EFFECTS OF DIVERGENT AND CONVERGENT EEG FREQUENCY FEEDBACK FROM BOTH CEREBRAL HEMISPHERES ON CHANGES IN SEQUENTIAL AND SIMULTANEOUS TASK SOLVING ABILITY

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PREFACE

The effect of relative EEG feedback from both cerebral hemispheres on their somewhat unique cognitive modes offers a challenging and important area of inquiry for the behavioral scientist. Individual preferences for problem solving techniques, vocational predilections and issues of learning disabilities are fields of research containing puzzles that may find a part of their answers with further exploration into the mechanisms of bilateral hemispheric task processing.

This study reports investigation of a blend of two fairly well confirmed concepts: hemispheric asymmetry and biofeedback. The first is the notion that the left and right hemispheres of the human brain have differing modes of operation. They are specialized and yet complementary to each other. The left hemisphere has been shown in many laboratories to be most efficient with verbal-symbolic, discrete, and sequential types of task processing. The right hemisphere appears to be specialized for visual-spatial tasks. The second concept is that of the typically instrumented, closed-loop feedback training situation. Thus, auditory feedback, analogous to hemisphere-specific electrical brainwave frequencies, was provided within a program for biofeedback learning to determine effects on various types of mental task processing.

The implications of the general hypothesis may best be understood when phrased in the form of several questions: (a) If a normal human subject receives reinforcing, discrete auditory feedback tones that are correlated moment-by-moment with given frequency levels of EEG, can the subject learn over a series of training sessions to produce or repress such activity at will and in a manner calculated to exert control over the feedback signals? (b) If the EEG frequencies are detected by hemispheric source, and resulting signals are fed back as intermittant sound to the left ear representing fluctuating frequencies of the left hemisphere and a separate tone to the right ear reflecting right hemisphere activity, can the subject learn to significantly alter the feedback tones at either ear? (c) Will learned control over the bilateral frequency production transfer to cognitive tasking situations wherein improvement in task processing is reflected as a correlate of hemispheric conditioning?

While considering these questions, assume the following conditions are met: (a) subjects to the experimental learning opportunities are females, developmentally and culturally adapted to hemispheric specialization; (b) a series of training sessions are conducted within an unchanging laboratory setting for each subject having the sole purpose of instrumentally shaping the subjects' ability to produce individually programmed levels of EEG frequencies; and (c) the frequencies each subject is trained to produce are those identified with certain hemisphere-specific cognitive processes, the modes disparate by the linear, verbal type processing of the left hemisphere versus the more gestalt, spatial type cognitive mode usually associated with processing by the right hemisphere.

These questions and assumptions lead to the central purpose of this investigation; will the dependent variable -- group mean changes

in scores between the pre and post training tests by type task by type training -- be significant? Of secondary interest are the directions of score changes and the correlations between some measures of training success and amounts of score change.

Many fine people contributed to the design, preparation and conduct of my research. Their roles were diverse, often tedious and time consuming, but always vital. Any list of pivotal names would include Dr. Larry Hochhaus and Dr. Phillip Murphy, my thesis committee members. My wife Mary Joan and daughter Marta provided encouragement and deft fingers upon the calculators. Bill Lakey contrived the essence of the initial design. The laboratory assistants Patti Bowen, Dave Johnson, John Kerry, Joe McPherson and Kwan-Hung Wong were obviously irreplaceable as a stabilizing influence. Many thanks are also owed to the host of tolerant and lovely ladies who served as subjects, punctually reporting to the lab time after time after time after time . . . .

Two persons made contributions that I could not have spared. Jan Bartow prepared over 150 photographic slides from the barest of verbal instructions. Nothing could have proceeded without her gifted insight and technical prowess. Arthur Ernest Harriman, Ph.D., Professor of Psychology, confidant, adviser, and chairman of my thesis committee was a beacon and a friend. Er spielte das Pokerspiel in diem wir beide gewinnen konnten.

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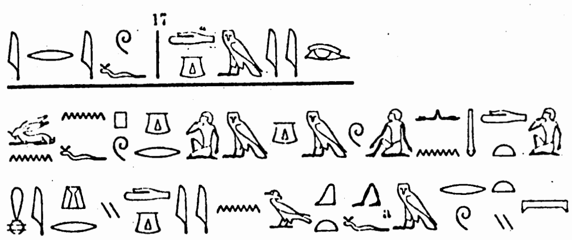
CHAPTER I

INTRODUCTION

Functional asymmetry of the human brain has been known for some time; yet its discovery may have preceded what many current authors consider the earliest psychological treatises. Cadwallader, Semrau, and Cadwallader (1971) comment that historians of psychology have often written as if the earliest studies of behavior can be traced only to about the fifth century B.C. Accounts usually begin with a discussion of the early Greek philosophical speculations on human motivation. These include the cosmology and reductionist theories of Democritus (c. 460-362 B. C.), the rationalism of Plato (427-347 B. C.), the empiricism of Aristotle (384-322 B. C.), and the fourfold typologies of Hippocrates (c. 460-357 B. C.) (Boring, 1950; Dennis, 1948; Murphy, 1973; Wittkower and Dudek, 1973; Chaplin and Krawiec, 1974).

Some functional differences between the cerebral hemispheres of man may well have been recognized as early as 3000 B. C. Cadwallader et al. call attention to a quite ancient record which ". . . may be the earliest physiological psychology recorded in history . . . preserved in what is known as the Edwin Smith Surgical Papyrus (Breasted, 1930) . . . traced to the Old Kingdom period of ancient Egypt (c. 3400-2475 B. C.)" (p. 719). The importance for psychological history lies in the papyrus' description of some behavioral consequences of brain injury, possibly including aphasia resulting from damage to the speech area of the brain. This journal antedates Broca's description by about 5000 years.

The papyrus, presented to the New York Historical Society following Smith's death in 1906, contains several hieratic accounts of medical cases involving descriptions of injuries to the head including crushed parts of skulls and exposed and damaged brain matter. As an example, the following picture-symbol facsimile is taken from "Case 22" wherein the surgeon's scribe wrote while the physician commented upon the patient's symptoms:



According to the late Egyptologist James Henry Breasted, who translated the entire papyrus, these hieroglyphics state, "He is speechless (enfeebled) because of something that has entered (his head) from the outside" (p. 296). In another case the surgeon carefully noted that some motor dysfunctions, i.e., an "eye is askew" and the patient "walks shuffling with his sole," are "on the side of him having that injury which is in his skull" (p. 299). Two other case reports from the translated papyrus contain references to the brain. It must be emphasized that individually the descriptions of injuries and accompanying symptoms merely represent the possibility of causal relationships. Breasted and others, including Cadwallader et al., have interpreted them collectively as indicating that the surgeon recognized that damage to the brain was responsible and that the side of the head on which the damage occurs is important.

Additional support for an experimental paradigm of hemispheric asymmetry and for the correlations psychologists have found between cerebral dominance and handedness can also be found in the field of anthropology. In his contribution to Hemisphere Function in the Human Brain, a chapter entitled "Psychobiological Implications of Bilateral Asymmetry," Jerre Levy commented on some findings of Dart (1949) and Gundara and Zivanovic (1968):

> Yet for all the vast differences between our apish ancestors and ourselves, the skulls of Papio (a species of prehistoric baboon) dead before the Pleistocene Epoch began, and those of modern man reveal that Australopithicus and Homo sapiens share a characteristic not possessed by the anthropoid apes. The modern skulls were asymmetric. The majority had an enlarged parieto-occipital region on the left side (Gundara and Zivanovic, 1968). The baboon skulls showed not only that the crushing blow (delivered by a predatory, hunting Australopithicus) had been administered quite deliberately with a weapon, but that the majority of the weapon wielders had been right handed (Dimond and Beaumont, 1974, p. 121).

While it is generally agreed there is some duplication of function between the two hemispheres, adequate laboratory as well as clinical studies have shown the dominant hemisphere, i.e., left side in right handed people, superior in processing words and verbally identifiable concepts. The non-dominant hemisphere, the right side in right handed people, seems to be primarily involved with the processing of non-verbal or spatially perceived stimuli (Sperry, 1961; Mountcastle, 1962; Levy-Agresti and Sperry, 1968; Zurif and Bryden, 1969; Galin and Ornstein, 1972; Dimond and Beaumont, 1974).

As an example, students of memory know there seems to be two overall organizational factors or techniques for memorizing lists of words. These have been called the "dual trace hypothesis" or the "verbal-symbolic system," and the "imaginal system" (Bower, 1970; Pavio, 1971; Cooper and Shepherd, 1973; and Richardson, 1969, in Hilgard and Bower, 1975). The verbal-symbolic system apparently involves a linear, step-by-step or sequential technique. The imaginal system seems to require contextual imagery, what might be called spatialization or visualization, in the "mind's eye." The familiar mnemonic rhyme "One is a bun, two is a shoe . . .," may serve to illustrate. We can remember the sequence of items in a list through verbal association with the pegwords "bun," "shoe," etc., and of course we have long ago indelibly stamped in the ordinal character of the rhyming number words. This helps little however, to associate any list word, e.g. "cigar," with a pegword such as "bun." We must additionally derive some image, however subjectively bizarre. In this example one might visualize an anthropomorphized bun smoking the cigar.

There is now a substantial body of evidence for asymmetry and the lateral specialization of the cerebral hemispheres (Mountcastle, 1961; Dimond and Beaumont, 1974). Documentation of hemispheric suzerainty is generally derived from several complementary sources. These include: (a) comparisons of the capacities of the two hemispheres following separation by transection of the corpus callosum, (b) studies of anatomical differences underlying lateral dominance including comparisons of specific deficits resulting from lesions of the left and right hemispheres, and (c) afferent stimulation of the left and right sides of the brains of normal subjects. Mountcastle's (1961) volume presents a comprehensive summary of experimental studies of both normal and unilaterally brain injured subjects. Dimond and Beaumont's Hemisphere Function in the Human Brain (1974) is an excellent later survey containing contributions from Gazzaniga, Geschwind, Kimura, Trevarthen, Zangwill and others.

As is the case with hemispheric asymmetry and specialization, considerable research has been accomplished in biofeedback laboratories. Instrumented feedback techniques can teach control over some very subtle bodily activities. Descriptions of studies outlining the variety and subtlety of learned control over many biological functionings have been reviewed in detail in Biofeedback and Self-Control, an annual publication of the Aldine Co. beginning with 1970; and in Biofeedback and Self-Regulation, a quarterly of the Plenum Publishing Co. in association with the Biofeedback Research Society.

Unfortunately, the term "biofeedback" as a descriptor, currently appears to be rather ambiguous. Its use in the lay press has been sensationalized in the past few years and perhaps has led to a "bandwagon" effect among professionals in both clinical and experimental applications. Brown (1974) may have been less than restrained when she wrote:

> Biofeedback is the newest, most exciting and potentially farthest reaching discovery ever to emerge from the busy basements of biomedical research . . . It has been a virtual explosion of discovery, and it is currently causing a revolution in both scientific and public thinking (p. 4) . . . a curious mixture of startling simplicity and challenging complexity (p. 9).

In a more conservative effort to describe the phenomena, Stoyva (1976) provides the following portrait:

> Biofeedback is a technology. It is also an idea--or rather, part of a more encompassing idea--one which intersects with a number of significant human concerns.

> And I think it is being part of this more encompassing something that gives biofeedback much of its special significance. To anyone who has worked with it, a notable feature of biofeedback is its way of spreading out, of connecting up with other phenomena, other ideas. Like one of those many limbed equatorial trees, it sinks roots from its own branches (p. 1).

As an appellative, the baseword "feedback" is of relatively recent coinage, and very late upon the scene at that. Conceptually, every animal is a self-regulating entity owing its existence and most of its behavior to incorporated feedback systems. Mayr (1970a) observes:

> Considering the universality of this process and the fact that the operation of feedback can be seen in a great variety of phenomena, from the population cycles of predatory animals to the ups and downs of the stock market, it seems curious that theoretical study of the concept of feedback control came so late in the development of science and technology (p. 111).

The principles and application of closed circuit, causal feedback loops apparently found their earliest expression in the technology of the Greek barber and mechanician Ktesbios, several thousand years preceding the invention of the rigorously defined term "feedback" itself. According to Mayr (1970b) a currently existing account of Ktesbian waterclocks contains a description of "the earliest feedback device on record" (p. 11), a float-valve regulator for controlling water input as the clockworks' power source.

In his <u>Dictionary of Psychology</u>, J. P. Chaplin (1968), defines feedback in part, as "a machine or system, a means of regulating input by linking it to output. Thus a governor on a steam engine or a thermostat in a home regulates output by reacting negatively to increasing output" (p. 182). So it was with the float-valve on Ktesbios' clock. The float, via its mechanical linkage and reaction to output, served to regulate the flow of water into the mechanism, keeping it relatively constant despite periodic natural fluctuations in pressure and volume.

The appearance of the term "feedback" as it applies to systems engineering appears to have been coined by pioneers in the design of regenerative radio vacuum tubes around the beginning of this century (Karlins and Andrews, 1972). Electronic feedback functioned in those earliest radio receivers to significantly increase signal detection sensitivity, providing amplification and modulation within the plate-grid oscillation circuitry. This appreciably reduced the need for external power control. Norbert Weiner, mathematician and founding father of self-regulation within electronic systems, concisely defined feedback as a method for controlling a system by reinserting into it the results of its past performance. Applying these definitions to bio-feedback; when we "shoot an arrow into the air and it falls to earth we know not where," monitoring (reinserting results of past performance) obviously does not occur and essential feedback cannot operate. If we had, however, seen the arrow's impact and thus discovered it had not struck its intended target, we would have monitored its (our) performance. The biofeedback loop became closed and we could regulate our subsequent output. Accordingly, we adjust bow tension, elevation, and windage before releasing the next arrow. The principal feedback mechanism in this case was vision. We saw the results. Reinsertion of external information occurred through our visual feedback system. Combining the prefix bio with the baseword feedback renders the resulting compound a descriptor referring to a particular form of feedback; biologic function information routed through the feedback loops of a living organism. Borrowing from Chaplin and Weiner then, animal systems output, i.e., behavior or past performance, is generally monitored and reinserted into the organism via the five classical senses. Subsequent output is then regulated in accordance with motivational aspects and perceived results of past performance.

We scratch ourselves because we itch. The intensity and location of the itch is monitored internally. The vigor, duration and location of our scratching is regulated via the relief we internally and consciously perceive. Various internal and completely unconscious operations of our autonomic systems exhibit no less a type of biofeedback. In these cases it may serve for example to create and maintain appropriate blood chemistry, activating and retarding glandular functions just as it served to initiate and terminate scratching our ear.

The instrumented feedback techniques used in this study are similar to those used in most biofeedback laboratories. They are merely a method for providing subjects with an externalized method for their conscious perception of what would otherwise generally be only internal and wholly unconscious. While the term "biofeedback" is not used in the title of this paper, its conceptual operation within the framework of my investigation is most germane.

CHAPTER II

LITERATURE REVIEW

Hemispheric Specialization

The work of Sperry in the early 1950s at the University of Chicago and after 1954 at the California Institute of Technology involved investigation into the functioning of the commissures, the interhemispheric nerve pathways of the brain. As Sperry (1964) reported:

> In 1940 the nerve physiologist Warren S. McCulloch, then working in the Yale University School of Medicine, summarized the situation with the remark that its (the corpus callosum's) only proved role seemed to be 'to aid in the transmission of epileptic seizures from one to the other side of the body.' As recently as 1951 the psychologist Karl S. Lashley, director of the Yerkes Laboratories of Primate Biology, was still offering his own jocular surmise that the corpus callosum's purpose 'must be mainly mechanical . . . i.e., to keep the hemispheres from sagging' (p. 42).

Pursuing the enigma of the large size and strategic location of the corpus callosum and the seeming lack of functional disturbance after its sectioning, Ronald E. Myers, one of Sperry's graduate students, developed a technique for "splitting the brain" of a cat. The work of Sperry and Myers involved a variety of different midline section preparations performed on cats and monkeys both before and after the animals undertook visual discrimination training exercises. In accordance with their earlier findings and those of many medical researchers before them, Sperry and Myers found there appeared to be surprisingly little disturbance of behavior following complete severing of the corpus callosum. Under special training and testing conditions however, especially those involving severance of the optic chiasm, Myers learned that the actual function of the cerebral commissure was transmission and exchange of information between the hemispheres (Sperry, 1964). Testing the performance of the two brain halves separately, Myers found that what was learned by one side of the brain (based on performance by the opposite side of the body when the corpus callosum was cut; based upon the stimuli received by the ipsilateral eye when the optic chiasm was also cut) was not transferred to the other side of the brain. In fact, the two sides could learn diametrically opposed solutions to the same experimental problem. Therefore, the animals' responses in given situations depended on which side of their brain received the triggering stimuli (Myers, 1955, 1961; Myers and Sperry, 1953, 1958).

Other collaborators with Sperry have continued special discrimination and testing situations with humans who have had their corpus callosums severed. In routine daily living these patients showed almost no abnormality. Subtle tests, however, uncovered evidence that the operation (usually performed in an effort to allow one side of the brain to take over control of the body following epileptic seizure initiation in the other side) clearly separated the specialized functions of the hemisphere.

Commissurotomized patients studied by Gazzaniga and Sperry responded differentially to visual stimuli across the retinas of their eyes. When asked to verbalize what they had seen, the subjects stated that they saw only that portion of the stimuli flashed to the right of their visual field. But when patients were asked not to verbalize but rather to point to what they had seen, they indicated they saw what had been flashed to the left visual field. The point to be made is that even though the right half of the brain received apparently equal stimulation as the left, the verbal left hemisphere either denied existence of the stimuli in the right hemisphere or was not "informed" of it. Similarly, objects held in a patient's right hand could easily be named and described. Objects held in the left hand could only be described vaguely and with difficulty, yet they could easily be matched by this hand with an identical object from a varied collection of objects. In another experiment their patients were asked to copy drawings projected briefly either to the right or left hemi-retinas. These tasks were clearly performed best by the right hemisphere (Gazzaniga, 1967; Gazzaniga, Bogen and Sperry, 1965; Gazzaniga and Sperry, 1967; Sperry, 1961).

In a study comparing lateralized dysfunction of brain damage patients and IQ scores, Parsons, Vega and Burn (1969) found patients with left hemisphere damage performed more poorly on the Vocabulary subtest of the Wechsler Adult Intelligence Scale (WAIS) than did a group of patients with damage to the right hemisphere. In this work, elaborate controls were used to avoid contamination of resulting data with extraneous variables. Control precluded differences attributable to lesion type, extent, or localization within a hemisphere as well as those that could be ascribed to age, education, or emotional disturbance of the subject. For their investigation, Parsons et al. performed factor analytic studies of the various Wechsler intelligence scales and selected two subtests as being the purest measures of verbal and performance abilities. These were the WAIS Vocabulary and Block Design tests. Their results showed that patients with left hemisphere damage had significantly lower Vocabulary scores than Block Design scores. These left damage patients also scored significantly lower on the Vocabulary test alone than did right hemisphere damage subjects. Additionally, both the left damage and right damage patients achieved comparable scores when the Similarities and Object Assembly tests were substituted for the Vocabulary test. A final comparison showed that bilateral lesion patients exhibited no significant differences between Vocabulary and Block Design scores when these results were compared to those of patients with no brain damage.

Geschwind (1972) outlines the well confirmed receptive and expressive language deficits from lesions of and between Wernicke's and Broca's areas of the left hemisphere. Bogan (1969) has provided a summary description of right hemisphere lesion disorders. It includes examples of disabilities for rendering line drawings marked by a general lack of appropriate form relationships and over-attention to details (Warrington, James and Kinsbourne, 1966); defects in cube counting, Kohs Blocks and Map Drawing (McFie, Piercy and Zangwill, 1950); and lack of appreciation of a spatial whole (Ettlinger, Warrington and Zangwill, 1957). Writing about the uses of neuro-psychological methods in attempts to lateralize brain lesions, Goldstein (1974) stated:

> The current working hypothesis used by many neuropsychologists is that the right cerebral hemisphere mediates a number of non-verbal functions that can generally be viewed as having to do with some aspect of spatial relations. Included here would be spatial orientation, perception of complex patterns, and ability to construct complex configurations . . . This syndrome may be simply defined as a disability

> with regards to organizing parts of an assembly into a single entity. Usually the (right hemisphere lesion) patient manifests this syndrome by having excessive difficulty in solving puzzles in which he must place parts in relationship with each other such that they match some model or otherwise constitute some meaningful whole (p. 279).

In comparing lesion studies of localization for specialized functions to studies conducted with normals, one must remember that the former is not a direct investigation of bi-lateral function, but rather one of dysfunction. Neuro-psychological reports of hemispheric specialization are usually results of investigation of patients who display a certain lack of talent or skills, and not reports of abilities they <u>do</u> possess. A high positive correlation of left hemisphere trauma to verbal cognition deficiencies does not necessarily imply that verbal cognitive functions and left hemisphere function are equally highly correlated among normals. Furthermore, interactions occur between the sites of lesions and the kinds of lesions which also contribute to behavioral outcome.

Biofeedback

Exquisite, instrumentally induced autonomic learning has been demonstrated to extend to a rife assortment of processes including: electrodermal activities (Crider, Shapiro and Tursky, 1968), muscle tension (Green, 1969), salivation (Brown and Katz, 1967; Delse and Feather, 1968; Frezza and Holland, 1971), and systolic blood pressure (Benson, Shapiro, Tursky and Schwartz, 1971). Learned control has also been achieved for heart rate in animals (DiCara, 1970) and in man (Weiss and Engle, 1971) to include patients with atrial fibrillation (Bleeker and Engle, 1973), in the classical electromyographic feedback studies for tension headache relief by Budzynski et al. (1973), and even for single spinal motor neurons (Smith, Basmajian and Vanderstoep, 1974).

To be sure, considerable discretion must be used in the evaluation of reported techniques and results. Many recent publications providing surveys and commentary of published research findings are now beginning to urge caution. Leo V. DiCara and other members of the editorial board for Biofeedback and Self Control 1974 (1975) selected for reprint the literature of Blanchard and Young (1974) which describes many clinical feedback studies as anecdotal case reports having no true scientific evidence. Other studies are illustrated as lacking valid conclusions or having trivial, transitory effects with marginal efficacy.

As a negative example of "feedback learning" Blanchard and Young cite, and DiCara et al. reprint, the findings of Lynch, Paskewitz and Orne (1974). They indicate data from their experiments do not support views by others that visual or auditory feedback situations produce levels of alpha activity (8-13hz) greater than those levels seen under natural baseline conditions. Furthermore, Lynch et al. found accurate feedback was apparently not even necessary to demonstrate gradual, trial-to-trial increases in alpha rhythm. In the first of three experiments investigating the production of alpha, they discovered that control subjects who were given false, non-contingent visual feedback about their alpha rhythm achieved results similar to subjects given accurate feedback. The suggestion was made that the visual stimuli they used (colored lights) appeared to function as a potent alpha blocking source. The alpha activity generated during the two-minute non-feedback resting period, which occurred in total darkness, was significantly higher than those alpha densities manifested during feedback for both the contingent and non-contingent groups. These results are considered with a large and varied literature reporting alpha blocking with visual stimuli.

In their final experiment, Lynch et al. used an auditory feedback tone in lieu of the earlier visual stimuli. They subsequently found a much higher lever of alpha production during trials; but again, no significant increase over baseline measures. Their overall view is summarized in the final sentence of their report:

> The data do suggest that alpha densities observed in the feedback situation have less to do with the feedback per se and any learning process, than with the experimental situation and the subjects' own natural alpha densities (p. 350).

Briefly stated, increases in alpha density seemed due to the subjects' learning to disregard environmental stimuli that suppress alpha, rather than learning to produce greater alpha densities.

Kamiya (1962, 1968), Dewan (1966), Mulholland (1967), Hart (1968), and others, however, have demonstrated that experimental subjects can learn to control the appearance of high amplitude regular alpha rhythms through an auditory feedback loop keyed to the subjects' alpha levels. This technique allows the subject to know when he or she is creating the desired electrical patterns. Kamiya (1962, 1967, 1968) has shown that subjects can learn to control both the amplitude and the frequency of alpha, depending on feedback contingencies.

Woodruff and Birren (1972), testing 15 subjects between 18 and 29 years of age and 15 subjects between 60 and 81 years, found both groups significantly and equally amenable to training for enhancement of alpha production. Schwartz, Shaw, and Shapiro (1972) used a pre and post test evaluation of 12 subjects' ability to control alpha wave production and heart rate. Post testing followed four daily, one-hour feedback training sessions. Significant control of alpha was found to be independent of any accompanying control of heart rate. In another study comparing mediation and alpha frequencies with somatic responses, Beatty and Kornfeld (1972) taught 14 subjects to product differential alpha and beta frequencies. Standard operant conditioning methods were used while measures of selected peripheral responses were recorded. Their data indicated that changes in the subjects' EEG spectra were not being mediated through any shifts in heart rate or respiratory connected responses. Bry (1970) found it possible to shape EEG amplitudes through progressive reinforcement of four human subjects. Bry used an escape avoidance paradigm. Subjects heard aversive white noise until the criterion EEG amplitude appeared; then the subject heard a period of music. Significant increases and decreases in EEG amplitude modification were learned depending on the reinforcement criteria.

In a study of lateralization of alpha activity during different tasks, McKee, Humphrey and McAdam (1973) found Left/Right alpha frequency ratios highest for musical tasks. Linguistic tasks tended to progressively reduce such ratios with increasing difficulty of the verbal tasks. The data suggest that alpha production increases in the left hemisphere with "right hemisphere (type) tasking" and beta production increases with "left hemisphere linguistic or verbal tasks." These results which were from the temporal-parietal site, parallel those of Morgan, McDonald, and McDonald (1971) and of Galin and

Ornstein (1972).

Morgan et al. collected data reflecting bilateral EEG alpha activity from 20 right-handed Stanford University students. Each subject's EEG was recorded during oral questioning involving linguistic tasks (e.g., "Tell me an English word that begins with L and ends with C"), arithmetic calculations (e.g., "What is 48 times 7?"), and instructions to derive non-analytic, spatial "picture scenes" (e.g., "Picture a child swinging in a swing"). The analytic linguistic and arithmetic tasks were designed to activate the left hemisphere and the instructions to picture a scene were designed to activate the right hemisphere. The investigators' prediction of proportionately less alpha in the left hemisphere and more in the right with the linguistic and arithmetic tasks, and vice versa with the spatial tasks was significantly borne out.

In their article Lateral Specialization of Cognitive Mode: An EEG Study, Galin and Ornstein (1972) showed hemispheric asymmetry for verbal and spatial tasks through ratios of EEG frequency in homologous temporal and parietal scalp electrodes. The ratio of average power (quantified EEG via integration of the raw signal, 1-35 Hz) was greater in right over left for verbal tasks than for spatial tasks. Their pilot investigations had indicated that the two cognitive modes could be distinguished as they occurred in normal subjects. Ten right-handed subjects with no familial history of left-handedness were used in the formal study. Two tasks in each cognitive mode were assigned to each subject. The verbal tasks involved writing a letter and mentally composing a letter. The spatial tasks included memorizing a modified Kohs block design and subsequently constructing it with colored wooden blocks, and mentally selecting answers to a modified Minnesota Paper Form Board test. The results confirmed Galin and Ornstein's hypothesis. Characteristic patterns of activity and inactivity were found. The ratio of right hemisphere power to left hemisphere power was greater on verbal tasks than on spatial tasks. They concluded their report with the speculation that "an index of lateralized functions may enable the training of ordinary individuals to achieve more precise control over their brains' activities. Instead of training 'alpha control' or 'theta control', it may be possible to train functionally relevant patterns of activity" (p. 418). This specific conjecture led to my present study.

Hypothesis

This study proposed to examine the effects of EEG frequency feedback training on the performance of subjects carrying out verbal and spatial mental tasks.

1. It was hypothesized that subjects trained to increase beta frequency production in the left cerebral hemisphere would show significant improvement in verbal task processing. Conversely, subjects trained to decrease beta frequency production in the left hemisphere would show a significant reduction in verbal task processing efficiency.
2. Subjects trained to increase beta frequency production in the right cerebral hemisphere will show significant improvement in spatial task processing. Conversely, subjects trained to decrease beta frequency production in the right hemisphere will show a significant reduction in spatial task processing efficiency.

CHAPTER III

METHOD

Subject Selection

Forty-eight right handed female undergraduate students controlled for equal representation of low, medium, and high creativity were selected from a pool of approximately 130 volunteers recruited from lower division psychology courses. Selection of only dextral subjects was made to enhance the opportunity for effects of hemispheric language dominance to appear in the data collected. There is abundant evidence in the literature indicating that in the vast majority of cases, right handers have left hemisphere dominance for language, while such dominance appears only in a smaller proportion (still a majority) of left handers (Zangwill, 1960; Levy and Nagylaki, 1972; Levy, 1974). This seems especially true among dextrals with no family history of sinistrality (Zurif and Bryden, 1969; Hines and Satz, 1971). Further, some evidence indicates that right handedness may reflect increased lateralization of hemispheric function (Hecaen and Ajuriaguerra, 1956; Levy, 1969).

That all subjects should be of one sex was a decision made to avoid confounding effects that might be introduced as a result of widely confirmed female superiority on verbal tasks, and a positive though limited indication of male advantage in numerical and spatial tasks (Kimura, 1973; Levine, 1966; Maccoby and Jacklin, 1974; Tyler, 1965). It was convenient that greater numbers of female volunteers were available since instructors of lower level classes offered course credit for participation in psychological research, and the majority of work being done in other laboratories required male subjects. The large pool of volunteers offered excellent opportunities for a careful elimination of left handed subjects. Further screening ensured equal representation among low, medium, and high creativity categories as indicated by an Alternate Uses Test.

In Appendix A is the modified Annett Handedness Questionnaire (Annett, 1970), given to all volunteers. Subjects were selected on the basis of an arbitrary, standard scoring system designed to indicate those showing least overt or latent use of left limbs. Potential subjects were not informed of the basis for discrimination prior to final selection.

Subject Scheduling

From the first of two sets of approximately 65 volunteers, 24 were chosen to participate in the first phase of the investigation. Upon selection and verification of individual availability for twelve laboratory sessions, subjects were scheduled for pre training and post training test sessions on a fifteen day cycle. Efforts were made to maintain an interval of thirteen days between tests to allow the pre and post tests to be given on the same day of the week. Both tests were scheduled for approximately the same time of day. A four-hour latitude between test times was successfully adhered to.

Ten training session dates for each subject were scheduled immediately following her completion of the pre training test. Training sessions were scheduled to be conducted at the convenience of the subject except that not more than two sessions could be taken during any one day. Sessions were spaced relatively uniformly throughout the thirteen days between tests. No training was conducted on the day of the post test. Following completion of the research with this initial group, a second session of 24 women was selected in a similar fashion.

Test Design

The pre feedback training test (Appendix B) and the post feedback training test (Appendix E) each consisted of 60 multiple choice questions presented one item at a time via a 35mm slide projector. The two tests were counterbalanced. Individual slides were projected on the instrument's built-in 9" (23cm) x 9" (23cm) screen. All verbal instructions and the mechanical presentation and removal of the slides were controlled automatically by an integral dual track magnetic tape system. By this method, timing, sequence of instructions, example test items, item viewing and processing periods, answer marking, and all other routine test situations were standardized among subjects. The system significantly reduced interaction between subject and experimenter thus minimizing subjective biasing effects (Rosenthal, 1963 reprinted in Jung, 1971).

The 60 items on each test were partitioned into a verbal division and a spatial division with three subtests in each division. Ten test items were used in each of the six different subtests. The verbal and spatial divisions were designed to maximize the dichotomy of the respective types of cognitive mode processing. Verbal type items required an ordered succession of steps, each step necessary and sufficient for progress contributing to an ultimate solution. Further, items were selected to avoid any step that might involve obvious, specific gestalt imagery. While arithmetic multiplication is often taught as a series of fixed steps to a solution it is also taught as involving memorization of tables, and of visualization of rows and columns (Osborn, Devault, Boyd and Houston, 1968). For that reason, multiplication items were avoided. On the other hand, spatial tasks were selected to avoid partial or complete solution through any culturally routine series of fixed steps. For example, the Kohs block type items were avoided because solutions to the overall question, "how many?" normally require some sort of sequential counting in addition to the requirement for visualizing the hidden blocks in space.

Subjects were provided with identical 13 page pre training and post training test booklets reproduced in quantity by a Xerox Model 7000 copier from a single photographically prepared master copy. Subjects were also provided with a lapboard and two pencils. The first page of the test booklet contained printed instructions and served as a cover sheet. Included in these instructions was the advisory that the subject was not to turn pages of the booklet until told to do so by the voice from the audio tape. Subsequent pages were alternately subtest cover sheets containing a printed example problem and brief written instructions pertaining to that subtest; followed by the subtest's respective answer sheet.

It was considered important that the spatial subtests' example problems and answer sheets be photographically reproduced from the test item slides. A preliminary review of standardized test materials and literature, and a pilot study for this investigation revealed a need for as close approximation to the original item as possible. The review and pilot study showed that even subtle disparity between spatial materials presented on slides and printed on the answer sheets served to confuse subjects and confound test results. The difficulty is most apparent in the hidden figures subtest (see pages 85 and 105). It is obvious that the hidden figure line drawings embedded within the scenic ground must correspond exactly to the multiple choice options of the answer sheet, and that there be no change in scale between any two or more correct responses taken from a single test item slide. The need for accurate rendition from slide to test booklet is further emphasized since spatial test items were not numbered, nor were answer options coded or labeled. Each slide contained the five available answer choices for that item. The facsimile reproduction further ensured identical spatial arrangement of answer choices.

In the case of verbal subtests, items were consecutively numbered 1 through 10, and answer options for each question were coded with Roman numerals I through V. Subjects were required to read the question, analyze it, identify the correct answer from among the options, code the answer to its respective Roman numeral, refer this coded choice to the answer booklet and finally mark the appropriate Roman numeral. Thus, sequential processing necessary for question and answer coding was prerequisite to correct verbal item responses, but was avoided in the spatial item responses.

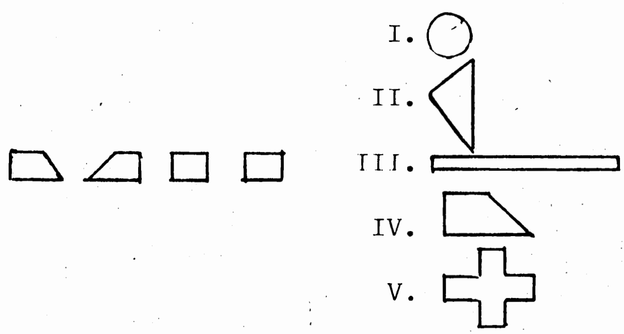
The linear, sequential, question and answer coding and decoding technique is commonly required for paper and pencil multiple choice tests. It may be unfortunate that many standardized tests have the requirement for obviously non-spatial encoding/decoding techniques embedded within the question and answer identification requirements of their "spatial abilities" subtests. As an example, compare the following verbal and spatial type items:

Verbal

1. Mary, of Mother Goose Rhyme fame, was often accompanied in her travels and on at least one occasion to her school by a:
   I. Pterodactyl II. Lockheed sales rep. III. mugger IV. pet rock V. lamb.

Spatial

2. The parts on the left, when assembled, would most likely resemble which of the figures on the right:



When the format for marking answers to both questions is:

1. I II III IV V

2. I II III IV V

both answer clusters contain the requirement to encode the Arabic question number and the Roman numeral answer identifier, using the left hemisphere. The sequential processing necessary to appropriately respond to the spatial item may interfere with the form analytic, simultaneous processing of the question itself by the right hemisphere.

The rationale for the unique treatment of the spatial and verbal subtests germinated with a review of the posthumously published report of Sheerer (1963) dealing with insight and fixation in problem solving. In the final paragraph Sheerer wrote, "If insight is the essential element in intelligent problem-solving, fixation is its archenemy. Fixation is overcome and insight attained by a sudden shift in the way the problem or the objects involved in it are viewed" (p. 128). This idea was nurtured with the split-brain studies reported by Sperry (1964) who, when discussing conflict between the separated hemispheres, stated, "As in split-brain cats and monkeys however, one hemisphere or the other generally prevails at any given time" (p. 52). Levy and Sperry (1968) and Levy (1969) proposed that verbal and nonverbal functions evolved in opposite hemispheres in order to reduce the interference of one system with the other (Brooks, 1970). Galin and Ornstein (1972) contributed the following:

> Our opinion is that in most ordinary activities we simply alternate between cognitive modes rather than integrating them. These modes complement each other but do not readily substitute for each other. For example, although it is possible to process complex spatial relations in words, it seems more efficient to use visual kinesthetic images. Consider what most people do when asked to describe a spiral staircase. They begin using words, but quickly fall back on gesturing with a finger. Processing in the inappropriate cognitive system may not only be inefficient; it may actually interfere with processing in the appropriate system (p. 413).

Items for pre training and post training subtests 1 - 5 (Appendices B and E) were modified from standard tests as indicated below:

<u>Subtest 1</u>

Missing Number from Simple Arithmetic Division (Kuhlman and Anderson, 1960). Letters refer to test items from Booklet H, Test H4.

Pre test: A, D, E, H, I, L, M, P, Q, T.

Post test: B, C, F, G, J, %, N, O, R, S.

Subtest 2

Form Assembly (Minnesota Paper Form Board, Rev., 1934). Numbers refer to items from test Series BB.

Pre test: 1, 4, 13, 17, 28, 32, 39, 45, 47, 54.

Post test: 2, 3, 14, 16, 29, 31, 40, 44, 46, 55.

Subtest 3

Missing Symbol from Number Sequence (Harmon and Nelson, Rev., 1961). Numbers refer to items from the Test of Mental Ability, College, Form A.

Pre test: 4, 23, 30, 34, 36, 55, 57, 79, 81, 94.

Post test: 7, 13, 31, 33, 43, 49, 59, 64, 82, 86.

Subtest 4

Shape Recognition (Thorndike and Hagen, 1971). Letters refer to items from the Cognitive Abilities Test, Levels A-H, Form 1. Three original items were created for each test where dashes indicate standard items were unavailable or deemed inappropriate for this study.

Pre test: OO, C, D, G, H, K, L, _, _, _.

Post test: A, B, E, F, _, J, M, N, _, _.

Subtest 5

Word Order Rearrangement (Kuhlman and Anderson, 1960). Numbers refer to items from Booklet G, Test G7.

Pre test: 1, 4, 5, 8, 9, 12, 13, 16, 17, 20.

Post test: 2, 3, 6, 7, 10, 11, 14, 15, 18, 19.

Subtest 6

Hidden Pictures (*Highlights for Children*, vols. 22-29), Highlights for Children Inc., Honesdale, Pennsylvania. The sequence of subtest ordering was rotated among subjects within each training group according to a Latin square design.

Apparatus

The equipment used in this study consisted of the following:

1. Sound Technology Inc., Model 1400A, Ultra-low Distortion Oscillator. This unit provided a distortion free, widely variable electrical impulse signal capable of simulating the frequencies and amplitudes of human EEG. It was used to establish initial settings for the variable controls of the E & M Instrument Co.'s preamplifiers, integrator, and physiograph, and to calibrate the entire feedback and recording system.
2. Two Autogenic Systems Inc. (ASI), Modified Standard Electrode Assemblies. Each assembly had two active electrodes which detected the EEG impulses as differential measures from the surface of the scalp, and one ground electrode serving as a common mode reference. Electrodes were metal wires in sponge discs housed in silicon rubber cups. The modification to the electrode assemblies was prepared at my request by the manufacturer. The modification required substitution of 120" (3m) lead cables in lieu of the 30" (76cm) cables normally supplied.
3. Elastic Electrode Retention Headband.
4. Singer Education Systems Inc., Model 8806 Caramate Projector. A self-activated instrument with built-in slide storage and viewing screen and audio cassette record and playback system.

5. Two ASI, Model 70, Feedback Encephalographs. Controls and feedback devices on these units used in this study were:

   (a) On/Off Volume Control. Moderated the volume of the feedback tone and served as the power switch for the unit.

   (b) Spectrum Modulation Index Dial. Provided for a variety of feedback tones, e.g., rising or falling pitch, volume fluctuation, etc. Only the discrete on-off mode was used.

   (c) Electrode Input Jack. Accepted the three-way plug from an electrode assembly cable.

   (d) Audio Output Jack. Accepted the two-way plug from the stereophonic headphones' harness. Audio output from both encephalographs was routed to the respective earphones of two headsets, one worn by the subject during training, the other used by the experimenter during monitoring.

   (e) Electrode Interference Monitor. When depressed this button tested the quality of the electrode-scalp contact and the presence of any environmental electrical interference. This control also allowed the experimenter to demonstrate artifact such as occurred when the subject wrinkled her brow or gritted her teeth while concentrating.

   (f) Battery Voltage Test Button. When depressed, provided a battery strength reading on the percent-time meter.

   (g) Upper Frequency Limit Dial. Set the upper threshold at which audio feedback was initiated and percent-time function was activated. This dial was used to determine the subjects' baseline frequency at the beginning of each session and to raise the upper frequency shaping parameters during training sessions.

(h) Lower Frequency Limit Dial. Used the same operational techniques as (g) above except for the lower thresholds and shaping parameters.

(i) Amplitude Threshold Dial. Set the lower amplitude limit at which the audio feedback was initiated and over which the percent-time function was activated. This control was used to determine the subjects' amplitude baseline only. During training and testing this setting remained at zero, thus allowing only frequency settings to establish the feedback parameters.

(j) Amplitude Scale Selector. Multiplied the scale of the amplitude threshold dial by a factor of one or two.

(k) Percent-time Meter. Provided non-digital readings for the percentage of time a subject's EEG fell within the given frequency limits.

(l) Percent-time Interval Selector. Set the time interval over which the percent-time function was activated. Time intervals of 10, 100, 200, 500, and 1000 seconds were available. The 10-second period was used for baseline measurements and training sessions. The 100-second period was used during the pre training and post training tests.

(m) Raw EEG Output Jack. Provided a 0.1 volt output signal, to the amplifying, integrating and recording instruments.

6. Two E & M Instrument Co., Model MKIII, Preamplifiers. Inputs to these instruments were the raw EEG signals from the encephalographs. The preamplifiers had several controls. Appropriate settings for the overall nature of this study were initially established prior to data collection, then remained unchanged.

7. E & M Co., Model MKIII Integrator. This unit allowed one of three active pens of the physiograph ink writing assembly to provide an amplitude integrated record of the raw EEG signal from either encephalograph, one at a time.

8. E & M Co., Physiograph. Components for this recording chassis included the coupler assemblies, three model 7070 amplifier modules and the chassis mounted chart paper drive and ink-writing assemblies.

Procedure

Subjects were randomly (by blind draw) assigned to one of five groups. Four groups received training. The fifth group was used as a control and received no training between the pre and post tests. During all training sessions subjects were provided with dichotic feedback tones correlated with their EEG frequencies. Amplitude parameters were not a factor in this training program. Tones were heard through a headphone set. Sound was either on or off at each ear as a function of EEG frequencies generated by the ipsilateral hemisphere. Volume and pitch changes were not produced. Volume level was adjusted to the subject's comfort at the onset of each training session, then remained constant.

The groups receiving training were: (a) right hemisphere up - left hemisphere down (RULD), (b) right hemisphere down - left hemisphere up (RDLU), (c) right and left hemispheres up (RULU), and (d) right and left hemispheres down (RDLD). "Up" training in this study refers to experimental shaping that attempted to increase hemisphere frequencies (Hertz) above the normal baseline resting level determined prior to the start of each training session. This shaping was accomplished by adjusting controls on the feedback encephalographs to produce the tone at lower than baseline rates and to quiet the tone with higher rates. "Down" training parameters were the reverse, i.e., sound was heard at frequencies above the baseline where silence was maintained through the subject's continuous suppression of oscillation rates above the baseline frequency. Subjects were reminded at the start of each training session to, "Turn the sound off at either or both ears if possible. Training success is in part a measure of the amount of time the sound is off." Frequency shaping schedules were determined by the degree of a subject's success in retarding the tones during a given training session. The instrument settings at which sound came on or went off were established initially for each training session based upon the individual subject's relaxed, eyes-closed, baseline frequency. These thresholds were modified by the experimenter during the training periods when monitoring indicated a subject was achieving success at a pre established rate.

Each subject assigned to one of the four training groups received ten, 21 minute training sessions. The schedule for adjustment of the instrument settings to provide the changing on-off tone thresholds necessary to continuous shaping of the subjects' EEG frequencies was as follows:

Session 1. No shaping was attempted during this session.

Sessions 2 - 4. As a subject was able to suppress the tone at either ear (effectively modify her EEG frequencies) for 90% of any 30 second period, the threshold for the instrumentally produced tone was adjusted by one Hertz in the direction of the desired shaping.

Sessions 5 - 7. Feedback thresholds were appropriately adjusted one Hertz for each 80% of any 30 second time period.

Sessions 8 - 10. Adjustments were made for each 70% time sound suppression for 30 seconds.

In all cases, percent-time readings were recorded at three minute intervals. These data, with a record of the number of shaping parameter changes by subject by training session, would provide subsequent measures of training success across subjects. A Training Record Form is presented in Appendix C.

A typical training session proceeded as follows: The subject reported to the laboratory and was escorted to an isolated, sound attenuated, 1.7m X 2.1m X 2.3m room. She was seated in a chair constructed to allow a semi-reclining position. The chair seat and back were thickly padded. Armrests were unpadded wood. The electrode sponges were soaked with a solution of salt water and liquid soap according to the manufacturer's directions. Active electrodes were positioned at coordinates T3, 01, and T4, and 02 as set forth by the International Federation of Societies for Electroencephalography and Clinical Neurophysiology. Left and right ground electrodes were placed on the forehead, centered one-half inch above the eyebrows.

The subject was then instructed that the experimenter would reduce the room illumination and depart for approximately five minutes; that meanwhile, she should relax completely with eyes closed, keeping her legs uncrossed with both feet on the floor and arms and hands in a comfortable position on the chair armrests. She was also told that the purpose of this period of relaxation was to allow her to rest from the walk to the laboratory and that the experimenter would be obtaining necessary resting-state data prior to beginning the training session. At this point the experimenter closed the door to the subject room and began monitoring and adjusting the instruments to determine the 50%-time frequency and amplitude baseline for each hemisphere.

Upon establishing and recording the resting baseline data the experimenter returned to the subject to tell her that the training period was about to start and to remind her of her task to suppress the sound in both ears if possible. The headphones were positioned, volume was adjusted, and the experimenter left the room to begin the training.

EEG data collected during the pre and post test sessions included baseline frequencies, amplitudes, and percent-time readings. Baseline information was obtained each time prior to onset of the actual test presentations. Percent-time data were collected from meters on the two ASI encephalographs during the actual tests. EEG monitoring instruments were set to provide the percent of time each hemisphere was producing alpha frequencies during the immediately preceding 100 seconds. Meters were read at the conclusion of the presentation of slides numbered 1, 3, 5, 7, 9, and 10 for each of the six subtests. The pre to post test changes in percent-time of alpha frequency production provided a measure of training success. The format for the collection of the data is shown in Appendix C.

CHAPTER IV

RESULTS

Of the 48 subjects selected for this study, three were dropped and their data withdrawn prior to the overall analysis. Subject #12 withdrew from the University, departing prior to completion of her training sessions. Subject #42 complained of feeling ill during her post test and stated she was unable to complete it. In order that equal cell sizes (N=9) could be maintained among the five groups, subject #29 was selected in a random drawing from among those women assigned to the RULU group. Her record was also deleted.

The independent variables for this study were the types of tasks involved within the pre and post tests, and the training conditions imposed during the ten training sessions. The dependent variables were the score changes (differences) between the pre and post tests.

Results supporting the hypotheses would be significant improvement in group mean scores for some or all verbal division subtests (1, 3, and 5) with ascending frequency shaping of subjects' left hemispheres; and improvement in scores for spatial division subtests (2, 4, and 6) with ascending frequency shaping of right hemispheres. A corollary decrement in verbal or spatial test scores was expected to occur following training to diminish frequencies in the left and right hemispheres, respectively.

It was predicted, for example, that the RULD and the RULU groups' post training test scores for one or more of the spatial subtests would be elevated over their counterpart scores from the pre training tests. On the other hand, the RULD and the RDLD groups' verbal subtest scores would be lowered as a function of the left hemisphere's alpha reinforcement, while the RULU and the RDLU groups' verbal scores would be boosted because of the beta frequency training of the left hemispheres. No indications of the effect of training to increase beta frequencies in both hemispheres simultaneously (RULU) were found in the literature. Neither was there augury for the consequences of bilateral alpha training (RDLD) on verbal and spatial task processing. However, it appeared only a minor extension to predict that the RULU group would find improvement in all subtest scores while the RDLD group's scores would all be lowered.

Arithmetic (plus or minus) and absolute (without consideration for direction) changes in scores from pre training to post training tests are shown in Tables I - V. A summary of the five groups' mean changes in scores is provided in Table VI. Results of an overall simple analysis of variance for the arithmetic score change values, by subtest and by division appears in Table VII. Results were not significant. Training by any of the methods used had little apparent effect on post test scores.

It can be seen from Table VI that the Control group's mean verbal arithmetic score increments were greater than those of the RDLU and RDLD training groups. The Controls' spatial increments were greater than the RULD, RDLU, and the RDLD groups. Of the eight comparisons available here, results opposite to those hypothesized occurred in three cases. Each contrary case happened with a divergently trained group.

TABLE I

RULD TRAINING GROUP ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
Subject	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
5	1	1	5	5	3	5	9	11	9	11
9	2	0	4	2	1	0	7	2	7	2
10	1	-1	-2	2	-1	2	-2	3	4	5
16	0	1	2	3	1	1	3	5	3	5
20	0	-2	2	1	1	-2	3	-3	3	5
28	0	0	0	1	0	2	0	3	0	3
31	1	0	3	2	4	0	8	2	8	2
32	2	-1	0	-1	4	0	6	-2	6	2
40	2	0	1	2	3	-2	6	0	6	4
Arithmetic Means	1.00	-0.22	1.67	1.89	1.78	0.67	4.44	2.33		
Absolute Means	1.00	0.67	2.11	2.11	2.00	1.56			5.11	4.33

TABLE II

RDLU TRAINING GROUP ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
Subject	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
2	0	-1	2	5	0	1	2	5	2	7
6	0	-2	0	0	1	1	1	-1	1	3
11	1	2	-1	0	3	-1	3	1	5	3
14	3	1	0	0	0	1	3	2	3	2
17	1	0	4	1	0	-4	5	-3	5	5
26	1	0	4	2	-2	2	3	4	7	4
33	-1	1	0	2	-3	-2	-4	1	4	5
35	3	3	2	2	0	2	5	7	5	7
46	1	0	-1	1	-2	3	-2	4	4	4
Arithmetic Means	-1.00	0.44	1.11	1.44	-0.33	0.33	1.78	2.22		
Absolute Means	1.22	1.11	1.56	1.44	1.22	1.89			4.00	4.44

TABLE III

RULU TRAINING GROUP ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
Subject	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
3	-2	0	3	3	3	3	4	6	8	6
7	2	-1	1	-1	0	1	3	-1	3	3
15	1	2	5	2	-1	-2	5	2	7	6
19	0	0	0	2	0	1	0	3	0	3
21	0	-1	1	-2	7	1	8	-2	8	4
24	1	2	0	3	2	-1	3	4	3	6
36	2	2	-1	0	0	0	1	2	3	2
38	4	2	1	2	-2	1	3	5	7	5
39	-1	2	0	5	4	1	3	8	5	8
Arithmetic Means	0.78	0.89	1.11	1.56	1.44	0.56	3.33	3.00		
Absolute Means	1.44	1.33	1.33	2.22	2.11	1.22			4.89	4.78

TABLE IV

RDLD TRAINING GROUP ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
Subject	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
1	-5	0	3	1	-1	1	-3	2	9	2
8	1	0	0	2	2	2	3	4	3	4
18	1	3	3	2	3	1	7	6	7	6
22	2	-2	2	-1	2	2	6	-1	6	5
23	0	9	-1	0	-1	5	-2	14	2	14
30	1	-3	2	3	-3	1	0	1	6	7
34	0	0	-1	0	3	-1	2	-1	4	1
43	0	2	4	-1	1	-3	5	-2	5	6
44	0	-1	2	0	0	2	2	1	2	3
Arithmetic Means	0.00	0.89	1.56	0.67	0.67	1.11	2.22	2.67		
Absolute Means	1.11	2.22	2.00	1.11	1.78	2.00			4.89	5.33

TABLE V

CONTROL GROUP ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest						Division			
	Arithmetic						Arithmetic		Absolute	
Subject	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
4	0	2	2	1	-4	2	-2	5	6	5
13	1	-2	1	2	3	0	5	0	5	4
25	4	1	-2	1	0	3	2	5	6	5
27	2	4	1	5	-4	-1	-1	8	7	10
37	0	-3	-1	3	-1	-3	-2	-3	2	9
41	1	-1	0	4	4	0	5	3	5	5
45	3	-3	2	9	0	-2	5	4	5	14
47	1	-1	1	0	1	0	3	-1	3	1
48	1	0	6	2	-1	2	6	4	8	4
Arithmetic Means	1.44	-0.33	1.11	3.00	-0.22	0.11	2.33	2.78		
Absolute Means	1.44	1.89	1.78	3.00	2.00	1.44			5.22	6.33

TABLE VI

GROUP MEAN ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SUBTEST AND BY DIVISION

	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
Group	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
RULD	1.00	-0.22	1.67	1.89	1.78	0.67	4.44	2.33	5.11	4.33
RDLU	1.00	0.44	1.11	1.44	-0.33	0.33	1.78	2.22	4.00	4.44
RULU	0.78	0.89	1.11	1.56	1.44	0.56	3.33	3.00	4.89	4.78
RDLD	0.00	0.89	1.56	0.67	0.67	1.11	2.22	2.67	4.89	5.33
Control	1.44	-0.33	1.11	3.00	-0.22	0.11	2.33	2.78	5.22	6.33

TABLE VII

SUMMARY OF ANALYSIS OF VARIANCE ON ARITHMETIC SCORE CHANGES BY SUBTEST AND BY DIVISION

Subtest	Source	df	MS	F	Prob F
1	Groups	4	2.5333	1.1041	0.368
	Residual	40	2.2944		
2	Groups	4	3.1111	0.6707	0.619
	Residual	40	4.6389		
3	Groups	4	0.6889	0.1692	0.951
	Residual	40	4.0722		
4	Groups	4	6.4778	1.6681	0.176
	Residual	40	3.8833		
5	Groups	4	8.1667	1.5605	0.203
	Residual	40	5.2333		
6	Groups	4	1.2777	0.3117	0.869
	Residual	40	4.1000		
Verbal Division	Groups	4	10.3111	1.0175	0.411
	Residual	40	10.1333		
Spatial Division	Groups	4	2.0778	0.1481	0.960
	Residual	40	14.0333		

Group mean variability may be read from the absolute score changes in Table VI. In every case the Control group's scores were shown to be more variable than any of the training group's. Variability shown here contradicts that found by Murphy, Lakey, and Maurek (1976).

Mean changes in scores by groups collapsed over hemispheric shaping directions (i.e., RU equals RULD plus RULU combined and treated as a single group with N = 18. RD is RDLU + RDLD. LU = RDLU + RULU, and LD = RULD + RDLD.) are shown in Table VIII. Here, arithmetic results show support of the hypothesis in half of the cases and in the other half are opposed. No apparent patterns can be seen in either the supportive or contradictory data. The absolute scores are in all cases less variable than those of the Control group.

Data for groups collapsed over shaping direction only (i.e., U equals the combined three groups RULD, RDLU, and RULU with N = 27, and D = RULD, RDLU, and RDLD) are shown in Table IX. This shows, not surprisingly, results similar to those seen in Tables VI and VIII.

Table X contains a summary of the probability values from 48 t-tests between means of groups collapsed over hemispheric shaping directions, and Table XI contains the probabilities from 56 t-tests between means of groups collapsed over shaping direction only. Significant probability levels ($P < .05$) were obtained in only five of the 114 total opportunities.

Table XII shows group mean changes and change standard deviations for baseline frequencies and amplitudes recorded during pre and post test sessions. In all cases mean group changes were less than or equal to group standard deviations. Group mean baseline frequency and

TABLE VIII

ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY HEMISPHERIC SHAPING DIRECTION BY SUBTEST AND BY DIVISION

Hemispheric Frequency Shaping Direction	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
RU	0.89	0.34	1.39	1.72	1.61	0.62	3.89	2.66	5.00	4.55
RD	0.50	0.67	1.34	1.06	0.17	0.72	2.00	2.45	4.45	4.89
LU	0.89	0.67	1.11	1.50	0.56	0.45	2.56	2.61	4.45	4.61
LD	0.50	0.34	1.61	1.28	1.22	0.89	3.33	2.50	5.00	4.83

TABLE IX

ARITHMETIC AND ABSOLUTE CHANGES IN SCORES BY SHAPING DIRECTION ONLY BY SUBTEST AND BY DIVISION

Shaping Direction Only	Subtest Arithmetic						Division			
							Arithmetic		Absolute	
	1	2	3	4	5	6	Verbal	Spatial	Verbal	Spatial
U	0.93	0.37	1.30	1.63	0.96	0.52	3.18	2.52	4.67	4.52
D	0.67	0.37	1.45	1.33	0.71	0.70	2.81	2.41	4.67	4.70

TABLE X

t-TEST PROBABILITY VALUES FOR DIFFERENCES BETWEEN MEANS OF GROUPS COLLAPSED OVER HEMISPHERE SHAPING DIRECTION BY SUBTEST AND BY DIVISION

Subtest	RU versus RDLD	RU versus Control	RD versus Control	LU versus LD	LU versus Control	LD versus Control
1	.54	.33	.16	.54	.38	.13
2	.64	.65	.65	.64	.56	.53
3	.93	.74	.78	.56	.29	.56
4	.25	.16	.02	.70	.63	.05
5	.05	.08	.68	.62	.57	.12
6	.86	.52	.51	.51	.40	.63
Verbal Division	.07	.23	.80	.52	.48	.50
Spatial Division	.72	.94	.83	.79	.84	.87

TABLE XI

t-TEST PROBABILITY VALUES FOR DIFFERENCES BETWEEN MEANS OF GROUPS COLLAPSED OVER SHAPING DIRECTION ONLY BY SUBTEST AND BY DIVISION

Subtest	U versus RDLD	U versus Control	D versus RULU	D versus Control	RULU versus RDLD	RULU versus Control	RDLD versus Control
1	.12	.32	.85	.17	.60	.61	.09
2	.53	.27	.53	.57	1.00	.19	.59
3	.73	.81	.66	.67	.62	1.00	.66
4	.14	.09	.74	.03	.32	.23	.04
5	.73	.21	.60	.28	.52	.22	.55
6	.55	.59	.84	.52	.54	.60	.33
Verbal Division	.55	.50	.68	.72	.56	.53	.94
Spatial Division	1.00	.93	.52	.80	.68	.66	.96

TABLE XII

GROUP MEAN BASELINE FREQUENCY AND AMPLITUDE CHANGES AND CHANGE STANDARD DEVIATIONS FROM PRE TRAINING TO POST TRAINING TESTS

	RULD		RDLU		RULU		RDLD		Control	
	Chng	SD	Chng	SD	Chng	SD	Chng	SD	Chng	SD
Left Hemisphere										
Frequency	0.1	1.6	0.4	0.6	0.0	1.0	0.1	0.6	0.8	0.8
Amplitude	-6.2	17.4	-4.0	6.2	-1.2	8.2	-0.7	9.7	-6.0	12.4
Right Hemisphere										
Frequency	0.4	1.2	0.2	1.0	1.1	3.4	0.1	0.9	0.5	1.8
Amplitude	-13.0	24.0	1.7	8.0	1.2	6.0	-1.1	8.9	-2.6	14.3

percent-time changes and change standard deviations from combined training sessions 1 and 2 to combined sessions 9 and 10 are shown in Table XIII. With the exception of the RDLU group's right hemisphere mean frequency change, this analysis also shows that mean group changes were less than group standard deviations. Despite the time devoted towards training subjects to enhance alpha and beta production, little such specific learning took place. This special prerequisite to predicted score changes thus may not have been achieved by the subjects.

TABLE XIII

GROUP MEAN FREQUENCY AND PERCENT-TIME CHANGES AND CHANGE STANDARD DEVIATIONS FROM COMBINED TRAINING SESSIONS 1 AND 2 TO COMBINED SESSIONS 9 AND 10

	RULD		RDLU		RULU		RDLD		Control*	
	Chng	SD	Chng	SD	Chng	SD	Chng	SD	Chng	SD
Left Hemisphere										
Frequency	0.3	0.8	0.3	0.9	0.2	1.0	-0.4	0.7	•	
Percent-time	-7.3	9.2	1.4	10.8	2.7	14.9	5.4	21.1	•	
Right Hemisphere										
Frequency	1.0	1.4	1.9	0.9	1.2	1.6	-0.3	0.5	•	
Percent-time	1.8	14.3	1.7	13.2	-1.0	16.4	2.9	13.6	•	

*No training received

CHAPTER V

DISCUSSION AND CONCLUSIONS

The overall results do not reflect significant changes in the subjects' task processing abilities. The hypothesis that verbal and spatial task efficiency may be improved with biofeedback training to increase beta frequency production, and attenuated with training to enhance alpha production is not confirmed.

Several measures of training success were taken to assess effectiveness. These included: (a) changes in pre to post test session baseline frequencies for either the left or right hemisphere, (b) changes in training session baseline frequencies for either hemisphere between sessions 1 and 2 combined and sessions 9 and 10 combined, and (c) an ad-hoc survey of pre to post test changes in the mean percent-time subjects were not producing frequencies in the desired bands (i.e., above or below test session baselines) during verbal and spatial test item presentation.

RULD Group

In comparison to the Control group's mean arithmetic score changes between their two tests, the RULD group's spatial and verbal post training test scores were expected to show significant differences from their pre test scores beyond the changes attributable to "practice effect" as reflected by the Control group. The Controls' mean arithmetic spatial score change was +2.78 (i.e., of the thirty items in the spatial division of each of the two tests, the nine subjects assigned to the Control group answered an average of 2.78 more items correctly on the post test than on the pre test). It was predicted that the RULD training mode would improve the group's spatial division post test scores by a significant amount beyond the +2.78 increment attributed to the practice effect. This did not occur. The RULD mean arithmetic spatial score change was only +2.33. This amount of change was actually less than the improvement shown by the Controls who received no EEG training. Similarly, results contrary to predictions occurred with the group's verbal post test scores. It was expected that their training would result in some decrement to their mean verbal score. Comparison with the Control group shows, however, that the RULD verbal scores actually improved beyond the practice effect increment. The Controls' mean verbal score change was +2.32. The RULD group improved 4.44.

EEG frequency data collected during the subjects' testing and training sessions indicated no durable shaping effects. Meaningful deviations from normal resting baseline frequency recordings, while apparent within most individual training sessions, did not appear to survive from training session to training session. The mean RULD right hemisphere frequency change from combined training sessions 1 and 2, to combined sessions 9 and 10, was less than a single hertz increase (+0.96 Hz). The left hemisphere change was also less than one hertz (+0.29), another increase despite the "LD" training received. Neither was there apparent training carry-over to the post test session. The pre to post test mean baseline frequency change for either hemisphere was again less than one hertz (+0.44 right and +0.06 left). Recordings of pre to post test changes in frequency production during actual test item presentations may indicate some marginal, though not significant training success. Percent-time measures were taken from both hemispheres during both verbal and spatial portions of the tests. Here, success is implied when data indicate a reduction of percent-time readings since these figures indicate periods when subjects were not producing the desired frequencies. In the case of this group the mean change for the right hemisphere during verbal items was -6.38 and during spatial items was -12.00. For the left hemisphere the figures are -7.38 verbal change and -8.25 spatial.

RDLU Group

Effects achieved with this training group were, in most essential respects similar to those with the RULD group. RDLU spatial scores were expected to be something less than the +2.78 practice effect shown by the Controls. Verbal scores were expected to improve beyond the Controls' +2.32. The mean arithmetic spatial score change achieved by the RDLU group was +2.22. The verbal change was +1.78. Here, spatial task efficiency was apparently reduced following the RD training, however, the marginal decrement was not significant. The verbal increase following the LU training was less than achieved by the Control group.

Data recorded during the RDLU testing and training also indicated that the experimental efforts to bilaterally shape hemispheric frequencies did not produce any major effect. The mean pre to post test right hemisphere baseline frequency change for the RDLU group was a 2.22 hertz increase despite the RD training. The LU training resulted in an increase as well; however it was less than a single Hertz. Changes from the early (1 and 2 combined) training sessions to the last two (9 and 10) for this divergently trained group were again positive, less than a single hertz, and statistically insignificant for both hemispheres. Analysis of percent-time that subjects of the RDLU group were not producing desired frequencies during verbal and spatial portions of the pre and post tests indicate that the change was opposite to that desired. In all cases, mean RDLU group results showed that subjects produced desired frequencies less during the post test than during the pre test.

RULU Group

In this training group some very limited indications of a valid hypothesis appeared. Post test scores in both the verbal and spatial divisions improved beyond the amount attributable to the practice effect. Verbal scores improved 3.33. Spatial scores improved 3.00. It would be gratifying at this point to be able to show a concurrent training effect for this unilaterally trained group. Unfortunately this was not the case. Baseline frequencies recorded during the two test sessions indicated no change to the left hemisphere and only a 0.2 hertz mean increase for the right. Training session changes were: left hemisphere +0.24 and right +1.21. Neither change was significant. Pre and post test percent-time recordings showed no significant change. Right hemisphere spatial and left hemisphere verbal and spatial percent-time did show some effect in the desired direction.

RDLD Group

While the degree of change in test scores for all groups were found to be insignificant, a small pattern may have appeared that might be worthy of future consideration. With the two groups receiving bilaterally divergent training (RULD and RDLU), results were fundamentally contradictory to the hypothesis. With convergent training (RULU and RDLD), the hypothesis seemed in each case to have some, albeit marginal, relevance. In both the spatial and verbal division tests the RDLD group's declined below the Control scores.

As described in Chapter III and Appendix D instruments were adjusted during training sessions to effect the shaping of each subject's EEG. The schedule for adjustments was the same for all subjects regardless of training group. Records reveal that the subjects assigned to the two convergently trained groups met training session criteria for instrument adjustments to affect the feedback parameters 271 times; while the two divergently trained groups met the same standards only 89 times.

In spite of the intra-session training success exhibited by the RDLD group, and in spite of the frequency suppression training of the subjects, the pre to post test baseline frequency changes for both hemispheres were positive rather than negative and were less than a single hertz.

Power

As a further study of the bilateral distribution of cerebral activity and as a technique to be used in quantification of EEG training sessions, raw signals from both hemispheres were integrated and recorded on chart paper by the physiograph as a continuously inked "power" trace. Power here refers to the micro-voltaic electrical potentials providing amplitude to the usual EEG. Power measurements are taken from the verticle deflection of the integrated channel pen trace. It was intended that samples abstracted, by hemisphere, from the integrator trace be utilized to provide a comparison of powers among like pre and post subtests. Additionally power measures were to be used to assess hemispheric asymmetry, by task by type training.

Malfunctioning equipment precluded adequate recordings for power measurements during pre test sessions. No training effect analyses were practicable. Post test sessions were recorded with a single integrator. The traces were initially recorded for the left hemisphere of each subject. At the mid-point of the test (immediately following the third of the six subtests as presented), the integrator was manually switched to the right hemisphere circuit. A balanced record was achieved. It was expected that power measures would differ among the training groups and the Control group, and that hemispheric asymmetry by task would appear. During the present experiment the onset of each of the sixty post test items was manually marked by the experimenter on the integrator trace. Galin and Ornstein found asymmetry, by type verbal or spatial task, using the integrated power technique. They expressed the difference as a ratio of right to left power and observed that the ratio was higher (more power in the right EEG) during verbal tasks than spatial tasks.

A standard series of ten sample measurements were taken from each test item record by three assistants naive to the purpose of their work. Assistant-linked bias was avoided.

The major finding was one of apparent equipment bias. In every case save one, the left hemisphere integrated measure exceeded the right. Table XIV describes this outcome. Further analyses revealed no other significant results. Conjecture as to the basis for these results leads to the suspicion that one or both of the preamplifiers, electrically positioned between the feedback encephalographs and the integrator, may have introduced some variable factor. A review of an informal diary kept during the course of preparation and conduct of this experiment reveals internal circuitry problems with the preamplifiers that may not have been corrected as had been thought.

Adequate evidence exists in the literature for hemispheric EEG asymmetry and state or task-linked wave patterns in the human brain. There is also considerable docummentation of the efficacy of a wide variety of biofeedback training techniques. Few demonstrations however, have been reported wherein conditioning of EEG frequencies has shown more than transitory specific effects. The result of this study provides no exception and a review of the recorded measurements provides little hint of a basis for the negative findings. Murphy, Lakey, and Maurek (1976) showed significant differences in verbal-spatial pre post variability for eighteen right handed college males following simultaneous divergent EEG feedback. Alpha training provided for either task increments or decrements, while beta training locked in the processing at pre test levels. Verbal task enhancement was found linked to success in producing left brain alpha. Similar variability and training-linked task enhancement was not confirmed in this present study, using females.

It is expected that experimental studies in the area will require a higher level of instrumented sophistication for data extraction and

TABLE XIV

SUMMARY OF POWER MEASURES

Group	#	Subtest Type	Power Scale L	Power Scale R	Subtest R/L Ratio	Verbal Division R/L Ratio
RULD	1	V	1.3	1.1	0.85	
	2	S	1.0	0.9	0.90	
	3	V	1.8	1.3	0.72	
	4	S	1.5	1.3	0.87	0.72
	5	V	1.9	1.2	0.63	
	6	S	2.1	1.8	0.86	
RDLU	1	V	1.6	1.5	0.94	
	2	S	1.8	1.1	0.64	
	3	V	1.2	1.2	1.00	0.80
	4	S	1.4	1.2	0.86	
	5	V	1.7	0.9	0.53	
	6	S	1.5	1.4	0.93	
RULU	1	V	2.0	1.0	0.50	
	2	S	2.2	1.1	0.50	
	3	V	1.5	1.2	0.80	0.70
	4	S	1.5	1.3	0.87	
	5	V	1.1	1.0	0.91	
	6	S	1.4	0.9	0.64	
RDLD	1	V	1.6	1.5	0.94	
	2	S	1.6	1.1	0.69	
	3	V	1.1	0.9	0.82	
	4	S	1.6	1.1	0.69	0.88
	5	V	1.4	1.2	0.86	
	6	S	1.7	1.4	0.82	
CONTROL	1	V	1.9	1.1	0.58	
	2	S	1.6	1.2	0.75	
	3	V	1.9	0.9	0.60	0.72
	4	S	1.3	0.9	0.69	
	5	V	1.2	1.3	1.08	
	6	S	1.3	0.9	0.69	

recording. This is particularly true where efforts are made to assess training success by the percent-time technique. Instruments are now available that provide digital readouts for brain wave analyses and automated numeric printing of several simultaneous measures. Further, provision should be made for additional periodic equipment testing and calibration to detect non-subject induced effects. The laboratory used during this experiment was located within fifty feet of electrical and mechanical services operating the building's elevator and heating and air conditioning machinery. Ambient fluctuating elctro-magnetic fields may have differentially affected the encephalographs. Testing and re-calibration was done only when data readings were subjectively viewed by the experimenter to be patently false.

In retrospect it also appears that the scope of this investigation was too broad. Fewer, more "capable" subjects might have received a greater amount of training and the investigation could have been limited to convergent type training. Attempts might be made to formulate more effective training methods than were used here. Subjects' personal introspection and opinions might be incorporated. For example the duration of training sessions could be made more flexible. Subjects could choose to lengthen or shorten individual sessions as their personal motivation and success rate dictated. A "minimum level of success" criterion for initial selection of subjects might also be incorporated. Volunteers could be required to demonstrate an ability to achieve minimum standards of training success. Personal observation and commentary by subjects during the pilot studies and early in this investigation indicated greater difficulty with the RULD and RDLU training modes than with the convergent RULU or RDLD modes. Fluctuation of the pointers on the two encephalograph percent-time meters often showed that one hemisphere tended to "imitate" the other during the divergent groups' training sessions. Results shown in Table VI indicate that both of the convergently trained groups increased or decreased their verbal and spatial scores as predicted while neither of the divergently trained groups did so.

CHAPTER VI

SUMMARY

The purpose of this study was to examine the effects of EEG frequency feedback from both cerebral hemispheres on changes in sequential and simultaneous task solving ability. Forty-five right handed female undergraduate college students were selected from a pool of approximately 130 volunteers. Nine subjects were randomly assigned to each of four treatment groups and a control group. Subjects took a written pre training test comprised of thirty verbal and thirty spatial items presented by an automatic slide projector and tape recorder. Two treatment groups received divergent hemispheric training and two received convergent training. Training consisted of ten 21-minute feedback conditioning sessions. Feedback was dichotic tones analogous to the left and right hemisphere frequencies. Controls received no training. Following the training, all subjects took a post test of verbal and spatial items counterbalanced for difficulty with the pre test.

Training mode appeared to have little effect on pre to post training test score changes. The hypothesis of improved verbal and spatial task efficiency with training to increase frequencies (enhance beta production) in the left and right hemispheres respectively, and of reduced efficiency with training to decrease frequency production

(enhance alpha) was not confirmed. Additionally several measures of training success revealed little durable effect. Session to session baseline frequencies were not significantly affected regardless of the treatment condition.

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APPENDIXES

APPENDIX A

MODIFIED ANNETT HANDEDNESS QUESTIONNAIRE

(Note)

An arbitrary scoring method employing this form was used as a criterion for subject selection. Following brief instructions, volunteers checked the appropriate boxes. Marks were subsequently scored as follows:

EITHER LEFT OR RIGHT	1 point
LEFT	
ALWAYS	2 points
USUALLY	3 points
RIGHT	
USUALLY	4 points
ALWAYS	5 points

Volunteers having the highest total scores were selected.

NAME ______________________

ADDRESS ______________________

TELEPHONE NUMBER ______________________

WITH WHICH HAND DO YOU NORMALLY PERFORM EACH OF THE FOLLOWING ACTIVITIES? PLACE AN X IN THE APPROPRIATE SQUARE TO INDICATE YOUR ANSWER.	EITHER LEFT OR RIGHT	LEFT ALWAYS	LEFT USUALLY	RIGHT USUALLY	RIGHT ALWAYS
WRITE WITH PENCIL OR PEN					
DRAW WITH PENCIL, CRAYON OR CHARCOAL					
DIAL A TELEPHONE					
HOLD A MATCH WHILE STRIKING IT					
USE A TOOTHBRUSH					
USE A HAMMER					
HOLD A KNIFE WHILE CUTTING FOOD					
HOLD SCISSORS WHILE CUTTING FABRIC					
USE A PING-PONG PADDLE					
SERVE THE BALL WITH A TENNIS RACKET					
THROW A BASEBALL					
PULL BACK A BOW-STRING					
ROLL A BOWLING BALL					
WHICH HAND PLAYS THE MOST ACTIVE ROLE WHILE CLAPPING					
UPON WHICH KNEE DO YOU GENUFLECT & TOUCH THE FLOOR					
CLASP THE FINGERS & THUMBS OF BOTH HANDS TOGETHER, NATURALLY & COMFORTABLY. WHICH THUMB IS UPPERMOST?					
CONFLICT DRAWING TEST #1.					
#2.					
#3.					

APPENDIX B

PRE TRAINING TEST BOOKLET

This test is part of an investigation of electroencephalographic (EEG) feedback research. It does not involve deception in any guise nor are there any types of aversive stimuli used.

The test is divided into six sets of ten multiple-choice problems per set. Each set of ten problems is preceded by an example slide projected on the screen. The correct answer for the example problem is marked on the respective answer sheet. All problems are presented on the self-contained slide projector on the stand in front of you. It will be necessary that you sit quite close to the screen. The projector also has a built-in audio tape playback system. Instructions are given verbally via this tape player throughout this first phase of your feedback training. You may already be familiar with several of the types of problems presented, however, the level of difficulty of this test is such that you probably won't get all answers marked 100% correctly. In any case if you have not decided upon an answer within the time allotted -- make your best guess! ! PUT A MARK ON THE ANSWER SHEET FOR EACH PROBLEM ! !

You must solve all problems "in your head." Make no marks with your pencil other than to mark an answer.

You may change any answer by erasing and remarking, however, it should be done quickly.

Do not turn individual pages of your answer booklet until the taped instructions tell you to do so.

Do not mark answers until told. Use any extra time to check your decision.

If you should experience any difficulties please raise your hand or tap on the one-way window to your left.

THANKS VERY MUCH FOR COMING. WE APPRECIATE

YOUR CONSIDERABLE CONTRIBUTION TO

OUR RESEARCH

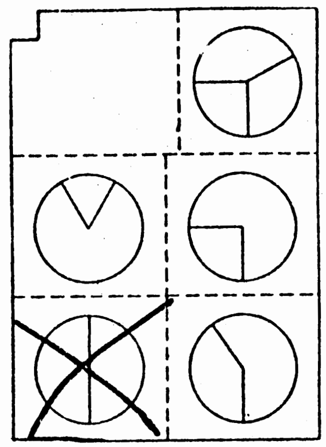
! ! !

I II III IV V

This set of problems is put in the form of simple division. In each problem one number is missing. A dotted line shows where the number is missing, either from the quotient or from the dividend.

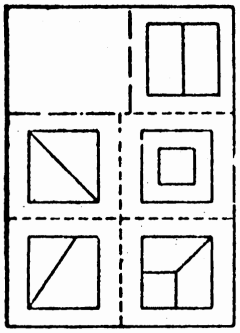
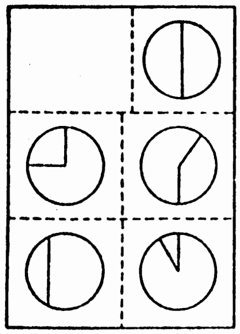
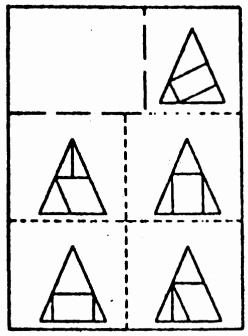
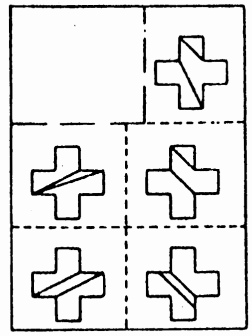
You are to select the one best answer to provide the missing number and when told to do so, mark an "X" directly over the roman numeral that identifies your answer.

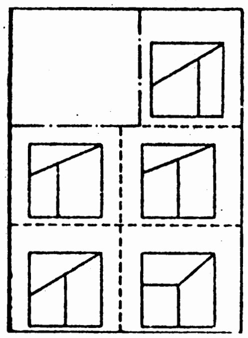
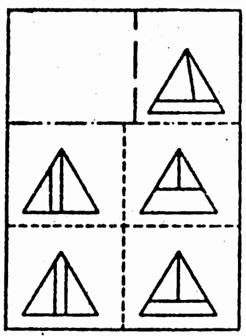
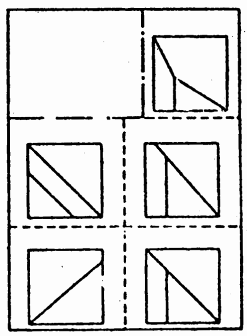
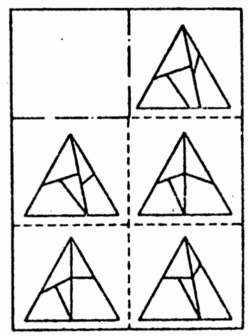
1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
8.	I	II	III	IV	V
9.	I	II	III	IV	V
10.	I	II	III	IV	V

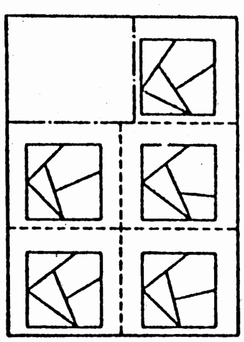
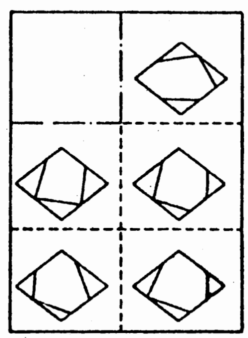


This set of problems is put in the form of pieces of figures as might be done with a small puzzle. The two or more pieces appear in the upper left hand corner of the problem and will fit together without overlapping to form <u>one</u> of the figures in the remaining squares of the problem.

You are to rotate or flip over the pieces as necessary, putting them together and select the <u>one</u> best figure representing the assembled pieces. When told to do so mark an "X" directly over the figure that indicates your answer.

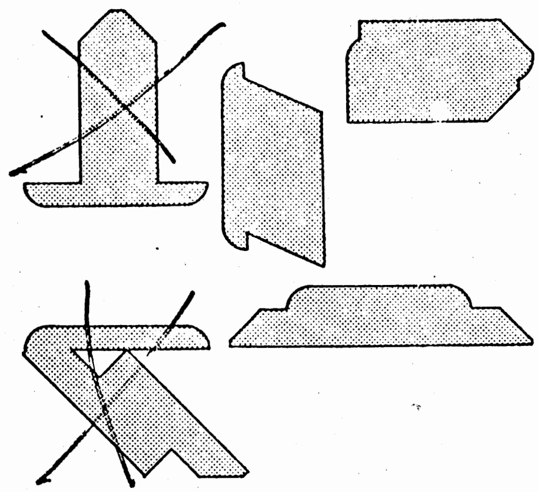
I II III IV V

This set of problems is put in the form of number sequences. The numbers are written out in words rather than appearing as numerals. Within the sequence one or two numbers are missing as indicated by dotted lines.

You are to select the one best answer which provides the missing number or numbers and when told to do so, mark an "X" directly over the roman numeral that identifies your answer.

1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
8.	I	II	III	IV	V
9.	I	II	III	IV	V
10.	I	II	III	IV	V

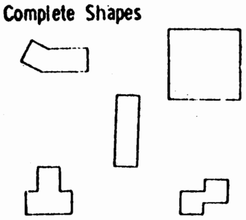
Complete Shapes



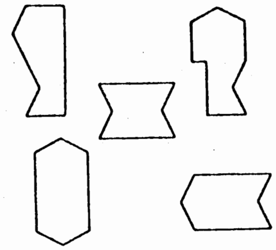
This set of problems is put in the form of parts of shapes. The parts are black and appear above the shapes. The shapes are lightly shaded with black lines around them. When arranged correctly the parts will just exactly cover <u>one or more</u> of the shapes with no overlapping of the parts.

You are to rearrange the parts as necessary, exactly fitting them to the shapes. When told to do so mark an "X" directly over the shape or shapes that indicate your answer/s.

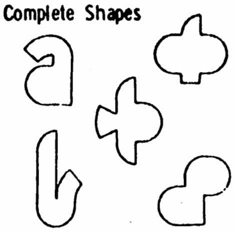
Complete Shapes



Complete Shapes



Complete Shapes



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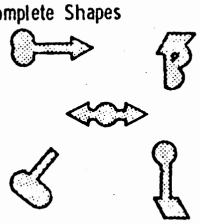
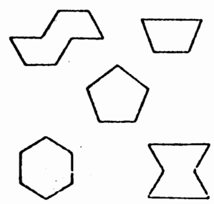
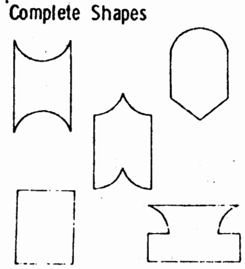


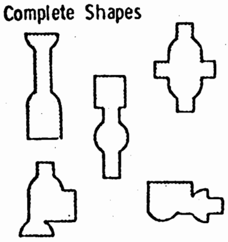
Complete Shapes



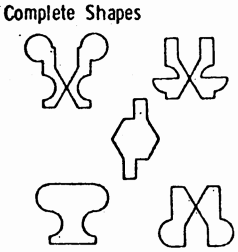
Complete Shapes



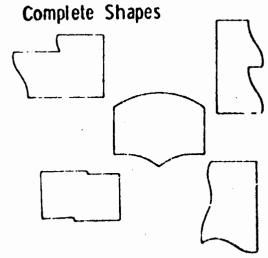
Complete Shapes



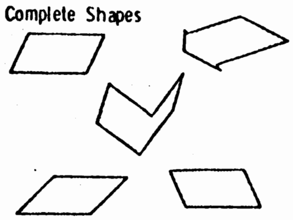
Complete Shapes



Complete Shapes



Complete Shapes



I II III IV V

This set of problems is put in the form of five words, each word identified by a letter directly beneath it. The words are not listed in any rank order, i.e., from one polar extreme to another.

You are to rearrange the words into a logical, descending rank order, then select the one best answer showing the respective letters beneath the words arranged in that same order. When told to do so mark an "X" directly over the roman numeral that identifies your answer.

1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
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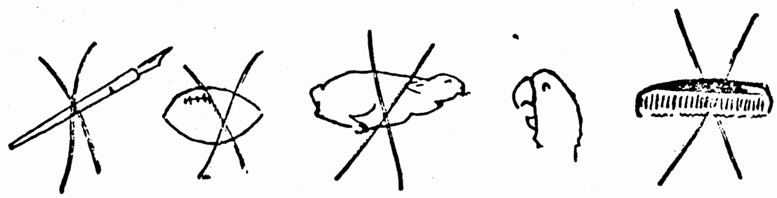
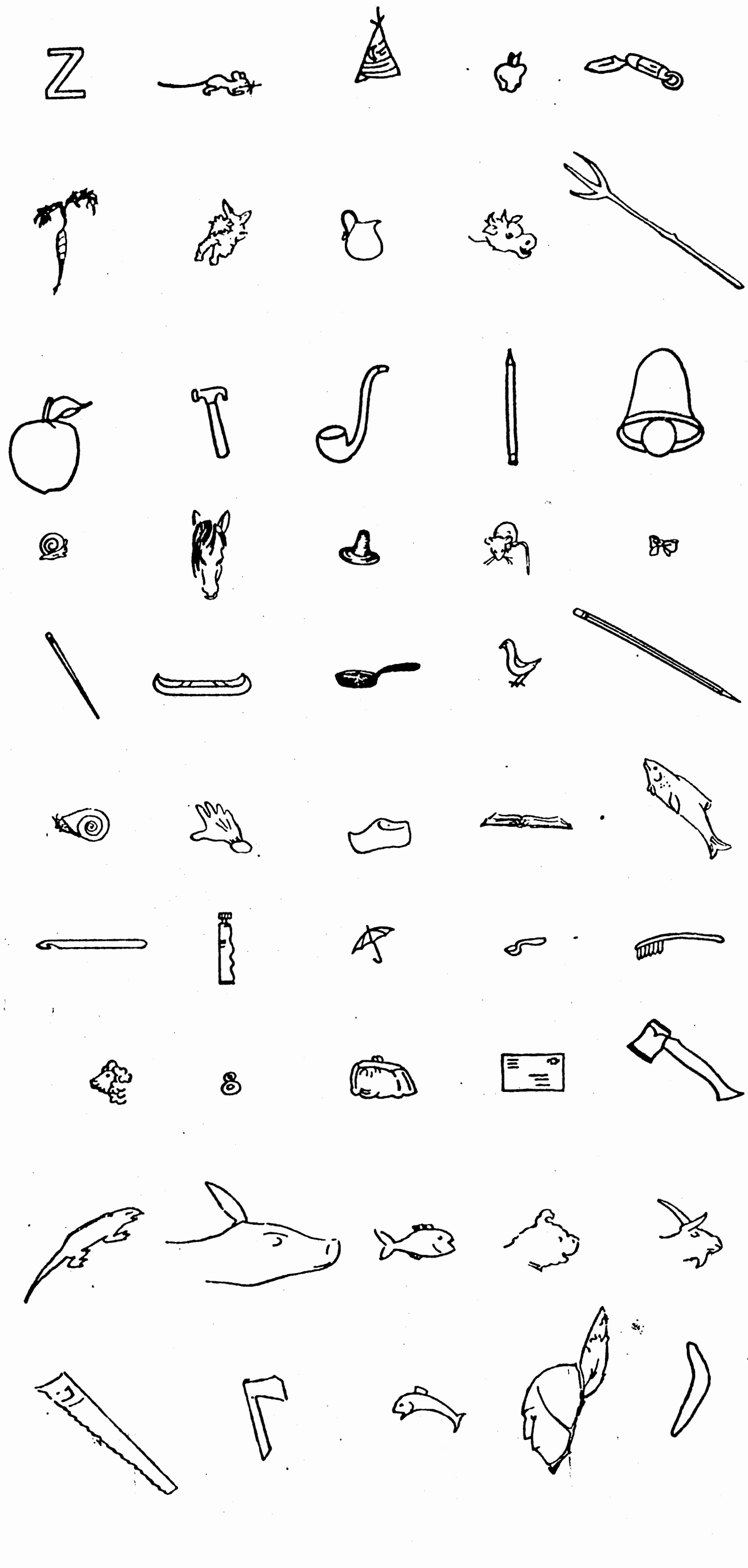
9.	I	II	III	IV	V
10.	I	II	III	IV	V



This set of problems is put in the form of hidden drawings. One or more of the small drawings at the bottom of the problem are exactly duplicated in the scene above them. Other drawings appear in the scene that are not shown at the bottom.

You are to determine which one or more of the small drawings are duplicated in the scene. When told to do so mark an "X" directly over the drawing or drawings that indicate your answer/s.



APPENDIX C

PRE AND POST TEST PERCENT-TIME

DATA COLLECTION FORM

TEST (PRE/POST) ______

SUBJECT # ______ NAME ____________________ GROUP ______ TEST SEQUENCE ______

BASELINE DATE: LEFT FREQ ______ RIGHT FREQ ______

AMPL ______ AMPL ______

INTEGRATE RIGHT ON PHYSIOGRAPH

SUBTEST ______		L	R	SUBTEST ______		L	R
	1	___	___		1	___	___
	3	___	___		3	___	___
	5	___	___		5	___	___
	7	___	___		7	___	___
	9	___	___		9	___	___
	10	___	___		10	___	___
SUBTEST ______	1	___	___	SUBTEST ______	1	___	___
	3	___	___		3	___	___
	5	___	___		5	___	___
	7	___	___		7	___	___
	9	___	___		9	___	___
	10	___	___		10	___	___
SUBTEST ______	1	___	___	SUBTEST ______	1	___	___
	3	___	___		3	___	___
	5	___	___		5	___	___
	7	___	___		7	___	___
	9	___	___		9	___	___
	10	___	___		10	___	___

INTEGRATE LEFT ON PHYSIOGRAPH

APPENDIX D

TRAINING SESSION INSTRUCTION AND

DATA COLLECTION FORMS

PHASE ONE

INSTRUCTIONS COMMON TO ALL GROUPS

SESSION #1 Demonstrate to subject the effects of artifact and a bad connection, on the tone (see manual). Instruct subject that the equipment is measuring and feeding back brain activity on both sides of her brain. Instruct subject that her goal throughout training is to get and keep the tone off in both earphones. No shaping during this session.

SESSIONS #2–#4 Shape in the following manner. When meter stays at 10% or less for 30 seconds, shift frequency dial by one digit in appropriate direction. For up training, appropriate means increasing upper frequency dial by one; for down training, decrease lower frequency dial by one.

SESSIONS #5–#7 Do as above but use 20% or less on meter as criterion for shifting frequency.

SESSIONS #8–#10 Do as above but use 30% or less on meter as criterion for shifting frequency.

Percent time readings are taken from meters at 3 minute intervals, with three readings per interval. The first at 10 seconds before marker time (i.e., 2:50); the second at marker time (i.e., 3:00); and the third at 10 seconds after marker time (i.e., 3:10).

PHASE ONE

TRAINING SESSION SHEET

GROUP ______	SESSION # ______	BASELINE SETTINGS	
DATE ______	SPECTRUM 7	LEFT	RIGHT
TIME ______	INTEGRAT. 6	FREQ ___	FREQ ___
SUBJECT ______	SCALE X 1	AMPL ___	AMPL ___
TRAINER ______	TIME INT. 10"		

TIME	% TIME READINGS 1	2	3	Upper Hz	Lower Hz	Amplitude
START						
3 Min						
6 Min						
9 Min						
12 Min						
15 Min						
18 Min						
21 Min						

RULU Set lower frequency dial at 2; set upper frequency dial at baseline for both A-70's. Caution: If baselines differ for right and left, upper frequencies will be different at the 2 A-70's.

RULD Set lower frequency at 2 and upper frequency at baseline on right A-70. Set lower frequency at baseline and upper frequency at 20 on left A-70.

RDLU Set lower frequency at baseline and upper frequency at 20 on right A-70. Set lower frequency at 2 and upper frequency at baseline on left A-70.

RDLD Set both A-70 lower frequencies at baseline and upper frequencies at 20.

PHASE TWO

SUBJECT____________________ GROUP________________

SESSION #__________________

DATE_________ TIME _________

EXPERIMENTER________________

BASELINE

LEFT_____RIGHT______FREQUENCY

LEFT_____RIGHT______AMPLITUDE

Set time interval @ 100"

	% TIME	UPPER	LOWER
start			
3			
6			
9			
12			
15			
18			
21			

LEFT

RIGHT

RD-LD Set Upper frequency on both Autogens at 20. Set Lower frequency on both Autogens at baseline.

RU-LU Set Upper frequency on both Autogens at baseline. Set Lower frequency on both Autogens at 2.

RD-LU On Left Autogen set Upper frequency at 20 and Lower at baseline.

RU-LD On Left Autogen set Upper frequency at 20 and Lower frequency at baseline. On Right Autogen set Upper frequency at baseline and Lower frequency at 2.

Set amplitude for all conditions at 0.

Whenever Both Autogens get below 10% for 30 seconds, change the time interval to 10". Then reset baselines for the appropriate group as follows:

RD-LD Decrease Both Lower frequencies until meter reads between 40 and 60%, then reset time interval to 100".

RU-LU Increase Both Upper frequencies until meter reads between 40 and 60%, then reset time interval to 100".

RD-LU Increase Upper frequency on Left Autogen and Decrease Lower frequency on Right Autogen until meter reads between 40 and 60%, then reset time interval to 100".

RU-LD Decrease Lower frequency on Left Autogen and Increase Upper frequency on Right Autogen until meter reads between 40 and 60%, then reset time interval to 100".

For first training session demonstrate artifact by (1) removing electrode plug, let her hear the sound and (2) ask her to clench her teeth and hear that sound.

Instruct subject that the goal is to keep the sound off as much as possible. Also, make the subject aware that we will be raising the criterion if she does especially well (Keeps the meter below 10%). So if she is keeping it quiet, then suddenly hears a burst of sound, it means we have increased the criterion and she is doing well.

Get baselines, then adjust the volume of the feedback sound so that it is comfortable for the subject and start the session.

APPENDIX E

POST TRAINING TEST BOOKLET

This test is part of an investigation of electroencephalographic (EEG) feedback research. It does not involve deception in any guise nor are there any types of aversive stimuli used.

The test is divided into six sets of ten multiple-choice problems per set. Each set of ten problems is preceded by an example slide projected on the screen. The correct answer for the example problem is marked on the respective answer sheet. All problems are presented on the self-contained slide projector on the stand in front of you. It will be necessary that you sit quite close to the screen. The projector also has a built-in audio tape playback system. Instructions are given verbally via this tape player throughout this first phase of your feedback training. You may already be familiar with several of the types of problems presented however the level of difficulty of this test is such that you probably won't get all answers marked 100% correctly. In any case if you have not decided upon an answer within the time allotted -- make your best guess ! ! PUT A MARK ON THE ANSWER SHEET FOR EACH PROBLEM ! !

You must solve all problems "in your head." Make no marks with your pencil other than to mark an answer.

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THANKS VERY MUCH FOR COMING. WE APPRECIATE

YOUR CONSIDERABLE CONTRIBUTION TO

OUR RESEARCH

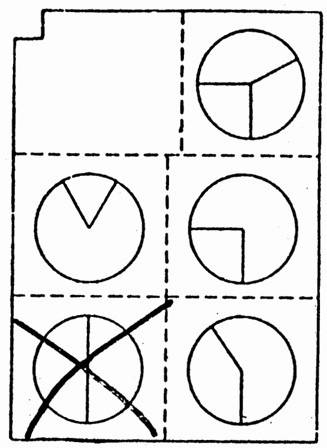
! ! !

I II III IV V

This set of problems is put in the form of simple division. In each problem one number is missing. A dotted line shows where the number is missing, either from the quotient or from the dividend.

You are to select the <u>one</u> best answer to provide the missing number and when told to do so, mark an "X" directly over the roman numeral that identifies your answer.

1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
8.	I	II	III	IV	V
9.	I	II	III	IV	V
10.	I	II	III	IV	V



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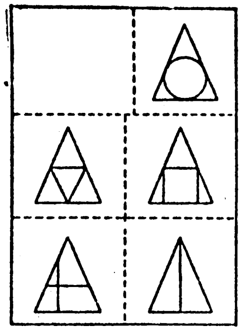
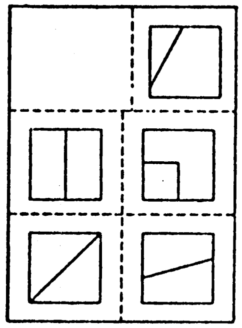
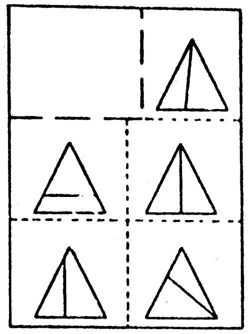
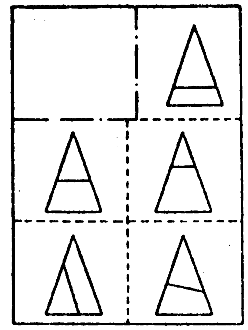
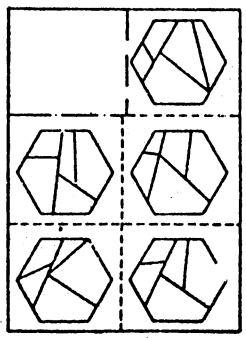
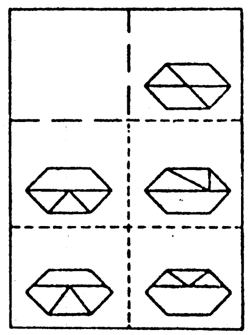
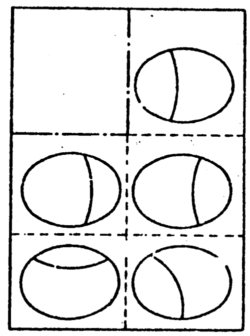
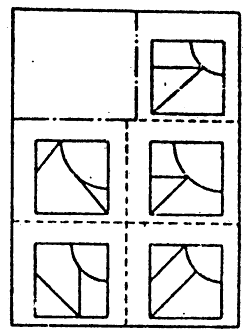
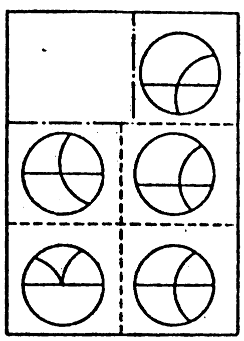
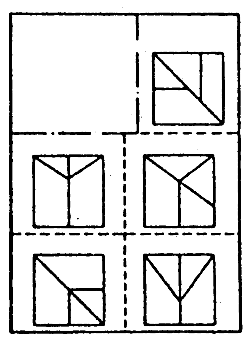
You are to rotate or flip over the pieces as necessary, putting them together and select the one best figure representing the assembled pieces. When told to do so mark an "X" directly over the figure that indicates your answer.

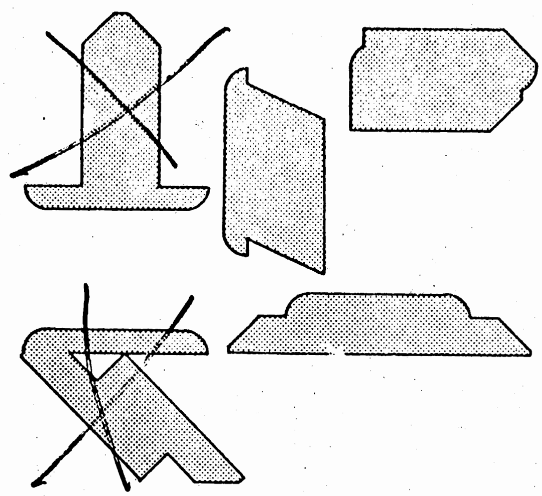
I. ~~II~~ III IV V

This set of problems is put in the form of number sequences. The numbers are written out in words rather than appearing as numerals. Within the sequence one or two numbers are missing as indicated by dotted lines.

You are to select the one best answer which provides the missing number or numbers and when told to do so, mark an "X" directly over the roman numeral that identifies your answer.

1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
8.	I	II	III	IV	V
9.	I	II	III	IV	V
10.	I	II	III	IV	V

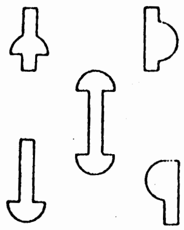
Complete Shapes



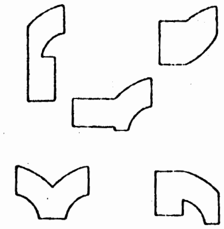
This set of problems is put in the form of parts of shapes. The parts are black and appear above the shapes. The shapes are lightly shaded with black lines around them. When arranged correctly the parts will just exactly cover one or more of the shapes with no overlapping of the parts.

You are to rearrange the parts as necessary, exactly fitting them to the shapes. When told to do so mark an "X" directly over the shape or shapes that indicate your answer/s.

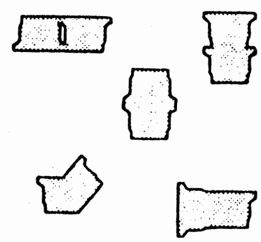
Complete Shapes



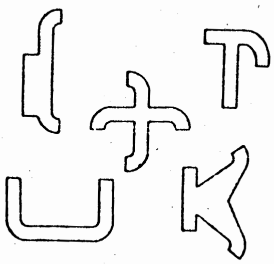
Complete Shapes



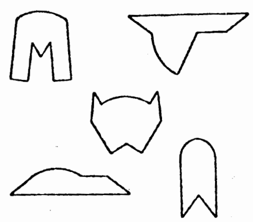
Complete Shapes



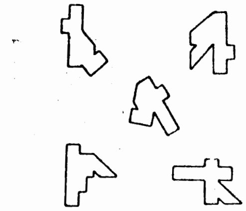
Complete Shapes



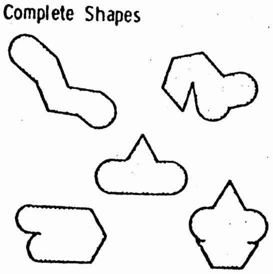
Complete Shapes



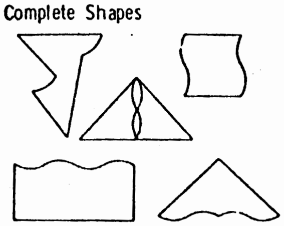
Complete Shapes



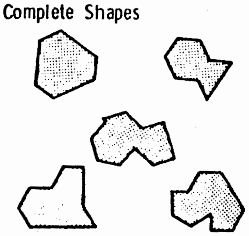
Complete Shapes



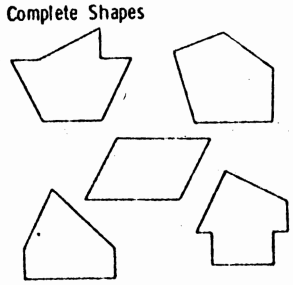
Complete Shapes



Complete Shapes



Complete Shapes

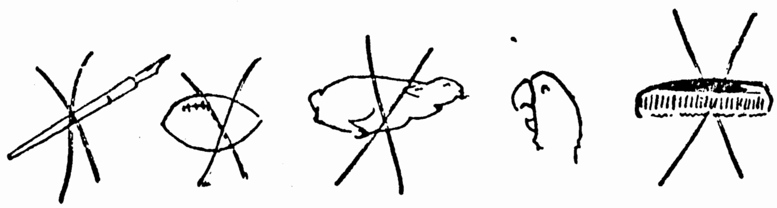


I II III IV V

This set of problems is put in the form of five words, each word identified by a letter directly beneath it. The words are not listed in any rank order, i.e., from one polar extreme to another.

You are to rearrange the words into a logical, descending rank order, then select the <u>one</u> best answer showing the respective letters beneath the words arranged in that same order. When told to do so mark an "X" directly over the roman numeral that identifies your answer.

1.	I	II	III	IV	V
2.	I	II	III	IV	V
3.	I	II	III	IV	V
4.	I	II	III	IV	V
5.	I	II	III	IV	V
6.	I	II	III	IV	V
7.	I	II	III	IV	V
8.	I	II	III	IV	V
9.	I	II	III	IV	V
10.	I	II	III	IV	V



This set of problems is put in the form of hidden drawings. One or more of the small drawings at the bottom of the problem are exactly duplicated in the scene above them. Other drawings appear in the scene that are not shown at the bottom.

You are to determine which one or more of the small drawings are duplicated in the scene. When told to do so mark an "X" directly over the drawing or drawings that indicate your answer/s.

VITA

Peter Atley Maurek

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF DIVERGENT AND CONVERGENT EEG FREQUENCY FEEDBACK FROM BOTH CEREBRAL HEMISPHERES ON CHANGES IN SEQUENTIAL AND SIMULTANEOUS TASK SOLVING ABILITY

Major Field: Psychology

Biographical:

Personal Data: Born in Clinton, Iowa, December 13, 1931, the son of Mr. and Mrs. Atley Maurek; married to Mary Joan Houser of Clinton, Iowa.

Education: Graduated from Clinton High School, Clinton, Iowa, June 5, 1949; received Bachelor of Science degree from Cameron University, Lawton, Oklahoma, in May, 1973; received the Bachelor of Science in Elementary Education degree from Cameron University, in May, 1974; completed requirements for the Master of Science degree at Oklahoma State University, Stillwater, Oklahoma, in July, 1978.