BIOFEEDBACK TRAINING OF 40 Hz EEG IN HUMANS: FOLLOW-UP ON CONTROL, GENERALIZATION OF EFFECT, AND MAINTENANCE OF CONTROL DURING PROBLEM SOLVING

A Thesis

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fullfillment

of the Requirements for the Degree

Master of Arts

By

Martin R. Ford

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ABSTRACT

Long-term voluntary control of 40Hz EEG activity was investigated in six subjects, originally trained to increase and suppress 40Hz EEG in a previous study. The elapsed time between initial biofeedback training and follow-up control testing varied from one to three years. No practice sessions were held during this period. Subjects were first instructed to alternately produce and suppress 40Hz EEG with feedback. Feedback was terminated for subsequent periods if and when consistent control was shown. During the final session, subjects were given a battery of test items and were instructed to alternately produce and suppress 40Hz EEG while solving problems. Forty Hertz EEG was monitered from the O_1-C_z. O_2-C_z. P_3-C_z, P_4-C_z leads during training and problem solving periods. Forty Hertz EMG was recorded from neck-temporal muscles. On-line comparator circuits prevented counting 40Hz EMG as 40Hz EEG.

Significant control of 40Hz EEG, without feedback, was shown for five of the six subjects. One subject was erratic only in the production of 40Hz EEG. Significant control was shown to generalize to the O_1-C_z, O_2-C_z, and P_3-C_z leads, regardless of which lead had been reinforced. The amount of 40Hz EEG during the suppression periods, while solving problems, was significantly greater than during the suppression periods without feedback.

It was concluded that, following biofeedback training, long-term voluntary control of 40Hz EEG can be maintained for long periods of time.

Furthermore, though the greatest control was demonstrated at the conditioned lead, the effects did generalize to other nonconditioned leads, indicating that it is an overall state that is learned. Finally, 40Hz EEG could not be suppressed during problem solving periods as compared to suppression periods without feedback. This further supports the association between 40Hz EEG and mental activity.

Other topics which were investigated were the changes in alpha and beta production during the training and problem solving sessions and the performance aspect during the 40Hz EEG production and suppression periods while problem solving. Relevance of the results of this study to the training of MBD children was discussed.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Research in the field of electroencephalography has consistently shown that there are certain characteristics of oscillatory neural activity that occur during resting periods and mental activity. During periods of mental relaxation, the electroencephalogram(EEG) is dominated by large amplitude, slow frequency, synchronous alpha waves. During mental activity, such as problem solving, there is a blocking of the alpha activity. It is replaced by low amplitude, fast frequency, non-synchronous beta waves which are prominent as long as attention is maintained. Only recently has it been shown that there is a select band width within the beta range that is associated with the consolidation process of short term memory. This band width is centered around 40Hz.

It has further been shown that college students can be trained to increase their 40Hz activity through biofeedback conditioning. The increase persisted through post-conditioning problem solving for those who were successfully conditioned. Evidence of control, i.e., the ability to increase or suppress 40Hz at will without feedback, was shown to persist for up to nine weeks following training. An index of subjective descriptors indicated that the production of 40Hz was accompanied by mental concentration and high arousal, whereas the suppression of 40Hz was accompanied by mental relaxation and low arousal.

This studv will investigate some of the questions raised by the previous studies with college students. The first question deals with the longevity of control of 40Hz activity. Lasting effect in the absence of feedback is a topic of essential importance to the field of applied biofeedback procedures.

The second question deals with the generalization of the effect of conditioning. This is also related to a basic question raised throughout the biofeedback literature. Does the training result in a specificity of effect solely in the system, or in this case EEG lead, being conditioned, or, does the subject learn to control an overall state for reinforcement? How this relates to the procedures involved in training minimal brain dysfunction (MBD) children to produce 40Hz will be discussed.

The final question concerns the ability of the subjects to maintain control of their 40Hz activity while solving problems. The specific hypothesis to be tested is that the subject will not be able to suppress their 40Hz during problem solving as well as they can during control sessions without feedback.

Other topics which will be looked at are performance aspects during problem solving where subjects are instructed to either increase or suppress 40Hz, the dissociation of 40Hz EEG, 40Hz muscle, beta, and alpha, and the effects of problem solving on alpha and beta activity.

EEG and Mental Activity

The first person to demonstrate the existence of neural oscillatory potentials or, more commonly, the electroencephalogtam (EEG), was Richard Caton in 1875. He was attempting to show that the action potentials generated along neural fibers might also be recorded from the brains of animals. In the process of demonstrating this, he discovered incessant oscillating potentials arising from the cortex. He termed these potentials "electric currents of the brain" (Caton, 1875).

The existence of the EEG in man was not shown until nearly fifty years had passed. Hans Berger (1929) is credited with being the first person to demonstrate the existence of ongoing, oscillatory potentials. Although his recording methods were quite crude, he was able to distinquish two distinct and prominent classes of rhythmic frequencies. The first was a synchronous, slow frequency-high amplitude series of oscillations which he labelled "alpha" waves, occurring at a frequency of approximately 8-13Hz (cycles per seconds). The other was a less synchronous, fast frequency-low amplitude set of waves which he called "beta" waves (14Hz and faster). Berger was the first to report the change from alpha waves to beta waves as a person became engaged in some form of mental activity. This "alpha block", as he called it, did not depend on the individual merely viewing some stimulus; the individual's attention to the stimulus was apparently the critical component in the maintenance of the alpha block. As the person's interest waned, the synchronous alpha waves became more prominent.

Berger had assumed that the waves he was observing were a result of the whole brain. It was not until several years later that some degree of localization was demonstrated. Adrian and Matthews (1934) showed that alpha waves occur primarily at the occipital cortex. They showed further that it was visual stimuli that have the greatest effect in blocking or attenuating alpha. Again, as Berger had noticed, it was the attention of the subject to the display that blocks alpha, not the display itself (Adrian, 1944). Adrian went on to postulate that the regularity of the brain waves meant that large numbers of brain cells must be firing in unison at the same rate. Therefore, during alpha production, large quantities of cells must be firing in synchrony, whereas beta represents a more nonsynchronous set of neural activity involving numerous subassemblies firing at different rates.

In agreement with Adrian and Matthews, Mundy-Castle (1957) demonstrated that visual imagery was far more effective in the diminution of alpha than either auditory or kinesthetic imagery.

The observation of neural desynchrony during mental activity is one of the most consistent findings in electroencephalography (Shagass, 1972). The fact that alpha is reduced or desynchronized by sensory stimulation, especially visual, as well as during periods of mental activity and heightened alertness is well documented. The characteristic high voltage-slow activity during periods of relaxed attentiveness clearly shows that alpha is an "idling rhythm" of the brain, indicating that neuronal populations are being inhibited. Similarly, the low-voltage-fast activity during periods of alterness and attentiveness show that beta is associated with ongoing processing of information, and is indicative of the neuronal population dividing into activated subpopulations (Lindsley, 1956). The essential factor underlying maximal synchrony, as found during alpha production, can clearly be interpreted as the relative functional inactivity of neural tissue (Kooi, 1971). Surface and in-depth recording in both animals and humans show consistent results with respect to the observable behaviors associated with the presence of alpha and beta activity.

It is well known that the mesencephalic reticular formation acts as an activation center for the nervous system. When stimulated electronically (Moruzzi and Mugoun, 1949), clear signs of behavioral alerting occur-signs similar to those occurring following normal peripheal stimulation. In terms of EEG activity, brain stem stimulation results in cortical desynchrony where alpha had been prominent. This resulting fast activity has been termed activation or arousal (Kooi, 1971). It has been advanced that the brain stem reticular is also the anatomical basis for bilateral synchrony of normal alpha and beta components (Garoutle and Aird, 1958). The importance of the reticular involvement in a learning situation will be discussed shortly.

Using depth electrodes in monkeys, Morrell and Jasper (1956) concluded: "The diffuse desynchronization is the cortical component of this [orienting] reflex and represent a general 'arousal' or increase in excitability of the entire cortex preparatory to dealing with a new situation." They go on to speculate that the localized activation pattern is limited to the sensory receiving area which is appropriate to the stimulus.

In in-depth recording with humans, Sem-Jacobsen (1956) reports a dominant frequency of 2-8 Hz with eyes closed, and a frequency of

4-8 Hz with eyes open. However, when the patient looked at a picture, a pattern of 27-50 Hz occurred and persisted as long as the patient was interested in the picture.

In a similar vein, Knott (1938) found waves up to 30Hz occurring while subjects were reading either aloud or silently. Andreassi(1973) found that alpha significantly decreased while "fast activity" increased during the period in which subject were instructed to make as many words as possible from the word ENGINEERING in a given time. Surwillo (1971) found increases in EEG frequencies over occipital and parietal areas during the WISC Digit Span memory task due to "arousal during learning."

From the vigilance task literature, it has been shown that significant decrements in performance occur during radar tracking tasks as a result of training the subject to maintain the presence of theta waves (Beatty, 1974). Theta waves (4-7Hz) are less common in adults and reflect a mentally relaxed, nonattentive, waking state.

Thompson and Obrist (1963, 1964) performed a series of experiments designed to investigate other characteristics of the desynchronous activity. The subjects' task was the memorization of nonsense syllables. Several important results were obtained. In the first place, the characteristic blocking of alpha was present, as well as increases in beta activity (12.5Hz and faster) during the verbal learning. Using period analysis, they found that the maximum desynchrony occurs during the critical stage of the learning process, that is, when the nonsense syllables were first being anticipated correctly, and new associations were being formed. Further, they report the occurrence of a "superimposed low voltage fast-activity" during the critical stage of acquisition.

There are numerous other studies (Tyler, Goodman, and Rothman, 1947; Elliot, 1964) which further support these findings. In summary, there is a decrement in production of alpha waves and an increase in the occurrence of nonsynchronous beta waves in the presence of various types of mental activities. The desynchrony persists as long as attention or interest is maintained. Conditioning of slow frequency activity (theta) results in a performance decrement. The desynchrony is attributed to, or as least correlated with, the brain stem retucular's activating influence on the cortex. Finally, the desynchrony is maximum at the critical stage of the learning process. The question that arrises with respect to the current research here is: Is there anything unique about this "superimposed low voltage fast-activity" that can be isolated from the remaining and overshadowing EEG frequencies? Or more specifically, is there perhaps a select frequency range that represents an essential component of neural functioning that occurs during the acquisition or consolidation phase of learning? The following discussion suggests that the answer to these questions if affirmative.

Overview of 40Hz EEG Research

There have been numerous studies throughout the EEG literature where activity including the 40Hz band was either passively observed or directly investigated. An exhaustive review of the animal literature was made by Hix (1969). Reviews of the human literature were made by Peters (1970) and Hix (1971). Since extensive reviews have already been made, only highlights of those studies will be included here to establish the trend of the research. More comprehensive treatment will be given to the latest research findings and accompanying theoretical positions.

Adrian and Ludwig (1938) were the first to report the existence of a pronounced rhythmic electrical activity in various subcortical structures in the catfish. Since then, many investigators have verified the existence of this activity among numerous rhinencephalic structures throughout the phylogenetic scale (Sheer, 1970). In most cases, the activity centers around 40Hz (Sheer and Grandstaff, 1969).

One of the most consistent findings is the presence of 40Hz activity in the olfactory bulb (Grandstaff, 1965). When air is taken in through the nostrils, there is an increase of 40Hz activity in the bulbs. When either nostril is occluded, the 40Hz activity in the corresponding bulb ceases. Recording from the amygdala, which is a higher-order center for olfaction in the limbic system, also show 40Hz activity (Sheer, 1970). The activity here, however, is not dependent solely upon respiration. It is related to the novelty of the stimulus, and only occurs with concomitant orienting behavior indicated by high alertness, EEG arousal patterns, and sniffing response. It was also shown that the 40Hz is most pronounced in the visual cortex of cats during the S_D period in which the cat had to discriminate between similar stimuli (different rates of light flickers) for reinforcement (Grandstaff, 1965; Jankel, 1975). A dissociation among 31.5Hz, 40Hz, and 50Hz, was demonstrated by the fact that only the 40Hz activity increased during the S_D periods (Sheer and Grandstaff, 1966.)

In both cases involving the olfactory and visual systems, the most prominent increases of 40Hz came during the period in which the stimulus acquired secondary reinforcing properties, or, in other words, when the stimulus became "meaningful" to the subject. When the stimulus no longer led to reinforcement, i.e., during the extinction trials, the 40Hz activity was no longer present. This, in part, has led to the conclusion that the 40Hz is a "consolidation rhythm" which is "optimal" for short term memory storage (Sheer,1970, 1975a). Other evidence aside from our laboratory findings show similar results.

Galambos (1959) reported the occurrence of 38-42 Hz activity from the caudate and globus pallidus during shock avoidance learning. Rowland (1959) showed the presence of 40Hz activity in the ectosylvian and lateral cortex, medial geniculate, reticular, center median thalamus, and hippocampus during the period in which a click was the conditioned stimulus to avoid shock. The 40Hz was not observed after extinction.

There have been a few reports where depth electrodes in humans were used. Sem-Jacobsen, Bickford, Dodge, and Peterson,(1953), observed 30Hz activity in humans olfactory bulbs in response to olfactory stimulation. Perez-Boria, Tyce, McDonald, and Vihlein,(1961) found 40-45 Hz focal fast response to different sensory stimulation from the region posterior to the pulvinar and anterior to the ventral calcarine region. Rapid habituation was also observed. Chatrian, Bickford, Vihlein, (1960) reported 50Hz activity occurring in deep structures as a result of switching a light on and off.

Most of the high frequency EEG activity in humans comes from scalp recordings. The trend of the results is rather similar to that which is observed in animals. Sakhiulina (1960, 1961) reported high frequency electrical activity, around 40-45 Hz, which appeared in one or another area of the cerebral cortex during problem solving. The activity was maintained during the phase in which a solution to a problem was decided upon, and disappeared once the problem was solved. The primary areas were the frontal and parietal lobes. Giannitrapani (1966, 1969) found high frequency EEG, 38-42 Hz activity, occurring during mental multiplication just prior to the subjects' answer. Using period analysis, he also found an increase during "thinking" (38.9Hz) as opposed to "resting" (32.8Hz) periods. He speculated that the fast activity was a consequence of other activites concomitent with the novelty of the situation, such as the orienting reflex.

Peters (1970) filtered selected band widths centered at 20,25,31.5, 40, and 50 Hz from frontal and occipital areas. From the occipital electrodes he found significant decreases of 20Hz during the stimulus period and significant increases of 40 and 50 Hz during the same period. The 40 and 50 Hz increases were interpreted as being associated with facilitation and orientation and the electrical corollaries of short term memory.

From a slightly different area, there has been reported, using spectral analysis, significant increases of 40Hz activity during meditation. Das and Gastaut (1955) reported high amplitude levels of 40Hz from the occipital leads of yogis during the samadhi state. This is the deepest level of meditation which requires maximum concentration. Banquet (1973) also observed 40Hz activity during the third deep stage of transcendental mediation. These studies are of unique importance because they require the subjects to be in a state of complete physical relaxation, thus greatly lessening muscle interference of the scalp recordings.

There is a commonality that may be extracted from the findings presented thus far. It has been shown that subcortical 40Hz activity is observed as a consequence of meaningful or arousing stimuli. In humans recording, 40Hz is most pronounced during periods of concentration, such as during deep meditation and problem solving. What is common in all cases is the state of the organism. In each situation, the organism is highly aroused and its attention is focused on the arousing stimuli. The EEG pattern is highly desychronized. It is during this activation period that 40Hz activity is most prominent.

There has been considerable interest in recent years in investigating a grouping of learning-disabled children classified under the loose lable of minimal brain dysfunction (MBD). Results from our laboratory have shown clinically significant results. Using continous power spectral functions with an analog computer, Hix (1971) filtered for select band widths of 31.5,40, 50, and 70Hz activity from the occipital-parietal areas of normal and MBD children during problem solving and resting conditions. She found a significant increase in 40Hz during a Visual-Verbal task in normal children, whereas no increase was observed in the MBDs. The MBD's also made more errors during this and another performance task. The 31.5 and 50 Hz bands showed no change during the resting and performance conditions. The results were interpreted as indicating that the MBDs were lacking in the generation of the 40Hz consolidation rhythm, which may, in part, have lead to the performance decrements.

Using the same computer system and task, Johnson (1975) recorded right and left occipital parietal, and frontal EEG activity in normal children. She found significant decreases of 40Hz in the occipital leads during the problem solving periods, with significant increases in the right parietal and increases approaching significance in the left parietal. No changes in the frontal leads were observed, and no asymmetries were found. The results were interpreted as indicating a limited cortical excitability for maintaining sequences in short term memory store.

Results such as these have lead to the following hypothesis: If the performance decrements in the MBD children are due, at least in part, to an insufficiency in production of this consolidation rhythm, then perhaps increases in this rhythm could result from the operant conditioning of it using biofeedback procedures. Normally, these children are given amphetamines which have the paradoxical effect of decreasing hyperactivity, and the beneficial effect of increasing attention. The amphetamines work directly on the reticular system, which has already been shown to have a role in cortical activation. Administering amphetamines in cats is known to increase 40Hz activity in the cortex (unpublished results). If the conditioning of 40Hz in MBD children is successful in achieving performance increases, then the biofeedback procedures might afford an alternative to the amphetamines approach. Numerous studies generated in the past few years have been aimed at investigating these ideas.

Using biofeedback techniques and the principles of operant conditioning, it has been shown that 40Hz activity and alpha can be independently manipulated by reinforcement contingencies in cats (Bird, 1975a). Behavioral concomitants of EEG activity following conditioning of either 40Hz or alpha were found. To obtain reinforcement for 40Hz activity, the cats would display noticeable head and eye orienting movements. For alpha reinforcement, the cats would sit quietly or lick the feeder with eyes closed.

In experiments with college students, it has clearly been shown that humans can learn to increase or suppress 40Hz using biofeedback procedures (Bird, 1975b; Newton, 1975a). A dissociation among 40Hz EEG, 40Hz muscle, and beta (21-30Hz) has also been shown both during conditioning sessions and problem solving. Newton (1975b) has shown significant increases in 40Hz during problem solving as compared to resting baseline. Successfully trained subjects showed more 40Hz in a post-test following conditioning than subjects who were unseccessfully trained. He also showed voluntary control of 40Hz in the absence of feedback for up to two months. A Q-sort (index of subjective descriptors) given to these subjects showed high arousal and mental concentration during the 40Hz increase state, whereas there was low arousal and little mental effort during the 40Hz suppress state. One group showed increases in performance following conditioning which were not completely attributable to an overall observed practice effect.

There is a research effort in progress attempting to increase 40Hz activity in MBD children at a school setting using a portable 40Hz biofeedback device (Sheer, 1975b). The present findings are incomplete but there is a trend that shows some children respond favorably to conditioning, and those who show the best conditioning also show performance increases over these who were unsuccessful at conditioning.

In summary, it is clear that 40Hz EEG activity increases from baseline levels in normal children and adults during problem solving sessions. No comparable increases occur in MBD children. Conditioning of 40Hz using biofeedback techniques can be accomplished in both animals and human adults. Whether or not conditioning is effective in increasing performance in MBD children is still a question under investigation. Finally, some degree of voluntary production and suppression of 40Hz without feedback can be achieved by college students.

The most comprehensive treatment of the theory behind the 40Hz activity is given by Sheer (1975,b). This account takes into consideration various findings involving the underlying neural mechanisms in terms of synaptic and postsynaptic events. For example, the evidence is strong that the synchronous 40Hz activity in the olfactory bulb is attributable to successive trains of excitement and recurrent inhibition. On a neocortical level, the 40Hz is interpreted as reflecting "repetitive stimulation at a constant frequency for a limited time over a limited circuitry". Furthermore, the 40Hz is optimal for consolidation because "repetitive synchronous excitation of cells maximizes the efficiency of synaptic transmission over the limited circuitry".

The role of the reticular formation is seen as follows. Direct stimulation of the reticular enhances the release of acetylcholine and results in an EEG activation pattern. Acetylcholine is known to facilitate the firing rate of the cortical cells activated by the reticular excitation. On a behavioral level, brain stem stimulation is known to facilitate learning when applied immediately after registration of information. Physostigmine, which increases acetylcholine action, has also been shown to facilitate learning in a one-trial avoidance situation.

Admittedly, the theory tries to connect a number of related areas, and at this time, its value is primarily heuristic. What can be concluded from the behavioral and physiological data is, however, that 40Hz EEG does reflect "a state of circumscribed cortical excitability or focused arousal which is 'optimal' for consolidation in short term store."

Present Focus of Investigation

Recent studies that involved training college students to increase and control their 40Hz brain waves have answered many important questions (Newton, 1975b; Bird, 1975b). These studies have also generated new questions and new topics for investigation. This paper will deal with some of these questions.

The first and foremost question with direct relevance to the theory behind 40Hz is this: Given that a subject can voluntarily increase and suppress his 40Hz activity without feedback, can this control be maintained if he is simultaneously required to solve a set of problems? Since 40Hz is associated with problem solving, subjects should not be able to suppress 40Hz during those sessions. The specific hypothesis is that subjects will not be able to suppress 40Hz EEG during problem solving as well as during control periods without feedback. Ability to increase the level of 40Hz during problem solving, relative to increase sessions without feedback, will also be investigated. Past findings on maintenance of control during problem solving are inconsistent (Newton, 1975b). This was probably due to the fact that the control, as such, was not a major topic under direct investigation. The number and type of problems varied across few individuals who had been trained under different procedures. It is one aim of this study, then,to show that although evidence of control may be present during problem solving, the amount of 40Hz will be greater in suppression periods during problem solving as opposed to the suppression periods without feedback. Reinforcements will include obtaining a larger group of individuals with good control developed through similar training procedures, as well as giving the same test items to all subjects.

The first step is to obtain a group of subjects who show demonstrable control. Since it would take many months of training to obtain a select subgroup with good control, an alternate plan was adopted. Of the thirty-two subjects tested previously for evidence of control, thirteen were judged to have adequate ability. It was decided to recall these individuals, reestablish their control through a standard procedure for all, and then test for control during problem solving.

In order to obtain the very best subjects, further criteria were imposed. The typical past experimental procedure was as follows:

PRETEST/CONDITIONING SESSIONS/POSTTEST/CONTROL SESSIONS
WITH FEEDBACK WITHOUT FEEDBACK

In order to qualify for this study, the subjects had to have shown (1), an increase in amount of 40Hz activity as the conditioning sessions progressed (i.e., an acquisition curve) (2), more 40Hz in the posttest than pretest, and (3), evidence of control during the control sessions without feedback. Essentially all of the subjects who showed an acquisition curve also showed more 40Hz on the posttest.

The recall of subjects after nearly three years, in some cases, presented another topic for investigation-the longevity of control. Previous results have shown control presisting at least nine weeks after training for eight of the thirteen subjects (Newton, 1975b). Since this entire study requires that subjects regain control, this issue is of pivotal importance. The question of biofeedback conditioning effects over time is also of major interest in the broader field of biofeedback. It is, in fact, of essential importance in the applied uses of biofeedback, and will be discussed further.

Finally, the last question concerns the generalization of effect. This question is another major issue in the field of biofeedback. Some data indicate that the effect is restricted to the specific system, of subsystem, being conditioned. Other evidence shows that the effects are more diffuse- as if the subjects are gaining control of an overall state. Previous results from our lab have shown that successful biofeedback training of 40Hz EEG in one hemisphere also produced comparable changes in the opposite untrained hemisphere (Bird, 1975b; Newton, 1975a). In cats, conditioning of 40Hz is area 18 in the visual cortex spread to areas 17 and 19, and probably area 21 also (Bird, 1975a). The equipment in use new allows for simultaneous monitering of 40Hz in both left and right occipital and parietal leads. By simultaneously recording EEG from several areas, the generalization of effect can be investigated. This issue will be further discussed in light of the results of this study.

The generalization of effect also has direct practical relevance in the training of MBD children because it will determine which lead(s) should be conditioned. If the effects are localized to the conditioned lead, then conditioning of the parietal leads makes more sense because they overlie the higher-order, non-specific association areas. The occipital leads, however, have a higher amplitude of 40Hz and are therefore easier to condition because the subject has greater opportunity to receive reinforcement. (Noise level limits the degree of sensitivity that can safely filter the 40Hz from the raw EEG. Very low amplitude 40Hz signal approaches the noise level amplitude). If it is an overall state that is being conditioned, then the occipital leads would therefore be preferred. The question of generalization to all leads is thus of potent relevance to this applied area, as well as to the field of biofeedback itself.

To summarize, three basic questions will be investigated. First, are the subjects able to retain or easily regain control of 40Hz production and suppression during sessions with and without feedback? Second, is the control limited to the lead being conditioned, or does it generalize to other cortical areas? And third, if a degree of control is demonstrated in the absence of feedback, can equivalent levels of control be maintained during problem solving sessions? The hypothesis is that more 40Hz will occur during suppression periods while solving problems than during suppression periods without feedback.

CHAPTER II

METHOD

Subjects

As stated the subjects (Ss) were selected on the basis of the effectiveness of conditioning. All met the following criteria:

1. All showed an acquisition curve during the conditioning sessions.
2. All showed more 40Hz activity on the posttest as compared to the pretest.
3. All showed evidence of control during the sessions without feedback.

Seven male Ss met these criteria based on two independent analysis of the data. Six Ss, age 20 to 24 years, were successfully contacted and found eager to participate. Table I shows the Ss, when they were originally trained, the leads conditioned, and their past ability to control 40Hz during alternating two-minute "on" and "off" periods without feedback.

Apparatus and Materials

The equipment used was virtually the same as that used in the previous studies involving college students. Ss' EEG waves were recorded while seated in a reclining chair in a shielded, sound attenuated, and dimly lit room. Paper records were recorded on a ten channel Model 78 Grass polygraph. EEG waves were amplified through seven Grass EEG amplifiers (Model 7P511). The high-pass filter was set a 10Hz (for alpha at

Table 1

Bursts per Minute of 40Hz EEG for Alternate "On" and "Off"

Control Periods (No Feedback)-Previous Results

S	Date Originally Conditioned	Lead Conditioned	On	Off	On	Off	On	Off	On	Off	On	Off
RK	May, 1973	O_1-P_3	20.5	0.0	18.0	1.0	21.0	0.0	0.0	0.0	7.5	0.0
			0.0	0.0	43.5	0.0	2.5	0.0	20.5	0.0	37.5	0.0
			26.0	0.0	0.5	0.0	32.5	0.0	13.5	0.5	4.0	1.0
			28.5	0.0	7.5	0.5	25.0	0.0	23.0	0.5	19.5	1.5
			18.5	0.0	22.0	0.5	26.0	0.5	17.5	0.0	27.5	0.0
			2.0	0.5	13.5	0.0	16.0	0.5	9.5	0.0	23.5	0.0
RH	May, 1973	O_1-P_3	38.0	1.5	36.5	11.0	31.0	5.0	1.5	4.5	10.0	36.0
			6.5	0.0	2.0	3.0	3.0	1.0	0.5	0.5	5.5	0.0
JB	Nov, 1974	O_2-C_z	57.5	2.0	45.5	2.0	48.0	1.5	36.0	2.0	44.5	0.5
RC	Nov, 1974	O_1-C_z	39.5	2.0	57.0	0.5	12.5	3.0	37.5	3.5	76.0	3.5
			74.5	1.0	57.5	0.0	39.0	1.5	39.0	0.0	--	--
MC	Jan, 1975	O_1-C_z	32.0	13.0	59.5	15.0	40.0	18.5	51.5	16.5	40.5	15.0
MR	Jan, 1975	O_2-C_z	27.0	8.0	37.5	15.0	29.5	19.5	8.5	10.5	15.0	9.5

3Hz), and the low-pass filter was set at 90Hz. All amplifiers were run at maximum sensitivity. The 60Hz filters were cut out. Chart speed varied from 5mm./sec. to 100 mm./sec. to allow visual inspection of low amplitude, fast activity.

EEG waves were recorded with Grass silver disc electrodes, which were filled with conductive paste and attached to acetone cleansed skin with squares of cotton gauze soaked in collodion. Placements for the EEG recordings followed the International Ten-Twenty System (Jasper, 1958). Muscle recordings were made between the neck muscle (splenius) and ipsilateral temporal muscle. Coordinates for the placement of muscle electrodes were:

Neck: 13 cm. ventral and 3 cm. lateral from the inion,

Temporal: approximately 3 cm. directly anterior from the auditory meatus.

Resistances for all electrodes were below 5,000 Ohms.

Comparators and Filters. The amplified EEG outputs were connected to four coincidence detection units, which served to control for muscle confounds (Appendices A and B). In each unit, there were two high Q, narrow band, twin-T analog filters (Model 3385, White Instrument Co., Austin, Texas). Both filters have a 23% roll-off. One filter in each unit is centered at 40Hz (range 37.5-42.5Hz) and the other is centered at 70Hz (range 68-72Hz). Outputs from the filters were first rectified to DC, then integrated and fed to digital counters. Outputs could be regulated both in terms of time constants and amplitude threshold levels.

Each unit also contained an anion gate which only allowed the 40Hz output to trigger a digital counter when it occurred in the absence of the 70Hz output. The latter was used to represent high frequency muscle activity based on the finding that 40Hz muscle is polyphasic with 70Hz activity, while 40Hz EEG is not (Hix, 1971). The time constant duration for both 40Hz and 70Hz was set at 75 msec., representing three cycles of 40Hz and five cycles of 70Hz. Any overlap between the 40Hz output and 70Hz output resulted in no digital counts. The amplitude level for 40Hz varied between 5 to 10 microvolts (μv).

The second control for muscle confounds consisted of a comparator and a 200msec. contingency window circuit. This circuit blocked the digital output of all 40Hz EEG burts that occured within 200msec. of 40Hz muscle outputs. (EEG and muscle defined by electrode placements).

In simple terms, the muscle control circuits worked as follows: No digital counts were registered for any 40Hz burst that was coincident with a 70Hz burst from the same lead (40Hz EEG/muscle inhibition by 70Hz muscle). No digital counts were registered for any 40Hz EEG burst from one lead that occured within 200msec. of any 40Hz muscle burst from the muscle lead (40Hz EEG inhibition by 40Hz muscle). These two controls greatly reduce the possibility of misinterpreting muscle activity as 40 Hz EEG.

Two other EEG filters were also used. One had a center at 10.5 Hz and a range of 8-13Hz which was used to filter alpha. The other had a center at 24.5Hz with a range of 21-30Hz which was used to filter beta. Time constants were set for three cycles of alpha and three cycles of beta. Amplitude levels were set at a minimum of 15 to 20μv. Separate digital counters registered bursts of the alpha and beta waves. Since the range of muscle activity does not extend to these frequencies, no muscle comparator circuits were necessary.

Feedback was given in the form of colorful, detailed slides made from popular magazine photos, which were projected on a 4 x 5 foot screen in the recording room. During control sessions with feedback, the circuit was designed so that only 40Hz EEG activity not inhibited by either muscle contingency circuit could trigger the projector. Slides were displayed for .5 seconds for each non-inhibited burst of 40Hz EEG. When no 40Hz was present, or when no feedback was given (as in baseline and control periods without feedback), a small square of light was projected on the screen.

EEG and muscle leads were recorded on chart paper along with event pens for 40Hz EEG, 40Hz muscle, and beta.

Procedure

The basic design for the study required each S to participate a minimum of two days. The first day served to reestablish the S's control over his 40Hz activity, with and without feedback. More than one day for doing so was anticipated. The second day consisted of testing the control while the subjects were solving problems. Procedures for each day were as follows.

Procedure for Day 1. As the electrodes were being applied, details of the experimental procedings were explained to each S. Since the goal of the first day was the reestablishment of control, there was predesignated number or sequence of "on" and "off" periods. Five minute baselines were run at the beginning and end of each daily session, during which the S was instructed to sit still, relax, and to keep eyes open. Following the first baseline were a series of alternating, two-minute "on" and "off" control periods with feedback given for 40Hz

EEG activity. Instructions for the "on" periods were:

> "During the next two minutes, we would like you to turn on as many slides as you can. Stay relaxed, and keep your eyes open."

Instructions for the "off" periods were:

> "During the next two minutes, try to keep the slide projector off. Stay relaxed, and keep your eyes open."

When Ss reliably showed more 40Hz during "on" periods than "off" periods, feedback was discontinued. Instructions for periods without feedback were similar to those above, with the words "brain waves" replacing "slide projector". Verbal feedback of performance was given immediately after each two-minute period without feedback. Control training was terminated when demonstrable ability was shown during four consecutive "on" and "off" periods, or when the S became fatiqued, in which case additional control days were required.

All Ss were given feedback for the same leads as those originally conditioned, with the following execptions. RK and RH were originally conditioned at the O_1-P_3 lead. It was decided to try to reestablish control through conditioning of the P_3-C_z lead to possibly show a greater effect during problem solving.

Forty Hz EEG was also recorded from the ipsilateral occipital or parietal lead not being conditioned. Both muscle contingency circuits were in effect for both 40Hz EEG leads. Muscle was recorded from the temporal-neck lead on the ipsileral side as that being conditioned. Beta was always recorded from the lead being conditioned. Alpha was always recorded from the occipital areas- either from the same side as that being conditioned (n=3), or from the contralateral side (n=3). All recording was referenced to C_z. Events on the chart paper registered bursts from both 40Hz EEG leads, as well as 40Hz muscle and beta bursts.

Procedure for Day 2. Procedure for the second day, or for the day of testing if more than one control day was needed, was the same for each subject. Baseline recordings were taken as before. Following the first baseline, two or three "on" and "off" warmup sessions with feedback were given. Following that were four "on' and "off" sessions without feedback. Instructions were the same as during the previous day. After two "on" and "off" periods without feedback, a battery of problems were given. There were four types of problems- ten problems of each type. While solving the first five problems of each type, the Ss were instructed to keep their "brain waves turned on." While solving the second five problems of each type, they were instructed to keep their"brain waves turned off". The ten items of each type were divided to make forms A and B. Presentation of forms was counterbalanced across Ss. Answers to problems were given verbally through a two-way intercom system.

Recording procedures were somewhat modified for the testing day. The second control for muscle (40Hz EEG inhibition by 40Hz muscle) was dropped. Previous analysis of existing data had shown that the second control only inhibited from 5 to 10% of the bursts of 40Hz from the head lead. Further, these Ss had all been trained with the second muscle contingency functioning. By dropping this control, two more 40-70 Hz comparator units could be used. Forty Hz EEG could thus be recorded simultaneously from four leads instead of two leads. Thus, for the testing day only, 40Hz EEG was recorded from the right and left occipital and parietal leads, referenced to C_z. Beta and alpha were recorded as on the previous day(s). Events on the chart paper registered bursts from the four 40Hz EEG leads.

Following testing, the Ss were completely debriefed as to the intent of the study. Ss were paid $5.00 for each day of participation.

Test Items. As stated, there were four types of problems with ten items of each type. (see Appendix C). The items were taken from the Revised Minnesota Paper Form Board Test, Series MA (PFB); from the Abstract Reasoning Form of the Differential Aptitude Test (DAT) and from verbal (VERB) and mathematical (MATH) sections of a graduate record examination preparation book (Gruber, E.C.). A larger battery of problems was presented to several classes of students and a probability-of-correct-response figure was calculated for each item. The ten items from each type with the most proximal probability levels were selected, matched, and divided to yield the two equivalent forms. Difficulty (probability of correct answers) was at a mean level of about .50 for each type.

Presentation of Test Items. All problems made into slides and projected to the S in the recording room. Order of presentation of type was counterbalanced across individuals. Immediately prior to the presentation of each of the four types of problems, a sample problem with a complete explanation was given. When the S fully understood the task, he was instructed to keep movement and talking to a minimum, and the session began. The format of presentation differed between the PFB/DAT items and the VERB/MATH items. The PFB and DAT items were on two separate slides. The test slide (separated portion in Appendix C) was displayed for thirty seconds, followed by a small square of light for fifteen seconds, then the answer slide for up to one minute. Both question and answer for each item of the VERB and MATH were displayed on the same slide for up to one minute. An inter-trial-interavl of 10 to 15 seconds separated the items. Ss were instructed to give the answers verbally as soon as they had solved the problem, yet within the allotted time, which was adequate for all subjects. The Ss' EEG activity was recorded throughout each block of five items.

CHAPTER III

RESULTS

Digital counts for all EEG, muscle, beta, and alpha frequencies were first reduced to mean number of responses per minute for each baseline, "on" and "off" period, and problem solving session. Significance levels were calculated using the Wilcoxen Sign Test for related samples (Bruning, J.L. and Kintz, B.L.). Results are presented with respect to control, generalization, and then effects during problem solving.

Control Data

The mean bursts per minute of 40Hz EEG from the conditioned lead for alternating "on" and "off" periods with feedback is shown in Table 2. The data provides strong evidence of control by most Ss during the first day. The exception was RK. Originally, RK was to be conditioned at the P_3-C_z lead, however, since negligible 40Hz was recorded from that site, it was decided immediately to reinforce the presence of 40Hz EEG from either the O_1-C_z lead or the P_3-C_z lead. During the second day of training, RK exhibited significantly ($p<.05$) more 40Hz during the "on" periods than "off" periods from the O_1-C_z lead, though the production of 40Hz was sometimes mimimal. At his suggesion, RK was given reinforcement on a variable ratio (VR) schedule. Maximum performance was obtained during these periods. On the third day of training, however, essentially no 40Hz activity was observed. It should be noted that although production of 40Hz for RK was erratic, when it was present, it was always greatest during the "on" periods. RK had no trouble suppressing 40Hz; only its production was difficult. Therefore, RK was considered to have acceptable

Table 2

Bursts per Minute of 40Hz EEG for Alternate

"On" and "Off" Control Periods, With Feedback

<u>S</u>	Lead Reinforced	On	Off	On	Off	On	Off	On	Off	On	Off
RC	O_1-C_z	64.0	0.5	72.0	1.0	64.5	1.0	18.5	5.0	44.5	10.0
JB	O_2-C_z	22.5	2.0	3.5	1.0	8.5	3.5	71.0	8.0	22.0	2.0
RH	P_3-C_z	1.5	1.5	5.5	1.0	2.5	2.5	5.0	9.0	8.0	1.5
		19.5	3.5	8.5	13.5	9.0	0.0	--	--	--	--
MC	O_1-C_z	5.0	2.5	3.0	3.0	1.0	10.5	10.0	1.0	1.5	1.0
		17.0	0.0	7.0	3.0	1.5	0.0	4.0	1.0	--	--
MR	O_2-C_z	17.5	0.5	18.0	0.0	14.0	4.0	20.0	0.0	48.5	1.0
RK (Day 1)	O_1-C_z	0.5	2.0	1.5	0.5	3.0	0.0	16.4	0.5	0.0	0.0
		0.7	0.0	0.3	0.5	4.0	0.0	--	--	--	--
	P_3-C_z	0.0	0.5	1.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0
		0.3	0.0	0.3	0.0	1.0	0.0	--	--	--	--

Table 2 (Continued)

Bursts per Minute of 40Hz EEG for Alternate

"On" and "Off" Control Periods, With Feedback

S	Lead Reinforced	On	Off	On	Off	On	Off	On	Off	On	Off
RK	O_1-C_z	26.5	1.0	38.5	1.5	2.5	0.0	3.0	0.0	23.7	2.0
(Day 2)		4.0	0.5	--	--	--	--	--	--	--	--
	P_3-C_z	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
		0.5	0.0	--	--	--	--	--	--	--	--
VR	O_1-C_z	10.5	--	19.5	--	57.5	--	44.5	0.5	--	--
Sched.	P_3-C_z	0.0	--	0.0	--	3.0	--	1.5	0.0	--	--
(Day 3)	O_1-C_z	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--
	P_3-C_z	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--	--

control.

A typical example of the EEG record for an "on" and "off" period with feedback is shown in Figure 1. The sample was, in fact, taken from RC's first "on" and "off" session. Note the high frequency and high amplitude muscle activity (TM_L-NM_L lead) during the "on" period. Reinforcement for the O_1-C_z lead 40Hz, as well as 40Hz muscle and beta, are shown by the event pens at the bottom. Visible 40Hz activity can be seen in the O_1-C_z lead. Note that the muscle activity during the "off" period is very similar to the "on" period, yet there is clearly no 40Hz EEG at the O_1-C_z lead. This sample clearly shows visible dissociations between 40Hz EEG and both 40Hz muscle and beta. There is a clear overall difference in the EEG pattern of the "on" period versus the "off" period in terms of voltage (amplitude) and frequency.

The critical question concerning control is: Can it be maintained without feedback? Table 3 shows the mean bursts per minute of 40Hz EEG, from the conditioned lead, during all alternate "on" and "off" sessions without feedback. The last four pairs of "on" and "off" periods were recorded on the day of testing. Significant control in the desired direction was displayed by five of the six Ss ($p<.01$ for two Ss, $p<.02$ for the other three Ss.) RK had essentially no 40Hz activity during these sessions.

A typical example of an EEG record during consecutive "on" and "off" periods without feedback is shown in Figure 2 (from day 2-JB). There is a clear difference between the "on" and "off" periods occurring across all leads. Alpha visibly dominates the "off" as 40Hz in the homologous contralateral lead (O_1-C_z) is observed in the "on" period.

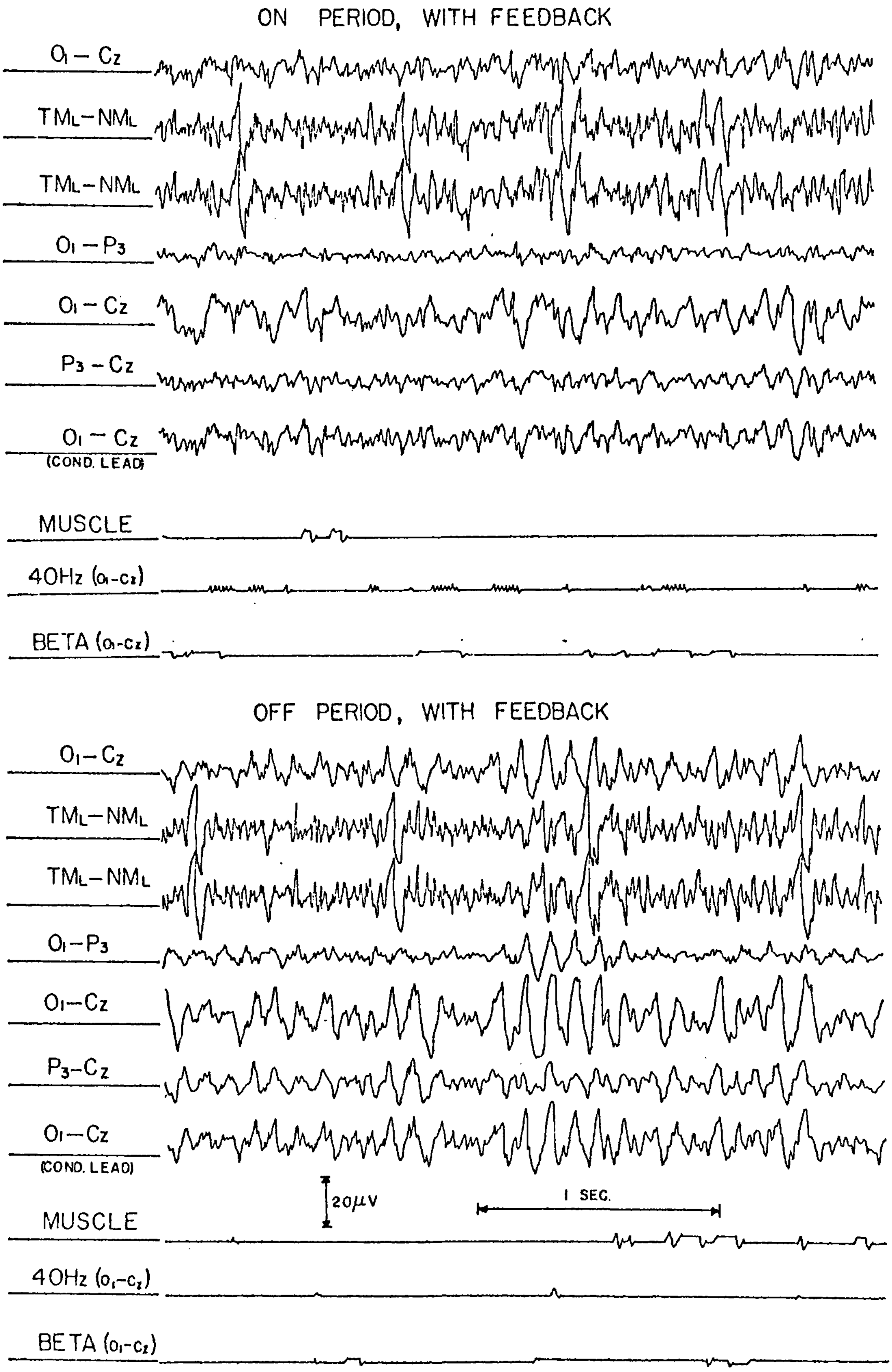

Figure 1
EEG Sample Record of "On" and
"Off" Periods With Feedback

Table 3

Bursts per Minute of 40Hz EEG for Alternate

"On" and "Off" Control Periods, Without Feedback

_S_	Lead Reinforced	On	Off	On	Off	On	Off	On	Off	On	Off
RC	O_1-C_z	7.0	3.5	11.5	3.0	2.0	1.0	12.5	2.5	4.5	2.0
		13.0	10.0	78.5	2.5	33.5	0.0	68.5	0.0*	--	--
JB	O_2-C_z	10.5	5.5	11.6	1.5	4.5	3.0	7.5	0.5	20.5	1.0
		34.0	3.5	58.0	5.0	63.0	4.5	49.0	4.5*	--	--
RH	P_3-C_z	8.5	2.0	20.5	8.5	10.0	6.5	15.0	14.0	9.0	0.0
		33.5	3.5	26.0	16.0	28.5	5.0**	--	--	--	--
MC	O_1-C_z	10.0	2.0	4.5	1.5	8.5	9.5	13.5	0.5	3.0	0.5
		14.5	3.0	35.5	1.5	15.0	1.0**	--	--	--	--
MR	O_2-C_z	30.0	2.0	40.0	5.0	12.0	2.5	34.5	0.0	59.0	0.0
		46.0	1.0	86.5	0.0	40.5	0.0**	--	--	--	--
RK	O_1-C_z	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	P_3-C_z	0.0	0.0	0.5	0.0	1.0	0.5	0.0	0.0	0.0	0.0

*$p < .01$
**$p < .02$

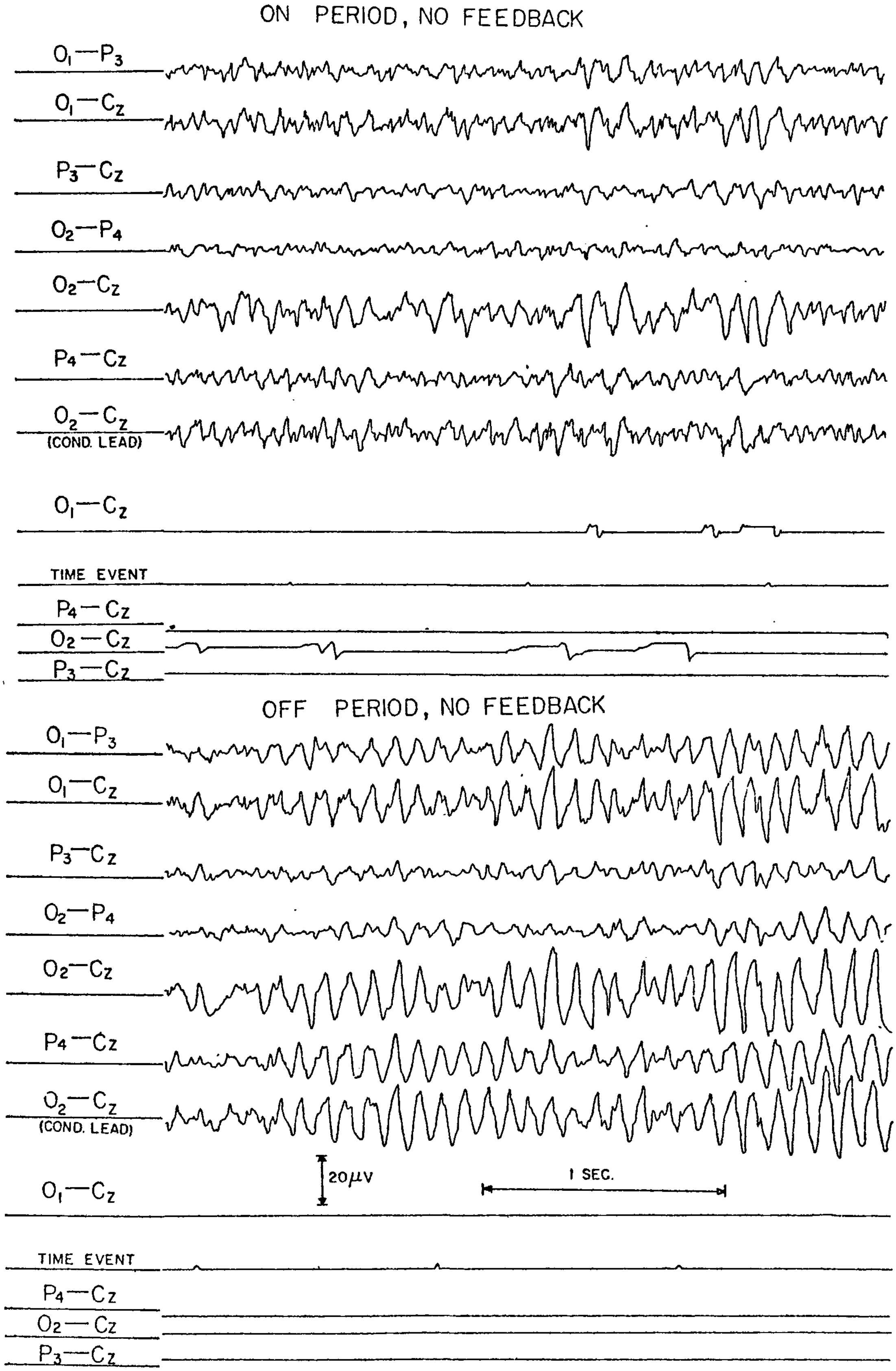

Figure 2

EEG Sample Record of "On" and "Off" Periods Without Feedback

As reported, there has been shown a dissociation between 40Hz EEG and both 40Hz muscle and beta. Table 4 shows the mean rate per minute of 40Hz EEG, 40Hz muscle, beta, and alpha, across all baselines and all "on" and "off" periods, with and without feedback, for each S. Table 5 shows the number of Ss showing increases for each frequency during the "on" periods as compared to the"off" periods. There was significantly ($p < .05$) more 40Hz EEG during the "on" periods, with and without feedback, than during the "off" periods, with and without feedback across Ss. No significant differences were found for muscle, beta, or alpha during the control periods.

Further examination of Table 4 reveals an important fact. In almost all cases, there was less alpha during the "on" sessions that the "off" sessions, which is not surprising since the "off" periods are correlated with subjective reports of mental relaxation. The exception is RH. RH also was the only one to show an increase of alpha during the "on" periods as compared to baseline. Furthermore, RH is the only S to show a marked decrease in the 40Hz "on" sessions as compared to baseline levels. Inspection of the EEG records showed that RH was using a unique strategy to obtain reinforcement. Long trains of alpha waves were observed in the record during "on" sessions. Frequently, the alpha was abruptly blocked, and at that moment, a burst or two of 40Hz was observed. This is somewhat reminiscent of the repeated orienting behaviors reportedly displayed by cats for obtaining reinforcement (see Bird, 1975a).

Not enough evidence was available to show any effect concerning different occurrence of alpha from the ipsilateral as compared to contralateral leads.

Table 4

Mean Bursts per Minute of 40Hz EEG, Muscle, Beta, and Alpha, for Baseline and Alternate "On" and "Off" Control Periods, With and Without Feedback

S	Frequency	Lead Recorded	Base	With Feedback On	With Feedback Off	Without Feedback On	Without Feedback Off
RC	40Hz EEG	O_1-C_z*	5.8	52.7	3.5	25.7	2.7
	Muscle	TM_L-NM_L	25.2	46.5	97.4	78.4	32.4
	Beta	O_1-Cz	63.6	59.3	49.5	51.0	55.9
	Alpha	O_1-C_z	58.3	1.7	50.9	22.5	124.1
JB	40Hz EEG	O_2-C_z*	11.3	25.5	3.3	28.7	3.2
	Muscle	TM_R-NM_R	17.5	38.2	26.8	19.0	23.1
	Beta	O_2-C_z	58.0	46.8	36.7	39.9	36.8
	Alpha	O_1-C_z	87.4	29.1	89.2	53.7	89.8
RH	40Hz EEG	P_3-C_z*	30.7	7.4	4.1	18.9	6.9
	Muscle	TM_L-NM_L	83.8	72.7	69.5	58.7	47.9
	Beta	P_3-C_z	48.8	40.1	42.2	44.4	55.8
	Alpha	O_2-C_z	32.8	95.4	24.9	107.8	8.1
MC	40Hz EEG	O_1-C_z*	2.5	5.1	2.1	13.1	2.3
	Muscle	TM_L-NM_L	21.5	19.4	18.6	15.5	17.8
	Beta	O_1-C_z	40.0	35.0	35.3	41.7	28.4
	Alpha	O_2-C_z	155.0	82.5	121.5	151.1	120.4
MR	40Hz EEG	O_2-C_z*	1.6	23.6	1.1	43.6	1.3
	Muscle	TM_R-NM_R	2.4	15.6	3.0	25.1	2.1
	Beta	O_2-C_z	35.0	53.5	37.2	74.8	39.2
	Alpha	O_2-C_z	66.3	39.5	80.1	40.9	58.0
RK	40Hz EEG	O_1-C_z*	1.3	10.3	0.5	0.2	0.0
	40Hz EEG	P_3-C_z*	0.7	0.4	0.1	0.3	0.1
	Muscle	TM_L-NM_L	34.5	39.5	32.3	4.8	--
	Beta	P_3-Cz	30.2	25.4	39.5	38.7	28.3
	Alpha	O_1-C_z	63.0	45.9	47.9	1.3	8.1

* Conditioned Lead(s)

Table 5

Significance Levels for 40Hz EEG, Muscle, Beta, and Alpha for Alternate "On" and "Off" Control Periods, With and Without Feedback

Frequency	Number of Ss Showing Increases During "On" Periods (With Feedback)	p	Number of Ss Showing Increases During "On" Periods (Without Feedback)	p
40Hz EEG (Conditioned Lead)	6	$<.05$	6	$<.05$
Muscle	5	N.S.	3	N.S.
Beta	3	N.S.	4	N.S.
Alpha	1	N.S.	2	N.S.

Generalization of Effect Data:

The mean bursts per minute for all occipital and parietal leads during "on" and "off" periods with and without feedback for each S is shown in Table 6. The number of Ss showing relative increases of 40Hz EEG during "on" periods as compared to "off" periods, as well as significance levels, are shown in Table 7. Significant increases ($p \leq .05$) of 40Hz during the "on" periods, with and without feedback, were found for the O_1-C_z, O_2-C_z, and P_3-C_z leads across Ss. The increase at the P_4-C_z leads were not consistent. The magnitude of differences in the "on" versus "off" periods is most pronounced for the conditioned leads. The effect at the nonconditioned leads was not as pronounced. More will be said about this later.

Control Data During Problem Solving

The two major comparisons made during problem solving were the amounts of 40Hz EEG for the "on" period (problem solving) versus the "on" period (no feedback), and the "off" period (problem solving) versus the "off" period (no feedback). Table 8 shows the mean bursts per minute of 40Hz EEG, recorded from the four leads, during the four tasks, for each S during the periods in which they were instructed to produce the "brain waves" while solving the problems. Table 9 shows the number of Ss displaying increases during problem solving over the "on" periods without feedback. Increases in the P_3-C_z and P_4-C_z were more frequent than the O_1-C_z leads, though no significant differences were obtained.

The most sensitive comparison is the "off" period (problem solving) versus the "off" period (no feedback) shown in Table 10. Bursts per minute of 40Hz EEG for all leads, during all tasks, for each S is shown.

Table 6

Generalization of 40Hz EEG to Occipital and Parietal Leads, With and Without Feedback (mean bursts/min.)

S	Lead	Base	With Feedback		Without Feedback	
			On	Off	On	Off
RC	O_1-C_z	5.8	52.7	3.5	25.7	2.7
	O_2-C_z	2.2	1.8	1.3	2.0	1.1
	P_3-C_z	1.4	3.9	1.0	1.8	1.3
	P_4-C_z	0.4	0.3	0.5	0.3	0.0
JB	O_1-C_z	9.7	13.3	4.0	16.1	1.3
	O_2-C_z*	11.3	25.5	3.3	28.7	3.2
	P_3-C_z	1.0	7.0	0.0	2.0	0.0
	P_4-C_z	0.4	0.7	0.0	0.3	0.0
RH	O_1-C_z	24.8	17.9	6.8	26.6	13.6
	O_2-C_z	72.4	73.5	41.5	68.0	39.6
	P_3-C_z*	30.7	7.4	4.0	18.9	6.9
	P_4-C_z	22.9	1.3	2.0	13.0	7.5
MC	O_1-C_z*	2.5	5.1	2.1	13.1	2.3
	O_2-C_z	0.8	1.3	0.5	9.6	1.0
	P_3-C_z	1.8	0.9	0.4	7.9	0.6
	P_4-C_z	1.3	2.8	1.5	26.0	2.8
MR	O_1-C_z	1.0	11.3	0.5	17.8	4.0
	O_2-C_z*	1.6	23.6	1.1	43.6	1.3
	P_3-C_z	0.0	0.5	0.0	0.3	0.4
	P_4-C_z	0.3	0.0	0.0	0.1	0.3
RK	O_1-C_z*	1.3	10.3	0.5	0.2	0.0
	O_2-C_z	0.6	0.8	0.3	1.3	0.4
	P_3-C_z*	0.7	0.4	0.1	0.3	0.1
	P_4-C_z	0.2	0.3	0.8	0.3	0.4

* Conditioned Lead(s)

Table 7

Significance Levels for Increases in 40Hz EEG for

Occipital and Parietal Leads, With and Without Feedback

Lead	Number of Ss Showing Increases During "On" Periods (With Feedback)	p	Number of Ss Showing Increases During "On" Periods (Without Feedback)	p
O_1-C_z	6	$<.05$	6	$<.05$
O_2-C_z	6	$<.05$	6	$<.05$
P_3-C_z	6	$<.05$	5	$=.05$
P_4-C_z	2	N.S.	4	N.S.

Table 8

Bursts per Minute of 40Hz EEG for "On" (Problem Solving)

Vs. "On" (No Feedback) Comparison

S	Lead	On - No Feedback	On PFB	On DAT	On MATH	On VERB
RC	0_1-C_z*	25.7	78.1	25.1	27.1	67.0
	0_2-C_z	2.0	3.6	2.8	4.9	1.5
	P_3-C_z	1.8	7.6	2.3	3.1	4.0
	P_4-C_z	0.3	1.0	0.8	1.4	0.5
JB	0_1-C_z	16.1	12.8	9.8	8.0	7.1
	0_2-C_z*	28.7	28.5	18.4	16.0	21.0
	P_3-C_z	2.0	0.7	0.7	1.7	0.5
	P_4-C_z	0.3	0.4	0.2	0.0	0.5
RH	0_1-C_z	26.6	39.6	30.7	17.0	16.5
	0_2-C_z	68.0	55.7	49.6	33.5	28.2
	P_3-C_z*	18.9	10.7	14.0	12.1	8.8
	P_4-C_z	13.0	6.6	10.2	7.4	5.3
MC	0_1-C_z*	13.1	46.2	11.0	32.1	15.0
	0_2-C_z	9.6	38.4	15.7	34.4	12.5
	P_3-C_z	7.9	50.0	8.6	46.5	29.6
	P_4-C_z	26.0	60.2	5.3	70.6	38.3
MR	0_1-C_z	17.8	8.6	9.6	0.4	27.6
	0_2-C_z*	43.6	1.3	0.7	0.9	2.4
	P_3-C_z	0.0	1.3	0.5	0.0	4.1
	P_4-C_z	0.1	1.6	0.7	0.7	2.9
RK	0_1-C_z*	0.2	0.1	0.2	0.3	2.7
	0_2-C_z	1.3	0.6	1.2	4.8	3.6
	P_3-C_z	0.3	2.3	0.8	1.0	4.5
	P_4-C_z	0.3	0.6	0.2	1.3	1.4

* Conditioned Lead

Table 9

Number of Subjects Showing Increases in 40Hz EEG for "On" (Problem Solving) versus "On" (No Feedback)

Lead	PFB	DAT	MATH	VERB
0_1-C_z	3	1	3	4
0_2-C_z	2	2	3	2
P_3-C_z	4	4	3	4
P_4-C_z	5	2	3	5

Table 10

Bursts per Minute of 40Hz EEG for "Off" (Problem Solving)

Vs. "Off" (No Feedback) Comparisón

S	Lead	Off-No Feedback	Off PFB	Off DAT	Off MATH	Off VERB
RC	O_1-C_z*	2.7	62.6	8.2	52.0	35.9
	O_2-C_z	1.1	6.1	3.5	3.1	0.4
	P_3-C_z	1.3	2.9	1.5	3.7	2.7
	P_4-C_z	0.0	1.2	0.6	0.0	0.4
JB	O_1-C_z	1.3	4.1	5.2	2.6	4.0
	O_2-C_z*	3.2	8.2	9.0	5.0	4.4
	P_3-C_z	0.0	0.2	0.0	0.5	0.0
	P_4-C_z	0.0	0.2	0.4	0.3	0.4
RH	O_1-C_z	13.6	27.3	30.0	12.3	10.0
	O_2-C_z	39.6	51.2	47.6	24.7	20.0
	P_3-C_z*	6.9	14.8	33.2	14.4	28.3
	P_4-C_z	7.5	7.9	8.4	6.5	1.1
MC	O_1-C_z*	2.3	6.6	8.0	5.9	3.8
	O_2-C_z	1.0	4.1	4.8	4.8	1.3
	P_3-C_z	0.6	4.2	5.4	5.0	4.7
	P_4-C_z	2.8	3.0	4.4	3.7	5.0
MR	O_1-C_z	4.0	8.0	9.1	0.9	6.5
	O_2-C_z*	1.3	0.9	0.5	0.2	1.5
	P_3-C_z	0.4	0.9	1.2	0.0	0.5
	P_4-C_z	0.3	0.5	0.4	0.4	1.0
RK	O_1-C_z*	0.0	0.2	0.0	0.6	0.0
	O_2-C_z	0.4	0.9	1.4	0.9	1.4
	P_3-C_z*	0.1	0.8	2.6	1.5	3.3
	P_4-C_z	0.4	0.3	1.1	0.6	0.0

*Conditioned Lead(s)

Table 11 shows the number of Ss displaying increases in 40Hz during the "off" period (problem solving) as compared to the "off" period (no feedback) and significance levels. All increases were in the expected direction, though not all were significant. There was significantly more 40Hz during the "off" period (problem solving) occurring from the O_1-C_z lead for the PFB and DAT problems; the O_2-C_z lead for the PFB and DAT; the P_3-C_z lead for the PFB, DAT, MATH, and VERB; and the P_4-C_z lead for the PFB and DAT ($p \leq .05$).

A typical example of the EEG records during "off" (problem solving) and "off" (no feedback) sessions show an entirely different picture between sessions (Figure 3). The S (MC) was clearly unable to suppress 40Hz while solving problems.

The number of items solved correctly is shown in Table 12. There was no significant difference in ability to correctly solve the problem when Ss were either trying to increase or suppress their 40Hz activity. A post hoc analysis showed that there was no difference in difficulty level between the two forms of the tests.

Analyses of beta and alpha during the "on" (problem solving) versus "on" (no feedback) sessions and the "off" (problem solving) versus "off" (no feedback) sessions are shown in Tables 13 and 14. Number of Ss showing decreases in the "on" (problem solving) and "off" (problem solving) as compared to "on" (no feedback) and "off" (no feedback) sessions, and significance levels, are shown in Table 15. There was a significant ($p < .05$) decrease in the amount of beta occuring over the MATH, VERB, and DAT "on" sessions, and the MATH and VERB "off" sessions. There was a significant ($p \leq .05$) decrease of alpha during every condition of problem solving.

Table 11

Significance Levels for 40 Hz EEG for "Off"

(Problem Solving) Vs. "Off" (No Feedback) (n=6)

	Number of Ss Showing Increases During "Off" (Problem Solving):							
Lead	PFB	p	DAT	p	MATH	p	VERB	p
O_1-C_z	6	$<.05$	5	$=.05$	4	N.S.	4	N.S.
O_2-C_z	5	$=.05$	5	$=.05$	5	N.S.	4	N.S.
P_3-C_z	6	$<.05$	5	$=.05$	5	$=.05$	5	$=.05$
P_4-C_z	5	$=.05$	6	$<.05$	4	N.S.	4	N.S.

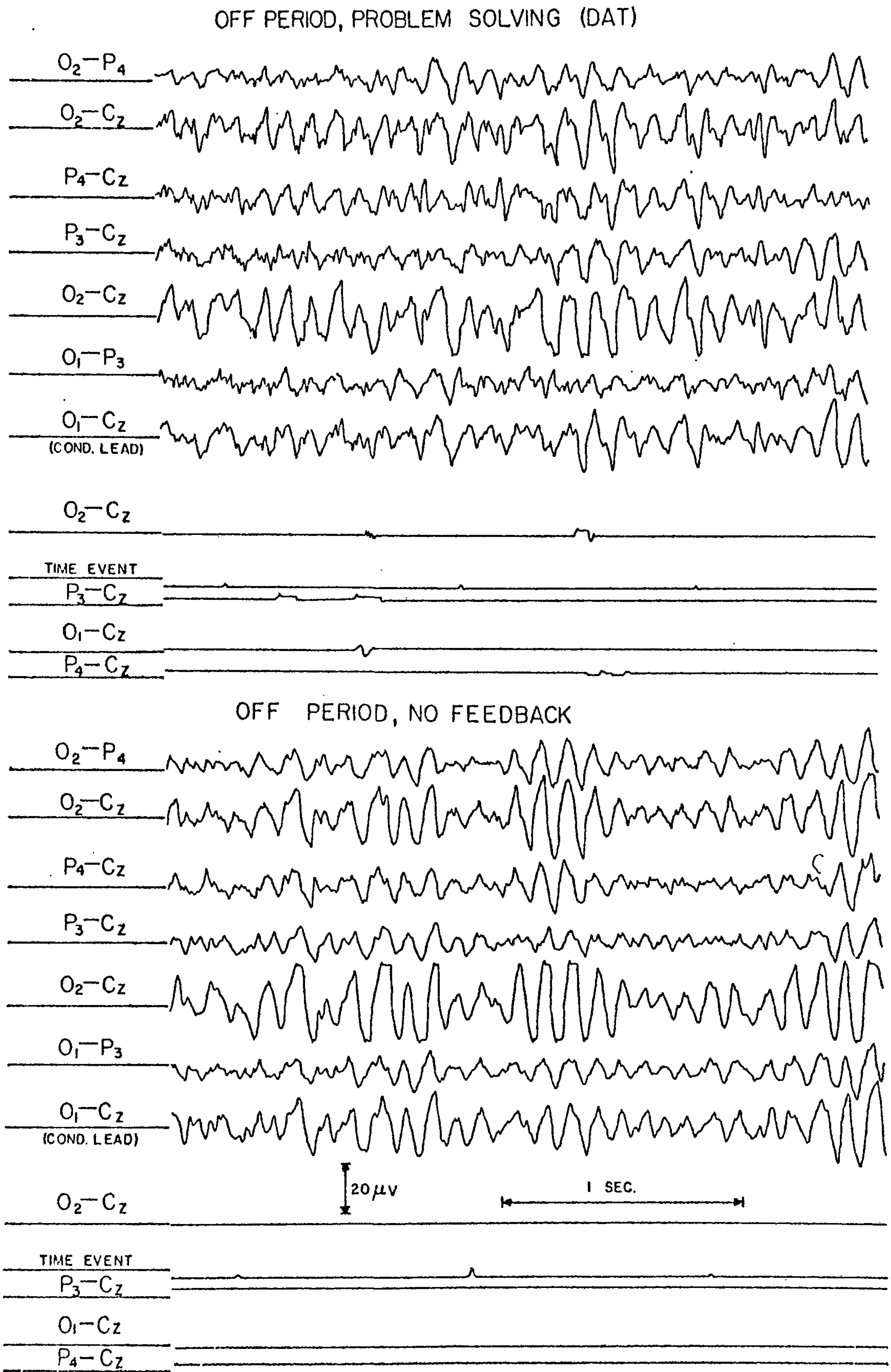

Figure 3

EEG Sample Record of "Off" Periods While Problem Solving and "Off" Periods Without Feedback

Table 12

Behavioral Results (Number Correct)

S	MATH On	MATH Off	PFB On	PFB Off	VERB On	VERB Off	DAT On	DAT Off	TOTAL On	TOTAL Off
RC	4	2	5	4	4	2	2	3	15	11
JB	4	3	3	3	3	4	3	5	13	15
RH	3	3	2	2	3	3	2	4	10	12
MC	4	3	3	1	4	3	4	2	15	9
MR	2	3	3	5	4	2	3	3	12	13
RK	2	3	3	4	3	2	2	4	10	13
Total	19	17	19	19	21	16	16	21	75	73

Table 13

Bursts per Minute of Beta EEG for Baseline, "On" (Problem Solving) Vs. "On" (No Feedback), and "Off" (Problem Solving) Vs. "Off" (No Feedback)

"On" (Problem Solving) Vs. "On" (No Feedback)

<u>S</u>	Lead	Base	On-No Feedback	On MATH	On PFB	On VERB	On DAT
RC	O_1-C_z	63.3	51.0	49.1	91.2	52.0	42.5
JB	O_2-C_z	58.0	39.9	30.0	44.8	35.7	37.0
RH	P_3-C_z	48.8	44.4	11.4	12.7	7.1	20.2
MC	O_1-C_z	40.0	41.7	8.5	12.2	5.8	9.2
MR	O_2-C_z	35.0	74.8	33.7	25.9	18.2	18.6
RK	P_3-C_z	30.2	38.7	21.0	49.3	15.5	33.1

"Off" (Problem Solving) Vs. "Off" (No Feedback)

<u>S</u>	Lead	Base	Off-No Feedback	Off MATH	Off PFB	Off VERB	Off DAT
RC	O_1-C_z	63.3	55.9	66.6	81.2	46.3	45.7
JB	O_2-C_z	58.0	36.8	17.9	33.2	14.4	35.6
RH	P_3-C_z	48.8	55.8	7.0	15.6	7.2	15.2
MC	O_1-C_z	40.0	28.4	4.6	6.3	4.7	5.9
MR	O_2-C_z	35.0	39.2	21.3	37.1	8.0	20.0
RK	P_3-C_z	30.2	28.3	9.7	47.3	20.0	42.5

Table 14

Bursts per Minute of Alpha EEG for Baseline "On" (Problem Solving) Vs. "On" (No Feedback), and "Off" (Problem Solving) Vs. "Off" (No Feedback)

"On" (Problem Solving) Vs. "On" (No Feedback)

S	Lead	Base	On-No Feedback	On MATH	On PFB	On VERB	On DAT
RC	O_1-C_z	58.3	22.5	0.6	12.8	1.0	7.9
JB	O_1-C_z	87.4	53.7	5.7	22.1	7.6	23.0
RH	O_2-C_z	32.8	107.8	4.4	6.4	2.9	5.1
MC	O_2-C_z	155.0	151.0	5.4	54.4	37.5	29.8
MR	O_2-C_z	66.3	40.9	7.0	6.1	12.4	4.1
RK	O_1-C_z	63.0	1.3	0.0	2.6	0.0	2.2

"Off" (Problem Solving) Vs. "Off" (No Feedback)

S	Lead	Base	Off-No Feedback	Off MATH	Off PFB	Off VERB	Off DAT
RC	O_1-C_z	58.3	124.1	5.1	17.0	4.8	36.1
JB	O_1-C_z	87.4	89.8	6.8	22.0	6.0	30.4
RH	O_2-C_z	32.8	8.1	0.7	0.0	0.0	3.4
MC	O_2-C_z	155.0	120.4	17.0	31.8	37.5	44.1
MR	O_2-C_z	66.3	58.0	18.4	14.5	15.5	8.4
RK	O_1-C_z	63.0	8.1	0.6	1.4	2.4	4.9

Table 15

Significance Levels for Beta and Alpha for "On" (Problem Solving) Vs. "On" (No Feedback), and "Off" (Problem Solving) Vs. "Off" (No Feedback)

	Number of Ss Showing Decreases During "On" (Problem Solving):							
Frequency	MATH	p	PFB	p	VERB	p	DAT	p
Beta	6	$<.05$	3	N.S.	5	$=.05$	6	$<.05$
Alpha	6	$<.05$	5	$=.05$	6	$<.05$	5	$=.05$

	Number of Ss Showing Decreases During "Off" (Problem Solving):							
Frequency	MATH	p	PFB	p	VERB	p	DAT	p
Beta	5	$=.05$	4	N.S.	6	$<.05$	5	N.S.
Alpha	6	$<.05$	6	$<.05$	6	$<.05$	6	$<.05$

CHAPTER IV

DISCUSSION

The first crucial question concerns the ability of the Ss to regain control of their 40Hz activity in the absence of feedback. The remainder of the study was, in fact, dependent upon their control capabilities. Significant control ($p < .02$) was shown for five of the six Ss during alternating "on" and "off" periods without feedback. The sixth S, RK, displayed erratic control during sessions with feedback. When there was 40Hz present, the control was always in the proper direction. It was therefore decided that RK should remain in the study, because when instructed to suppress 40Hz, he was always able to do so. It was only in the voluntary production of the 40Hz that he was sporadic.

The question of control of biofeedback effects over time without any practice is an important concern to the applied aspects of biofeedback therapy. Research which directly investigates this parameter is not that abundant, probably due to the time committments and subject attrition rates which are involved. The relevant past studies have shown that control can be demonstrated after various periods of time. Significant heart rate control for up to three months after training was shown in the rat (Miller and DiCara, 1971). Persistent control over time in the presence of periodic feedback was shown in humans for tension headached reduction (Reinking and Hutchings, 1976) and for heart rate (Blankstein, Lyon, Darte, and Dale, 1976). Significantly shorter sleep latencies and better sleep efficiency was shown for up to one month following EMG (electromyogram) biofeedback training (Coursey, Frankel, and Gaarder, 1976). Further, a significant reduction in epileptic seizures persisted from one to two years following reinforcement of the sensorimotor rhythm (SMR, 12-15 Hz) in humans who were gradually weaned from the feedback sessions (Lubar,1976). The results reported here show that 40Hz EEG activity can easily be regained after many months without any practice sessions.

The second question deals with the generalization of effect. As mentioned earlier, this is a very potent issue in the field of biofeedback. In short, the question is : Is the effect of biofeedback conditioning limited specifically to the muscle, finger, EEG lead, etc., that is being conditioned, or is it rather an overall state that the subjects learn to control for reinforcement? The typical belief of those supporting the first approach (operant approach), such as Shapiro, Kimmel, Miller, and DiCara, has been that the operant conditioning leads to specificity of response based upon reinforcement contingencies (see Schwartz, 1976). The classic example is the "remarkable autonomic and central nerous system gymnastics" performed by the curarized rats of Miller and DiCara. Other examples with humans showing specificity are the mutual independence of biofeedback conditioning of heart rate, EMG,(frontalis muscle), and EEG (theta) (Birbaumer, Lutzenberger, and Steinmetz, 1976); and the findings that skin potential responses could be controlled without simultaneously affecting heart rate, respiration rate, or skin potential level (Shapiro, Crider, and Tursky, et. al.,1964). Also, neither temperature not plethsmograph measure showed significant correlation with heart rate during biofeedback conditioning (Surwit, Shapiro, and Feld, 1976).

On the other hand, early feedback researchers such as Kamiya and Brown attempted to show that different "states" of the individual could be controlled (state or pattern approach), such as the "alpha state". Schwartz (1972) showed that it was easier for subject to make their systolic blood pressure and heart rate go together than to make them go apart, and that when instructed to lower them both simultaneously, subjects reported general feelings of calmness and relaxation. Freedman (1976) reports that EMG feedback to the frontalis muscle shows significant gereralization to the masseter, though only half of the subjects showed significant correlations between the frontalis and forearm extensor muscles.

Our own past findings (see introduction) have indicated that the conditioning spreads through areas both within the occipital lobe and across to the nonconditioned occipital lobe. The present findings here show an interesting development, even though the number of subjects was unfortunately limited. Signficant control for the O_1-C_z, O_2-C_z, and P_3-C_z leads was found in spite of the fact that different subjects were conditioned at different leads. This indicates that there must be an overall arousal state, or pattern, that the subject learns to control. The subjective Q-sort data, in the past, also correspond to this interpretation (see introduction). Why the P_4-C_z lead does not follow is not known.

If, however, the individual results for sessions with feedback are examined, it can be seen that for five of the six subjects, the effect was clearly the most pronounced at the lead which was conditioned. This holds true for three of the six subjects during sessions without feedback.

One subject showing consistently different results was RH. RH, though conditioned at P_3-C_z, showed the greatest effect at the occipital leads. This is probably due to the alpha blocking strategy, discussed previously, which he developed. Since alpha is primarily found in the occipital regions, perhaps that is why there was more 40Hz activity found there is this case.

In conclusion about generalization of effect, the amount of 40Hz over areas, EEG recordings over areas, and Q-sort data all suggest that an overall arousal state is learned, nevertheless, the maximum effects appear to occur at the lead being conditioned. Thus, there may be a combination of an operant <u>and</u> a pattern effect in this situation.

The final and most important question with respect to theories of 40Hz activity and problem solving concerns the ability of the subjects to maintain control during problem solving. The most sensitive measure is the comparison between the "off" periods during problem solving and the "off" periods without feedback. The results show that the subjects had significantly more 40Hz activity, across all leads, during the "off" periods while solving PFB and DAT problems. Significant increases were also shown at the P_3-C_z lead during similar periods while solving MATH and VERB problems. The three remaining leads showed increases in the desired direction for MATH and VERB, though they were not significant. It was noted earlier that RK showed essentially no 40Hz during the control sessions on the test day. It is interesting that when the 40Hz was present for him on that day, it was during problem solving sessions. It is also interesting to note that the tasks which included a fifteen second retention period before the answer slide was displayed (PFB and DAT) showed the greatest effect of 40Hz during the "off" problem solving sessions. This fits very nicely into the previous theories that consider the 40Hz band to be a "consolidation rhythm" of short term memory store.

One might expect to find the most 40Hz activity during the "on" problem solving periods. During these periods subjects were trying not only to produce 40Hz, but also to solve problems which should also increases 40Hz. The data, however, do not support this hypothesis. Random increases during the "on" problem solving periods as compared to the "on" no feedback periods were shown at the occipital leads. The parietal leads showed increases during the "on" problem solving periods, though they were not significantly greater than chance. One factor that affected these results is the alpha blocking strategy that RH employed. During "on" no feedback sessions, he could engage in this strategy throughout the period. It would be very difficult for him to do so while simultaneously solving problems. The disappearance of alpha while solving problems shows that RH was not using that strategy. His individual results for 40Hz show decreases for essentially every type of problem over every lead when compared to "on" sessions without feedback. It is concluded, however, that the "on" comparisons are probably not as sensitive as the "off" comparisons.

One might also expect to find behavioral concomitants occurring during the "on" and "off" periods during problem solving. It was found, however, that subjects got essentially the same number of problems correct whether they were trying to increase or suppress 40Hz. It should be kept in mind that these subjects were college juniors, seniors, and graduate students who were very adept in taking tests. It could be that their primary concern was to solve the problems, not to try to maintain a nonconcentration state which would suppress the 40Hz. Showing the increases of 40Hz during "off" problem solving sessions where the subjects perform well should be just as convincing as showing an absence of 40Hz during those periods where decreases in performance are found. The present findings suggest that the former situation is more likely to occur. Perhaps a more sensitive measure than right or wrong, such as reaction time or how certain the subject is of his answer, might show differences in performance during the "on" and "off" problem solving periods. Further research investigating this possibility is anticipated.

The one other finding of interest concerns the amount of alpha and beta during "on" and "off" periods of problem solving with respect to the "on" and "off" periods without feedback. That fact that alpha essentially drops out entirely during all types of problem, for almost all subjects, is not surprising when compared to past findings throughout the EEG literature. It is somewhat surprising to find beta decreasing in as many cases as it did. What may have been happening during the problem solving periods is that the relative amplitude of the beta activity may have decreased as a result of the cellular assemblies being subdivided into more functional units (desynchrony). The critical amplitude criteria was set during resting baseline conditions when more cells may, presumably, have been firing it conjunction, thus creating a higher amplitude signal. There may have, in fact, been more beta activity during the problem solving periods, though at an amplitude slightly lower than baseline levels, and therefore below criteria.

Numerous references have been made to the conditioning of 40Hz EEG activity in MBD children. The finding that adults can easily regain voluntary control after many months without feedback is encouraging. If the conditioning proves to be successful in the MBD children, then perhaps only occasional sessions with feedback would be necessary to maintain any effect. Another aspect of this study which has particular practical relevance to the training of MBD children is the generalization of effect. Although significant control was found for most areas, the main effects were predominately localized to the lead being conditioned. Therefore, maximum performance increases might be obtained from conditioning either, or perhaps both, parietal leads-even though the amplitude of 40Hz activity is greater at the occipital leads.

In summary, three basic topics were investigated. It was shown that subjects could easily regain control of 40Hz EEG activity, both in the presence and absence of feedback, after one to two and a half years had passed without any reinforcement. The effect of conditioning, in terms of ability to control 40Hz, was shown to be greatest at the lead conditioned, though significant control did generalize to other non-conditioned leads. The EEG records showed frequency and voltage differences over all leads between the "on" and "off" periods, indicating an overall generalization of effect. And finally, the data strongly suggest Ss were not able to suppress 40Hz EEG during problem solving as well as they could during sessions without feedback.

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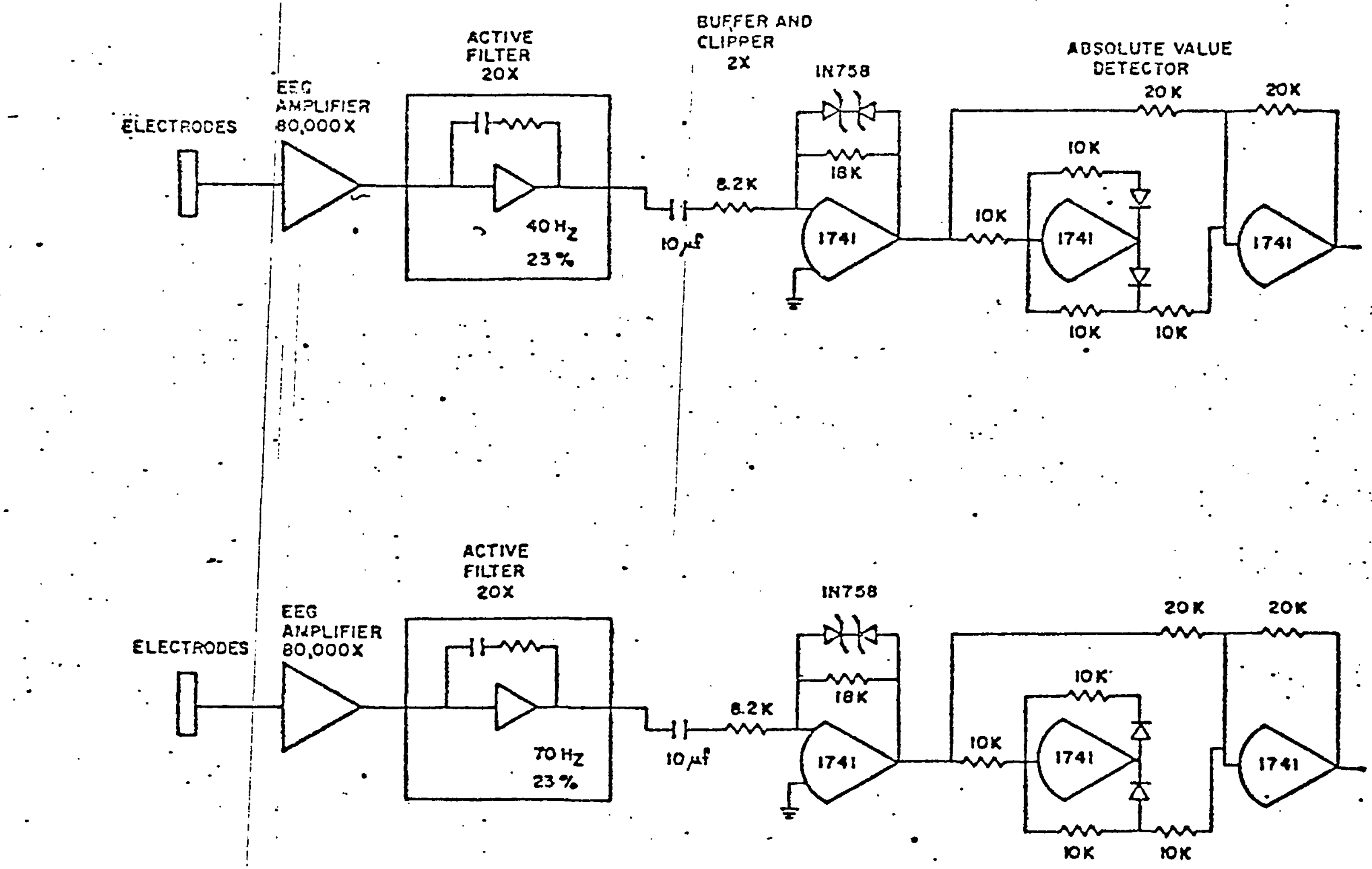
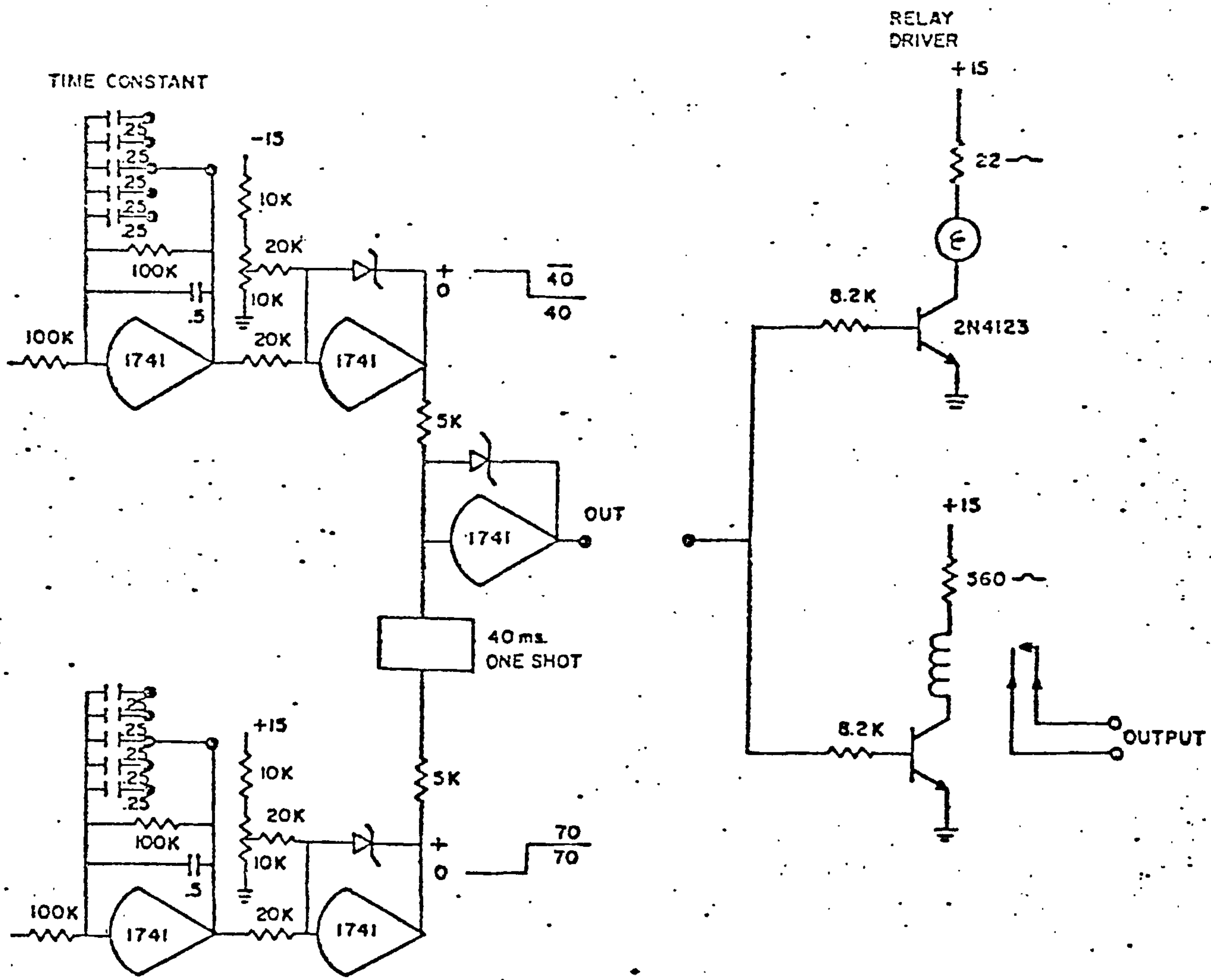
APPENDIX A

Filter Circuit


ACTIVE FILTER 20X
BUFFER AND CLIPPER 2X
IN758
ABSOLUTE VALUE DETECTOR
20K
20K
EEG AMPLIFIER 80,000X
ELECTRODES
10K
18K
8.2K
10K
1741
1741
1741
40 Hz
23%
10 μf
10K
10K
ACTIVE FILTER 20X
IN758
20K
20K
EEG AMPLIFIER 80,000X
ELECTRODES
10K
18K
8.2K
10K
1741
1741
1741
70 Hz
23%
10 μf
10K
10K

APPENDIX B

Comparator Circuit


TIME CONSTANT
.25
.25
.25
.25
.25
.25
100K
.5
100K
1741
-15
10K
20K
10K
20K
1741
+
0
40
40
5K
1741
OUT
40 ms.
ONE SHOT
.25
.25
.25
.25
.25
.25
100K
.5
100K
1741
+15
10K
20K
10K
20K
1741
5K
+
0
70
70
RELAY
DRIVER
+15
22
8.2K
2N4123
+15
360
8.2K
OUTPUT

APPENDIX C

Test Items and Answers

FORM A - VERBAL

<u>Sample</u> frame : picture ::
- a. cup : saucer
- b. table : floor
- c. radio : sound
- d. cover : book

1. explosion : debris ::
   - a. train : car
   - b. bruise : fall
   - c. television : dial
   - d. locusts : halocaust

2. money : embezzlement ::
   - a. bank : cashier
   - b. passage : plagiarism
   - c. remarks : insult
   - d. radition : bomb

3. adversity : happiness ::
   - a. fear : misfortune
   - b. solace : adversitv
   - c. vehemence : serenitv
   - d. troublesome : petulance
   - e. graduation : felicitation

4. naive : cheat ::
   - a. sensible : succeed
   - b. contentious : scorn
   - c. gullible : convince
   - d. hurt : retaliate
   - e. simple : win

5. corrugated : striped ::
   - a. box : zebra
   - b. paint : crayon
   - c. roughness : smoothness
   - d. pit : dot

FORM B - VERBAL

1. threat : insecurity ::
   - a. challenge : fight
   - b. reason : anger
   - c. thunder : lightning
   - d. speed : acceleration

2. energv : dissipate ::
   - a. batterv : recharge
   - b. atom : split
   - c. food : heat
   - d. monev : squander

3. clouds : rain ::
   - a. wind : hurricane
   - b. thunder : lightning
   - c. water : H_2O
   - d. sky : universe

4. caucasion : Saxon ::
   - a. white : colored
   - b. Chinese : Indian
   - c. furniture : chair
   - d. carriage : horse
   - e. city : house

5. cat : feline ::
   - a. horse : equine
   - b. tiger : carnivorous
   - c. bird : vulpine
   - d. chair : furniture
   - e. sit : recline

FORM A - MATHEMATICS

Sample Item

Of the following sets of fraction, the set which is arranged in increasing order is :

A. 7/12, 6/11, 3/5, 5/8
B. 6/11, 7/12, 5/8, 3/5
C. 6/11, 7/12, 3/5, 5/8
D. None of these.

1. It is proposed that a state income tax be set at a rate of x on the first A dollars of income and a rate of y on the additional B dollars of income. A fixed allowance of K dollars is to be deducted from this estimated tax for each dependent to obtain the net amount due. If d is the number of dependents, the net amount due can be expressed as :

A. xA + yB + Kd
B. x(A-Kd) + (B-Kd)
C. xA + yB - Kd
D. xy(A+B) - Kd
E. x(A+B) + y(A+B) - Kd

2. In the two fractions a/b and c/d, b is twice as large as d, whereas a and c are the same. The two fractions will be equal in values if:

A. a is multiplied by 2
B. a is divided by 2
C. c is multiplied by 2
D. d is divided by 2
E. a and c are both multiplied by 2

3. When a shipment of light bulbs was received, it was found that k bulbs out of the total of m bulbs were broken. Which of the following expressions indicates the percentage of the bulbs that were <u>not</u> broken?

A. $\frac{100(m-k)}{k}$
B. $\frac{100m-k}{k}$
C. $\frac{100(m-k)}{m}$
D. $\frac{100km-k}{m}$
E. $\frac{100(m-k)}{m+k}$

4. If the results of squaring a number is less than the number the number is :

A. Negative and greater than -1
B. Negative and less than -1
C. A positive fraction greater than 1
D. Positive and less than 1

5. Suppose you are dividing 1 by y. As y gets closer to zero, what does the result of the division of 1 by y get closer to?
   A. Zero
   B. y
   C. 1
   D. 0/y
   E. None of the above.

FORM B - MATHEMATICS

1. A is 15 years old. B is one-third older. The number of years ago when B was twice as old as A is:
   A. 3 C. 7.5
   B. 5 D. 10

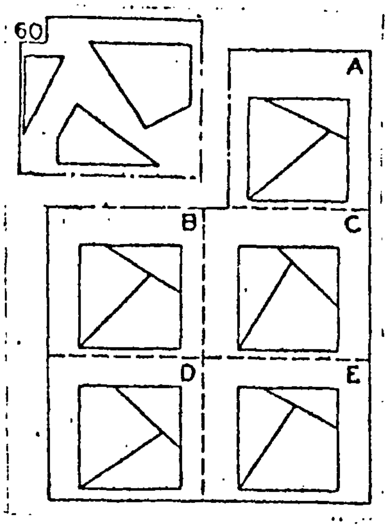
2. Assume that c and b are positive numbers. You can <u>decrease</u> the value of the fraction c/b regardless of the value of c and b by:
   A. Increasing c
   B. Decreasing b
   C. Multiplying both c and b by the same positive numbers
   D. Adding the same positive number to both c and b
   E. Increasing b

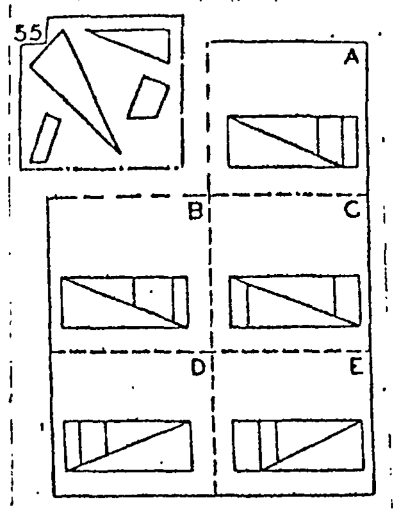
3. The charge for postage on a certain type of mail is T cents for the first ounce and W cents for each ounce over one ounce. A special handling stamp for this kind of mail costs Z cents. What will be the total cost in cents of mailing a package weighing R ounces (R is a whole number greater than one), with special handling?
   A. $T + W(R-1) + Z$
   B. $T + WR - Z$
   C. $T + Z + W + R$
   D. $TR + WR + Z$
   E. $R(T + W) - Z$

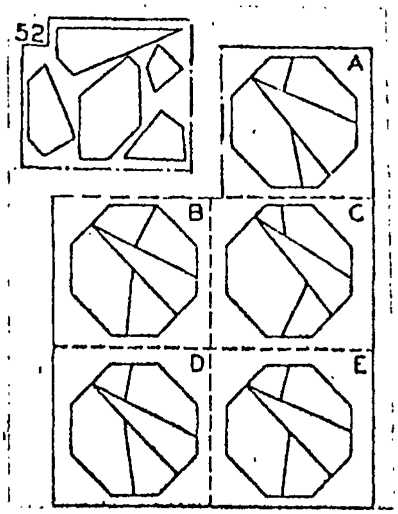
4. In a circle graph a segment of 108 degrees is shaded to indicate the overhead in doing $150,000 gross business. The overhead amounts to :
   A. $1,200.00 C. $12,000.00
   B. $4,500.00 D. $45,000.00

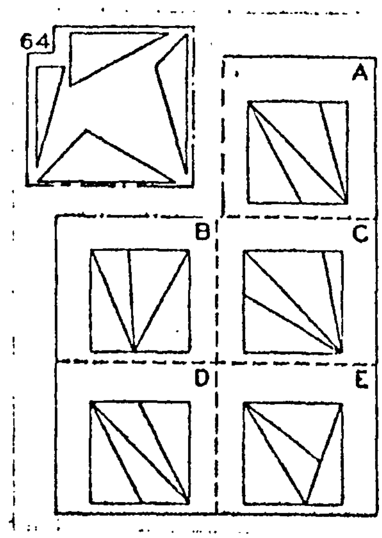
5. If Paul can paint a fence in 2 hours, and Fred can paint the same fence in 3 hours, Paul and Fred working together can paint the fence in :
   A. 2.5 hours C. 5 hours
   B. 1.2 hours D. 1 hour

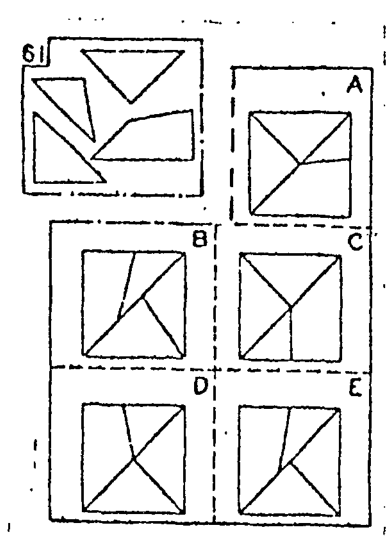
Form A - PFB



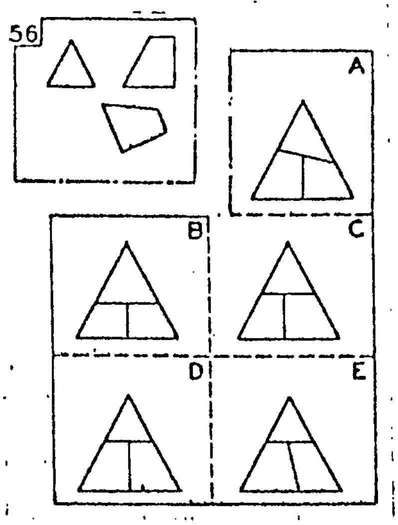


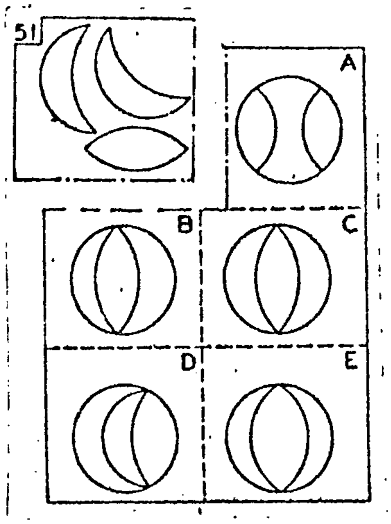


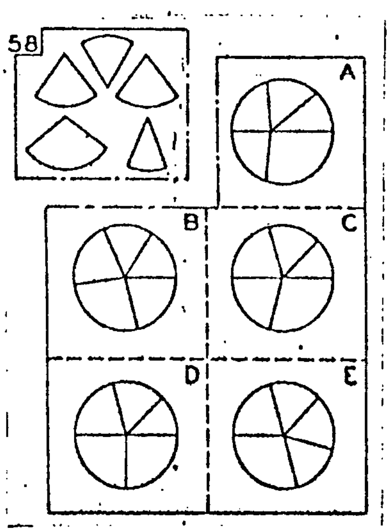


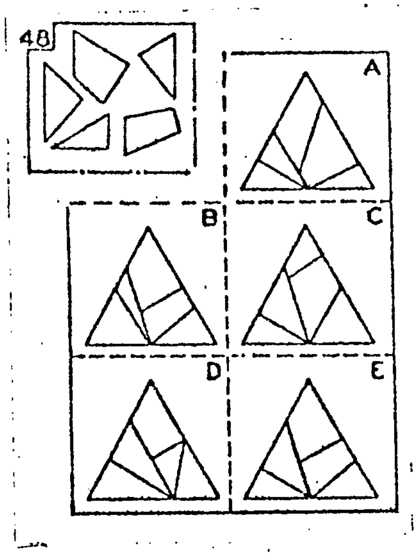


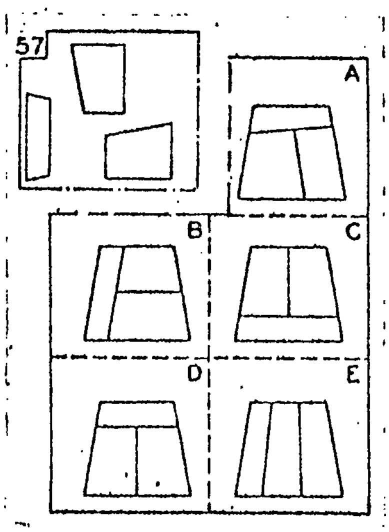
Form B - PFB



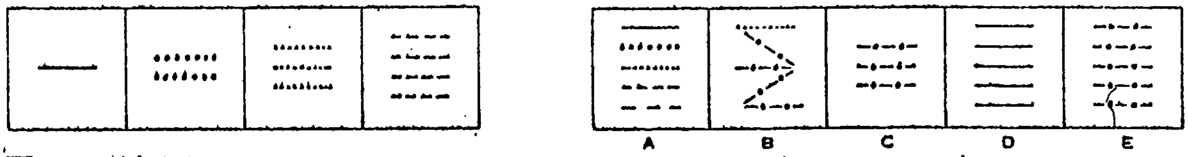


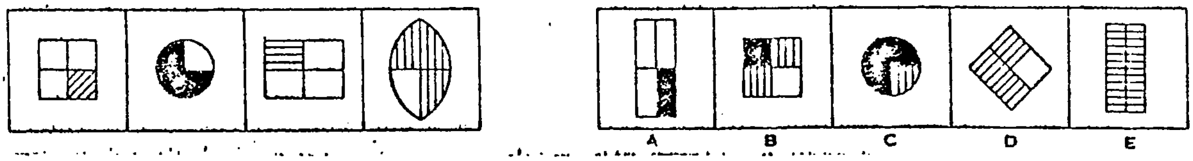


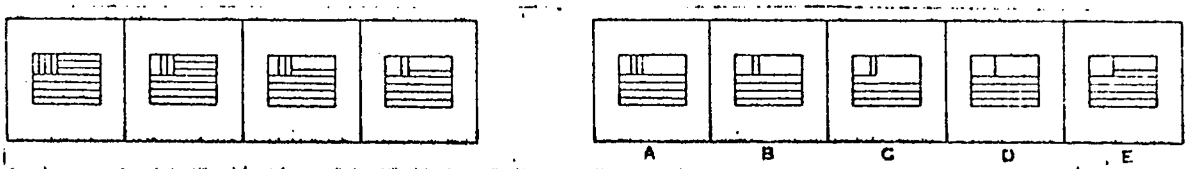


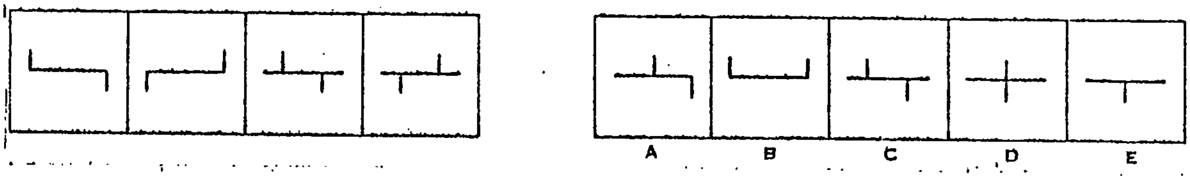


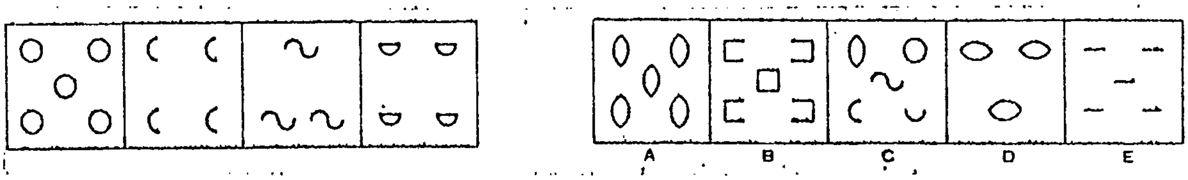
Form A - DAT



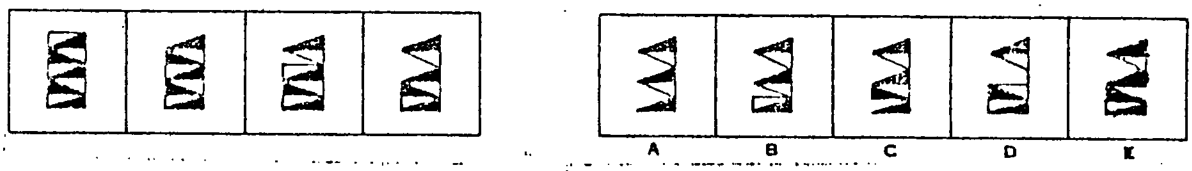


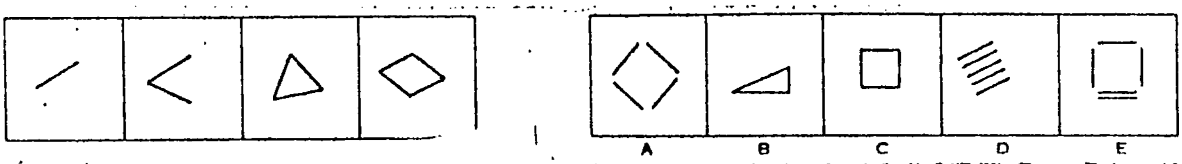


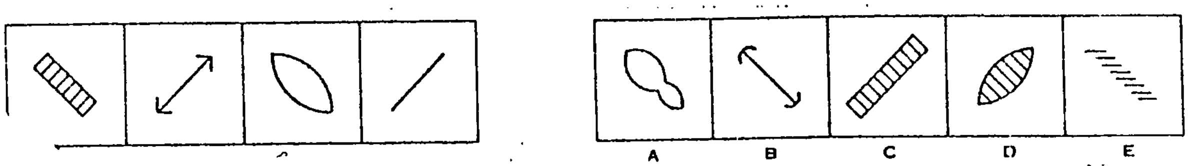


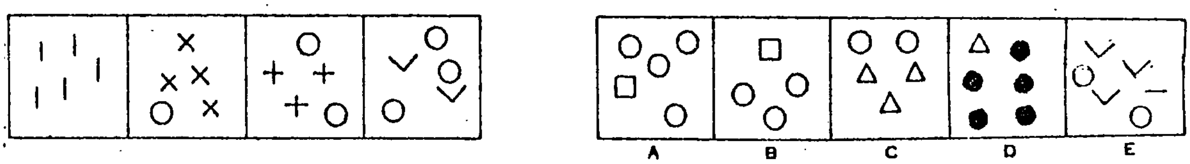


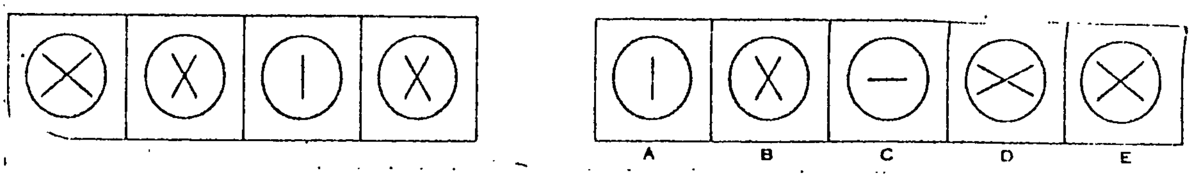
Form B - DAT











CORRECT ANSWERS TO PROBLEMS

	FORM A		FORM B	
VERBAL	1.	D	1.	A
	2.	B	2.	D
	3.	C	3.	A
	4.	C	4.	C
	5.	D	5.	A
MATH	1.	C	1.	D
	2.	A	2.	E
	3.	C	3.	A
	4.	D	4.	D
	5.	E	5.	B
PFB	1.	E	1.	D
	2.	D	2.	C
	3.	E	3.	C
	4.	A	4.	E
	5.	E	5.	D
DAT	1.	E	1.	B
	2.	A	2.	D
	3.	B	3.	A
	4.	D	4.	A
	5.	A	5.	E