responds to rest. This phase takes three sessions. Phase II is the training phase where you learn to control brain waves and lasts three sessions. Phase III is used to determine how well you have learned to control your brain waves and takes place at the end of the third session in Phase II.

The total time of the experiment is about six hours which are spread out over six different sessions. All sessions take place at the Faculty of Psychology, 1245 Kilborn.

During all three phases of the experiment, measurements will be made on the electrical activity of your heart, brain and skin. After measuring electrodes are attached to the surface of your skin you will be taken to the next room where you will be seated comfortably. In this first phase you will then be left alone to relax with your eyes closed and listen to a periodic tone which is meant to keep you awake by promoting a steady level of arousal. The lights will be dimmed and the door shut. Through an intercom system you will be able to communicate with the experimenter at all times.

Since this first phase is principally for determining how your body responds to rest, your primary task is to just relax. You will be given further instructions once you are seated in the experimental room.

Any questions?

Subjects were then seated and EEG, HR and GSR electrodes attached. Each step in the electrode application was preceded by a brief explanation of how the electrode was to be applied and assurance that no pain would be experienced. This was necessary only in the first testing session. After electrodes were attached such that the subject experienced no discomfort, he was taken to a near-by sound-deadened, light controlled, 6'x7'x7', insulated, double-doored chamber and seated comfortably in a heavy, padded chair. All physiological leads were then connected and the subject was informed that the experimenter would be in the next room and two-way communication was possible through an intercom mounted on a table next to his chair. The subject was further told that more instructions would be given once the experimenter left the room. He was then asked if there were any questions. Since no subject asked for clarification, it was

assumed that instructions were understood. The experimenter then closed the double doors to the chamber and tested the intercom. While the equipment was being calibrated for recording, the subject was listening to the instructional tape, specifying his task during the baseline (listen to a tone and relax), which was played on a Webcor portable cassette tape recorder with a speaker in the chamber. The instructions were as follows:

As you already know, this experiment has three phases. Today we begin the first phase which will last about half an hour. The purpose of the first phase is to determine how your body responds to rest. During this time you are asked to sit as comfortably as you can and relax with your eyes closed. Try to avoid making any unnecessary, large body movements until the experiment is over. Periodically you will hear a tone. This tone is to insure that you remain awake and relaxed. It is your task to simply rest and listen to the tone.

In summary, you are to sit comfortably and relax with your eyes closed making as little movement as possible while listening to a tone.

Any questions?

If no questions followed the taped instructions, the lights were dimmed to an ambient one-foot candle of intensity with constant background (air-conditioner) noise of 40 db. Over the intercom the subject was again told to close his eyes and relax at which time a feedback tape of the author's EEG was played. The variably occurring tone was the point upon which the subject was told to focus his attention. The session lasted 30 minutes after which the subject was released. Each

session was scheduled to occur once a week. The procedural details of the remaining two baseline sessions were identical to the first with the exception that the explanation of electrodes and instructional tape were omitted.

Parietal-occipital alpha was defined for each subject individually in the following way. The first baseline was recorded on tape and later replayed through the variable band-pass filter set at 8 and 13 Hz. When the frequency meter showed a rhythm in the alpha frequency, the microvolt threshold was adjusted to the point where the alpha frequency no longer produced a tone. This was repeated until a fairly reliable estimate of maximum alpha amplitude was determined. Following Mulholland's⁹ criteria alpha was considered present if the amplitude of the rhythm reached 25% or more of the resting rhythm and lasted longer than 0.2 seconds. Thus, alpha was determined individually for each subject in terms of an occipital-parietal, 8-13 Hz rhythm of an amplitude equal to or greater than 25% of the resting rhythm and lasting at least 0.2 second.

Having established these criteria, the first baseline tapes were re-run through the filter and timers for determining alpha presence over the 30-minute session in two minute subtotals.

⁹ T. Mulholland, "Occipital Alpha Revisited," Psychological Bulletin, Vol. 78, 1972, pp. 176-182.

This same criterion was maintained throughout the experiment and enabled on-line assessment of alpha presence during subsequent sessions. Once established, these amplitudes appeared to be fairly reliable over sessions. Only two subjects required recalibration since virtually no alpha was being registered. Both of these occurred during the baseline sessions.

On the fourth meeting the feedback phase of the experiment began. Each subject had earlier been assigned to either the contingent or non-contingent feedback condition at random by a person who knew nothing about the experiment. Randomness was defined by the following procedure: each subject's number (1-24) was entered on a separate card. These cards were then shuffled and drawn one at a time and placed on one of two piles in an alternating fashion. One of the piles was arbitrarily assigned as the contingent feedback group and the other the non-contingent feedback group. To avoid experimenter bias or "Rosenthal Effect"¹⁰ during baseline sessions, the experimenter was unaware of subject feedback contingency until the moment before the experiment began. This information was coded on cards and filed with the subject's name to be opened at the beginning of the feedback phase of the experiment.

¹⁰ R. Rosenthal, "Research on Experimenter Bias", Paper Presented at the American Psychological Association, Cincinnati, September, 1959.

Whether subjects were to receive contingent or non-contingent feedback, the procedural details were identical with the exception that the contingent feedback group was given true discriminative feedback whenever alpha was present while the non-contingent feedback group listened to a tape of the feedback tone.

Once electrodes were attached and the subject was seated comfortably in the experimental chamber, taped instructions, modified from those used by Walsh¹¹, were given (see Appendix III). Although no direct reference was made to the term "alpha", subjects were told that different EEG frequencies may relate to different states of consciousness such as alert and drowsy states and that their task was to "learn control over brain wave activity" in general.

The feedback session was divided into five, six-minute feedback periods staggered by six, two-minute rest periods. Each session began with a two-minute rest period during which the feedback tone was off and was followed by a six-minute feedback period during which time the tone was operating. The beginning of each rest and feedback period was signaled by a 40 db click through a small speaker in the experimental chamber.

11 D.H. Walsh, 'Effects of Instructional Set, Reinforcement and Individual Differences in EEG Alpha Feedback Training'; Paper Presented at the Biofeedback Research Society, Boston, 1972.

Feedback periods were thus divided by rest periods. The session always began and ended with a rest period. The six-minute feedback periods were analyzed for alpha density on-line in terms of two minute epochs. In this way feedback and rest periods were temporally comparable allowing within sessions changes in alpha density to be assessed. Although Kamiya¹² observed increases in EEG alpha during rest periods, he interpreted this to mean that the alpha state was pleasurable and therefore the preferred mode of rest. Lynch and Paskewitz¹³ reinterpreted these rest period increases in terms of a baseline shift phenomena where the subject is spontaneously producing more alpha regardless of feedback.

The non-contingent feedback group was treated in exactly the same manner as the contingent group, with the exception that a tape of the feedback tone was used. A different tape, taken from the author's EEG during rest was used in each session. The tape was recorded so that alternating two and six-minute periods of rest and feedback were delivered. To check the comparability of the feedback tapes, an independent judge was asked to discern between the tapes and real feedback. At no

12 Joe Kamiya, op. cit., 1969.

13 James Lynch and D. Paskewitz, op. cit.

time was the judge able to distinguish between the two.

Immediately following the last (third) feedback session, the lights were turned on in the chamber and a five minute rest period was given during which time final taped instructions were played. This marked the beginning of the third phase of the experiment during which the subject was to attempt to control his brain waves which were associated with the tone without aid of feedback. Instructions were as follows:

Now that you have had some practice in controlling your brain waves, we would like to see if you can produce these brain waves without the aid of a feedback tone. Therefore, you are asked to sit with your eyes closed, as before, and try to control your brain waves which normally associate with the tone as much as possible for the next six minutes. Any questions?

If no questions followed the instructions, the lights were re-dimmed to one foot-candle ambient intensity and that phase of the experiment began. On-line EEG analysis was exactly the same as earlier except one minute totals were calculated. This phase lasted exactly six minutes. At the end, subjects were released from the chamber, cleansed of electrode paste, thanked for their cooperation and immediately paid. At no time did any subjects in the non-contingent group verbalize suspicions of having received false-feedback during or after any feedback session. Within two weeks of their last session subjects were mailed details of the experiment, their exact role in it and a representative example of a tracing of their HR, GSR and EEG with accompanying explanation.

6. Statistical Procedures

A two factor analysis of variance (ANOVA) with repeated measures on the last factor¹⁴ was the statistical model employed. In the first analysis, a 2x15 ANOVA, the two factors under consideration were feedback groups and trials during baseline. The feedback factor was divided into two levels corresponding to contingent and non-contingent groups. Twelve subjects were nested under each level of feedback. The trials factor divided into fifteen levels (five levels per day). Each level represented a six-minute trial block. Any significant main effect on the trials factor would invoke the use of Tukey's¹⁵ a posteriori procedure for multiple comparisons. Significant baseline by trials interaction would be followed by the procedure for simple main effects.

The second analysis involved regrouping the above data such that the trials factor was collapsed into days, with five trials representing one day. This yielded a 2x3 ANOVA with repeated measures on the day factor. Subsequent a posteriori procedures remained the same.

The third and fourth analyses were identical to the first two with the exception that the two levels of baseline

¹⁴ B.J. Winer, Statistical Principles in Experimental Design, New York, McGraw-Hill, 1971, pp. 302-312.

¹⁵ Ibid., pp. 198-201.

changed to two levels of feedback, contingent and non-contingent. Thus, feedback data were regrouped as 2x3 and 2x15 ANOVAs.

The post-feedback retention data were analyzed with the same two factor ANOVA model except the trials factor had only six levels corresponding to one minute trial blocks. The contingent and non-contingent groupings remained the same, as well as earlier post hoc procedures.

The t-test¹⁶ was chosen to test the significance of any differences existing between contingent and non-contingent groups on Extraversion, Neuroticism and Lie scores obtained from the EPI (form A).

The 0.05 level of probability was selected as the interval beyond which significance was declared for all statistical procedures employed including post hoc tests.

It should be noted that EEG alpha in seconds was the sole dependent measure used in this investigation. To reduce between session variability in the absolute abundance of alpha produced, raw alpha scores in seconds were transformed to deviation scores from zero by subtracting each score within a days recording from the first alpha score obtained during a calibration period.

16 B.J. Winer, op. cit., p. 28.

All data in deviation score form were programmed in A Programming Language (APL)¹⁷ from a remote terminal which enabled all analyses to be performed by existing statistical programs in an IBM 360/120 computer.

A graphic presentation of trial by trial and day by day mean alpha activity during baseline and feedback was plotted regardless of whether statistical significance was achieved. This enabled a discussion of the shape and direction of the data.

In the next chapter the results of the study are presented and discussed.

17 M. Boss and M. Cooper, A Course in APL for Students and Researchers in the Behavioural Sciences, Faculty of Education, University of Ottawa, 1972.

CHAPTER III

PRESENTATION AND DISCUSSION OF RESULTS

In this chapter the experimental results are presented and discussed. Section one is concerned with reporting the results of statistical operations performed on the data and is divided into four sub-sections as follows: subjects selection data, baseline data, feedback data, and post-feedback retention data. Section two interprets and discusses these results in terms of theoretical and practical considerations. In section three suggestions for further research are offered.

1. Presentation of Results

A. Subject Selection Data

The twenty-four ambiverts (subjects who scored between 8 and 16 on the EPI) who were selected to participate in this study were divided at random into two groups of twelve. To insure that both groups were initially homogenous with respect to Eysenck's dimensions of personality, t-tests were performed on each of the three scores obtained from the EPI. As evidenced from Table I, the means on Extraversion, Neuroticism and Lie scores were remarkably similar between the two groups giving rise to non-significant t-ratios of 0.978, 0.125 and 0.276 (df 22), respectively.

Table I

EPI (Form A) Scores and T-Ratios Between Contingent and Non-Contingent Feedback Groups

Score	n	t-ratio*	Contingent Feedback		Non-Contingent Feedback	
			Mean	S.D.	Mean	S.D.
Extraversion	12	0.978	11.50	2.84	12.42	1.56
Neuroticism	12	0.124	9.50	4.34	9.25	5.43
Lie	12	0.276	2.08	1.08	1.92	1.78

* $t .05 (df 22) = 2.074$

Note: Raw EPI scores for each individual appear in Appendix IV.

These results indicate the process of randomization was successful in equalizing the two groups with respect to Eysenck's personality dimensions of extraversion and neuroticism before the experiment began.

B. Baseline Data

Prior to receiving the experimental treatment of contingent or non-contingent feedback, subjects in each group underwent extensive baseline assessment. This included three days of recording EEG activity under experimental conditions exactly like those given during feedback. Each day of baseline was divided into two minute periods and presence of alpha in seconds was recorded within this time frame over a thirty-minute epoch. This data was then reduced to fifteen six-minute trial blocks and then into deviation scores for statistical analysis.

Analysis of variance performed on the overall means of alpha density produced across the three days of recording resulted in an F value of 0.009 which was not significant. This indicates that the two groups did not differ substantially in overall baseline alpha densities prior to treatment. An F of .358 (non-significant) for days further substantiates this lack of difference between groups at the between days level. The groups by days interaction was similarly non-significant (F= 0.176). These results are summarized in Table II.

Table II

Analysis of Variance on EEG Alpha Deviation Scores by Days
During Baseline Between Contingent and
Non-Contingent Feedback Groups

Source of Variation	SS	df	MS	F	p
Between subjects					
A (Groups)	110.01	1	110.01	.009	n.s.
R:A _{error}	245466.81	22	11157.58	---	
Within subjects					
B (Days)	15379.00	2	7689.50	.358	n.s.
AxB	7568.44	2	3784.22	.176	n.s.
BxR:A _{error}	944892.56	44	21474.83	---	

When days (factor B) are reduced to trial blocks (five trials per day), within session differences in alpha densities between the two groups can be assessed. As seen in Table III an F value of 3.99 for trials is significant at the 0.001 level. To determine where among the trials differences exist, Tukey's a posteriori test was employed. As seen in Table IV, the only significant differences between consecutive trials occurred between trials one and two on days one (trials 1-5) and two (trials 6-10). Significant differences reliably occurred between first and third, first and fourth, and first and last trials across all three days of baseline. Seven significant differences were seen on day one, six on day two and only three on day three of baseline. Generally speaking, this suggests that the magnitude of the change in alpha density declined over days. In Figure 1 the shape and direction of baseline alpha can be observed for both groups. It is clear from the relatively consistent decrements appearing in this graph that alpha densities declined over trials within days for both groups of subjects. Since the scores in Figure 1 are deviation scores from zero each day of recording starts at the same point. By noting raw scores which appear in Figures 3 and 4 it can be seen that

Table III

Analysis of Variance on EEG Alpha Deviation Scores by Trials
During Baseline Between Contingent and Non-
Contingent Feedback Groups

Source of Variation	SS	df	MS	F	p
Between subjects					
A (Groups)	22.00	1	22.00	.009	n.s.
R:A _{error}	49093.37	22	2231.52	---	
Within subjects					
B (Trials)	62398.52	14	4457.04	3.99 *	.001
AxB	7384.87	14	527.49	.472	n.s.
BxR:A _{error}	344260.21	308	1117.73	---	

* F .001 (14, 308) = 2.51

Table IV

Tukey's Multiple Comparisons Between Means of Trials Across
Contingent and Non-Contingent Groups During Baseline

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	38.33*	50.58*	74.73*	85.34*										
2		13.25	36.40*	47.01*										
3			24.15	34.76*										
4				10.96										
5														
6					37.33*	53.17*	68.42*	86.92*						
7						15.84	31.09	49.59*						
8							15.25	33.75*						
9								18.50						
10														
11									30.25	42.17*	39.25*	41.25*		
12										11.92	9.00	11.00		
13												2.92	.92	
14														5.00
15														

* $p < 0.05$

Table V

Scheffe's Multiple Comparisons Between Means of Trials
Within the Non-Contingent Baseline Period

Day	Comparison	F'	p
1	b1-b2 at A1	1.10	ns
	b2-b3	8.45	ns
	b3-b4	16.79	ns
	b4-b5	< 1	ns
2	b6-b7	2.98	ns
	b7-b8	9.56	ns
	b8-b9	11.40	ns
	b9-b10	18.01	ns
3	b11-b12	1.57	ns
	b12-b13	< 1	ns
	b13-b14	17.70	ns
	b14-b15	14.79	ns
	b1-b5	5.87	ns
	b6-b10	5.82	ns
	b11-b15	5.85	ns

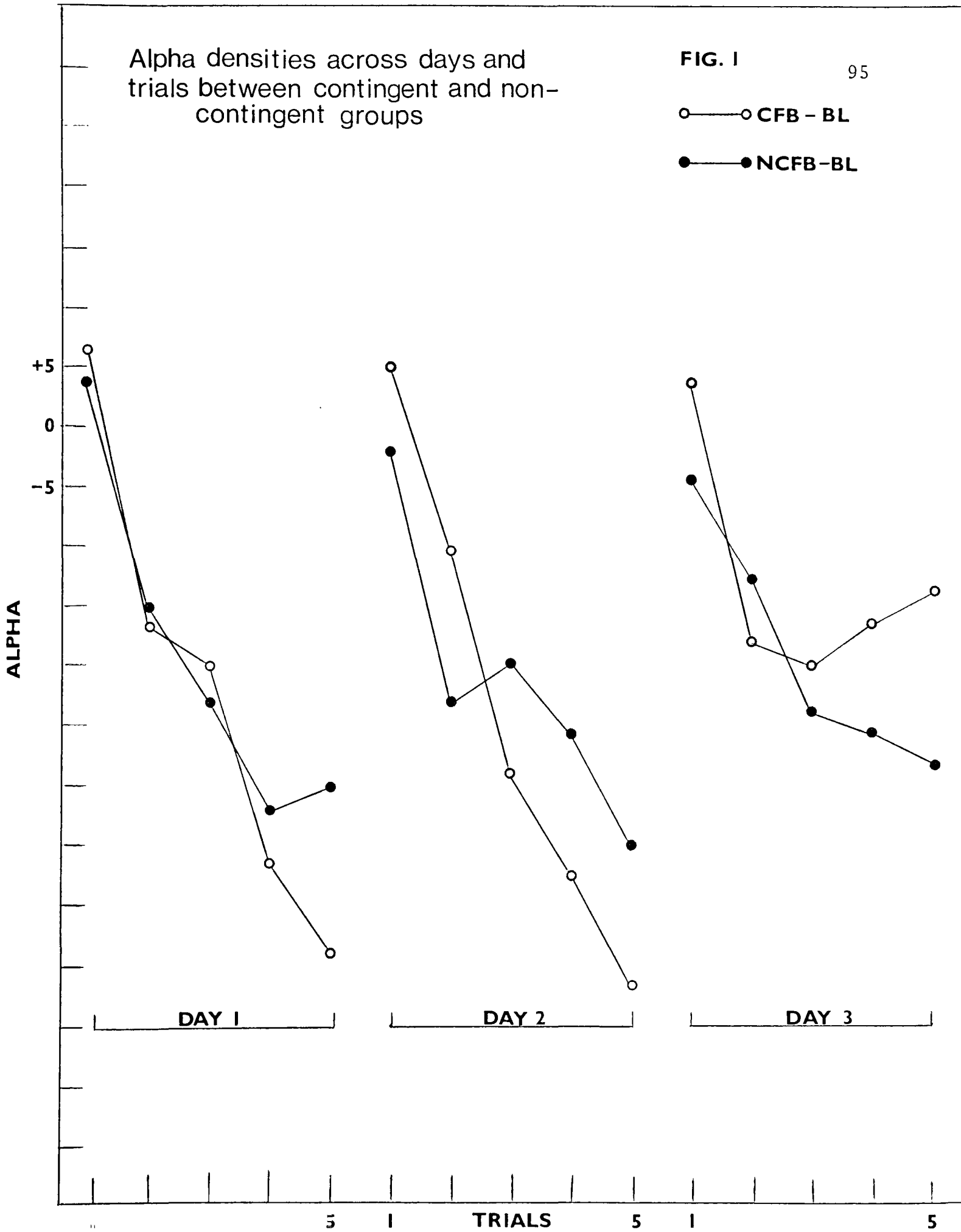
F' .05; (14, 308) = 24.05 (pooled).

Alpha densities across days and trials between contingent and non-contingent groups

FIG. 1

○—○ CFB-BL

●—● NCFB-BL



means for contingent and non-contingent groups continue to decrease between as well as within days.

These results indicate that the following null hypotheses are not rejected:

1. There is no significant difference in alpha density between overall contingent and non-contingent baselines.
2. There is no significant difference in alpha density by days between contingent and non-contingent baselines.
3. There is no significant difference in alpha density between days within baseline sessions for the contingent feedback group.
4. There is no significant difference in alpha density between days within baseline sessions for the non-contingent feedback group.
5. There is no significant difference in alpha density between trial blocks within baseline sessions for the non-contingent feedback group.

On the other hand, hypothesis six, restated here was rejected.

6. There is no significant difference between trial blocks within baseline sessions for the contingent feedback group.

C. Feedback Data

Following the three days of baseline, subjects assigned to the contingent group were given three days of training to increase alpha densities. Subjects in the non-contingent group were given three days of false feedback in an identical milieu as the other group except, unknown to them, they received false feedback.

Analysis of variance performed on the overall alpha densities produced by the two groups resulted in a significant F at the 0.001 level. Neither the Days factor nor Feedback by Days interaction reached significance suggesting that the two groups did not produce a greater abundance of alpha on one day than on another. These data appear in the analysis of variance summary in Table V.

When these data for feedback are re-grouped for analysis by trials all factors achieve significance. The A factor (Feedback) remains significant at the 0.001 level, the B factor (Trials) becomes significant at the 0.001 level ($F= 3.23$) and the Feedback by Trials interaction also achieves significance at the 0.001 level ($F= 6.60$). Thus, the groups differed with respect to trial by trial increases in alpha but the significant interaction qualifies this finding.

The results of this analysis of variance are summarized in Table VI.

In Table VII simple effects analysis of variance are reported which were performed on every trial between contingent and non-contingent feedback (Factor A). Inspection of these results indicate that with day one of feedback (b1-b5) only the last two trials differed significantly from each other. Day two (b6-b10) showed a substantial number of significant differences between trials. Only

Table V

Analysis of Variance on EEG Alpha Deviation Scores by
Days During Treatments Between Contingent
and Non-Contingent Feedback Groups

Source of Variation	SS	df	MS	F	p
Between subjects					
A (Feedback)	426118.35	1	426118.35	44.83*	.001
R:A _{error}	209599.86	22	9526.27	---	
Within subjects					
B (Days)	29082.33	2	14541.17	1.29	ns
AxB	38261.44	2	19130.72	1.70	ns
BxR:A _{error}	495870.89	44	11269.79	---	

* F .001 (1,22) = 14.38

Table VI

Analysis of Variance on EEG Alpha Deviation Scores by
Trials During Treatments Between Contingent
and Non-Contingent Feedback Groups

Source of Variation	SS	df	MS	F	p
Between subjects					
A (Feedback)	85316.01	1	85316.01	44.84*	.001
R:A _{error}	41859.06	22	1902.68	---	
Within subjects					
B (Trials)	31463.15	14	2247.37	3.23**	.001
AxB	64191.57	14	4585.11	6.60**	.001
BxR:A _{error}	213990.61	308	694.77	---	

* F .001 (1,22) = 14.38

**F .001 (14, 308) = 2.51

Table VII

Analysis of Variance Summary Table For Simple Effects on
the Trials by Feedback Interaction

Source of Variation	SS	df	MS	F	p
Between subjects					
A at b1	92.04	1	92.04	<1	ns
A at b2	80.66	1	80.66	<1	ns
A at b3	770.66	1	770.66	~1	ns
A at b4	5340.16	1	5340.16	6.89*	.01
A at b5	14016.67	1	14016.67	18.08	.001
A at b6	204.20	1	204.20	<1	ns
A at b7	2035.04	1	2035.04	2.62	ns
A at b8	8893.50	1	8893.50	11.47	.001
A at b9	26533.50	1	26533.50	47.12	.001
A at b10	34808.16	1	34808.16	44.90	.001
A at b11	15.04	1	15.04	<1	ns
A at b12	2109.88	1	2109.88	2.70	ns
A at b13	8588.16	1	8588.16	11.08	.001
A at b14	22143.37	1	22143.37	28.56	.001
A at b15	23877.04	1	23877.04	30.80	.001
Within cell _{error}	255849.67	330	775.30	---	
Within subjects					
B at a1	21546.41	14	1539.03	2.22**	.01
B at a2	74108.31	14	5293.45	7.62	.001
AxB	64191.57	14	4585.11	6.60	.001
BxR:A _{error}	213990.61	308	694.77	---	

* F .01 (1, 330) = 6.63

**F .01 (14, 308) = 2.01

the first trial showed no significant difference. Day three (b11-b15) followed a similar pattern of differences. Trial by trial activity differed at all levels except for the first trial.

In Figure 2 the performance of contingent and non-contingent feedback groups is graphically displayed with trials on the X-axis, seconds of alpha expressed as a deviation score on the Y-axis and days above trials. From this figure it is easy to visualize the differences between groups by trials over days.

The simple effects analysis also revealed significance at 0.01 and 0.001 levels between trials within groups for non-contingent and contingent feedback conditions, respectively. Tukey's a posteriori test was employed within both treatments to determine the location of differences between trials. The results of these analyses are reported in Tables VIII and IX. Within the contingent group no consecutive trials reached significance. Only the first and last trials within each day of feedback were consistently significant over the three days of feedback. Nevertheless, mean values are observed to clearly increase across trials, within days in the contingent feedback group unlike the non-contingent feedback group.

Alpha densities across days and trials between groups.

○—○ CFB
●—● NCFB

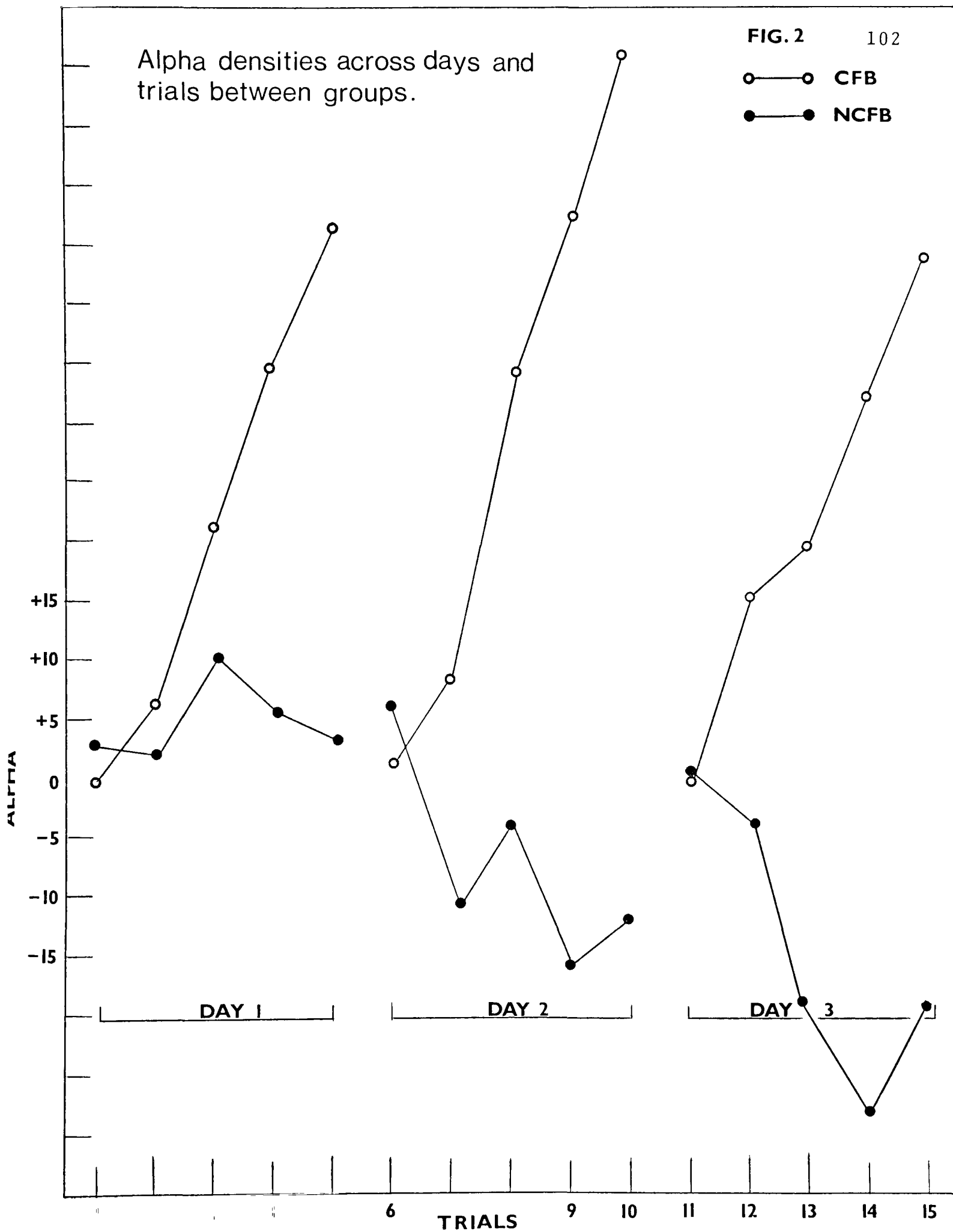


Table VIII

Tukey's Multiple Comparisons Between Means of Trials
Within the Contingent Feedback Period

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	6.58	21.83	35.66	52.00*										
2		15.25	29.08	45.42*										
3			13.83	30.17										
4				16.34										
5														
6						7.17	33.75	49.25*	63.50*					
7							26.58	42.08*	56.33*					
8								15.50	29.75					
9									14.25					
10														
11											15.84	19.17	33.17	44.84*
12												3.33	17.33	29.00
13													14.00	25.67
14														11.67
15														

*p < 0.05

When Tukey's multiple comparisons are performed on consecutive trials within the non-contingent feedback treatment, no pair of contrast reaches significance at the .05 level. In this same vein, comparisons between first and last trials (i.e., 1- 5; 6- 10; 11- 15) across the three feedback days yielded no significant differences. These data are reviewed in Table IX.

The temporal shape and direction of raw alpha scores by trials across days is available in Figure 3. At no time are non-contingent feedback trial blocks of alpha observed to increase above the highest value observed during baseline (trial one; day one). Nor is there any obviously consistent departure from random fluctuation between trials within the non-contingent feedback group as a result of training.

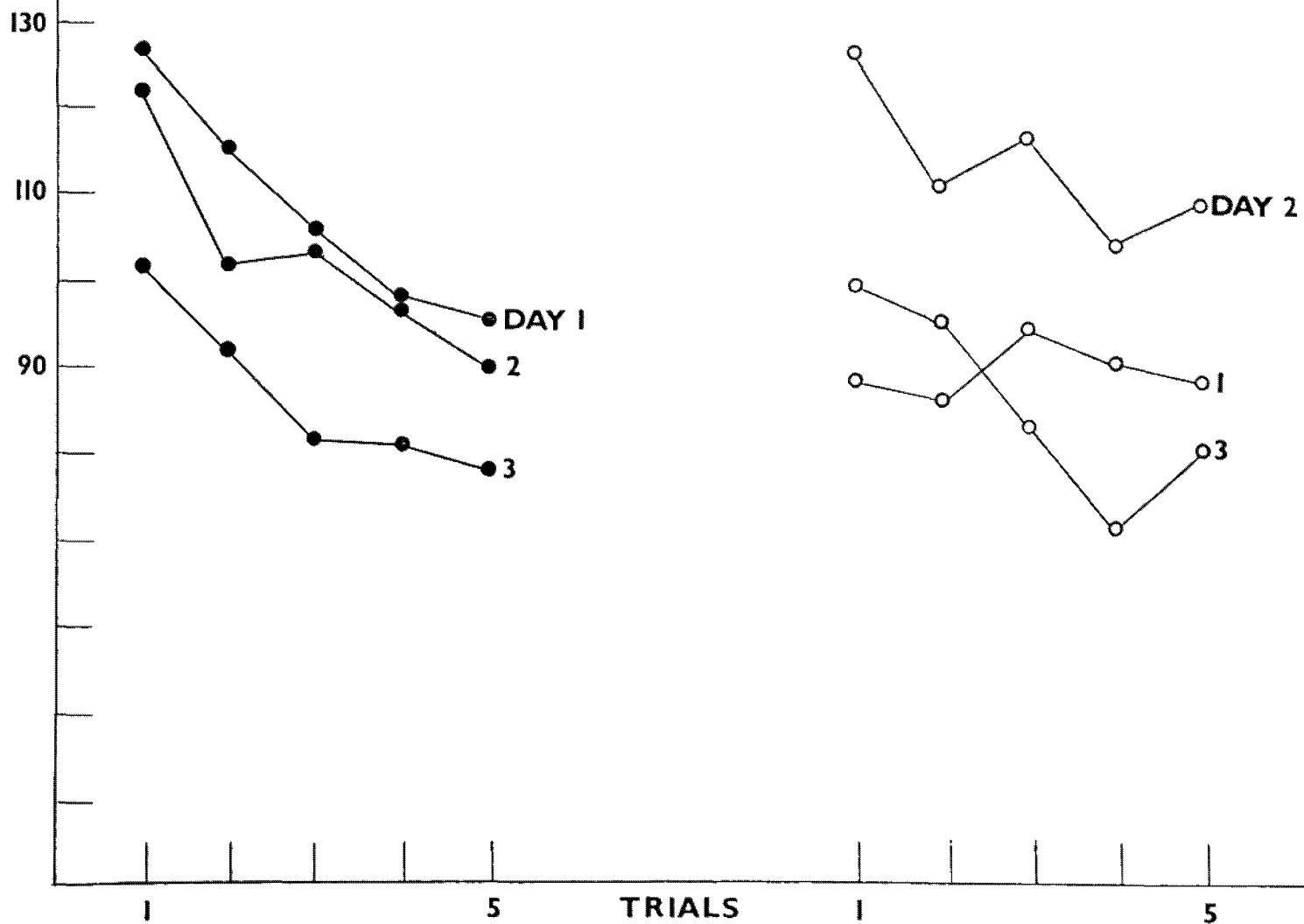
Figure 4 presents raw scores for baseline and contingent feedback by trials across days. By comparison with Figure 3, it is apparent that the consistent downward trends observed during the three days of baseline are reversed in an incremental fashion during contingent feedback. Although showing a clearly upward trend during feedback, at no time does the highest feedback trial value exceed the highest trial value observed during baseline (trial one; day one).

Baseline and non-contingent alpha densities by days and trials.

FIG. 3

●—● BL
○—○ NCFB

106



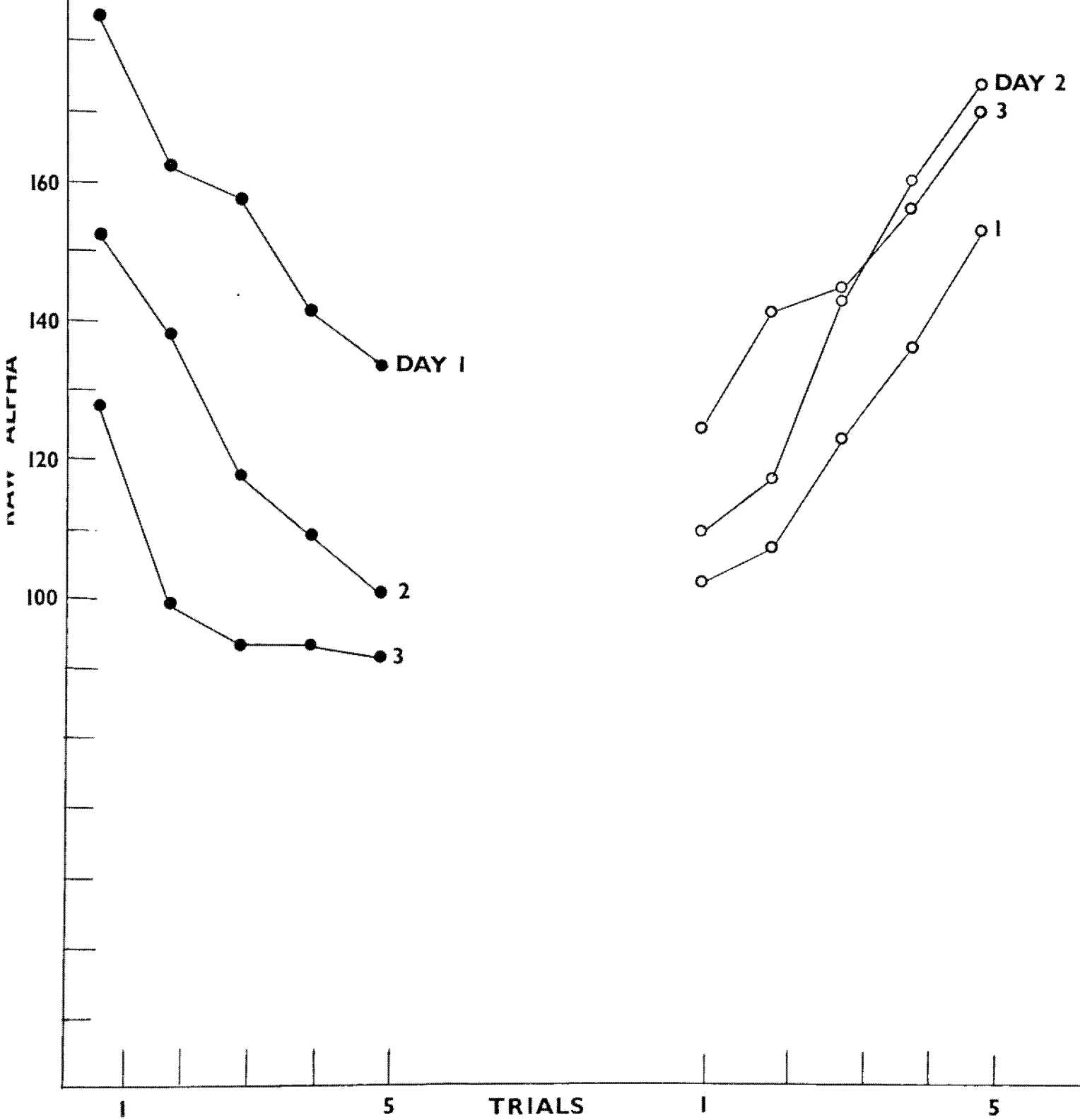
Baseline and contingent alpha densities by days and trials.

FIG. 4

○—○ CFB

●—● BL

107



From the results reviewed in this sub-section the following null hypotheses are not rejected:

8. There is no significant difference in alpha density by day between contingent and non-contingent feedback.
10. There is no significant difference in alpha density between days within the contingent feedback group.
12. There is no significant difference in alpha density between days within the non-contingent feedback group.
13. There is no significant difference in alpha density between trial blocks within non-contingent feedback sessions.

The following null hypotheses were thus rejected:

7. There is no significant difference in overall alpha density between contingent and non-contingent feedback groups.
9. There is no significant difference in alpha density by trial blocks between contingent and non-contingent feedback.
11. There is no significant difference in alpha density by trial blocks within contingent feedback sessions.

Hypothesis 15 which is descriptive rather than statistical was stated in the affirmative. This hypothesis which is considered to be supported by data previously reviewed is stated as follows:

15. Alpha densities produced over trial blocks by the contingent feedback group never exceed the highest trial value achieved during baseline.

D. Post-Feedback Retention Data

Immediately following the third and last feedback session the tone was shut off and both groups of subjects were instructed to control their brain waves as much as

possible, as before, but without aid of feedback. Group differences in trial by trial and total alpha densities during this retention phase of the experiment were subjected to analysis of variance. Table X summarizes the results of this statistical procedure. F values obtained were .029, 1.92 and 1.01 for Feedback (factor A), Trials (factor B) and Feedback by Trials (AxB), respectively. None of the ratios were significant.

In Figure 5 trials by trial alpha activity expressed as a deviation score from zero for contingent and non-contingent feedback groups are presented. It is clear that alpha densities across trials are flat, showing little appreciable increment or decrement. On the whole very little change is observed from the first to the last trial block. Thus, it is concluded that subjects do not differ significantly with respect to their abilities to control and produce EEG alpha, after contingent and non-contingent.

As a result of the above findings, null hypothesis fifteen was not rejected. This hypothesis is stated as follows:

14. There is no significant difference between contingent and non-contingent feedback in alpha densities produced voluntarily without aid of feedback.

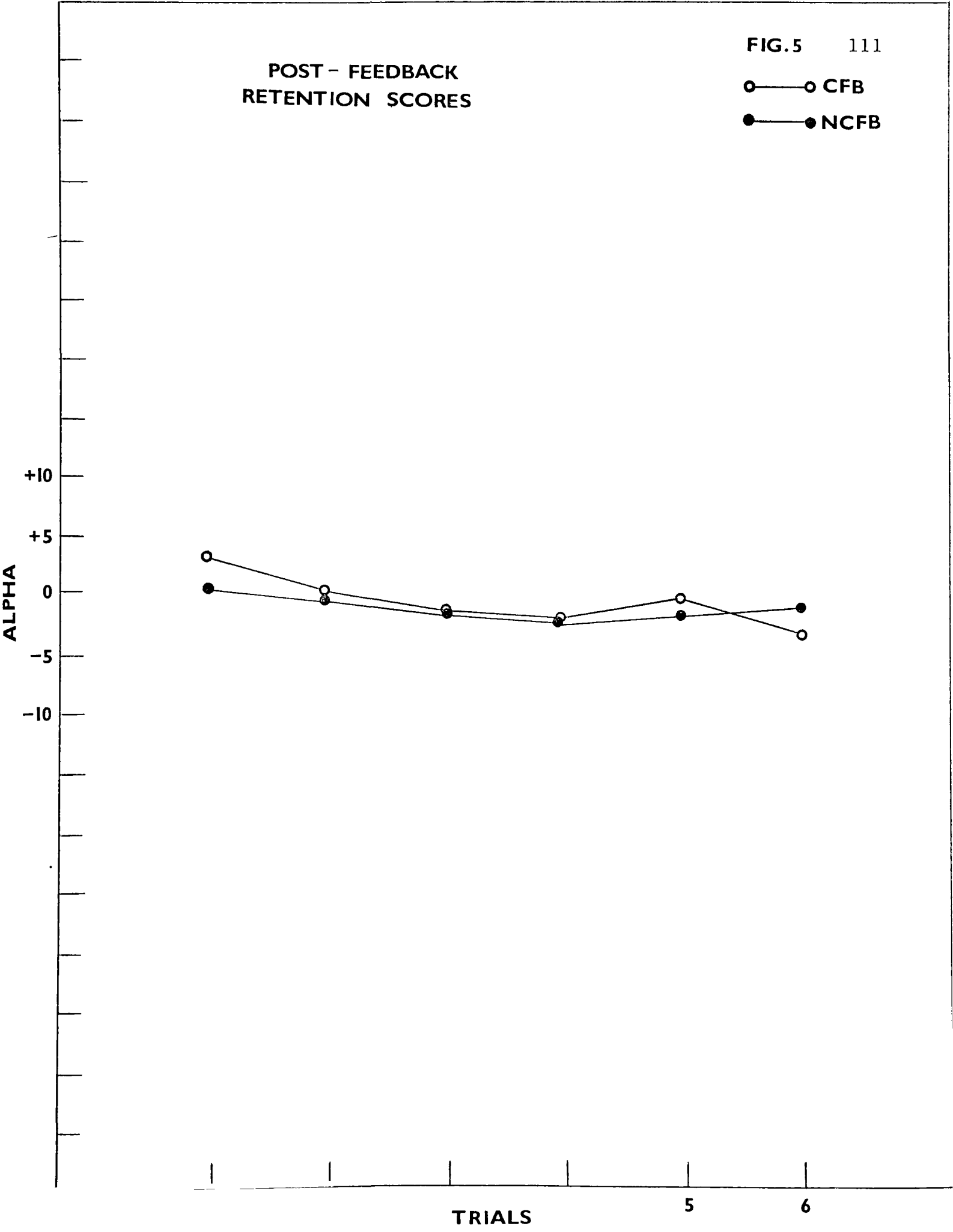
Table X

Analysis of Variance on EEG Alpha Deviation Scores by Trials
 During Post-Feedback Retention Between
 Contingent and Non-Contingent Groups

Source of Variation	SS	df	MS	F	p
Between subjects					
A (Feedback)	3.67	1	3.67	.029	ns
R:A _{error}	2757.99	22	125.36	---	
Within subjects					
B (Trials)	289.78	5	57.96	1.92	ns
AxB	152.28	5	30.46	1.01	ns
BxR:A _{error}	3317.43	110	30.16	---	

POST - FEEDBACK
RETENTION SCORES

○—○ CFB
●—● NCFB



2. Discussion of Results

In general, the results of this study indicate that certain portions of the disinhibition hypothesis are correct while others are in need of revision. Specifically, the first phase of the experiment was designed in an attempt to establish stable baselines of EEG alpha for comparison with later densities. It was thought that three separate days of recording would be sufficient for establishing these baselines. Based on Sokolov's¹ construct, the author, consistent with Lynch and Paskewitz², expected that subjects would, in general, be initially effected by the novelty, "demand characteristics"³, etc. of the experimental situation and thus evoking frequent orienting responses. The EEG component of these responses is alpha blocking. Thus, as the subject gradually habituates to those factors within the experimental situation, his orienting behaviour decreases giving rise to corresponding increases in alpha density. Habituation of the EEG component of the orienting reaction,

1 E. Sokolov, "Neuronal Models and the Orienting Reflex," In M.A. Brazier (Editor), The Central Nervous System and Behavior, New York, Josiah Macy Fdn., 1960, pp. 187-276.

2 James Lynch and D. Paskewitz, "On the Feedback Control of Human Brain Wave Activity," Journal of Nervous and Mental Diseases, Vol. 153, 1971, pp. 205-217.

3 M.T. Orne, "On the Social Psychology of the Psychological Experiment," American Psychologist, Vol. 17, 1962, p.779.

in this manner, is a widely accepted phenomena. It was expected on the basis of Sokolov's theory, that curves resembling an ogive or "S"-shape would asymptote providing a "plateau" level of alpha over trials. The asymptote, or highest alpha value, would then be used as an operational definition of "optimal baseline alpha"⁴ against which comparisons of alpha activity during feedback could be made.

Under the present experimental conditions a quite different curve was obtained from baseline sessions. Within any baseline day subjects consistently produced less and less alpha giving rise to curves of a decreasing function. At the beginning of each day alpha densities would return to their approximate initial level observed from the previous session and then decrease. Since the experimental chamber, tone volume, instructions, electrode attachment and virtually all other details were identical from session to session, ample opportunity existed for habituation to occur. Apparently, some elements or combination of elements are consistently operating in the experimental situation to suppress alpha densities.

In retrospect, three internal and one external factor may possibly explain the decreases in alpha abundance observed within baseline sessions. Internally, subjects may have

4 James Lynch and D. Paskewitz, op. cit., p. 209.

experienced boredom, drowsiness, or sleep individually or in concert. Following Berlyne's⁵ view, putting a subject in a context which can be considered boring or monotonous gives rise to increased stimulation to the brainstem reticular activating system "(...) to keep arousal high and at the same incapacitate the cortex from performing its normal moderating function, so that habituation does not take place". He goes on to suggest that if escape from the boring situation is not immediately possible, as a result of social pressure or other obstacles, arousal may even be pushed higher. If the experimental situation during each 30-minute baseline produced such a state of monotony and thus increased reticular activation, corresponding decreases in alpha densities, observed during baseline, are understandable. On the other hand, had drowsiness consistently set in, patterns of EEG activity would have been initially abundant with alpha giving way to mixed components (e.g., theta and beta) out of the alpha bandwidth⁶. The consequence of drowsiness during baseline would have likely led to an initial increase followed by decrements in alpha as the session progressed. On the same continuum, had sleep set in, overall reductions in alpha density characteristic of

5 D.E. Berlyne, Conflict, Arousal and Curiosity, New York, McGraw-Hill, 1960, p. 191.

6 W. Dement and N. Kleitman, "The Relation of Eye Movements During Sleep to Dream Activity," Journal of Experimental Psychology, Vol. 53, 1957, pp. 339-346.

the obtained curves would have resulted. The sleep hypothesis is less tenable than the boredom or drowsiness ideas since post-session inquiry revealed that only one subject reported that he "thought" he fell asleep. Examination of his EEG tracing did not confirm his suspicion as alpha and beta components characteristic of the waking state were apparent. Also, neither delta (.5-4 Hz), sometimes present during Stage I sleep⁷ nor 14 Hz spindling or high frequency K-complexes obvious during Stage II sleep were evident.

An external stimulus perhaps responsible for baseline decrements may have been the periodic tape recording of the feedback tone. This may have served as a monotonous stimulus responsible for boredom and/or drowsiness during the experiment.

Although difficult to explain with any certainty, the reliable decrements in alpha activity present within baseline sessions suggests that habituation of the EEG component of the orienting reaction may not be a viable construct to invoke in explanation of observed increases in alpha densities during feedback.

These results can also be interpreted as supporting

7 W. Dement and N. Kleitman, op. cit.

the view advanced by Lynch and Paskewitz⁸ and Paskewitz and Orne⁹ that social-situational factors such as boredom, curiosity, anxiety, fear of failure, etc. are operating, which initially suppresses alpha activity. On the other hand, their belief that habituation can account for increases noted during feedback seems unwarranted from this data.

In keeping with the original design of the present study, the maximum alpha produced during baseline was used as the criterion against which to compare feedback outcome. Consistent with Lynch and Paskewitz's¹⁰ hypothesis

The alpha densities which can occur in the feedback situation may approach those seen in the same individual under optimal baseline conditions, but will not significantly exceed them.

The present investigation found that at no time were maximum alpha densities produced during baseline exceeded during either contingent or non-contingent feedback. While supporting their original contention these results are limited in that this study's operationalization of maximum baseline alpha is restricted to the experimental setting in which it was recorded. Indeed, the most alpha capable under existing

8 James Lynch and D. Paskewitz, op. cit., p.215.

9 D. Paskewitz and M. Orne, "Visual Effects During Alpha Feedback Training," Psychophysiology, (Abstract), Vol. 9, 1972, p. 269.

10 James Lynch and D. Paskewitz, op. cit., p.215.

conditions was evoked during the early trials of each baseline day but perhaps the "constitutional" or hereditary maximum suggested by Lynch and Paskewitz¹¹ was never approached.

The likelihood that "spurious" factors in the feedback setting proper may contribute heavily to alpha increases reported as being due to feedback and the increasing number of experiments which report that other factors may be responsible for alpha increments^{12,13,14} encouraged the use of controls. Therefore, in this study the control group that received non-contingent feedback was compared to the contingent feedback group. The two groups differed rather dramatically (significant at the 0.001 level) in overall alpha densities and by trials. Not only was the contingent group superior in this respect but an obvious break in the decremental baseline trend to an increasing function occurred. In contrast to this, the non-contingent group continued their generally downward trend.

11 James Lynch and D. Paskewitz, op. cit.

12 J Hart, Autocontrol of EEG Alpha, Paper Presented at the Society for Psychophysiological Research, San Diego, 1967.

13 D. Paskewitz, J. Lynch, M. Orne and J. Costello, "The Feedback Control of Alpha Activity: Conditioning or Disinhibition?," Psychophysiology, (Abstract), Vol. 6, 1970, pp. 637-638.

14 Charles Cleeland, H. Booker and Kiyoshi Hosokawa, "Alpha Enhancement: Due to Feedback or the Nature of the Task?," Paper Presented at the Society for Psychophysiological Research, New Orleans, 1970.

It should be noted that on the first day of non-contingent feedback, subjects seemed to initially reverse their decreasing alpha trend producing somewhat of a "U" shaped function. Although tentative, this may suggest that the tone, with the new instructions that it represents brain wave activity, takes on a temporary reinforcing quality. Each non-contingent, aperiodic burst of the tone then evoking a short duration of alpha activity. Such an interpretation is consistent with the work of Wyrwicka and Sternman¹⁵.

These results, in part, do not replicate the earlier findings cited nor support the implications from the disinhibition hypothesis that the feedback (contingent) situation may not be the best method for producing high alpha indices.

The lack of a significant difference between days within the contingent group suggests that performance of learning was not improving with added training days. Subjects appeared to begin each day's feedback session at about the same initial level and produced consistent increments in alpha abundance approximating "curves of learning". Thus, the idea, advanced in chapter I, that short training periods, common in the existing literature, may be insufficient for establishing reliable curves of feedback activity was not supported.

15 W. Wyrwicka and M Sternman, "Instrumental Conditioning of Sensorimotor Cortex EEG Spindles in the Waking Cat," Physiology and Behavior, Vol. 3, 1967, pp. 703-707.

Conversely, alpha densities between trials within the contingent group in some instances achieved significance. The tendency was for the first and last trials to differ significantly ($p < 0.05$) from each other. Although mean alpha activity continued to increase between trials only the first and last trials reliably differed from each other over the three days of training. It would be understandable that after repeated trials within sessions some success or learning would take place. Although promising to the idea of learning control of brain wave activity, these findings are viewed in light of the fact that learning did not appear to transfer from day to day (i.e., non-significant difference between days in Table V). Between trial activity within the non-contingent sessions at no time approached significance. This would explain the significant trials by feedback interaction.

Thus, it is unwarranted to conclude that social-psychological factors inherent in both contingent and non-contingent situations, which were identical, are responsible to any significant degree for augmented alpha densities. In short, biofeedback of EEG alpha is effective in producing enhanced alpha densities.

Furthermore, these data support the proposition that such increases reflect a process of overcoming those factors, both internal and external, which normally act to block the alpha rhythm. But whether this process can be

attributed to an orienting reaction habituation phenomena is questionable.

Since this experiment was unable to demonstrate that contingent feedback was any better than non-contingent feedback in fostering the ability of subjects to voluntarily control alpha rhythm activity without aid of feedback, it is concluded that this ability is limited to the feedback situation. This dependency on the contingent feedback indicates that transfer of training from the laboratory to everyday situations does not occur. This would imply that the clinical potential of EEG feedback is limited to the laboratory or clinic in which the training takes place. In the case where alpha training is initiated so that it can be practiced in everyday life, a portable feedback device that the patient can take home with him would be feasible.

While the arguments advanced by Lynch and Paskewitz¹⁶, that factors in the feedback setting tend to suppress alpha activity and that alpha will never go above baseline are generally supported, it is difficult, using their disinhibition construct, to explain the superior performance of the contingent over the non-contingent feedback group. This, coupled with the finding that no transfer of training either between days or without aid of feedback suggest that some form of learning

16 James Lynch and D. Paskewitz, op. cit.

is taking place, but it may be situation or state-dependent.

3. Suggestions for Further Research

The infancy of the biofeedback movement precludes a thorough unfolding of the manifold regions remaining to be explored. But certain questions can be raised regarding the present research which may be worthy of further experimentation.

First, the unexpected suppression of alpha activity during baseline, when augmentation was expected, raises questions regarding the EEG component of the orienting response and how it behaves in the feedback situation. It would be feasible to explore a variety of social-psychological, as well as physical, settings, in hopes of discovering one in which habituation is rapid and stable. Such a context may prove to be the "optimum" environment in which feedback training could take place. Had such an environment been established, the question of whether alpha goes above baseline could be firmly answered.

Methodologically, future studies involving extended baseline assessment would profit from employing procedures which control for drowsiness and/or sleep. By placing an electrode at the canthus, it is possible to detect the presence of slow rolling eye movements characteristic of drowsiness and the early stages of sleep.

Since it has been suggested by some authors^{17,18} that the alpha state is analogous to the altered states of consciousness brought on by various meditations, it would be feasible to examine such a relationship.

The dramatic changes in physiological state achieved through transcendental meditation¹⁹ and well as Zen²⁰ and Yoga²¹ share in common an increase in rhythmic slow potentials in the alpha range. It would seem worthwhile to see if training subjects to augment their alpha densities through biofeedback may effect similar changes. Biofeedback of different EEG frequencies may thus provide a methodology with which the complex relationship, if any, between patterns of autonomic and EEG activity can be explored.

17 Joe Kamiya, 'Operant Control of the EEG Alpha Rhythm and Some of its Reported Effects on Consciousness', In C.T. Tart (Editor), Altered States of Consciousness, New York, John Wiley, 1969, pp. 507-517.

18 B. Brown, 'Recognition of Aspects of Consciousness Through Association with EEG Alpha Activity Represented by a Light Signal', Psychophysiology, Vol. 6, 1970, pp. 442-452.

19 R. Wallace, H. Benson and A. Wilson, 'A Wakeful Hypometabolic Physiologic State', American Journal of Physiology, Vol. 221, 1971, pp. 795-799.

20 A. Kasamatsu and T. Hirai, 'An Electroencephalographic Study on the Zen Meditation (Zazen)', Folia Psychiatrica et Neurologica Japonica, Vol. 20, 1966, pp. 315-336. (Translation)

21 B.K. Anand, G. Chhina and B. Singh, 'Some Aspects of Electroencephalographic Studies in Yogis', Electroencephalography and Clinical Neurophysiology, Vol. 13, 1961, pp. 452-456.

CONCLUSIONS

That portion of the disinhibition hypothesis which claims that factors in the experimental setting tend to reduce alpha initially and that alpha never goes above baseline has found support in the present investigation.

The implication of their theory, that learning of an operant variety is not taking place and therefore, non-contingent feedback should produce similar changes in alpha state as contingent feedback was found to be incorrect. This finding, linked with the fact that post-feedback retention between groups was essentially the same, necessitates revision of the theory, perhaps in the direction of a state or situation-dependent learning. Such learning which does not appear to transfer may find explanation in terms of an attentional hypothesis.

Abundant alpha which is correlated with a reduction in orienting activity suggests that attentional processes are suspended or at least reduced. Furthermore, discrimination learning is known¹ to be hampered when attention is not optimum. Under these circumstances, increments in alpha during feedback may require the subject to unfocus his attention. As he produces more alpha his attention correspondingly declines and the

¹ Ernest Hilgard and Gordon Bower, Theories of Learning, New York, Appleton-Century-Crofts, 1966, pp. 512-515.

potential for learning which transfers is reduced. The paradox in this situation may thus account for the increases during feedback, suggesting learning, yet the lack of ability to control alpha without feedback.

This study attempted to control for individual differences which may have spuriously effected outcome. But possibly such an approach may sidestep a fruitful area of research. Differences in subject performance during feedback noted by the author during the experiment require explanation. Lynch and Paskewitz² invoke a hereditary or "constitutional" hypothesis to account for these differences, but such a supposition is not readily amenable to empirical test. It occurred to the present author that individual differences in performance during feedback may relate to the subject's need level. As the individual has less need for the psychological consequences of increased alpha (e.g., relaxation³, daydreaming⁴, etc.), his ability or desire represented as a performance

2 James Lynch and D. Paskewitz, "On the Mechanisms of the Feedback Control of Human Brain Wave Activity", Journal of Nervous and Mental Diseases, Vol. 153, 1971, pp. 205-217.

3 B. Brown, "Recognition of Aspects of Consciousness Through Association with EEG Alpha Activity Represented by a Light Signal", Psychophysiology, Vol. 6, 1970, pp. 442-452.

4 Gary Mills and L. Solyom, "Biofeedback of EEG Alpha in the Treatment of Obsessive Ruminations, An Exploration", Journal of Behavior Therapy and Experimental Psychiatry, In Press.

curve may be correspondingly diminished. Thus, high anxious individuals may be more motivated and ultimately more successful at the task than those who are more relaxed.

As more information is accumulated in the area of operant neural conditioning or biofeedback, the need for theories which unite and integrate findings, as well as provide testable hypotheses, becomes pressing. With revision, the theory advanced by Lynch and Paskewitz⁵ may meet this need.

⁵ James Lynch and D. Paskewitz, op. cit.

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Anand, B.K., Chhina, G. and Singh, B., Some Aspects of Electroencephalographic Studies in Yogis, Electroencephalography and Clinical Neurophysiology, Vol. 13, 1961, pp. 452-456.

An early attempt to scientifically explore the effects of Yoga meditation on EEG activity. Tremendous stability of alpha rhythm activity in the face of a sometimes painful stimulation was noted.

Andersen, Per and Andersson, Sven, Physiological Basis of the Alpha Rhythm, New York, Appleton-Century-Crofts, 1968, vii-235 p.

An excellent comprehensive review of research and theory underlying the physiological basis of the alpha rhythm. In chapter I the "Facultative Pacemaker Theory" is proposed which explains EEG activity as being controlled by all major thalamic nuclei.

Barber, T.X., DiCara, Leo, Kamiya, Joe, Miller, N.E., Shapiro, D. and Stoyva, J., Biofeedback and Self-Control, 1970, Chicago, Aldine-Atherton, 1971, xvi-546 p.

A valuable source of direct journal article reprints in the area of biofeedback. This volume contains only six articles in the EEG area.

Brown, B., Recognition of Aspects of Consciousness Through Association with EEG Alpha Activity Represented by a Light Signal, Psychophysiology, Vol. 6, 1970, pp. 442-452.

Using a visual feedback signal, increases in alpha density were reported. Concomitant subjective experience during alpha was reported which suggested the relationship between meditation and EEG feedback-produced alterations in consciousness.

Kamiya, Joe, Conditioned Discrimination of the EEG Alpha Rhythm in Humans, Paper Read at the Western Psychological Association, San Francisco, 1962.

This represents the first account of operant control of alpha activity in humans using a simple discrimination learning paradigm. This paper marked the birth of biofeedback.

-----, Operant Control of the EEG Alpha Rhythm and Some of its Reported Effects on Consciousness, In C. Tart (Ed.), Altered States of Consciousness, New York, John Wiley, 1969, pp. 507-517.

Kamiya attempts to link the "high alpha state" with "introspective", "meditative" personalities and speculates on the relationship between this state and those achieved through Zen and Yoga meditation.

Kamiya, Joe, Barber, T.X., DiCara, Leo, Miller, N.E., Shapiro, D. and Stoyva, J., Biofeedback and Self-Control, Chicago, Aldine-Atherton, 1971, xvi-806 p.

This is a comprehensive accumulation of biofeedback articles as they appeared in journals. It allows convenient access to most of the autonomic conditioning studies in animals and humans. Only three articles on EEG feedback with humans appeared.

Kasamatsu, A. and Hirai, T., An Electroencephalographic Study on the Zen Meditation (Zazen), Folia Psychiatrica et Neurologica Japonica, Vol. 20, 1966, pp. 315-336 (Translation).

This is a frequently cited article of EEG activity during Zen meditation. Rather marked alterations in EEG activity towards synchronization, were reported. Also, no habituation of the EEG component of the orienting reaction occurred during Zen.

Lynch, James and Paskewitz, D., On the Mechanisms of the Feedback Control of Human Brain Wave Activity, Journal of Nervous and Mental Diseases, Vol. 153, 1971, pp. 205-217.

This article provides the theoretical background and rationale for the present investigation. The "Disinhibition Hypothesis" and the literature germane to its formulation are reviewed.

Miller, Neal, Learning of Visceral and Glandular Responses, Science, Vol. 163, 1969, pp. 434-445.

Miller reviews his past work on autonomic conditioning in the rat. This is an easy-to-read overview of Miller and his colleague's past work and future endeavors in this area. Ample references to original articles are included.

Mulholland, T.B., Feedback Electroencephalography, Activitas Nervosa Superior, Vol. 10, 1968, pp. 410-438.

In this lengthy article, Mulholland considers the problems and prospects eminent in the "Biofeedback Revolution". He suggests the pressing need for a theory to unite findings and proposed his "Oculo-motor Hypothesis" to account for alpha increases.

Stoyva, J., Barber, T.X., DiCara, Leo, Kamiya, Joe, Miller, N.E. and Shapiro, D., Biofeedback and Self-Control, 1971, Chicago, Aldine-Atherton, 1972, xiv-565 p.

Like the other Aldine editions, this text is a series of previously published biofeedback articles up to 1971. Seven articles relating to EEG control are included.

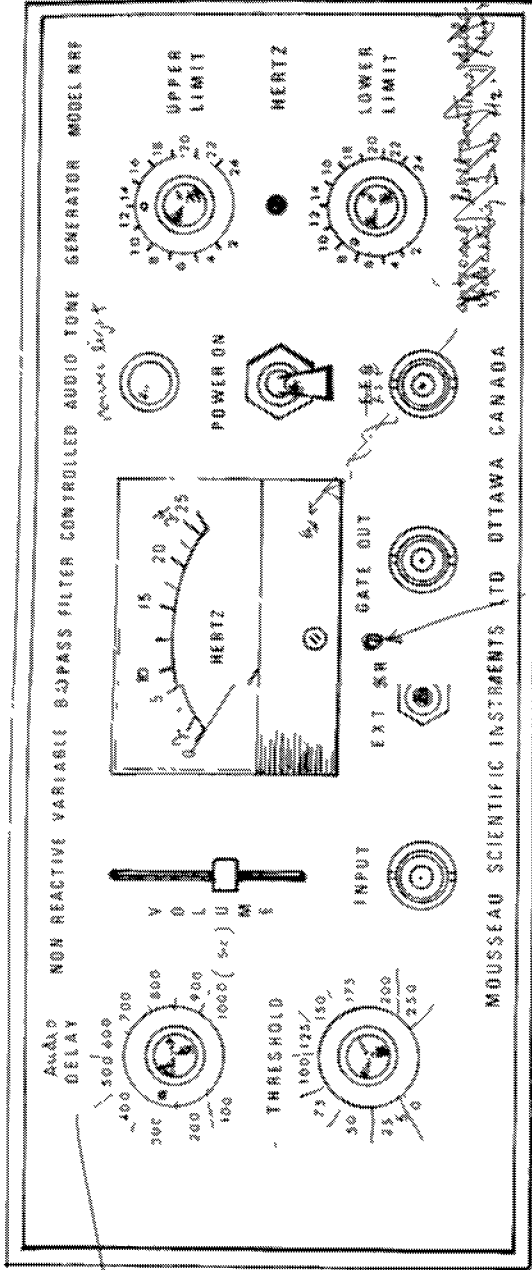
Watanabe, T., Shapiro, D. and Schwartz, G., Meditation as an Anoxic State: A Critical Review and Theory, Psychophysiology, Vol. 9, 1972, p. 279.

The authors of this article reviewed literature on the psychophysiology of various meditations and conclude that alpha rhythm activity may be influenced by oxygenation to the brain. They conclude with an Anoxia Hypothesis.

APPENDIX 1

PANEL LAYOUT FOR NON REACTIVE VARIABLE BANDPASS FILTER
CONTROLLED AUDIO TONE GENERATOR

DESIGNED FOR RESEARCH AND LABORATORY TRAINING IN EEG RECORDING



*attenuator
time in
milliseconds*

*range of
millivolts
signals are in
microvolts*

input metering for when in freq. loop band

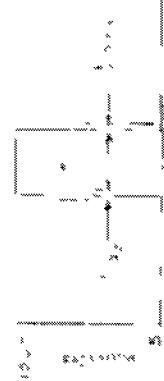
- BANDWIDTH ADJUSTABLE 1 CM 2 T. HERTZ
- FREQUENCY REGULATION 0.2 HZ
- INPUT AMPLITUDE RANGE > 5 TO 50 mV
- INPUT IMPEDANCE > 1 M OHM
- AUDIO OUTPUT 600 Hz 1 mV (adjustable)
- GATE OUT +2.4 V IN BAND SIGNAL PRESENT
- LEG OUTPUT SIGNAL OUT IF SIGNAL IS WITHIN THE SET REFERENCE LIMITS
- AUDIO DELAY ADJUSTABLE FROM 100 TO 1000 mS
- THRESHOLD ADJUSTABLE FROM 5 mV TO 200 mV
- TO ACTIVATE GATE OUT AND 4E 600 HZ TONE
- POWER SUPPLY 117 V AC

speech tone

units -

1 mV @ 10 K EEG

separate power supply?



HYSTERESIS 0.2 HZ FREQUENCY RISING (12 Hz)
(1 Hz/min) 0.1 HZ FREQUENCY DECREASING
RED LIGHT EMITTING DIODE ON IF INPUT IS IN BANDWIDTH SET

SEE DRAWING 4 0-1 776 5/83 77

APPENDIX 2

PANEL LAYOUT FOR CYCLE-TIMER CONTROLLED DUAL CHANNEL ELAPSED
TIME METERS

APPENDIX 3

INSTRUCTIONS GIVEN TO BOTH CONTINGENT AND NON-CONTINGENT
FEEDBACK GROUPS ON THE FIRST FEEDBACK SESSION

APPENDIX 3

INSTRUCTIONS GIVEN TO BOTH CONTINGENT AND NON-CONTINGENT FEEDBACK GROUPS ON THE FIRST FEEDBACK SESSION

You are now ready to being phase III of the experiment. During this phase you will experience brain wave feedback training under controlled laboratory conditions. To give you a little background for this training you should know that brain wave activity consists of electrical signals of various frequencies ranging from approximately one cycle per second to fifty cycles per second. An individual's feelings or state of consciousness seems to be related to the prevailing frequency. However, the relationship between specific frequencies and feelings or states of consciousness is not yet clearly established. Some frequencies appear to be associated with calm, contemplative, dream-like or even high states. Others seem to be associated with alert, hyperattentive states. Still others seem to be related to drowsy or dull states. While these particular relationships must still be determined by experiments such as this, it appears that man is not far from gaining control over his feelings and states of consciousness through the control of his brain waves. Researchers hope that someday brain wave feedback, which is harmless, may replace the use of drugs with all their harmful side-effects as societies way of altering feelings or states of

consciousness.

Your brain continually produces electrical activity of varying frequencies although you are not aware of it. The goals of brainwave feedback training are to increase your awareness of the brain's activity and thus, gain control over such activity. To assist you in becoming aware of and controlling your brain waves we will do two things: First, you will hear a tone whenever a particular type of brain wave occurs, and second we will instruct you to try to keep the tone on as much as possible, by whatever means seem to work best. This is an individual matter which only you can discover. It may help if you remember that feedback training takes time. If you become too impatient or frustrated in the beginning it will tend to reduce the brain waves that keep the tone on, thus, defeating what you are attempting to do. Try not to become frustrated if you find that you cannot keep the tone on at first.

This first training session will last 45 minutes. It will begin with a three minute rest period. Then there will be five feedback periods each lasting six minutes, followed by one-minute rest periods. A buzzer will sound signalling the beginning and end of feedback and rest periods. Only during the feedback periods will you hear the tone. It is during these periods that you are to attempt to keep the tone on as much as possible. During rest periods the feedback tone will not

be operating. You should just relax with your eyes closed during these rest periods and wait for the next trial period. As before, please remember to close your eyes. relax and avoid making any unnecessary large body movements until the session is over.

In summary, this is the brain wave training phase of the experiment. This session lasts about 45 minutes and is broken up into feedback and rest periods. During feedback periods you will periodically hear tones representing your brain's activity which you are expected to attempt to keep on as much as possible. During rest periods the tone is shut off and you are to continue relaxing with your eyes closed. After the last feedback period, there is a three minute rest period which ends the session. Remember, don't feel frustrated if you cannot keep the tone on at first. It takes time to learn how to do this.

Any questions?

-APPENDIX 4

EYSENCK PERSONALITY INVENTORY RAW SCORES ON EXTRAVERSION,
NEUROTICISM AND LIE FOR CONTINGENT AND
NON-CONTINGENT FEEDBACK GROUPS.

Eysenck Personality Inventory Raw Scores on Extraversion,
Neuroticism and Lie for Contingent and
Non-Contingent Feedback Groups.

EXTRAVERSION

	Non-Contingent	Contingent
	10	12
	12	13
	11	11
	13	8
	14	16
	15	8
	11	13
	12	16
	15	13
	12	10
	12	8
	12	10
	<hr/>	<hr/>
Sum:	149	138
SS:	26.92	89
Mean:	12.41	11.50
t-ratio:	0.978 (df 22)	

NEUROTICISM

	Non-Contingent	Contingent
	4	7
	6	3
	7	6
	9	8
	3	15
	16	10
	4	14
	17	11
	11	6
	6	18
	9	7
	19	9
	<hr/>	<hr/>
Sum:	111	114
SS:	324.25	207
Mean:	9.25	9.50
t-ratio:	0.125 (df 22)	

LIE

	Non-Contingent	Contingent
	6	3
	1	2
	1	0
	3	1
	2	3
	2	3
	0	1
	2	3
	2	2
	0	3
	4	1
	0	3
	<hr/>	<hr/>
Sum:	23	25
SS.	34.92	12.92
Mean:	1.92	2.08
t-ratio:	0.276 (df 22)	

APPENDIX 5

RAW ALPHA SCORES IN SECONDS FOR CONTINGENT AND NON-CONTINGENT
FEEDBACK GROUPS

RAW ALPHA SCORES IN SECONDS FOR CONTINGENT AND NON-CONTINGENT
FEEDBACK GROUPSBaseline

Subject	Trials															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
NCFB	1	47	38	40	30	34	206	174	180	180	175	134	105	95	100	98
	2	57	50	50	30	40	213	108	93	79	95	32	67	86	115	73
	3	171	159	140	137	120	109	63	57	48	48	56	51	45	34	25
	4	152	179	117	68	83	90	86	149	103	112	42	17	13	15	18
	5	149	130	91	77	71	107	74	69	81	75	251	242	165	104	110
	6	97	49	54	51	50	116	98	51	51	45	71	69	71	86	80
	7	72	52	44	48	50	58	48	38	63	31	104	55	45	36	51
	8	58	55	50	48	46	108	102	84	74	46	113	122	105	72	80
	9	192	175	160	169	148	87	59	42	38	40	117	150	163	223	204
	10	132	129	140	150	141	104	120	143	128	119	150	108	87	78	80
	11	175	164	156	161	152	59	82	134	126	88	49	34	48	51	45
	12	219	201	206	194	198	223	211	215	207	198	90	92	59	61	57
CFB	13	72	53	71	53	41	54	40	28	42	45	188	178	163	187	152
	14	239	238	215	203	214	193	183	151	177	172	266	250	223	239	210
	15	313	324	316	179	106	284	266	248	249	238	154	113	101	102	104
	16	287	280	286	284	277	208	193	176	159	120	106	69	71	41	49
	17	194	117	111	107	114	111	104	59	41	52	73	37	44	53	60
	18	72	54	44	48	45	230	235	215	141	120	55	43	55	43	50
	19	175	135	143	129	120	51	31	80	52	37	116	67	49	46	54
	20	218	163	155	130	124	66	48	42	47	45	97	74	76	78	70
	21	149	158	153	150	153	123	91	62	48	41	70	61	73	58	92
	22	140	119	118	124	119	73	70	71	66	61	78	59	50	55	49
	23	150	121	112	120	120	191	137	73	75	49	71	37	41	40	36
	24	205	186	173	180	175	252	243	216	218	218	262	209	175	168	168

Feedback

Subject	Trials															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
NCFB	1	38	50	69	74	93	88	95	108	79	66	223	233	122	139	171
	2	45	78	97	89	110	12	43	54	17	40	134	117	119	108	105
	3	28	18	20	19	21	117	80	100	95	87	54	63	48	49	51
	4	75	55	63	83	74	68	36	66	42	59	26	26	31	24	26
	5	32	42	88	35	60	78	38	41	37	42	39	40	43	54	79
	6	143	136	127	140	138	82	60	63	67	68	50	40	34	41	65
	7	173	132	133	143	142	198	197	191	174	156	95	97	83	33	80
	8	60	75	81	68	55	68	45	34	31	123	14	14	24	9	3
	9	151	152	156	167	172	218	198	184	153	161	168	169	165	138	130
	10	151	131	145	86	78	179	156	185	195	173	86	68	42	79	101
	11	95	89	84	81	67	209	178	187	184	165	111	116	93	64	58
	12	72	87	79	101	100	212	198	194	178	167	198	161	181	110	91
CFB	13	133	141	146	151	157	77	101	142	150	128	143	136	149	138	149
	14	109	155	153	160	161	126	133	173	189	190	222	230	231	254	257
	15	202	202	214	216	216	178	207	260	222	281	140	182	175	193	200
	16	56	67	75	77	75	194	203	222	241	248	210	221	233	255	270
	17	118	133	157	187	218	172	160	214	270	241	170	177	170	184	185
	18	75	42	49	73	48	40	66	93	100	110	57	64	67	74	80
	19	51	60	81	87	149	158	103	108	99	119	75	75	101	135	151
	20	106	125	153	142	225	104	132	150	150	150	56	69	99	116	116
	21	107	76	89	116	118	70	100	117	109	120	41	87	78	74	113
	22	69	113	152	171	166	49	89	92	104	209	169	187	186	204	210
	23	27	64	80	123	151	72	55	68	174	180	154	189	180	196	204
	24	170	124	136	138	152	86	73	92	109	112	74	84	72	84	114

APPENDIX 6

DEVIATION ALPHA SCORES FOR CONTINGENT AND NON-CONTINGENT
FEEDBACK GROUPS

DEVIATION ALPHA SCORES FOR CONTINGENT AND NON-CONTINGENT
FEEDBACK GROUPS

Baseline

Subject	TRIALS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
NCFB	1	-3	-12	-10	-20	-16	-5	-37	-31	-31	-36	-14	-43	-53	-48	-50
	2	-1	-8	-8	-28	-18	19	-86	-101	-115	-99	3	38	57	86	44
	3	2	-10	-29	-32	-49	-2	-48	-54	-63	-63	-3	-8	-14	-25	-34
	4	11	-16	-46	-95	-80	-6	-10	53	7	16	3	-22	-26	-24	-21
	5	9	-10	-58	-72	-78	-10	-43	-48	-36	-42	-10	-19	-96	-157	-151
	6	-2	-50	-45	-48	-49	4	-14	-61	-61	-66	2	0	2	17	11
	7	0	-20	-28	-24	-22	-6	-16	-26	-1	-33	4	-45	-55	-64	-49
	8	-4	-7	-12	-14	-16	-4	-10	-28	-38	-66	-13	-4	-21	-54	-46
	9	5	-12	-27	-18	-39	0	-28	-45	-49	7	-11	22	35	95	76
	10	1	-2	9	19	10	-7	9	32	17	8	-14	-56	-77	-86	-84
	11	-11	-22	-30	-25	-34	-5	18	70	62	24	0	-15	-1	2	-4
	12	4	-14	-9	-21	-17	7	-3	1	-7	-16	-1	1	-32	-30	-34
CFB	13	1	-18	0	-18	-30	4	-10	-22	-8	-5	8	-2	-17	7	-28
	14	-1	-2	-25	-37	-26	3	-7	-39	-13	-18	7	-9	-36	-20	-49
	15	2	13	5	-132	-205	0	-18	-36	-35	-46	24	-17	-29	-28	-26
	16	-4	-11	-5	-7	-14	8	-7	-24	-41	-80	-3	-40	-38	-68	-60
	17	12	-65	-71	-75	-68	11	4	-41	-59	-48	1	-35	-28	-19	-12
	18	1	-17	-27	-23	-26	29	34	14	-60	-81	1	-11	1	-11	-4
	19	29	-11	-3	-17	-26	-7	-27	22	-6	-21	18	-31	-49	-52	-44
	20	3	-52	-60	-85	-91	4	-14	-20	-15	-17	16	-7	-5	-3	-11
	21	0	9	4	1	4	11	-21	-50	-64	-71	0	-9	3	-12	22
	22	-10	-31	-32	-26	-31	-5	-8	-7	-12	-17	-6	-25	-34	-29	-35
	23	24	-5	-14	-6	-6	4	-50	-114	-112	-138	-3	34	50	93	121
	24	19	0	-13	-6	-11	6	-3	-30	-28	-28	-16	-62	-50	-48	-34

Feedback

Subject	TRIALS														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-10	2	21	26	45	8	15	28	-1	-14	12	22	-89	-72	-40
2	-5	28	47	39	60	-2	29	40	3	26	-4	-21	-19	-30	-33
3	7	3	-1	-2	0	-8	-45	-25	-30	-38	-5	4	-11	-10	-8
4	28	8	16	36	27	8	-24	6	-18	-1	0	0	5	-2	0
5	2	12	58	5	30	-3	-43	-40	-44	-39	-2	-1	2	13	38
NCFB 6	11	4	-5	8	6	11	-11	-8	-4	-3	7	-3	-9	-2	22
7	-6	-47	-46	-36	-37	6	5	-1	-18	-36	4	6	-8	-58	-11
8	2	17	23	10	-3	14	-9	-20	-23	69	-2	-2	8	-7	-13
9	2	3	7	18	23	19	-1	-15	-46	-38	4	5	1	-26	-34
10	0	-20	-6	-65	-123	8	-15	14	24	2	12	-6	-32	5	27
11	10	4	-1	-4	-18	3	-28	-19	-22	-41	-5	0	-23	-52	-58
12	2	17	9	31	30	18	4	0	-16	-27	-1	-38	-48	-89	-108
13	-6	2	7	12	18	7	31	72	80	58	-9	-16	-3	-14	-3
14	-2	44	42	59	60	-6	1	41	57	58	8	16	17	40	43
15	13	13	25	27	27	-16	13	66	28	87	-11	31	24	42	49
16	-5	6	14	16	14	4	13	32	51	58	9	20	32	54	69
17	-6	9	33	63	94	-12	-24	30	86	57	11	18	11	25	26
CFB 18	7	-26	-19	5	-19	4	20	57	64	74	-2	5	8	15	21
19	3	12	33	39	101	7	-48	-43	-52	-32	7	7	33	67	83
20	6	25	53	42	125	4	32	50	50	50	10	23	53	70	70
21	13	-18	-5	22	24	-5	25	42	34	45	-13	33	24	20	59
22	-1	43	82	101	96	-1	39	47	54	159	-13	5	4	22	28
23	-31	6	22	65	93	9	-8	5	111	117	8	43	34	52	58
24	5	-41	-29	-27	-13	17	4	23	40	43	-4	6	-6	6	36

APPENDIX 7

ABSTRACT OF

OPERANT CONTROL OF EEG ALPHA AFTER EXTENDED BASELINE ASSESSMENT,
A TEST OF THE DISINHIBITION HYPOTHESIS

APPENDIX 7

ABSTRACT OF

OPERANT CONTROL OF EEG ALPHA AFTER EXTENDED BASELINE ASSESSMENT, A TEST OF THE DISINHIBITION HYPOTHESIS¹

The Disinhibition Hypothesis advanced by Lynch and Paskewitz considers biofeedback increases in EEG alpha to be the result of a spontaneously occurring orienting reaction habituation phenomenon. On the basis of this hypothesis, feedback increases in alpha abundance should never 1) exceed an optimal baseline value, 2) reflect a feedback contingent phenomenon, 3) represent learning which is reproducible without aid of feedback. This is in contrast to the growing body of feedback literature which suggests that alpha does exceed baseline, is dependent on contingent feedback for these increases and transfers beyond the laboratory.

To test this hypothesis, two groups of twelve subjects, who fell in the ambivert range on the Eysenck Personality Inventory, underwent three separate days of baseline, to allow habituation of the orienting reaction, and to establish reliable baseline alpha densities. Following this, the two groups received either contingent or non-contingent feedback after which they were to produce as much alpha as possible (i.e., control) without aid of feedback.

¹ Gary K. Mills, doctoral thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario 1973, pp. x-149.

The resulting data, analyzed by two factor analyses of variance with repeated measures on the last factor, revealed, in opposition to expectations from orienting reaction theory, reliable within session decreases in alpha densities during baseline. As predicted from the disinhibition hypothesis, feedback increases in alpha never exceeded the highest value observed during baseline.

On the other hand, contingent feedback effected a significant increase in alpha while non-contingent feedback showed little effect on alpha rhythm densities. It was noted that added days of training did not produce a significant improvement in performance. Following training, the post-feedback retention task revealed no significant difference between groups.

These findings warranted only partial support of the disinhibition hypothesis. An attention hypothesis was invoked by this writer to account for the lack of transfer of learning from the feedback situation. Since an unfocussing of attention is believed to enhance alpha densities and since learning is impeded when attention is reduced, it is possible for increases in alpha to occur during feedback, which suggests learning, while at the same time transfer of this learning beyond the feedback situation does not occur.

The importance of generating testable theories such as the disinhibition model to unify the relatively fragmented, and sometimes conflicting biofeedback literature was stressed.