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John Romann Schweitzer

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James R. Nord

James R. Nord
Major professor

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LATERAL HEMISPHERIC SPECIALIZATION
FOR VISUAL INFORMATION PROCESSING
IN NORMAL HUMAN ADULTS

By

John Romann Schweitzer

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ABSTRACT

LATERAL SPECIALIZATION FOR VISUAL
INFORMATION PROCESSING IN
NORMAL HUMAN ADULTS

By

John Romann Schweitzer

The primary focus of this investigation was to determine if a particular frequency of brain wave activity (i.e., 8-14 hz), known as the "alpha wave" is reduced in the right hemisphere when a recently memorized human face is projected to the left visual field as compared to a right visual field presentation. Previous studies have indicated that the alpha wave is attenuated in the right hemisphere when a subject engages in cognitive activity such as mentally manipulating geometric objects. The projection of visual stimuli via a tachistoscope has been used to present the stimulus to either one side of the brain or the other. This is accomplished by presenting the stimulus in the right or left hemifield (the far right or left visual field) for a duration of 160 milliseconds.

A secondary focus was to investigate possible correlations between a standardized test of imaging ability (the Bett's QMI short form of the Sheehan's imaging test) and the measure of alpha activity. Imaging, defined as the ability

to generate internal sensory constructs, is thought to be related to the right hemisphere. The collection of EEG data provided the experimenter with a record of electrical activity of the subject while viewing a picture of a human face which was projected to either the left, right, or both hemispheres simultaneously.

An experiment was designed in which ten college-aged, adult humans were presented a thirty-item facial recognition test via a tachistoscope while EEG data were collected. The EEG records were analyzed using a computer-assisted Fourier transformation for the alpha spectrum. The amount of alpha frequency contained in two second periods EEG wave form (which was recorded in synchrony with the presentation of the visual stimuli) was analyzed statistically to test for hypothesized differences.

The facial stimuli consisted of randomly constructed, black and white line drawings of human faces mounted on 5" X 7" cards. A "memory test face" was reproduced and presented to the subjects for three minutes in the central, normal visual field prior to the test sequence. Thirty faces were presented at random to the subject's right, center and left visual field for an intra-trial duration of 160 milliseconds. Of the thirty test items, the memory target was presented six times. Inter-trial times ranged from 8-10 seconds. Subjects were not required to manually or orally respond to stimuli, but were instructed to "be aware of the sameness or difference of the face as compared to the memory face".

Results of this experiment showed that there were no statistically significant differences in right versus left hemispheric alpha activity while viewing facial stimuli, nor between "same" or "different" stimuli as compared with the memory target stimulus. The presentation mode (i.e., right, central, or left visual hemifield t-scope projection) yielded no statistically significant differences in alpha frequency activity. The statistical test used for each of these hypotheses was the dependent t-test with the level of significance fixed at the .05 level. A Spearman rank correlation was performed to test for correlation between right hemispheric alpha activity and the scores on the Bett's QMI Vividness of Imaging Ability. For the experimental sample, scores on this test ranged between high and medium imaging ability. No statistical correlation between these scores and right hemispheric, alpha activity was found. Although not significant at the .05 level, right hemispheric alpha frequencies were reduced in the subjects when compared with left hemispheric alpha activity.

Further research is needed before the alpha frequency spectrum can be used with assurity as a dependent measure of right hemispheric bias in information processing of such visual stimuli as facial recognition tasks. However, the findings of a reduction in right hemispheric alpha activity, though not significant at the .05 level, suggest that this measure may prove useful in future studies.

ACKNOWLEDGEMENTS

The reader will please forgive my use of the analogy of an explorer navigating relatively unknown waters, for indeed this is often how the research seemed. This section of the dissertation is perhaps doomed to failure from the offset for in looking back over "my charts" it is impossible to mention all those who helped, supported and encouraged me during this research effort. In keeping with the metaphor, I would like to thank first my wife. She, unlike those wives of old waiting impatiently on the shore, was charting her own course through a dissertation. Seeing her beside me (and often ahead) forging steadily toward the goal was a constant source of encouragement to me as well as a way of calibrating our instruments of navigation. With her help, advice and encouragement, my exploration effort was much more meaningful and infinitely less lonely.

Secondly, I would like to acknowledge my advisor, Dr. Nord. He was not only full of knowledge of the "New World" I sought, but constantly advised me to share my newly drawn (and often out of scale) maps with other explorers and map-makers. Through this process many inaccuracies were corrected. Though the improvements seemed endless and tedious,

when already several months "at sea", I appreciated the guidelines.

Moreover, as senior explorer (researcher) in this endeavor, Dr. Nord encouraged my two colleagues, Sue Awbrey and Terry Shaffer to embark on parallel courses of investigation. As a research team, perhaps our naiveté was matched only by our capacity to learn. And learn we did. Without them, the scope and scale of my own research would have been greatly diminished. Indeed, risking the mix of metaphors, with the three of us using a navigational technique of "triangulating" variables, my own particular research questions seemed more meaningful and reasonable. Perhaps more personally, their help always seemed to come when I most needed it.

More than thanks are also in order for Dr. James Cunningham who, by way of this perhaps leaky analogy, lent us a vessel to sail in. By making an EEG recorder available for us to train with, by coordinating with Dr. King in providing a training base in Giltner Hall, by providing us with access to his clinical expertise and knowledge, and by introducing us to his colleagues and assistants, our data collection phase was made both feasible and meaningful.

Mrs. Anne Reike of the Special Diagnostics Section, Clinical Center at Michigan State University is also remembered and thanked for helping us with the EEG data collection.

The Clinical Center's staff is also greatly appreciated in their willingness to innovate and assist in this research application with their facility and technologies.

Of my committee, special thanks are in order for Dr. Raywin Huang for his help with my "mapmaking" and design. His excellence in his Science was matched by his personal interest and help during this research. His guidance during the data analysis and statistical testing reduced much of the equivocality of "information overload" and made my return voyage in this exploration possible.

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To all of these, and many other unmentioned fellow explorers, I hail, "Boy Voyage!"

PREFACE

Educational Technology and the
"two-brain" Hypothesis

By

James R. Nord, Ph.D.
Major Professor

One or two men cannot develop a science or technology; they must communicate what they have thought and what they have done to others lest it be lost. But in order for their knowledge to be preserved so as to contribute to a growing accumulation of knowledge, it must be repeatable. Historically, two of man's most important media of communications were words and pictures. But these differed in their degree of repeatability. Once a word is adopted by a culture, it can be spoken or written with many variations of vocal sound or graphic design and still represent the same word or symbol. Even though there are some subjective components of meaning for each individual, the abstract and arbitrary nature of word meanings, tends to make them relatively repeatable, even though their visual or auditory forms vary somewhat.

On the other hand, a picture which is copied by hand is not exactly repeatable; each time it becomes a different picture. The visual graphic is a direct analog of an individual's thought. It tends to be much more concrete, more representational and less arbitrary than words. The transfer of thought through visuals is modified by inexact reproduction. Each reproduction of a visual graphic by hand reproduction means, tends to modify, alter and reduce the fidelity of the original. Words on the other hand, being arbitrary symbols standing for abstracted references, tend to be more repeatable through many sayings or writings, and still retain the original meaning.

Not until men learned to print pictures were they able to repeat exactly a pictorial statement in the same sense that they had been able to repeat verbal statements for thousands of years. Not until the fifteenth century did Western man learn how to reproduce pictures mechanically, so to speak, thus making it possible to repeat his pictorial statements exactly. The repeatability of words over the many centuries created a dominance of the word over the visual which is only recently being extensively questioned. It influenced the major systems of thought through the centuries, and it is still influencing education today.

The ancient Greeks, whose systems of thought are still revered today, could repeat their verbal statements by hand copying, but had no technology for exactly repeating pictorial statements. Consequently, their intellectual activity was structured mainly along verbal lines. The Greeks were full of all sorts of ideas about all sorts of things, but they rarely checked their thought by experiment.

Lacking concrete reference systems, they sought reality in the abstractions represented by words. Plato's ideas and Aristotle's forms, essences, and definitions are specimens of this transference of reality from the object to the exactly repeatable and therefore seemingly permanent verbal formula. The only sciences in which the Greeks made significant advances were geometry and astronomy; for the first, words and repeatable line drawings serve to store and communicate meaning, and for the second, the stars on a clear night serve as repeatable visual patterns for every one. Other natural sciences were not advanced by the Greeks. There were certain botanists who wrote descriptions of plants and illustrated them with realistic drawings, but the drawings suffered so much at the hands of copyists that the Greeks finally gave up even trying to describe the plants and simply listed all the various names by which each plant was known in different locations and told what ailments it was good for.

The development of methods of printing pictures in the fifteenth century heralded the downfall of the tyranny of words in man's systems of knowledge. Modern science and technology gradually took shape as their indispensable pictorial components were cut or engraved or etched on printing surfaces for widespread dissemination. The linear time order in which words must be used, led naturally to a verbal breaking down of real things into their definable qualities which had only conceptual existence. The repeatable pictures allowed the real objects and mental mappings to be presented as a unity. The availability and use of repeatable visuals has had enormous effects upon the sciences and technology.

The effect upon public education has been far less dramatic. The educational profession, like the ancient Greeks, seems to be heavily dependent upon a repeatable verbal coding system for the majority of teaching in the formal school systems. The repeatable visual statements now available are often referred to as "visual aids", and treated as a secondary form of communications. There is however, one group of educators who might yet have some influence in breaking down the tyranny of words within the educational profession. There is a group of educators, called educational technologists, whose origin began with the development of printing repeatable pictures, and whose growth has been nurtured by a wide range of newer technologies, most of which are improvements in the communication of pictures.

Educational technology might be said to have begun with the publication of Orbus Pictus by Johann Comenius in 1658.

This is the first known educational publication to use and promote the use of both visual and verbal means of communication. It did not however have much effect upon the educational establishment. Very little more was done about the use of repeatable pictures in education until the invention of the motion picture in the later half of the 19th century. From this invention sprang the general "audiovisual" movement in American education during the middle 20th century. As Saettler has expressed it, "Although the term visual instruction was used since the beginning of this century to refer to a variety of visual instructional media, it is not surprising that the instructional film intensified its use and provided a great impetus to the audiovisual movement in American education." (Saettler, 1968, p. 118). The interest in film led to the creation of the National Education Association Department of Visual Instruction in 1922. Later, when motion picture films added sound, this organization was changed into the Department of Audiovisual Instruction (DAVI). This in turn was the forerunner to the present professional organization known as the Association of Educational Communications and Technology (AECT). This organization is the American counterpart of a world wide movement more generally known as educational technology.

During the early days of the audiovisual movement, there was not much concern expressed for theory. The emphasis was on the practical use of audiovisual tools in the classroom. A few experimental studies were attempted to determine learning effects, but they were neither systematically theoretical, nor rigorously experimental. In the 1950's, the audiovisual movement began to grow into a more professional organization. Concerns for theory arose, concern for standards grew, and in general a more professional attitude was developing. Throughout the 1960's there began a basic debate between two fundamentally different points of view. Each of these points of view saw man, the nature of man, and the nature of learning differently.

When seen from a structural point of view, man was seen as a growing, developing organism which self-organized its own internal cognitive structure based upon its sensory interactions with its environment. The perceptual input was seen as the primary cognitive food to help grow a cognitive structure. Since visual perceptual input was a major source of information, this became a focal interest of this group. Learning was seen to be tied closely with the processes of perception, memory, conceptual formation and cognitive processing. External behavioral responses were seen as a result or consequence of learning which had already taken place within the cognitive structure. Teaching was seen primarily in terms of developing the stimuli which would help the individual grow the appropriate cognitive structure. This was, therefore, sometimes referred to as a <u>stimulus-oriented</u> approach, based on the psychology of the configurational school of thought.

When seen from a functional point of view, man was seen as a plastic, trainable being, whose behaviors were the consequence of certain relationships between the response and the immediately following stimulus. The man was not seen as an organism so much as a series of actions, of behaviors. The focus of concern was therefore on the responses and on defining appropriate responses and then manipulating the consequent stimulus in a way which would "reinforce" the response. The response is a time-oriented sequence, and learning was viewed as a change in a response pattern over time. Teaching was seen primarily in terms of shaping a response to the desired one. This functional viewpoint has therefore sometimes been referred to as a <u>response-oriented</u> approach, based on the psychology of the connectionist school of thought.

Recent studies in neurology and neuropsychology now seem to indicate that there is evidence for concluding that the two hemispheres of the human brain are different. The left hemisphere seems to be specialized to process verbal material on a temporal basis, while the right hemisphere seems to be specialized to process primarily visual-spatial material on a configurational basis. This paradigm of lateral hemispheric specialization, holds promise of illuminating the two major forms of communication, verbal and pictorial. It holds the promise of illuminating the basic conflicts between a structural point of view and a functional point of view. It appears to hold the promise of providing the professional field of educational technology with the scientific basis for finally tearing down the tyranny of words in our public educational institutions and replacing it with a more balanced use of both hemispheres of our brain.

For most of the past 100 years, the focus of neurological studies was on the left hemisphere. This was largely because the cognitive functions of language was found to reside there. Because of the prevailing view that our capacity for language set us apart from "lower species", it seemed logical that the hemisphere in which the comprehension and production of language takes place should be the more highly developed hemisphere, and thus in ultimate control over the rest of the brain. The left hemisphere was, therefore, called the "major", "dominant", or "leading" hemisphere, while the right was considered to be the "minor" or "subordinate" hemisphere. It was not until the middle 1960's that the research on split brain patients opened up the gap between left and right hemispheres enough to recognize that this dominant-subordinate role model just didn't fit the facts. The research on split brain patients combined with reviewed research on brain damaged patients caused neurologists to look at the hemispheres of the brain with a new pair of spectacles and they discovered that each hemisphere tended to process information differently. The concept of hemispheric dominance soon gave way to the concept of hemispheric specialization.

What does this specialization mean? In almost all right handers, the left hemisphere dominates or specializes in the processes of most sequential mental tasks. These tend to be verbal/analytical, as opposed to the intuitive or gestalt quality of the right hemisphere. Most left handers have brains lateralized in the opposite manner, although other forms of organizations have been found in this group (Levy, 1977, p. 51). While numerous terms have been used to describe the two contrasting forms of mental organization, Neisser (1966, p. 297) called one of the basic organizations, one of sequential processing; while the other he called multiple processing, which carries out many actions simultaneously or at least independently. An analogy has been made between a digital computer which processes information one bit at a time sequentially, and an analog computer which can take in a large number of inputs simultaneously and process them literally instantaneously. It might be noted here that the digital computer has been considered the slower but more accurate type of computer, while the analog computers have been faster but with a larger potential for error, that is, they are not as precise. Bogen has described the two hemispheres as "propositional" and "appositional" (Bogen, 1977, p. 138). In right handers, he points out that the left hemisphere has propositional dominance for speaking, writing, calculations, and so forth. By contrast, the right hemisphere tends to be more involved in complex visual-spatial information processing such as those necessary for music, art and athletic activities. Bogen suggests that "the most important distinction between the left and right hemisphere modes is the extent to which a linear concept of time participates in the ordering of thought". Thus, the right hemisphere is considered as specialized for processing "time-independent stimulus configurations", while the left is specialized for "time-ordered stimulus sequences.

The importance of pictures in education has been an article of faith with educational technologists since the first publication of Orbus Pictus in 1658. Attempts to establish a scientific foundation to the use of visual materials in learning has not met with a great deal of success in the past. Part of the reason for the lack of success may have been the general use of a learning model which was based upon animal learning in a time-organized manner. Almost all of the learning models associated with the testing of visual materials in the learning process have been time-oriented, rather than spatial-visual oriented. Associationism, S-R learning models, etc., are oriented to the learning of response actions via the use of a subsequent or consequent stimulus event or "reinforcement". Cybernetic feedback research on the other hand has accumulated a considerable body of evidence showing that somatic response is controlled by detection of spatial differences in stimulus patterns and that temporal organization in behavior is derived from its continuous spatial patterning. (Smith and Smith, 1966, p. ix). Neurological evidence and the lateral hemispheric specialization theory indicate that the two hemispheres are specialized, one for temporal event processing but the other for visual-spatial information processing. This new viewpoint of neural activities seems thus to indicate a way of breaking away from a temporally oriented learning theory and establishing a clearly distinctive configurational learning theory. Such a learning theory may then allow the educational technologist to base his support of visual materials in the educational process on solid scientific evidence.

The acceptance of the importance of visual materials in the educational process can have important effects according to lateral hemispheric specialization theory. Schools have traditionally considered the verbal medium of communication as the more critical, and the "visual aid" as secondary. But as Meredith (1972) has pointed out:

> Traditionally instruction has been dominated by the spoken word....The dialectic of the 'socratic method' in which the whole burden of communication is carried by a single medium, is still regarded as prestigious rather than parasitic because, apart from onomatopeia and intonation, amplified by gesture, the structure of the verbal medium bears no determinate relation to its messages. The latter depend entirely upon associated experiences. Words are effective only when the experiences are first guaranteed. (pp. 10-11)

And Von Foerster (1972) adds:

> We seem to be brought up in a world seen through descriptions by others rather than through our own perceptions. This has the consequence that instead of using language as a tool with which to express our thoughts and experiences, we accept language as a tool that determines our thought and experience. (p. 34)

Teyler emphasizes some of the neurological dangers of excessive dependence on verbal activity to the exclusion of visual spatial activity in light of the two-brain hypothesis. "Furthermore, it has been shown that brain processes present at birth will degenerate if the environmental stimulation necessary to activate them is withheld. It appears that the genetic contribution provides a framework which, if not used, will disappear, but which is capable of further development given the optimal environmental stimulation. The social and political implications of this fact of brain functioning are obvious and far-reaching" (Teyler, 1972, p. 31-32). In case it is not so obvious, Bogen clarifies the point for educators. "Since education is effective only insofar as it affects the working of the brain, we can see that an elementary school program narrowly restricted to reading, writing, and arithmetic will educate mainly one hemisphere, leaving half of an individual's high-level potential unschooled" (Bogen, 1977, pp. 141-142). Therefore, any effort to clarify and illuminate the role of visuals in education, and particularly as this relates to basic brain functions seems justified. Indeed, any further efforts at more fully exploring and defining the role of visual materials in education through the uncharted and complex neurological pathways of the brain, should be both welcomed and encouraged by the field of educational technology.

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INTRODUCTION

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Background

Instructional technology continues to investigate methods to apply psychological principles in the design of instructional materials which enhance learning. One approach has been to develop and validate audiovisual systems based on scientific learning theory. The relationships between the use of auditory and visual stimuli in the design of these systems has been a focus of much theorizing and study. Recent evidence from studies in neuropsychology indicate that normal humans have developed specialized cognitive modes for processing visual information from their environment.

Lateral hemispheric specialization in the human brain is the phenomenon whereby humans seem to interact with visual perceptions primarily with the right hemisphere, whereas symbolic verbal information such as written language appears to be primarily a function of the left cerebral hemisphere. This human trait has been investigated primarily from the focus of neurology and physiology and few studies have related the characteristic to the learning process. Identifying by controlled experimentation how visual information is processed by normal human learners could have profound implications for the future design of visual, educational communication.

The establishment of an empirical base for instructional application of visual information processing could aid designers in making decisions about curriculum, instruction, and evaluation questions. A curricular question might be, "Should the desired goal of learning require the learner to process visual information?" Similarly, in the construction of a particular instructional message the designer may be faced with the question, "Would the most efficient and effective means of learning be through the presentation of visual messages?" Finally, in the evaluation of whether learning had been achieved, the decision maker needs to ask, "How can I know if the visual information was processed and learned?" In making decisions relevant to all three of these functions of instructional design, the designer needs the most accurate and complete empirically derived information to arrive at the best solution.

Identification of the Problem

This study is part of a larger research effort to investigate the relationship between visual message design and cognitive information processing in humans. The general research paradigm involves the clinical recording of cerebral electrical activity associated with carefully designed visual presentations. These recordings are then analyzed to determine the A/P ratio of a subject when presented with a particular visual stimulus. An A/P ratio is the comparative information processing activity of the two hemispheres of the cerebral cortex. The term A/P refers to the relative degree of appositional (right hemisphere) to propositional (left hemisphere) information processing. The A/P ratio is defined operationally by the ratio of "alpha wave" activity in each hemisphere of the cerebral cortex. The amount of information processing is assumed to be inversely proportional to the amount of alpha wave activity in the hemisphere. For example, if the left hemisphere indicates more alpha wave activity than the right hemisphere, it is assumed that the right hemisphere is processing more information than the left. An alpha wave is an electrical wave pattern in the brain of approximately 8-14 Hz in frequency. Electrical wave patterns in the brain may be directly measured with an electroencephalograph (EEG) and later analyzed through a computer program to determine the amount of alpha wave occurring at any one period of time. From the calculations an A/P ratio of relative hemispheric information processing may be determined.

This particular study focused on investigating the relationship between cognitive information processing and the viewing of previously unknown human faces. This research asks the question, "Is information processing associated with viewing and recognizing faces primarily a right hemispheric function?" The use of a picture of a face as a visual stimulus is part of a general concern for information regarding the hemispheric processing of visual stimuli. The psychological task of facial recognition has been identified in the literature as a feature of right hemispheric information processing. However, the majority of these studies have dealt with patients suffering from neural disorders or disease. More recently, some studies (Geffen, et al. 1971) have investigated differences in performance between the two hemispheres in facial recognition tasks with normal humans. No studies of EEG correlates with facial recognition were however found by this researcher.

Purpose

This study involved the experimental investigation of lateral, hemispheric specialization and its relationship to the viewing (and concurrent cognitive activity) of tachistoscopically presented pictures of human faces. The collection of EEG data provided the experimenter with a record of mental activity of the subject while viewing a picture of a human face projected directly to either the left or right hemisphere or both simultaneously. A computer program was used to analyze the data to determine the relative amount of alpha wave activity in each episode. Inference from such data was then made as to the relative amount of information processing which was going on in each hemisphere.

The primary focus of this investigation was to determine which hemisphere, if any, is dominant for facial recognition. A secondary focus was to determine if there was any correlation between a subject's relative imaging ability and the level of information processing going on within either hemisphere. Individual relative imaging ability was measured by the Bett's QMI short form of the Sheehan's imaging test.

Because of the physiological connections between the two hemispheres of the brain, and the cross-over of visual information via the optic system (see Figure 1), it is difficult to detect differences in information processing capacities between the two sides of the brain in normal humans in most instructional settings. One method of isolating hemispheric differences in processing iconic, visual information is to attempt to use the physical limits of perceptual performance (i.e., speed and angle of presentation of stimulus within the visual field) as a control for presenting the stimulus to each hemisphere selectively.

In this experiment, there was included a specific set of stimuli (faces) which were then shown to each hemisphere separately and then both hemispheres together. The presentation of a specific stimulus to a specific hemisphere was done by means of a tachistoscope (t-scope) which presented the stimulus for only a fraction of a second to that part of the retina of the eye which is directly connected to a specific hemisphere. For example, when a picture is flashed approximately 4 degrees to the right of center (right visual field) by means of a t-scope, only the left half of each eye will receive this information. Because of the bilateral cross-over system in the human optic system, the information received by the left half of the retina of each eye is sent to the left hemisphere. Therefore, when a visual such as a face is flashed to the right side of the screen, the left hemisphere of the cerebral cortex will receive it first and directly from the optic nerve. Similarly, something flashed to the left of center (left visual field) will be received first and directly by the right hemisphere. Pictures presented on the center line will be received by both hemispheres simultaneously.

Because of the bilateral cross-over system between the two hemispheres called the corpus callosum, all information in one hemisphere may be passed over to the other hemisphere for processing. The hemisphere which actually receives the information first, may not always be the one which processes most of the information. Information may be received in the left hemisphere for example, and be passed over to the right hemisphere via the corpus callosum for processing. For example, a picture of a face might be presented to the right of center on a screen. This would then be seen on the left side of the retina only. This information would then be sent first and directly to the left hemisphere. Yet much of this information may then be passed over to the right hemisphere for processing. The data is never clean and both hemispheres are constantly processing some information, but if the stimuli is presented to various areas of the brain, and yet one hemisphere tends to be most active during these periods, then there should be some cause to infer that one hemisphere is specialized to process that particular type of information.

Thus, if there were found a difference in hemispheric alpha activity, and this difference were constant regardless of the location of stimulus introduction to the brain, then there would be some empirical support for the hypothesis that the hemispheres of the brain are specialized to process certain types of information.

Need for the Study

The use of visual stimulus in instruction has been an on-going concern of the field of instructional technology. The majority of studies of the use of visual stimulus in instruction have produced little evidence of how they enhance learning. Schramm (1977) in discussing the lack of guidelines for selecting a medium of instruction based on solid evidence or scientific theory has summarized the need for experimental investigations of this type. He writes:

> We have no taxonomy that matches media experiences to cognitive results or to learning tasks. We have only begun to understand what goes on cognitively when a learner is given instructional experience in one symbolic code rather than another; and it is a great advance even to hear it said that "the learner needs this kind of experience," rather than "the lesson needs a picture." (p. 92)

The need to develop strong theoretical understanding of information processing involved with learning from visual stimuli is further given support by an increased interest in the field of instructional psychology with cognition and message design. In the 1977 Annual Review of Psychology, Wittrock and Lumsdaine write:

> Instructional psychology is now involved in a notable shift in emphasis in psychological research and theory... The current shift emphasizes the study of central cognitive processes...The shift to greater emphasis on the study of cognitive processes has important implications for changing teaching and instruction. If learning is conceived primarily as change in behavior due to reinforced practice, instruction would often be designed to provide differential reinforcement of the correct behavior in the presence of the appropriate environmental

> stimulus...By contrast a cognitive approach emphasizes that one can learn by observing others, by watching a model, by viewing a demonstration. In brief, cognitive approaches emphasize that one can learn without practice or reinforcement of overt behavior, and that one may learn by actively changing perceptions of experiences, by constructing new meanings and interpretations of events. (pp. 417-418)

Modern technology, for example 35 mm slides, television, 16 mm film, etc., provide the educational systems designer with the tools and potential for providing learners with realistic and iconic visual presentations of the content to be learned. A theoretical understanding of the principles of message construction in the visual mode (i.e., how to construct and sequence a visual message) becomes a necessary prerequisite for a professional educational technologist.

Recent studies of cognitive information processing have investigated the phenomenon of lateral, hemispheric specialization. This evidence suggests that the human brain develops a bilateral, functional specialization for processing information. Generally, this specialization is manifested in physiological activity in the left hemisphere when the information to be processed is verbal. Conversely, the right hemisphere is primarily involved when the information is visual.

Several researchers (Krashen, 1977; Bogen, 1977; Levy, 1969; Semmes, 1968; Gazzaniga, 1967; and Kimura, 1966) have investigated various features of the laterality phenomenon. However, there is a need for studies focused on the learning relationships involved with this cognitive processing human trait. Wittrock and Lumsdaine (1977) write:

> Since Roger Sperry's early papers on the lateralization processes of the human brain, only a few studies have elaborated or explored some of the implications of the research for the improvement of instruction. (p. 435)

Importance

The importance of pictures in education has been an article of faith among educational technologists since the first publication of Orbus Pictus in 1658. Attempts to establish a scientific foundation to the use of visual materials in learning did not have a great deal of success in the past. The lack of this success has hampered the increased use of visual materials in the formal educational institutions. Part of the reason for the lack of success has been the use of a behavioral learning model which is based on animal learning in a time-organized manner. Almost all of the learning models associated with testing visuals in the learning process have been time-organized as implied by associationism, S-R learning models, etc. Cybernetic feedback research on the other hand has accumulated a considerable body of evidence showing that somatic response is controlled by detection of spatial differences in stimulus patterns and that temporal organization in behavior is derived from its continuous spatial patterning. Recent neurological studies and the new neurological viewpoint of lateral hemispheric specialization indicate that the two hemispheres are specialized, one for temporal event processing but the other for visual-spatial information processing. This new viewpoint of neural activities seems thus to indicate a way of breaking away from a temporally oriented learning theory and establishing a clearly distinctive configurational learning theory based upon solid neurological evidence. Visual learning processes are a proper sub part of this theoretical base rather than a part of connectional or functional learning theories.

The present study is important for the field of instructional technology since it is aimed at the need for increased knowledge of the lateralization function as a learning variable. This experiment was designed to test whether the information processing associated with observing and learning visual stimuli (in the form of pictures of faces) involves a difference, by hemisphere, in electrical activity. The development and use of experimental procedures for the present study should be helpful to future research efforts in this area. For example, the use of the tachistoscope (t-scope) as an experimental control for such variables as lateral eye movement, length of viewing and other extraneous variables, is posed as an effective research tool for those interested in visual studies.

Specifically, the use of optical controls in the form of the tachistoscope provide greater experimental control as compared to the conventional technologies such as a slide projector and screen presentations of visual stimuli. The use of two or three channel tachistoscopes could be useful in measuring the effectiveness and lateral information processing differences with multi-screen viewing, for example.

The use of EEG technology in collecting data associated with internal, cognitive processing of visual information is seen as an important feature of the current study. Although the EEG has been primarily useful for clinical diagnosis, Ornstein and Galin (1972) demonstrated the usefulness of EEG data collection as a valid indication of information processing in normal humans. Using the alpha brain wave pattern as an indication that one hemisphere was in a "resting or monitoring state", the investigators were able to infer that the alternate hemisphere was processing the information associated with the stimulus treatment. The increased availability and relatively reduced cost of this technology offer experimenters the capability of gathering data about internal processing functions such as covert, sub-verbal responses which would be impossible to measure as an observed behavior. This is posed as being important for future study of cognition as it relates to learning and instruction.

Finally, the development of research competency in this area of cognition is seen as important to gathering data and furthering the possibility of instructional applications of knowledge about lateral, hemispheric specialization in learners. This experiment was a "first approximation" in investigating this phenomenon of laterality. Two other experiments by other researchers were conducted concurrently with this study (Awbrey, Shaffer, 1979). One attempted to investigate the characteristics of the stimulus in the dimension of boundary complexity. The second experiment measured information processing associated with viewing displays of real objects with diagrams and print labels.

A number of writers from the field are already calling for instructional applications targeting the laterality function (Grady, 1977; Sullivan, 1978; and Nord, 1979). The current study has presented one experimental approach to measuring information processing associated with this psychological phenomenon.

Facial Recognition

The importance of understanding how humans process information contained in pictures of human faces has wide social implications. The child who is able to visually recognize people is far less likely to have difficulty in discriminating "friends" from potential dangerous "strangers". The adult who has developed this skill has an increased probability of surviving the social milieu where it is often very important as to "who you know". A number of persons have developed training programs to improve people's ability to learn and remember faces (Lorayne, 1978). Police investigations involving the discrimination of suspects from the population are usually more successful where the victim or informant has developed a memory for faces.

One question posed by this research bears on the issue of memory for faces. The research question was asked, "Is there a reduction in alpha activity in the right hemisphere when a test face stimulus is the same as the memorized face?" A positive answer to this question may be supportive of the notion that recently stored information contained in pictures of faces may be a memory function of the right hemisphere. A number of studies (Warrington and James, 1967; Jones, 1969) have suggested that the right hemisphere may play an important role in the transfer of visual information from short term to long term memory. If short term memory of visual information is considered important to learning, then evidence that this phase of memory is a right hemisphere function may increase our general understanding of learning.

In summary, if a picture of a human face can be characterized as a meaningful, complex pattern of information, and that this visual, iconic pattern is more efficiently processed and stored in the right hemisphere of normal humans, it should follow that applications of this knowledge can be made. For example, instructional sequencing of pictures and words may be designed to use this human characteristic to enhance the cognition and learning of new patterns and concepts.

Limitations of the Study

In this experiment the focus was on the collection of data relevant to the dependent variable of information processing. In this case information processing was operationally defined in terms of electrical brain wave activity. Moreover, since a manual or verbal response mode was deemed incompatible with the research design, the present study is not an investigation of behavioral response differences between the two hemispheres on a facial recognition task. A previous study by Geffen, et al. (1971) found that subjects who were presented a facial recognition task via a tachistoscope stimulus to the left visual field (i.e., the right hemisphere) produced more rapid response times when the test face was either the same as or different than the memorized face. The current study followed the guidelines of the Geffen, et al. study in terms of the stimulus materials and presentation procedures but collected brain wave data via an EEG recording system.

Another limitation of the research design is that the Bett's QMI short form test of imaging ability was not used as a sampling criteria nor as a control for experimental treatment between subjects. All subjects received the same, randomized sequence of facial recognition test items. Therefore, it should be noted that the comparisons between high and medium imager groups was necessarily a post hoc analysis. This limitation holds true for other demographic information collected from subjects but not used as either a selection criterion nor as an experimental control.

Explanation of Important Terms

Alpha Power: This term refers to the amount of the total, original wave form which is contributed by the alpha spectrum.

Alpha Wave Patterns: Measured electrically by a clinical electroencephalogram (EEG), the alpha brain wave is characteristic of a "resting state" in either hemisphere of the cerebral cortex. It is inferred that the presence of alpha patterns in one hemisphere, when the other is stimulated, is evidence that the opposite hemisphere is the primary site of information processing.

Alpha Spectrum: In the analysis of brain wave activity it is useful to break the complex wave form into its component frequencies. In the case of the alpha frequency spectrum, this is usually defined as 8-14 hz.

Cerebral Cortex: Embryologically, the most recently developed part of the human brain, this structure is the surface of the brain. Physically, it is greyish in color and has characteristically convoluted surface tissues. The cerebral cortex is functionally specialized for higher cognitive functions in humans. It is divided into two nearly symmetrical hemispheres and is connected by a bundle of nerve cells called the corpus callosum.

Corpus Callosum: As described above, this structure connects the two hemispheres of the cerebral cortex in humans. It is associated with the cross-over or transfer of information between the two hemispheres in cognitive tasks requiring interaction between the two sides (see Figure 1).

Epoch: A period of time during which the dependent variable is observed. In this research it is defined as the two seconds immediately following presentation of the test stimulus.

Fourier Transform: A method of frequency analysis in which a complex waveform (such as an EEG recording) is separated into a number of components that are harmonically related, beginning with the fundamental which has a period equal to the sample length. This analysis technique allows some comparisons of the frequency components of wave forms between two channels. In this research, those channels might be, for example, P3 and P4, (parietal left and parietal right).

Hemisphere: The cerebral cortex of the human brain, generally recognized as the brain structure involved with higher order mental activities and cognition, is divided into

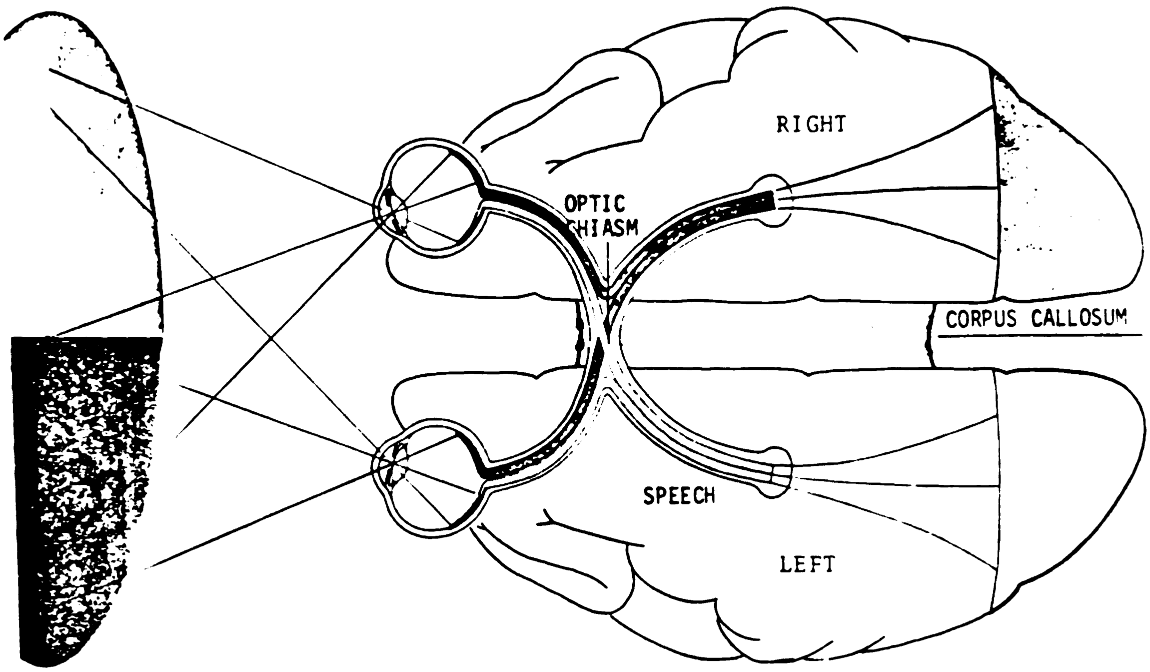


Figure 1. Human Eye-Brain Connection

nearly symmetrical hemispheres. In normal humans the hemispheres are connected at the surface by a structure called the corpus callosum (see Figure 1).

Imagery: This is defined as the internal stimulation or reconstruction of a sensory concept.

Optic Chiasma: The optic nerve structure which connects the eyes to the visual cortex of the brain. It is anatomically crossed over, so that visual information from both eyes is conveyed to both hemispheres of the cerebral cortex (see Figure 1).

Tachistoscope (t-scope): A device generally used in psychological and perceptual research, a t-scope uses a light box and mirror system to present visual stimuli to an individual subject. Typically, t-scopes have a timing system which allows very precise control of the duration of the stimulus.

Assumptions and Rationale

Some basic assumptions which support the thinking behind this research are stated in this section. Perhaps most fundamental of these is the assertion that human cognition associated with perception is a process which is "knowable". As such, this process of cognition represents a system which is a legitimate area for research and scientific study. This assertion should not be construed to deny a spiritual component of the human being, but rather to distinguish this set of mental events from those of a metaphysical set of concerns. Therefore, assuming the process under study to be a physical reality, it follows that it should be feasible to measure cognition either directly or indirectly.

Closely related to the first assumption is the posing of "human information processing" as a model for investigating human cognition. According to this model, human beings abstract information from their environment in a complex system of processing steps. The precise characteristics of each step are not completely known. However, this model has been basic and useful to the development of this research effort.

A third assumption is considering that the electrical activity measureable at the scalp of a human being is directly or indirectly related to the physical events of information processing. There exist more precise, micro-level measurement devices, such as micro-electrodes measuring evoked potentials at the cellular level in the brain. However, the constraints of working with volunteer human subjects precluded this technology's application in the present study. Although the EEG data collection method represents a relatively gross "average" of several thousand neural cells firing per site, it may represent a more valid measure of information processing than is generally available to the educational researcher.

The rational assessment of these assumptions is considered critical to the understanding of the results of the present study. Moreover, it is hoped that further theory construction and refinement will be facilitated by this research effort.

Hypotheses

Based on the assumptions and purposes of this research, the following null hypotheses were posed. The dependent variable is alpha activity as measured by alpha spectrum.

1. There will be no difference between left and right hemispheric alpha activity when test faces are presented in left, right, or central visual fields.

2. There will be no significant difference between left and right hemispheric alpha activity when test faces in comparison with the memory face are the same as or different than the memory face.

3. There will be no significant difference between left and right hemispheric alpha activity when faces are presented in the left, right, or central visual field, or when in comparison with the memory face, test faces are the same as or different than the memory face.

4. There will be no significant relationship between alpha power and the Bett's QMI scores (medium and high imagers).

The tests of these hypotheses provide empirical evidence for further understanding of the phenomenon of lateral, hemispheric specialization as investigated in this study. Based on these findings, it is anticipated that further investigation of possible instructional applications will be facilitated and justified.

CHAPTER II

REVIEW OF THE LITERATURE

Overview

In reviewing the scholarly literature for the present study, four topical areas related most meaningfully with the research variables of interest. Therefore, in discussing the literature, the review will be arranged in four sections: 1) the use of visual stimulus in instruction, 2) relationship of visualization to learning, 3) functions of the human brain, and 4) facial recognition as a human learning variable.

Section one reviews the history of the theory and application of visual stimulus in instruction. Section two relates some experimental studies which have investigated the attributes of visual stimulus and their relationships with learning. Section three describes the physiology, hemispheric functions, the concept of hemisphericity, and other cerebral functions of the brain which relate to the processing of visual information. Section four reviews the theoretical and empirical literature regarding the psychological and physiological variables of learning and memory of human faces.

Section One

Use of Visual Stimulus in Instruction

The use of visual stimuli to enhance learning has long been a concern of educational technology. Perhaps the first "visual aid" textbook was published by Johann Comenius in 1658 entitled Orbus Pictus. Near the turn of the century, in 1907, films were used in instruction. A film catalog was published by Kleine in 1910. Saetler points out that the use of visual instructional methods were enhanced by the development of the instructional film. He writes, "Although the term visual instruction was used since the beginning of the century to refer to a variety of visual instructional media, it is not surprising that the instructional film intensified its use and provided a great impetus to the audiovisual instruction movement in American Education" (Saetler, 1968).

As visual instructional technologies began to be applied in the schools, visual instructional organizations began to appear. In 1919, the National Academy for Visual Instruction was formed and the American Educational Motion Picture Association was organized. These were followed in succession by The National Academy of Visual Instruction (1920), Visual Instruction of America (1922), and The National Education Association Department of Visual Instruction (1922). A teacher training course in visual instruction was offered at the University of Minnesota in 1918.

The application of visualization to instruction was advanced to a great measure by industrial and military training applications during World War II. Research in the areas of effectiveness of pictorial instructional techniques began to be more sophisticated as described in May (1958). The Yale Motion Picture Research Project produced a significant number of studies of learning effects achieved with visual instruction.

Beginning in mid-century, a transitional period began in visual education. Television, multi-media presentations, and computers began to be used. This era was different from previous visual educational approaches in more than just the number of new media hardware. The philosophy of education of the new period shifted from viewing visual methods as isolated, novel "aids" used at the whim of the teacher to their use as part of an integrated instructional system. Research, based on psychological principles, increased understanding of the effectiveness of the various visual instructional strategies. These instructional strategies began to be considered as valid, important research areas in their own right.

Hovland, Lumsdaine, and Sheffield (1949) designed a slide film teaching the phonetic alphabet in a "plain" and "fancy" version. The basic program merely presented the concepts in alphabetic verbal format without pictures or music. The "embellished" versions had music and humorous cartoons. Learning actually was less in the version which had the unessential added information. This suggests a design principle of using presentation modalities which convey information relevant to the objectives of the visual program.

Schulz and Kasschau (1966) and Schulz and Hopkins (1968) found that pictorial presentations were superior to auditory-verbal modes when the information presented was of low to moderate meaningfulness. This suggests that visual presentations may be of use as "advance organizers" when information is novel to the learner.

Lumsdaine (1963) also studied the effect of pictures as associative cues as compared with printed words. Four possible combinations of association learning were investigated: picture-picture, picture-word, word-picture, and word-word. Lumsdaine (1963) reports the findings (which have since been replicated in a number of settings):

> The results showed rather conclusively that the use of pictures to represent the first object of the pair was better than verbal presentation, but that verbal presentation (printed words) was definitely superior to pictorial presentation for the <u>second</u> "response" term of the pair. This was true for both college and grade school learners, for brighter learners as well as slower ones, and held regardless of the number of systematic variations in conditions of presentation. (p. 636).

More recently, Allen (1967) found that pictorial illustrations increased learning when embedded in printed, programmed instruction, but only when the referent to the content was of a "concrete" (e.g., an object) nature.

It may be argued that the long history of use of visual methods in education and a continued commitment to make the most appropriate application of these techniques might be best served by furthering our understanding of how visual information is processed by the learner. Further, the application of this increased knowledge might afford a more solid foundation for future design principles in the production and use of visualized instruction. Levie and Dickie (1973) in their overview of the field (from the Second Handbook of Research on Teaching) make the following recommendations:

> If improved theory is to be a goal of research, independent variables must relate to the constructs which are central to the theory--in this case, the implicit human processes which mediate instructional stimuli and learning outcomes.
>
> Understanding media may be furthered by 1) specifying media in terms of attributes, 2) defining these attributes in terms which relate to the ways in which information is processed internally, and 3) discovering relationships between these attributes and other important instructional variables. (p. 877).

Section Two

Relationships of Visualization to Learning

Research is needed which relates media attributes to the internal processing of information. However, researchers have attempted to specify media attributes and to relate these attributes to other instructional variables.

Investigations based on the Travers (1967) model of human information processing have been conducted to study the relationship between single versus two-channel presentation modes (i.e., visual versus visual plus auditory presentation of the stimulus). This model proposes that only one piece of information can be processed by the individual at any given instant. It was subsequently modified to include a secondary processing system which theoretically can hold additional information for brief periods pending the release of the first system from its processing task. In other words, as the information load of the main system is reduced, the short-term memory system may transfer information to be processed sequentially by the main memory system.

In processing redundant information in stimulus sets, Van Mondfrans and Travers (1964) found that subjects showed no differences in recall scores when presented common words with vision and audition simultaneously versus vision and/or audition presentation alone. They conclude that when the information is redundant the use of two channel presentations is no more effective than one channel. When the information presented in the visual channel is pictorial (rather than word stimuli) it may be advantageous to present stimuli in two channels simultaneously. Van Mondfrans and Travers (1965) found that the simultaneous presentations of pictures of geometric figures with associated names was more efficient than sequential presentation in terms of recall scores.

Levie and Dickie (1973) in their literature review, speculate that if the channels of an audio-visual presentation present different stimulus the subject may be required to shift attention back and forth between stimulus channels. They suggest that interference may be a problem when presentation rate and content is high. Research which investigates the information processing functions of the learner are needed to clarify the relationship between multi-channel presentation of stimuli.

During the past decade, several studies have investigated the stimulus characteristics of visual, pictorial media. Wicker (1970) investigated differences between the use of photographs and line drawings in paired-associate learning. He found no differences. Also concerned with the amount of visual detail in pictorial presentations, Travers (1969) found that the addition of shadow detail in outline drawings increased recognition scores of subjects viewing pictures via a tachistoscope. It appears that in this study the added information was facilitative in the recognition task.

Dwyer (1970) found that in comparing a variety of visual presentation modes (i.e., simple versus complex line drawings, photographs, color versus black and white images, models, etc.), that when the presentation was fixed (as with slides or television) pictorials with less information were more effective. However, when the subject controlled the presentation rate (as in programmed texts) visual stimulus which were more complex tended to result in more learning.

Recent attention has been again focused on the characteristic of the pictorial stimulus. Borg and Schuller (1979) with comparisons of relative effectiveness of simple versus complex drawings of military equipment, found that the use of complex drawings did not significantly increase the learning of the soldiers of the material in training manuals. They conclude that perhaps less effort should be extended in the development of "realistic" visual stimuli in training materials.

In apparent contrast with the Borg and Schuller findings, Myatt and Carter (1979) found that children and young adults (K-11) do not prefer simple art drawings, but rather choose photographs first and realistic drawings second. They recommend further studies investigating the interaction between viewer preference and learning styles.

Recent investigations have continued to use an information processing model to study recognition of visual presentation of verbal and non-verbal material. Levie and Levie (in Orwig, 1979) used a method of "shadowing" (using verbal distraction to create "noise" while subjects process information) to investigate whether verbal interference affected verbal processing more than visual information processing. They found that the use of verbal shadowing had almost no effect on the recognition of memory pictures while the memory for words was significantly reduced. They were concerned, however, that there may have been a "ceiling effect" in which the pictures were too easy to remember for the verbal shadowing to have an observable effect.

To further investigate this, Orwig (1979) developed a study which investigated recognition using pictures which were more difficult to discriminate between since they were designed with inter-stimulus similarity. In this set of experiments, even in trials where the recognition task for pictures was rendered more difficult due to the similarity of distractors, the verbal shadowing had no significant effect of interfering with the visual information processing of the pictures. The author concludes that these results tend to support a dual-encoding model for memory.

In studying the cues that subjects use to recognize pictures of human faces, Harmon (1973) programmed a computer to mask or systematically degrade the picture stimuli. By designing stimuli thusly, with carefully controlled "noise" distractors, he investigated how people recognize or reconstruct the facial stimulus. In his series of studies he found that of all the numerous possible facial characteristics people could use to recognize a face, twenty-one features are most commonly used. These features include for example, lip thickness, chin profile, ear size, etc. In describing some of the general findings of the studies he writes:

> It is as though the mind's eye superimposes additional detail on the course optical image. Moreover, once a face is perceived, it becomes difficult not to see it, as if some kind of perceptual hysteresis prevented the image from once again dissolving into an abstract pattern of squares. (pp. 74-76).

Standing, Comezio, and Haber (1970) have investigated the limits of the capacity of the memory for pictorial information. Subjects were presented with 2,560 photographs of real objects and scenes. After several sessions over a period of several days of showing pictures every ten seconds, it was found that subjects could recognize between 85 and 95 percent of the stimulus pictures. This relatively large capacity for storage of visual information led them to consider a dual-information processing system as a model for human memory.

From this section of the literature review, it is apparent that research has developed to investigate more than main effects of the use of visual information in learning and memory studies. Interest has been generated in recent years with testing how subjects process visual stimuli. The specific characteristics of the visual stimuli have become an empirical focus, with increased theoretical work attempting to understand how these characteristics influence the way information is processed. In the following section, literature will be reviewed which describes functions of the human brain and their relationship with information processing.

Section Three

Functions of the Human Brain

This section of the literature review discusses functions of the human brain relevant to those variables of concern in the present study. Background anatomical and physiological descriptions will be followed by explanations of "hemispheric functions", research involving the so-called "split brain" patients, studies of "normal" subjects' hemispheric functions, discussions of the concepts of "hemisphericity" and "imagery" as related to the brain's functions.

Anatomically, the human brain is a nearly symmetrical organ weighing three or more pounds in an adult. Its outer surface, called the cerebral cortex, is convoluted in texture and contains several billion neurons or brain cells. The young adult has approximately twelve billion neurons which are non-regenerative (i.e., they are not replaced during subsequent years). Moreover, it has been found that unexcited neurons (i.e., those not stimulated in cognition) undergo degenerative changes (Burns, 1958). Normal adults lose about 100,000 of their neurons per day (Guilford, 1967). It can be argued that these losses may possibly be attenuated by learning activities and cognitive exercising of the brain.

The cortex is further divided into two lateral hemispheres, left and right. These hemispheres are connected by a fibrous nerve bundle called the corpus callosum which functions as a coordinative and transfer component between the two hemispheres. The two hemispheres are further divided into four "lobes" called the frontal, parietal, temporal and occipital. These lobes have been shown to be differentiated for sensory-motor functions, musculature and associational activities. The former are believed to be important in the information processing involved with higher cognitive functions.

The cerebral cortex portion of the brain is one of the major structures of the "forebrain". Major differences across phylogeny are most apparent in the forebrain's structures. Another important structure of the forebrain is the thalmus which is involved with the processing of and relay of visual information to the cortex. Other parts of the forebrain are a set of structures called the limbic system. This system includes the amygdala, hippocamus, and the septum. Specific functions of the limbic system are still being investigated, but they appear to be linked to memory, the inhibition of behavior, and the ability to track objects in environmental space.

Hemispheric Functions

Although nearly symmetrical, the hemispheres of the cortex have been demonstrated to be highly specialized in their functions. Psychologists have long discussed the apparent "dichotomies" of mental organization. Speculative terms such as rational versus intuitive, realistic versus impulsive, analytic versus gestalt, successive versus simultaneous, objective versus subjective, and so forth, have been used to highlight these apparent dichotomies in cognitive modalities. For a full discussion of these ideas the reader is directed to Bogen (1969). Although these descriptions of "cognitive style" have been used in a number of different contexts, there seems to be a common thread in the origins of these polar descriptions of human thought.

During the last century investigations of the brain's physiology advanced the speculation that the apparent dichotomies may stem from the differences between the two hemispheres. Hughlings Jackson in 1864 raised the possibility that "expression" resided in one hemisphere, whereas "perception" was the domain of the other. At the same time a theory was developed which posed that the left hemisphere, the center for speech and language, was the dominant hemisphere for information processing. Subsequent to this time, physiologists were concerned primarily in studying localization of left hemisphere functions and hence rational and analytic cognitive modes.

This theoretical position was prominent until the 1940's when multi-factorial theories of human intelligence were proposed. This development led to the conceptual shift: "the subsequent replacement of the concept of hemispheric dominance by one of hemispheric specialization" (Nebes, 1977). In other words, instead of describing the hemispheres as "dominant" or "minor" both were presumed to have specific functions which tended to be particular to each. It remained to be shown precisely what those special functions were.

Investigations of patients with various physical and psychological deficits resulting from disease or trauma to the brain have been helpful in furthering knowledge of the hemispheric functions. Firstly, these studies have supported the idea that each hemisphere is specialized. Secondly, studies of specific deficits by hemisphere have given investigators a better picture of what the different functions are.

Reitan (1958) reported a loss in spatial orientation in patients with right hemisphere damage. Shure and Halstead (1958) reported verbal-logical deficiencies in left-hemisphere damaged patients. Fitzhugh, Fitzhugh, and Reitan (1962) found lowered verbal ability in persons with left hemisphere lesions. Zangwill (1960) also attributed defects in abstractions regarding visual objects to right hemisphere damage. Verbal difficulties were incurred by patients with left hemisphere, temporal lobe damage.

Although these case studies provided strong support for the theory that the cerebral hemispheres are specialized for different cognitive functions, the so-called "split-brain" research of the past decade has perhaps spurred the most interest in this area of neural research. In 1960, Dr. Joseph Bogen, of the Los Angeles Neurological Society, proposed surgical sectioning of the corpus callosum to halt the spread of epilepsy from one side of the brain to the other in patients suffering from this disease. The corpus callosum is the major commisure joining the cerebral hemispheres and is thought to be the channel across the hemispheres by which the disease is spread.

Experiments of R. W. Sperry and M. S. Gazzaniga (Gazzaniga, Bogen and Sperry, 1965) provided a number of psychological tests to Bogen's patients following the commisurotomy (Gassaniga, 1977). No dramatic changes were discovered in the patients' temperaments, personalities, or general intelligence. Repeated tests did show that the right hemisphere was "completely divorced" in perception and knowledge from the left after the operation (Gazzaniga, 1973). Each hemisphere was functioning as if it were a separate brain. In follow-up tests Gazzaniga found that the main difference between hemispheres appeared to be that the left hemisphere in most individuals is specialized in verbal abilities. The right tends to be more adept at visual-spatial performance.

Gazzaniga describes one visual experiment in which the patient is shown moving lights in the right visual field only. When asked to verbally report what he saw, the patient could not. However, when asked to respond to the lights in a psychomotor mode (i.e., press a button with the left hand) the patient had no difficulty. Gazzaniga concludes that the verbal report, requiring information to be processed in speech centers of the left hemisphere, was difficult because the information about the lights remained exclusively on the right side. The motor.response, controlled by the same hemispheres which received the visual information, however, presented no difficulty for the patient.

In a collaborative study with Trevarthen and Sperry (Levy, Trevarthen, and Sperry, 1972) a number of visual tests were performed by commisurotomy patients. In one, a facial recognition test, chimeric stimuli (i.e., faces which were split-half composite faces made up from two different photographs of people) were projected to the patients who then were asked to choose the face they had seen from a number of alternatives. The chimeric stimuli had presented one half a face to the right hemisphere and a different half to the left. When asked to point to the face they had seen, the large majority responded by selecting the face seen by the right hemisphere. This supports the theory that facial recognition may be one of the special functions of the right hemisphere.

To provide evidence which is generalizable to the larger population of human beings, research with "normal" persons (i.e., those without brain damage, neural disfunctions or commisurotomies) was needed to study hemispheric specialization. A review of this literature reveals that this type of research also supports the theory that the cerebral hemispheres are specialized.

Kinsbourne and Cooke (1971) performed an experiment in which subjects were asked to balance a wooden dowel on their right and left index fingers alternately. After establishing a baseline for balancing performance, the subjects were asked to simultaneously balance the dowel and perform a verbal task. The addition of the verbal task yielded shorter balancing times for the right hand but longer ones for the left. Because the right hemisphere controls the left hand and the left hemisphere the right hand, the balancing discrepancy could be explained as an interference function. The processing of verbal information, predominantly a left hemisphere function, probably interfered with the balancing performance of the right hand.

In an earlier experiment, Doreen Kimura (1966) used a tachistoscope to control the visual fields of "normal" persons and investigated the relationships between the hemisphere's processing of visual information presented in the two fields. She found that letters of the alphabet were more accurately identified when flashed to the right visual field, i.e., left hemisphere, than the left. Nonverbal forms and dots were more efficiently identified when flashed to the left visual field.

Galin and Ornstein (1972) used an electroencephalograph (EEG) to measure the differential of information processing between the two hemispheres of normal people. The subjects engaged in a number of verbal and non-verbal tasks requiring only manual or thinking responses. The tasks included composing a letter, writing a letter, mentally constructing shapes from paper forms, and manually constructing patterns with colored blocks. EEG's were recorded and alpha wave ratios of the two hemispheres were compared. Alpha waves are indicative of the resting mode, therefore the hemisphere with the higher alpha output is less likely engaged in the task. Accordingly, the non-verbal, visual-spatial tasks were found to engage primarily the right hemisphere. The verbal and constructive tasks generally engaged the left hemisphere. These findings again tend to support the lateral specialization concept.

Trevarthen and Sperry (1973) tested the ability of the two hemispheres to separately perceive and respond to stimulus patterns and exercise control of motor functions. Their results indicated that "a distinct deficiency in basic pattern apprehension" exists in the language hemisphere. More notably, they found that when the task could be performed by either hemisphere distinctively different strategies were used by each to carry out the task. Levy (1969) in an earlier study refers to research by Levy, Agresti and Sperry (1968) in which each hemisphere was tested for its ability to visualize in three dimensions. Levy states that this research indicated that "while the left hemisphere seemed to analyze the stimulus properties, the right hemisphere seemed immediately to abstract the stimulus gestalt..." "Thus each hemisphere used a different strategy in solving the problems".

Josephine Semmes (1968) has also found two contrasting modes of neural organization which provide a clue to the duality of the hemispheric specialization. She theorizes that focal representation of elementary functions in the left hemisphere favors specialization for fine sensorimotor control such as that needed in speech. Her study indicates a diffuse representation of elementary functions in the right hemisphere. Therefore, specialization requiring multimodal coordination, such as in spatial ability, is favored in that side.

The preceding pages have reviewed a number of studies which have investigated the differences in the two hemispheres' abilities and capacities for handling information. Evidence has been shown which indicates that the right hemisphere is specialized for handling visual-spatial information and the left hemisphere tends to specialize for verbal, sequential, and symbolic information. Additionally, there is evidence which indicates that the modality of the two hemispheres is different in selecting, storing and retrieving information. This appears to support Paivio's (1971) contention that information processing in humans is conducted by two separate, but integrated systems.

As the evidence has accrued that the hemispheres are neither "dominant" nor "minor" the concept of specialization of function has gained scientific support. The more recent literature reflects a refinement of the specialization concept.

Hemisphericity

The duality of mental organization, demonstrated by evidence from lateral specialization studies, may lead to "hemisphericity". This is a term used by Bogen, Tenhouten, and March (Krashen, 1977) to describe the tendency of individuals to appeal to one hemisphere and its mode of information processing more than the alternate hemisphere.

Research has investigated indicators of this tendency of hemisphericity. Handedness has been studied in this regard. Harris (1975) has described the general American population as 90-98 percent right handed. Approximately 99 percent have language functions represented in the left hemisphere. Only 53 to 65 percent of left-handed people, according to Harris, have left-hemisphere language laterality. Harris concludes that left-handed persons are less well lateralized for language functions.

The direction of a person's gaze while contemplating a problem has also been explored as a possible indicator of hemisphericity. The human visual field has crossed connection to the hemispheres. However, the left eye is not simply connected to the right hemisphere. The left half of the visual field from both eyes is connected to the right hemisphere. The right half of the visual fields is connected to the left (see Figure 1).

Kinsbourne (1974) has found that while engaged in verbal thought subjects look to the right whereas during spatial thought they look up and to the left. This effect can be disrupted by central fixation and the visual or auditory presence of the experimenter. Kinsbourne concludes that "if proper precautions are taken in these respects, the phenomena is a useful index of cerebral lateralization of cognitive function".

Harris (1975) found that when facing the questioner subjects moved their eyes in predominantly one direction regardless of the type of question. When not facing the questioner, right-handed subjects moved their eyes left when solving spatial problems and right for verbal problems.

The EEG has also been employed in an attempt to find an indicator of task specific hemispheric functioning. Using evoked potentials on the EEG, Buchsbaum and Fedio found that verbal and nonsense stimuli produced differences in evoked waveforms for both hemispheres with greater differences evident in left hemisphere tracings.

Doyle, Ornstein, and Galin (1974) conducted experiments in which subjects performed verbal, arithmetic, and spatial tasks. They again found that the hemisphere engaged in the cognitive activity develops proportionately less alpha activity.

Imagery

One ability that has been used as an indicator of "hemisphericity" is the production of imagery within the mind. Imagery is defined as the ability to internally stimulate or regenerate sensory constructs such as a visual scene. Imagery has been associated with right hemisphere processes.

The concept of mental imagery has experienced both high and low periods of interest in educational and psychological study (Holt, 1964; Paivio, 1971). There is currently a resurgence of interest in the concept as Paivio notes: "...it is not surprising that we find the concept of imagery reappearing essentially in its pristine form but with its respectability enhanced by a behavioristic cloak. On the basis of results from experimental investigation involving a classical conditioning paradigm, Leuba (1940) felt justified in referring to images as conditioned sensations".

D. O. Hebb has distinguished various types of imagery based on locus of arousal. Memory imagery, he posits, is aroused centrally. Hebb believes this accounts for its lack of detail. However, eidetic images involve the first order cell assemblies that are characteristic of perception. Thus, according to Hebb, eidetic images would appear in detail (Hebb, 1968).

Other researchers have similarly suggested that the activation of cell assemblies or neural patterns are the basis of imagery (Bruner, 1957; Pribram, 1960; Taylor, 1962; Tomkins, 1962, all in Paivio, 1971).

Paivio relates Sheehan's (1966) findings that the accuracy of visual memory is related to individual differences in imaging ability. Sheehan reports that low imagers are more dependent on (verbal) symbolic coding and use coding devices to organize their perceptions while vivid imagers perceive directly and literally.

DiVesta (1971) studied the interaction of imagery-ability and instructional procedures. He conducted a series of seven studies attempting to link imagery ability to stimulus aspects and learner information processes. Some of his findings include: imaginal processing is more effective for the processing of concrete words while the verbal mode is more effective for processing abstract words; self reports of imaging are strongly related to social desirability; and Paivio's model of associative learning is also supported.

Summary

With the advent of studies on lateral specialization and hemisphericity, it has become increasingly apparent that the right hemisphere is specialized for visual-spatial information and the left is more facile in processing sequential verbal information. In problem solving these two modalities appear to combine to produce an integrated solution.

However, the fostering of growth in the right hemisphere functions has largely been ignored in American education. Emphasis has been placed on the linear processing functions of the left hemisphere (Nebes, 1977; Bogen, 1977; Crinella, 1971; Sullivan, 1978). In view of the literature reviewed here, it would appear that this country's educational system fosters hemisphericity with a left hemisphere bias.

A number of researchers hold that a more balanced development of the hemispheres is an important goal of human education (Bogen, 1977; Nebes, 1977; Rennels, 1976). However, the phenomena of lateral specialization and hemisphericity as learner variables have been relatively unresearched in learning experiments. The need for studies investigating the capacities of the right hemisphere is perhaps best stated by Bogen (1977) when he writes about the dangers of "teaching only half a brain":

> Since education is effective only insofar as it affects the working of the brain, we can see that an elementary school program narrowly restricted to reading, writing and arithmetic will educate mainly one hemisphere, leaving half of an individual's high-level potential unschooled.

Section Four

Facial Recognition

This section of the review of literature summarizes a number of studies which have investigated the perception and recognition of human faces as tasks which evidence suggests are a hemispherically specialized function of the right hemisphere of the cortex. A number of these studies use a design which is modelled after an information processing approach. The experimental designs generally investigate a manual or verbal response as the dependent variable of facial recognition rather than EEG data.

DeRenzi and Spinnler (1966), in an experimental design, investigated the relationship of unilateral cortical lesions with performance on a facial recognition test which tested ability to match a recently learned memory face (i.e., a "previously unknown face from immediate memory"). They found that the group with right hemispheric lesions did significantly poorer than the group with left hemispheric lesions. Moreover, this reduced performance correlated positively with recognition of abstract designs from "immediate memory in each group". They concluded that the basic impairment was "an impairment of subtle discrimination and integration of visuo-perceptive data...." (p. 151).

Warrington and James (1967) tested the hypothesis that the right hemisphere is the primary cerebral site involved with facial recognition tasks. The authors distinguished between the recognition of familiar faces and those recently learned. They tested patients with unilateral, temporal and parietal lesions using facial images of famous people and recently learned (within the time frame of the experiment), previously unknown faces, as stimuli. The recognition errors of the patients with right hemispheric lesions significantly exceeded those of the left hemispheric groups in response to both stimulus modes. Correlations between the two recognition tasks, however, were not significant. This indicated to the authors that the two tasks may be separate cerebral functions. Additionally, correlations between the within-the-hemisphere groups (i.e., temporal or parietal, see Figure 1) did not achieve a level of significance. This suggests that recently learned faces may be stored differently from the memory for faces which have been known (and memorized) for a long time. The authors conclude that:

> There may be a long term memory 'store' for visual data within the right hemisphere which is separately organized for processing or integration of perceptual data which is necessary for recognition of drawings and immediate memory for faces. (p. 326).

In quite a different methodological approach, H. P. and P. O. Bahrick and R. P. Wittlinger (1975) studied nearly four hundred subjects' abilities to identify and match names and faces with pictures from high school year books. Their methodology, testing memory of names and faces of a sample which ranged from two weeks to fifty-seven years since graduation, utilized multiple regression techniques to control the effects of "various conditions that influence original learning, such as class size and other conditions that influence rehearsal such as attendance at class reunions". Their findings, "that identification and matching of names and faces remain approximately ninety percent correct for at least fifteen years even for members of very large classes" is important for understanding the long-term memory function of this probably right hemisphere ability. Moreover, the interaction with the memory for names (a probably left hemisphere function) is also important. They found that "free recall of names is independent of class size and of recognition memory and declines with negative acceleration by sixty percent during forty-eight years". This study, though not as tightly controlled as an experimental design, has major implications for the development of a theory for short and long-term memory functions.

Jones (1969) in his discussion of the research in the area of facial recognition in relation to lateral hemispheric differences, points out that the majority of the early investigations dealt with patients who evidenced cerebral damage to one or the other, or both hemispheres. He writes:

> A number of recent studies (DeRenzi and Spinnler, 1966; Warrington and James, 1967; DeRenzi, Faglioni and Spinnler, 1968; Benton and Van Allen, 1968) have investigated facial recognition in patients with cerebral disease. Typically these studies have involved immediate memory (DeRenzi and Spinnler, 1966; Warrington and James, 1967), both immediate and delayed memory (DeRenzi, et al., 1968) or no demand on either immediate or delayed memory (Benton and Van Allen, 1968). Despite these differences in procedure, a number of consistent findings have emerged, the most salient of which has been the finding that patients with lesions of the right hemisphere perform significantly worse on these tasks than patients with lesions of the left hemisphere. (p. 290).

The results of his own study investigating the influence of mode of presentation on facial recognition task performance indicate that the correlation between a series of paired comparison tests and matching tests was significantly lower than the test-retest reliability of either of the tests. This suggests that the type of response task which is employed and the manner in which the visual information is presented is an important variable to investigate. Moreover, the author points out that visual search and stimulus complexity should be the variables of interest in future research.

The characteristics of the visual, facial stimulus was the dependent variable in a study by Gilbert and Bakan (1973). They investigated an earlier finding of Wolff (1933) that demonstrated that one side of the human face is perceived by others as a better visual identifier of the person than the other side of the face. Their study indicated that the effect is due to "asymetrical left-field perceptual bias rather than to qualities of the faces themselves" (p. 355). Using photographic reversal of human faces in a controlled experiment, the authors found that the majority of subjects used visual information from the left visual field to identify the target face from the right visual field. In their discussion they write:

> Visual field research leads to the conclusion that a more direct (non-commissural) information transfer is somehow more efficient; stimulus material carried via visual pathways directly to the hemisphere specialized for processing it is more clearly perceived than stimulus material which must be transferred from the opposite hemisphere. (p. 360).

Geffen, Bradshaw, and Wallace (1971) describe a comprehensive series of experiments measuring reaction time as a function of inter-hemispheric effects in subjects' response to verbal and non-verbal visual stimuli. Using a t-scope to control the visual field of presentation of various verbal and non-verbal stimulus (i.e., drawings of human faces), the authors measured the response time in a number of recognition tasks.

They summarize their findings:

> Response times were found to be sensitive to laterality differences in visual perception. Non-verbal stimuli, such as faces, were processed faster when presented in the left visual field. Conversely, stimuli which were verbally encoded and required an identificatory response were processed more quickly when presented in the right visual field. These differences could be due either to the time taken to cross from one cerebral hemisphere to the other or to asymetries between the hemispheres in their capacities to process verbal and non-verbal material or to both". (p. 415)

Their results indicate that lateral, hemispheric specialization, since they found it in a series of controlled experiments with normal human subjects, is generalizable to the larger population. However, as they indicate, the use of response time alone does not clarify whether the more important variable is trans-callosal information transfer time or differences in hemispheric capacities for processing information. One approach to assess this difference might be to utilize an EEG recording of the relative alpha wave activity involved with this facial recognition task rather than measure response time.

Summary

This section of the literature review has discussed the findings of a number of studies which relate facial recognition abilities as learning and memory variables to lateral hemispheric differences for information processing. As has been indicated, there is a need for research which relates this phenomenon to EEG correlates of cerebral activity. If the ability to memorize and recognize pictures of the human face can be characterized as the ability to memorize and recognize complex, but potentially meaningful patterns, then the demonstration that this is a right hemispheric specialized learning task should have some implications for instruction.

CHAPTER III

DESIGN OF THE STUDY

This chapter describes the research design of this study. Information is presented in the following sequence: 1) a statement of testable hypotheses, 2) the design matrix, 3) a description of the instruments and measures used to gather data from the sample, 4) analysis techniques, 5) description of the population and sampling procedures, and 6) a summary of the procedures.

Research Hypotheses

The following hypotheses have been developed to test the questions associated with the subject's information processing in terms of lateral hemispheric specialization while observing the thirty item facial recognition test. They are stated in the "null form" to facilitate the use of statistical tests of significance.

1. There will be no difference between left and right hemispheric alpha activity when test faces are presented in left, right, or central visual fields.

2. There will be no significant difference between left and right hemispheric alpha activity when test faces, in comparison with the memory face, are the same as or different than the memory face.

3. There will be no significant difference between left and right hemispheric alpha activity when faces are presented in the left, right, or central visual fields, or when in comparison with the memory face, test faces are the same as or different than the memory face.

4. There will be no significant correlation between alpha power and the Bett's scores (high and medium imagers).

The EEG data collected to test these hypotheses will be analyzed according to the procedures presented below.

Design Matrix

Figure 2 diagrams the research variables of interest in this experiment.

Stimulus Variables

CVF = Central Visual Field
LVF = Left Visual Field
RVF = Right Visual Field
Same and Different refer to a comparison with the memory face.

Dependent Variable: Alpha Power

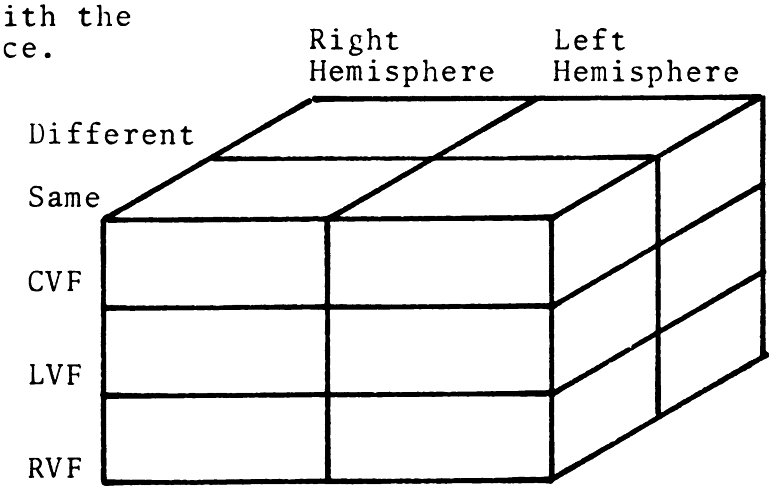


Figure 2. Design Matrix

Instruments and Measures Used

The Bett's QMI Vividness of Imagery Scale as described on page 66 consists of five questions for each of seven imagery modalities: visual, auditory, cutaneous, kinaesthetic, gustatory, olfactory, and organic. The subject marked a seven point scale from "no image at all" (7) to "perfectly clear and vivid" (1). A mean (e.g., 2.68 for visual) and standard deviation (e.g., 1.39 for visual) has been established for each modality as well as an overall mean for the test score. A subject's overall means were computed and used to differentiate high imagers from low imagers. This test has been demonstrated to be a useful and valid research instrument for the population of this investigation. Scores on this test were calculated and correlated with the EEG data collected during the facial recognition test. The test scores were used for a post-hoc comparison rather than as a control or selection procedure. A copy of the short form is included as Appendix A.

The EEG is a recording of the generally rhythmic fluctuations of electrical potential which occur in the brain. The origin and function of these "brain waves" is not completely understood by neurological science. However, they are generally regarded as developing in the large populations of neural cells in the cerebral cortex. Moreover, there are interactions between these rhythms and those of the central portions of the brain.

In recording this electrical activity through the scalp, there is a reduction (or attenuation) of the potential differences by a factor of one third. To record this activity at the scalp, a number of small, cup-shaped silver or gold alloy electrodes are used. Typically, an electrode jelly similar to that used in ECG recording is placed between the scalp and the EEG electrodes, allowing the conductance of electrical signals to the pre-amplifiers. The electrodes are held in place during the recording by a paste adhesive which is later removed with warm water.

Since the varying potential differences between the recording sites are very small (usually between 10 and 200 microvolts), the EEG recording machine has amplifiers which increase the potential differences about a million times. The amplified signals operate a series of galvonometers which in turn deflect ink-writing pens. These pens write out on a continuous moving paper as a number of lines or channels which correspond to the change in electrical activity from the recording site. The resultant lines are complex waveforms.

The selection and placement of electrodes' recording sites has become standardized to the "10/20 International System". This technique records information from the frontal, temporal, parietal, and occipital lobes of the brain. Additional electrodes record electrical activity from the center-line sites of the scalp. Figure 6 on page 69 illustrates the relationship of these sites and their placement on the scalp.

"Artefacts" are contaminating recordings which are caused by "noise" entering the recording system. Muscle movement, particularly of the scalp, face, and neck areas may produce artefacts during the recording session. Usually these are readily recognized by a skilled EEG technician, but must be monitored and marked on the record to avoid false readings. Other sources of artefacts may be eye movement, sweat and resultant changes in skin resistance, poorly conducting leads, etc. Additionally, most clinical EEG recording areas have been screened with copper mesh to avoid recording unwanted 60 cycle electrical activity from the large number of electrical appliances and lighting systems present in most modern buildings. The protocol for EEG recording at Michigan State University is included in Appendix B.

Analysis Techniques

The data analysis conducted in this research followed four major steps. These steps were: 1) selecting and sampling specific epochs (two second period) from the EEG records for analysis, 2) digitizing the selected EEG wave forms, 3) Fourier transformation and spectral power analysis of the wave form, and 4) statistical analysis and hypothesis testing. A description of these techniques, their rationale and application in this research follow.

Selection and sampling epochs: The selection of which channels to compare by hemisphere was based on Galin and Ornstein (1972) who advise that the parietal and temporal recording sites demonstrated the most laterality or neural activity. In this study channels three and seven were analyzed. These channels corresponded to the parietal and temporal sites (P3-T5 and P4-T6, see Figure 6).

In order to analyze the data relevant to the experimental treatment, it was decided to delimit analysis to two second epochs beginning with the presentation of the stimulus and ending with the start of the intertrial rest period (a ten second period with eyes closed). The assumption was made that the subject was attending to the stimulus and was actively processing the information associated with it.

The appropriate epochs were referenced on the EEG charts by the manual marker and numbered by the experimenter's assistant during the experimental treatment. In analyzing these epochs, a visual check of each section of the chart was made to insure that they were free of muscle or sweat artefacts or other contaminating "noise" in the recording.

Prior to the digitizing step (conversion from analog to digital data) in the analysis, it was necessary to further reduce the amount of data to be analyzed. The rationale for this decision was amount of time and labor required in the digitizing. A purposive method of block sampling trial epochs by subject was devised to reduce the data analysis to a manageable amount without losing essential information.

This method was to select a number of trials which presented "different" faces with the six trials which presented the "same" face. All trials which were of "different" faces were renumbered and using a table of random numbers, six of these trials were selected for digitizing and further analysis. This resulted in twelve trials analyzed per subject.

To further reduce the data load it was decided to randomly select ten of the subjects to digitize for analysis. The twelve epochs on each of these ten subjects' EEG charts were visually checked for absence of artefacts and "noise" and were marked for the digitizing phase of analysis.

Digital conversion of the data: In order to conduct statistical analysis of the EEG data, it was necessary to convert it to digital or numerical values. In this study the EEG records were collected on paper strip charts and to convert this data to a digital form it was necessary to digitize it by hand. This phase of the analysis was augmented by the use of the Michigan State University Computer Center's Digitizer system. This consists of a light board and cursor with a cross-hair sight which is attached to a series of pressure switches. This assembly is controlled by a keyboard console which is used for the X and Y coordinate format statements and a CRT terminal which is interfaced with the CDC 6500 computer. Figure 3 illustrates this arrangement.

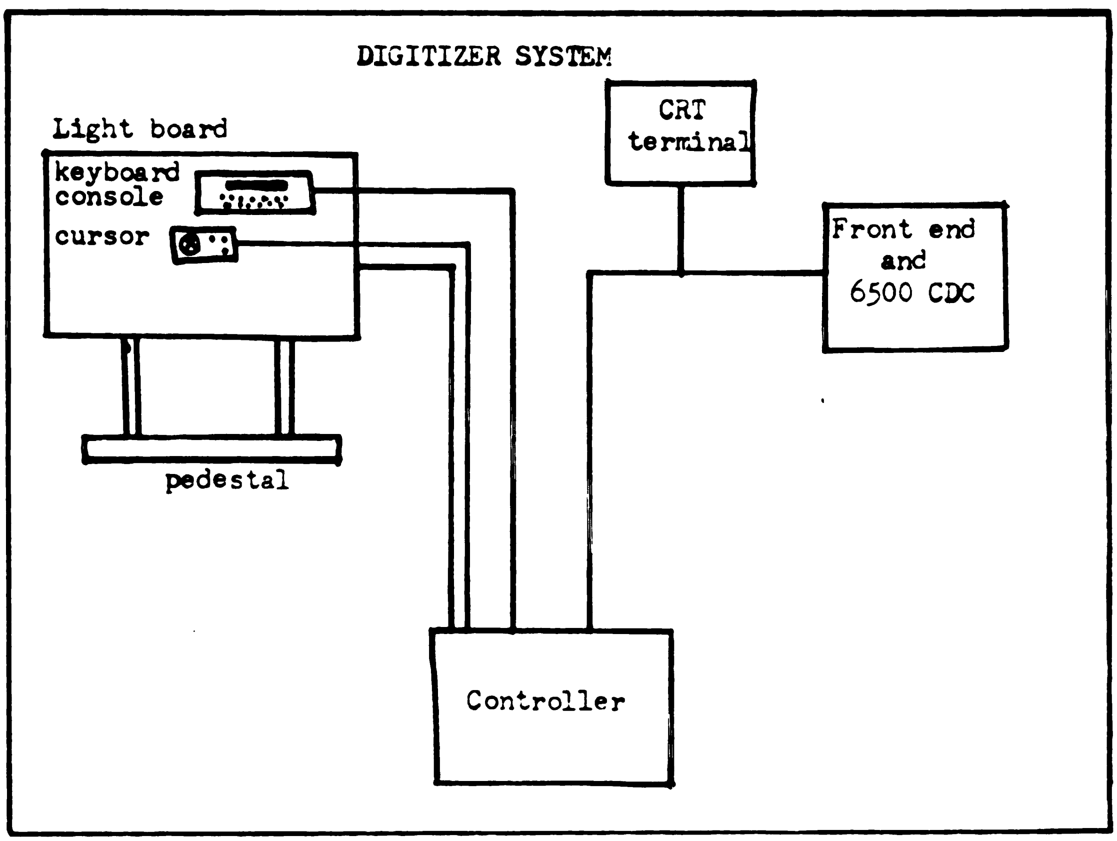
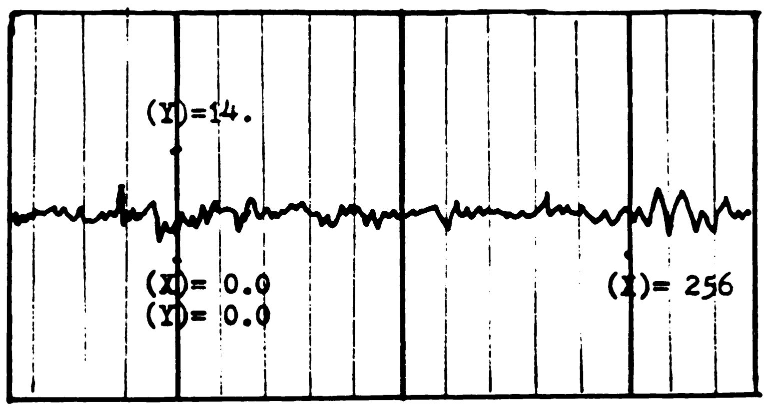


Figure 3. Digitizer System

A "three point set-up" was used in digitizing the data. This procedure for digitizing wave forms was to first determine the X and Y coordinate system appropriate to the data being analyzed. The next step was to develop a format statement at the keyboard console which allowed the digitizer system to "read" the specific data points chosen and to convert these data points into numerical values to be held in the CRT terminal. If these data points and their equivalent number values were judged by the analyst to be adequate (i.e., free from format errors) for further analysis, then they were catalogued onto a permanent file on the CDC 6500.

In this study, the X and Y coordinates were defined by time of the epoch and height (or amplitude) of the wave form. In this case two second epochs were equal to 60 millimeters on the chart paper. The height was seven millimeters above and below the mid-line of the wave form. The assumption was made that the distance relationship between the pens enscribing on the chart paper was constant. The height of the wave form was referenced on each record using the calibration marking done by the EEG technician at the beginning of each recording session. See Figure 4 for an example of the relationships between the X and Y coordinates and the wave forms.



A two second epoch with the three-point set-up

Figure 4. The Relationship Between X and Y Coordinates and the Wave Forms

The second X value was defined as 256 to utilize the digitizer's "incremental mode" for sampling data points along the wave forms. According to Shannon's theorem, the sampling rate "must be at least twice that of the highest frequency component occurring in the signal to be sampled" (Ponsen, 1978). Since the EEG data collected in this experiment contained some frequency components of the 60 hz, it was necessary to digitize at least 120 data points per second (60 x 2 = 120). The closest value available in the Digitizer format was 128. Therefore, for a two second epoch, the digitizer was programmed to incrementally select at random 256 data points per two second epoch while the analyst physically moved the cursor along the wave form.

Possible sources of error using this manual digitizing method included hand-eye judgment errors and variances in the thicknesses of the lines in the wave form. The large numbers of data points (over 30,000 for all subjects and trial) required careful management of the permanent files containing this data.

Fast Fourier transformation: In this study a computer program was specially modified to break down the input (EEG wave form) into its component frequencies. As has been described, the electrical activity measured at the scalp contains frequencies between 1 and 60 hz. The frequencies of particular interest in this study were between 8-14 hz (a usual definition of the alpha wave form). To find out what percentage of these frequencies contributed to the hypothesized differences between hemispheres, a Fourier transformation was utilized to analyze the frequency spectrum present in the EEG data collected. For a graphic illustration of a hypothetical spectral analysis, see Figure 5.

The Fourier series and transform equations are based on the work of the French mathematician, Jean Baptist Joseph Fourier who developed a model for the analysis of composite wave forms based on sine and cosine waves as the elementary components. The Fourier transform may be described as a mathematical filtering operation. For a

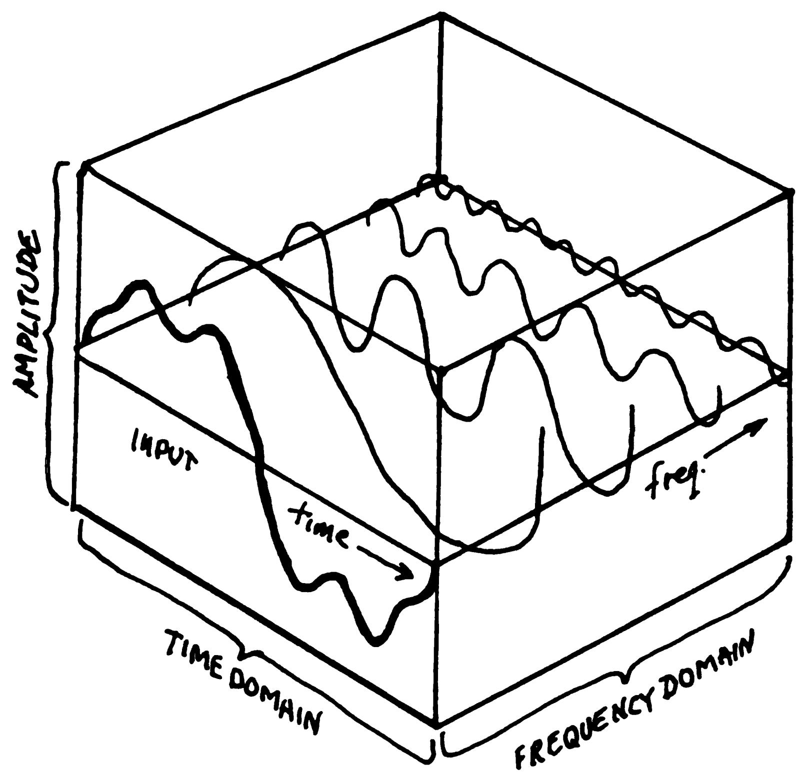


Figure 5. Hypothetical Spectral Analysis

mathematical elaboration of the Fourier transform and series, refer to Fourier Analyzer Training Manual, Application Note 140-0. A more complete description of the computer program used to complete the Fourier transform on the data for this analysis is included in Appendix B.

Statistical analysis and hypotheses testing: A dependent t-test for matched-pairs was used to test for significant differences between alpha activity by hemispheres in cases where the stimulus was presented in the left, center or right visual field. This test was also used to test for significance of differences for right and left hemispheric alpha activity when the test stimulus was the same or different than the memory stimulus.

An analysis of variance (ANOVA) was used to determine interactions between the mode (manner in which the stimulus was presented), the stimulus (same or different), and alpha activity by left and right hemispheres. A significance level of .05 was chosen for these tests. To test for the relationship between the amount of alpha activity in the right hemisphere and the subjects' scores on the visual imaging section of the Bett's QMI test, a Spearman Rank correlation coefficient was computed.

Facial Recognition Test

In order to test the subject's electrical brain activity while comparing faces with a memorized face, a facial recognition test was constructed. Stimulus items (i.e., faces) were constructed systematically using component line segments from a facial recognition kit similar to those used by police investigators to construct facial likenesses with witnesses. Items of facial lines (i.e., noses, eyes, ears, chin lines, and hair lines) were selected randomly from a pool of each line segments. As these items were place together, a face was constructed. After each face was completed and copied graphically, the component items were returned to the pool for subsequent construction of another face. Each constructed face was reduced on a Goodkin tracing booth, drawn to the appropriate size with # 1 and # 3 Rapidograph technical pens and then copied on 5" x 8" white index cards for presentation via a Scientific Prototype two-channel tachistoscope. Following guidelines of Geffen, et al (1971), the facial stimuli were placed centrally and/or at least three degrees to the left or right of center of the card. A template, which corresponded to the aperture of the tachistoscope, was used to aid the experimenter in the placement of the faces on the cards. Evidence indicates that the placement of the stimuli three degrees left or right of the central visual field is sufficient, when presented at 160 milliseconds, to project the visual information to the contralateral hemisphere (i.e., the left hemisphere for visuals presented to the right visual field and vice versa). For a full discussion of interhemispheric transmission of information, the reader is referred to Geffen (1971), Moscovitch and Catlin (1970), and Bradshaw and Perriment (1970).

The facial recognition test consisted of thirty items of which six were the same as the memory face. The subject was shown the memory face for three minutes. Geffen reports allowing ten minutes for the subjects to memorize the target face. This investigator chose a shorter period for economy of time, after a pilot test indicated that the shorter time was sufficient. The memory face was centrally located in the learner's visual field prior to the series of test face presentations.

Test faces were randomly presented to the learner's right, left or central visual field for a period of 160 milliseconds. Following the stimulus presentation, subjects were advised to close their eyes to avoid visual interference between trials. The presentation of the test face was controlled by an electric timer within the t-scope. The task was to view the series of thirty faces and to be aware if the test face was the same or different than the target face. No manual or verbal response was required of the subject.

The Population

The population under study in this research was normal, human, young adults attending Michigan State University during Spring term, 1979. The designation of "normal" is used in this context to mean those who demonstrate adequate, binocular, visual performance with no uncorrected visual pathology. Normal is further intended to designate human beings who have no known history of epilepsy, brain lesions or trauma, psychological disorders (such as hallucinations, trances, or loss of memory) nor any other psychosocial traits which would be identified by clinical, psychological testing.

The population is further delimited to include only dextrals, i.e., right-handed people. Since evidence regarding sinistrals (left-handed individuals) is inconclusive as it relates to the variables of interest, the study is only generalizable to the general population of right-handed people. Harris (1975) has described the general American population as 90-98 percent right-handed. Of this segment, approximately 99 percent have language functions in the left hemisphere. Only 53-65 percent of sinistrals, according to Harris, have left hemisphere speech specialization. He concluded that left-handed persons are less well-lateralized for language functions.

Taking the Sample

The sample for this investigation was taken from the current population of students and members of Michigan State University. Since the study was somewhat exploratory and involved several unknown variables, volunteer subjects were sought and data from ten subjects are included in this report. Selection criteria included: 1) willingness to be a subject for each of three experimental treatments, 2) absence of psychological or physical disorders, 3) right handedness, 4) no report of use of drugs or medication, and 5) being of the age of legal consent (or having parental consent). For an example of the data collected concerning these criteria, see Appendix C for a copy of the subject demographic data dorm.

Selection screening included a simple test of handedness to determine that the subject was dextral. This consisted primarily of noting which hand the subject used to receive a pencil to fill out a subject data sheet. Additionally, the subject was observed while filling out the form to determine if the so-called "hook" hand position was present, indicating the possibility of left-handedness.

Other criterion required that the subject be free from a known history of epilepsy or related neural disorders. This criteria was established primarily to avoid any danger of triggering a seizure with any of the stimulus material in the experiment. Also important was the consideration of possible interactions of this neural condition with the EEG data collection. Subjects were queried about their previous experience, if any, with psychological testing and if they had ever engaged in an EEG recording. Information was given by self-report and was voluntary and privileged according to the guidelines of the University Committee for Research Involving Human Subjects.

All subjects were administered the paper-pencil Bett's QMI questionnaire to assess their imaging ability. This questionnaire has been used to assess a person's ability to generate mental images in a variety of sensory modalities. The Bett's version of this test consists of thirty-five items and takes approximately ten minutes to complete. This form of the test is very nearly as accurate at producing overall imagery scores as the original Sheehan's questionnaire of 150 items. A comparison between the original and the shortened format achieved r = .98 correlation with a sample of teacher college students (Paivio, 1971). Moreover, the test's suitability for American subjects (Bett's short form was developed in Australia) was demonstrated in a test-retest procedure which found a Pearson correlation of .78 after a seven month period.

Experimental Procedures

The summary of the experimental procedures used in this study is presented in the following sequence: 1) management of the subjects, 2) diagram of the procedures, and 3) a narrative summary of experimental treatment.

Subjects were introduced to the experimenters and the EEG technician and were given a brief, but thorough explanation of each of the component pieces of equipment. They were asked to fill out a one page questionnaire (see Appendix C) which asked them to volunteer demographic information. Prior to the experiment, they were asked to complete the Bett's short form test of imaging ability (see Appendix A).

Prior to the actual experiments the subjects were again asked if they wished to continue and were advised if they became uncomfortable or fatigued that the experiment would be terminated. None of the subjects declined to continue, nor were any of the experimental treatments terminated by the subject's request or other reasons. A required release form was filled out by each subject (see Appendix C). See Appendix C for standard instructions to subjects.

A videotape showing the experimental equipment, physical layout of the data collection site, examples of the stimulus materials, explanation of the experiment to the subject, and EEG application and recording procedures was produced by the experimenters. A copy of this is available for review of the procedures by other investigators.

Following a briefing and explanation of the procedures to the subject, final consent to continue with the experiment was secured from the subject. Attachments were made at scalp sites C3, P3, T5, C4, P4, T6, 01, and 02 (following 10/20 International Montage). These codes correspond to temporal left and right, parietal left and right, and occipital left and right lobes of the cerebral cortex. Gold alloy electrode discs were attached using water-soluble paste and cotton as adhesive. ECG cream was used as an electric conductant (see Figure 6).

Two grounding electrodes were placed on the earlobes and the lead to the forearm. The 10/20 International Montage was dialed in on the Beckman unit. Sensitivity was adjusted for 7.5 mV/mm with high linear filters adjusted to

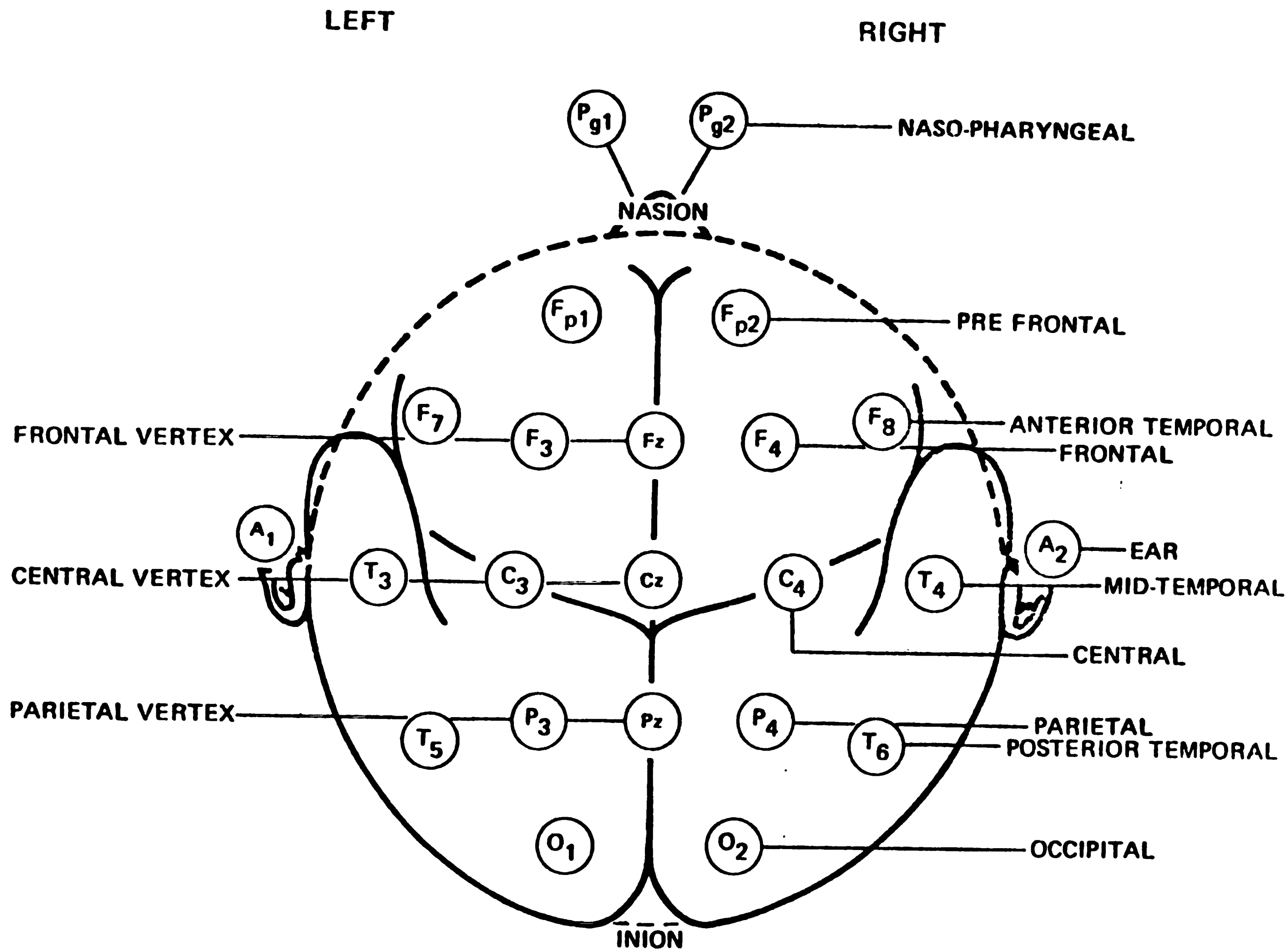


Figure 6. The 10/20 International Montage

seven and low linear-filters set at 1 hz (see Appendix B for EEG recording protocol). The strip chart speed was standardized at 30 mm/second.

Following attachments, check-out of the adequate conductance of the electrodes, determination that there was a minimum of 60 cycle "noise" and muscle artefacts, the repeated measures (visual stimulus materials) were made. Three separate experimental treatments were given to each subject (a facial recognition test, Fractal Curvilinear graphics, museum displays). To control for possible serial effects of these treatments and possible subject fatigue as a contaminating variable, treatments were rotated from subject to subject.

The facial recognition test consisted of sequential presentation of thirty items. The correct item (i.e., the memory face) was presented on the average of every fifth trial. Test faces were presented in the subject's left, right, or central visual field for 160 m/seconds in a random fashion. To avoid guessing or anticipation of the field of presentation, subjects were advised to focus on the central "X" which appeared via the blank channel of the t-scope between each test item. Intra-trial delays were ten seconds on the average. This time was partly required to change the test items manually between the trials. More importantly, this time controlled for possible "after image" effects from the strobe-like speed of presentations. See Figure 7 for a diagram of these procedures.

Show Memory face with normal vision for 3 minutes	Present test faces to left, right or central field randomly for 160m/seconds	Subject observes "same" or "different" faces for 30 trials eyes closed between trials	Reference stimulus events (left right or center of visual field) on EEG recording

→Record EEG's→

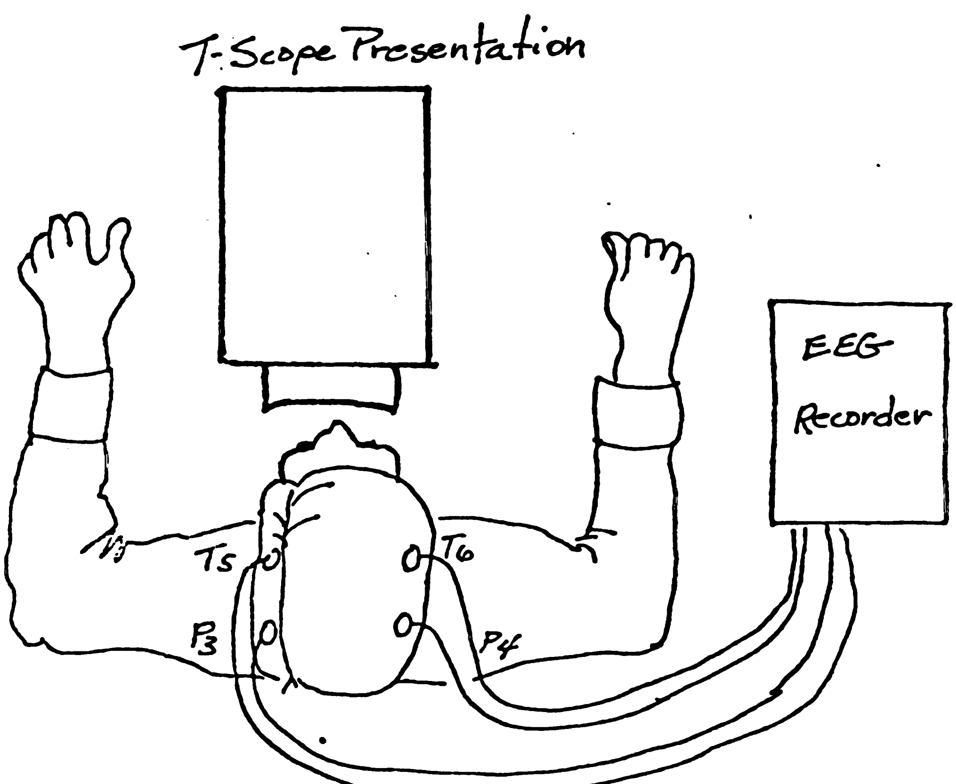


Figure 7. Diagram of Procedures

A series of five practice trials were provided to ascertain that the experimental procedures were understood by the subjects. The instructions to the subjects were read to each subject (see Appendix C, "Instructions to Subjects"). This procedure was used to assure that each subject received the same instructions.

Galin and Ornstein (1972) used EEG's of subjects performing a series of different cognitive tasks as a measure of lateral, hemispheric differences. Specifically, they attached EEG leads to the subjects' scalps using the 10/20 International Montage as their sampling sites. This arrangement allows the acquisition of brain wave activity at paired sites over important lobes of the brain. The assumption was made that the presence of alpha brain wave activity signified that the site could not be processing the information relevant to the cognitive tasks.

In the present study EEG data was collected using a sixteen channel Beckman Model Accutrace 16. The decision to focus data collection on the temporal and parietal lobes (i.e., T5/T6 and P4/P3) was made based on Galin and Ornstein's guidance:

> Selection of electrode placements on clinico-anatomical grounds: a wealth of evidence suggests that temporal and parietal leads should be the most functionally asymmetrical, and occipital leads the most similar. (p. 417).

Epochs following the presentation of the stimulus were referenced by the experimenter using the manual marker on the EEG recording unit. These reference marks allowed subsequent analysis by hemisphere and presentation mode of the stimulus.

Concurrent with the experimental treatment, EEG brain wave measures were collected from the sites as described above. Presentation events were marked on the strip chart by the experimenters to provide reference points for subsequent analysis of the brain wave patterns. EEG data were collected continuously during the experimental treatment (for both inter- and intra-trial epochs). However, between experimental treatments, or when adjustments or rearrangements were required in the experimental equipment, EEG recordings were halted to avoid collecting useless data. Recorded data were indexed and numbered for subsequent analysis and statistical treatment.

CHAPTER IV

ANALYSIS OF RESULTS

This chapter contains a review of methods and an analysis of the results of the study. Each testable hypothesis is presented individually with findings obtained from the investigation. The discussion section follows the presentation of results.

Methods

A sample of ten, normal adults from Michigan State University were given a facial recognition test via a two-channel Scientific Prototype Tachistoscope. Normal subjects were defined as those with no history of psychological or neurological pathology or uncorrected visual impairment. Evidence of the lack of these conditions was provided by self-report during pre-experimental interview. All subjects chosen were right-handed. The facial recognition test consisted of thirty test items which were black and white, pen-and-ink, line drawings of human faces on 5 x 8 inch, white index cards. The subjects were given a face to memorize for three minutes via the blank channel of the t-scope. Following this, thirty test faces were presented in either the left, center, or right visual field for a period of 160 milliseconds. Six of the test faces were the same as the memory face, the remainder were different. Placement of the faces in the visual field was randomized, as were the sequence of same or different faces.

Data Collection

EEG recordings were gathered and referenced for each of the thirty trials. Data collection followed a standard, 10/20 International system and was conducted with the assistance of a clinical, diagnostic EEG technician. The EEG recordings were manually referenced to the presentation of the stimuli. These reference marks and numbered trials were later used to analyze the EEG waveforms which resulted from the presentation of the stimulus to the subject. The EEG waveforms produced by subjects from scalp sites P3, P4, T5, and T6 (which correspond to the left and right parietal and the left and right temporal lobes of the cortex) were subsequently used for data analysis. Focusing the investigation on these particular sites was recommended by Galin and Ornstein (1972). Two second epochs were chosen for analysis, since it was reasoned that the perception of the facial test items, the recognition of its match or difference to the memorized face, and the information processing involved with these processes would occur during this period of time.

Since subsequent data analysis required that the EEG records be digitized (i.e., converted from analog to digital form) by hand, the decision was made to block sample the two second epochs by subject and trial. For the ten subjects, all trials which presented the target (i.e., the memory face) were digitized. All trials which presented different faces were renumbered and, using a table of random numbers, six of the remaining twenty-four trials were selected for digitizing.

Digitizing was accomplished by using the Michigan State University Computer Center's Digitizer System (see Figure 3). The sequence of the data analysis steps is diagrammed (see Figure 8).

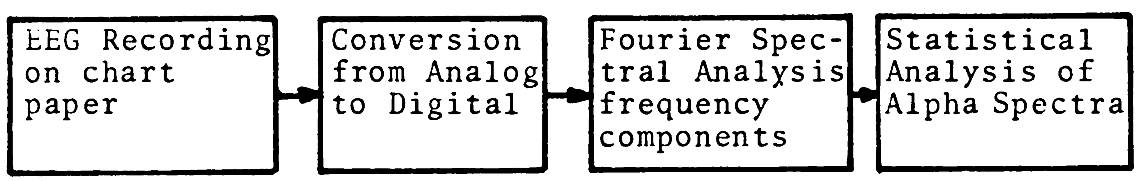


Figure 8. Sequence of Data Analysis

The digitizing procedure involved a three point set-up for the Digitizer's incremental mode. In this mode the digitizer samples according to a time series, 256 data points, while the analyst traces the original EEG waveform. A program from the International Mathematics Statistical Library was modified by Applications Programming of the Michigan State University Computer Center to break the digitized EEG data into its frequency components. This program utilizes a variation of the Fourier Transform to analyze the frequency components of the original wave form. This step allowed the subsequent statistical analysis of the differences in alpha spectral power. The output of this program provided numerical values for the alpha frequency (8-14 hz) contained in the two second epoch associated with the stimulus trial. For a fuller description of the Fourier Transform, see Ponsen (1979) or Bloomfield (1979) and Appendix B.

Statistical Methods

A dependent t-test for matched-pairs was used to test for significant differences between alpha activity by hemispheres in cases where the stimulus was presented in the left, center or right visual field. This test was also used to test for significance of differences for right and left hemispheric alpha activity when the test stimulus was the same or different than the memory stimulus.

An analysis of variance (ANOVA) was used to determine interactions between the mode (manner in which the stimulus was presented), the stimulus (same or different), and alpha activity by left and right hemispheres. A significance level of .05 was chosen as the level at which the null hypothesis would be rejected for these tests.

Hypotheses Testing

Results of testing each hypothesis are presented in this section. Each hypothesis is stated in the testable form and the findings are presented for each.

Differences in Hemispheric Alpha Activity by Presentation Mode

H_0: There is no significant difference between left and right hemispheric alpha activity when test faces are presented in the left visual field.

For the left visual presentation mode, a t-value of 1.11 was found with a two-tailed probability of .296. This t-value was not statistically significant at the .05 level, therefore, the null hypothesis was not rejected. (See Table 1).

TABLE 1

Dependent t-test for Left and Right Alpha Activity by Left Visual Field Presentation Mode

Variable	No. of Cases	Mean	(Diff.) Mean	t-value	df	2-tail Proba-bility
Left Hemisphere	10	38.900	7.300	1.11	9	.296
Right Hemisphere		31.600				

H_0: There is no significant difference between left and right hemispheric alpha activity when test faces are presented in the central visual field.

For the central visual presentation mode, a t-value of 1.91 was obtained with a two-tailed probability of .088. This t-value is not statistically significant at the .05 level, therefore, the null hypothesis was not rejected. (See Table 2).

TABLE 2

Dependent t-test for Left and Right Alpha Activity by Central Visual Field Presentation Mode

Variable	No. of Cases	Mean	(Diff.) Mean	t-value	df	2-tail Probability
Left Hemisphere	10	37.700	9.400	1.91	9	.088
Right Hemisphere		28.300				

H_0: There is no significant difference between left and right hemispheric alpha activity when test faces are presented in the right visual field.

For the right visual presentation mode, a t-value of .99 was obtained with a two-tailed probability of .346. This t-value is not statistically significant at the .05 level, therefore, the null hypothesis was not rejected. (See Table 3).

Differences Between Right and Left Hemispheric Alpha Activity for Stimulus

H_0: There is no significant difference between left and right hemispheric alpha activity when test faces, in comparison with the memory face, are the same as the memory face.

The test for differences in cases which presented the same face as the memory face resulted in a t-value of .76 with a two-tailed probability of .468. With nine degrees of freedom, this t-value is not statistically significant at the .05 level, therefore, the null hypothesis is not rejected. (See Table 4).

TABLE 3

Dependent t-test for Left and Right Alpha Activity by Right Visual Field Presentation Mode

Variable	No. of Cases	Mean	(Diff.) Mean	t-value	df	2-tail Probability
Left Hemisphere	10	38.100	4.600	.99	9	.346
Right Hemisphere		33.500				

TABLE 4

Dependent t-test for Left and Right Alpha Activity for Same Presentation Stimulus

Variable	No. of Cases	Mean	(Diff.) Mean	t-value	df	2-tail Probability
Left Hemisphere	10	33.100	3.400	.76	9	.468
Right Hemisphere		29.700				

H_0: There is no significant difference between left and right hemispheric alpha activity when test faces, in comparison with the memory face, are different than the memory face.

The test for differences in cases which presented a different face than the memory face resulted in a t-value of 1.57 with a two-tailed probability of .150. With nine degrees of freedom, this t-value is not statistically significant at the .05 level, therefore, the null hypothesis is not rejected. (See Table 5).

TABLE 5

Dependent t-test for Left and Right Alpha Activity for Different Presentation Stimulus

Variable	No. of Cases	Mean	(Diff.) Mean	t-value	df	2-tail Probability
Left Hemisphere	10	40.400	6.400	1.57	9	.150
Right Hemisphere		34.00				

Interaction Effects Between Stimulus, Mode, and Hemisphere for Alpha Activity

H_0: There is no significant interaction effect between Hemisphere and Stimulus for Alpha Activity.

A three-way ANOVA was performed on the possible sources of variance of subject's alpha activity (i.e., by sameness or difference of the stimulus face, by left, center or right visual presentation mode, by left or right hemisphere). The F test for interaction effects between the stimulus and hemisphere for alpha activity resulted in an $F(1,9) = .3641$ with a $p = .56$ which is not significant at the .05 level, therefore, the null hypothesis was not rejected.

> H_0: There is no significant interaction effect between hemisphere and mode of presentation for alpha activity.

The F-value obtained for this test was $F(1,9) = .6712$ with a $p = .52$. Since this value is not significant at the .05 level, the null hypothesis was not rejected.

> H_0: There is no significant interaction effect between stimulus and mode of presentation for alpha activity.

The F-value obtained for this test was $F(1,9) = 2.3402$ with a $p = .12$. Since this value is not significant at the .05 level, the null hypothesis was not rejected.

> H_0: There is no significant interaction effect between hemisphere by stimulus by mode of presentation for alpha activity.

The F-value for this test of interaction was $F(1,9) = .1175$ with a $p = .89$. Since this value is not significant at the .05 level, the null hypothesis was not rejected.

In each of these four tests for interaction effects, none of the F-values were significant at the .05 level and none of the null hypotheses were rejected. The results of the three-way ANOVA are presented in Table 6. Interaction plots are displayed as Figures 9 through 12. The interaction plots show that there were no first or second order

TABLE 6

Analysis of Variance of Subjects by Same or Different Stimulus, by Presentation Mode, by Left or Right Hemisphere for Alpha Activity

Source	SS	df	MS	F	P
Between Subjects	.0196	9	.0021		
Within Subjects	.05474	110			
Hemisphere Side	.00138	1	.00138	3.7054	.08
Subject by Side	.00335	9	.00037		
Stimulus (same or different)	.00201	1	.00201	3.5748	.09
Subject by Stimulus	.00506	9	.00056		
Presentation Mode (Left, Center or right)	.00036	2	.00018	.2141	.81
Subject by Mode	.01500	18	.00083		
Hemisphere by Stimulus	.00008	1	.00008	.3641	.56
Subject by Hemisphere by Stimulus	.00186	9	.00001		
Hemisphere by Mode	.00017	2	.00008	.6712	.52
Subject by Hemisphere by Mode	.00226	18	.00013		
Stimulus X Mode	.00360	2	.00180	2.3402	.12
Subject by Stimulus by Mode	.01386	18	.00077		
Stimulus by Mode by Hemisphere	.00007	2	.00004	.1175	.89
Subject by Hemisphere by Stimulus by Mode	.00568	18	.00032		

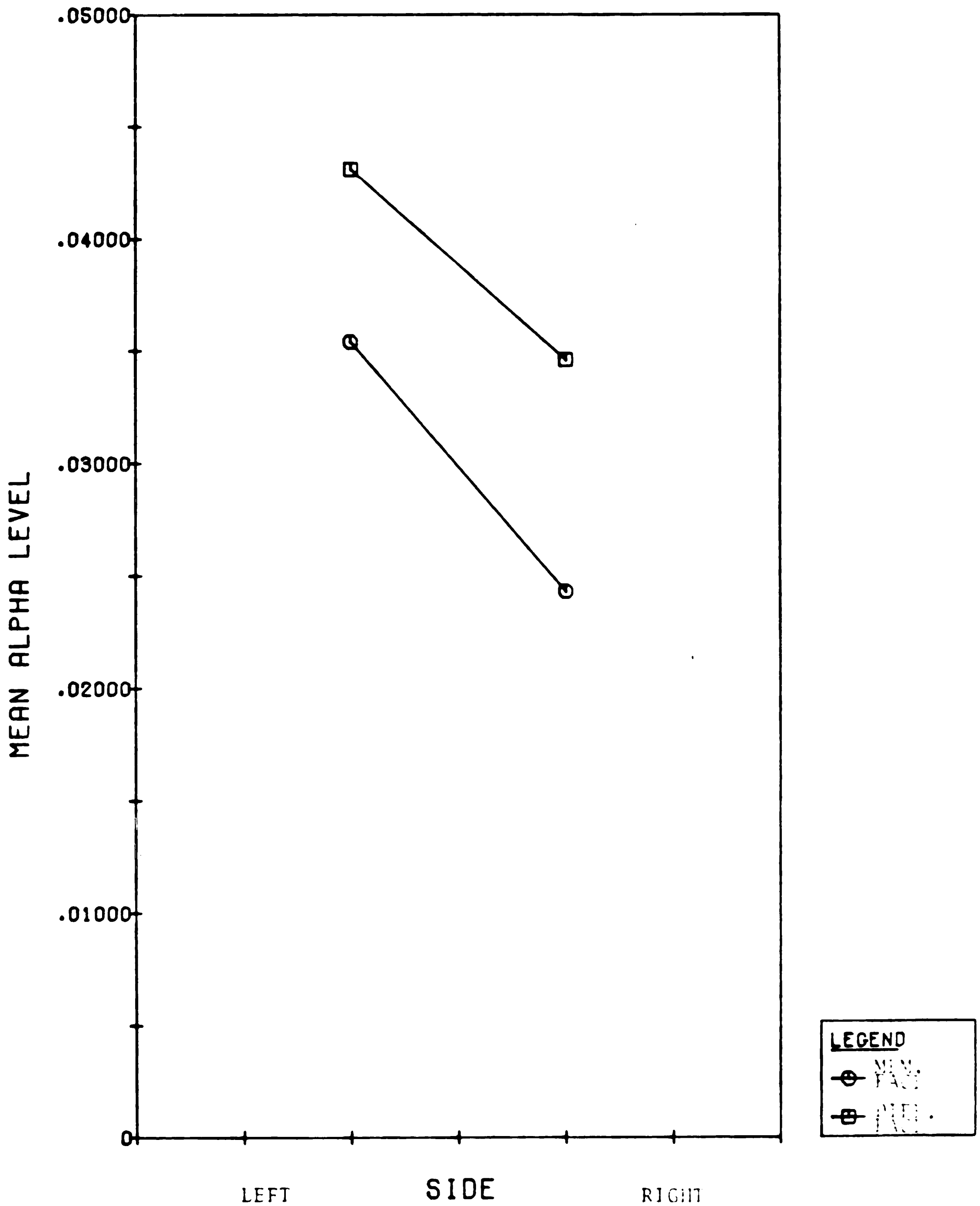


Figure 9. Plot ~~of~~ Side by Stimulus Interaction

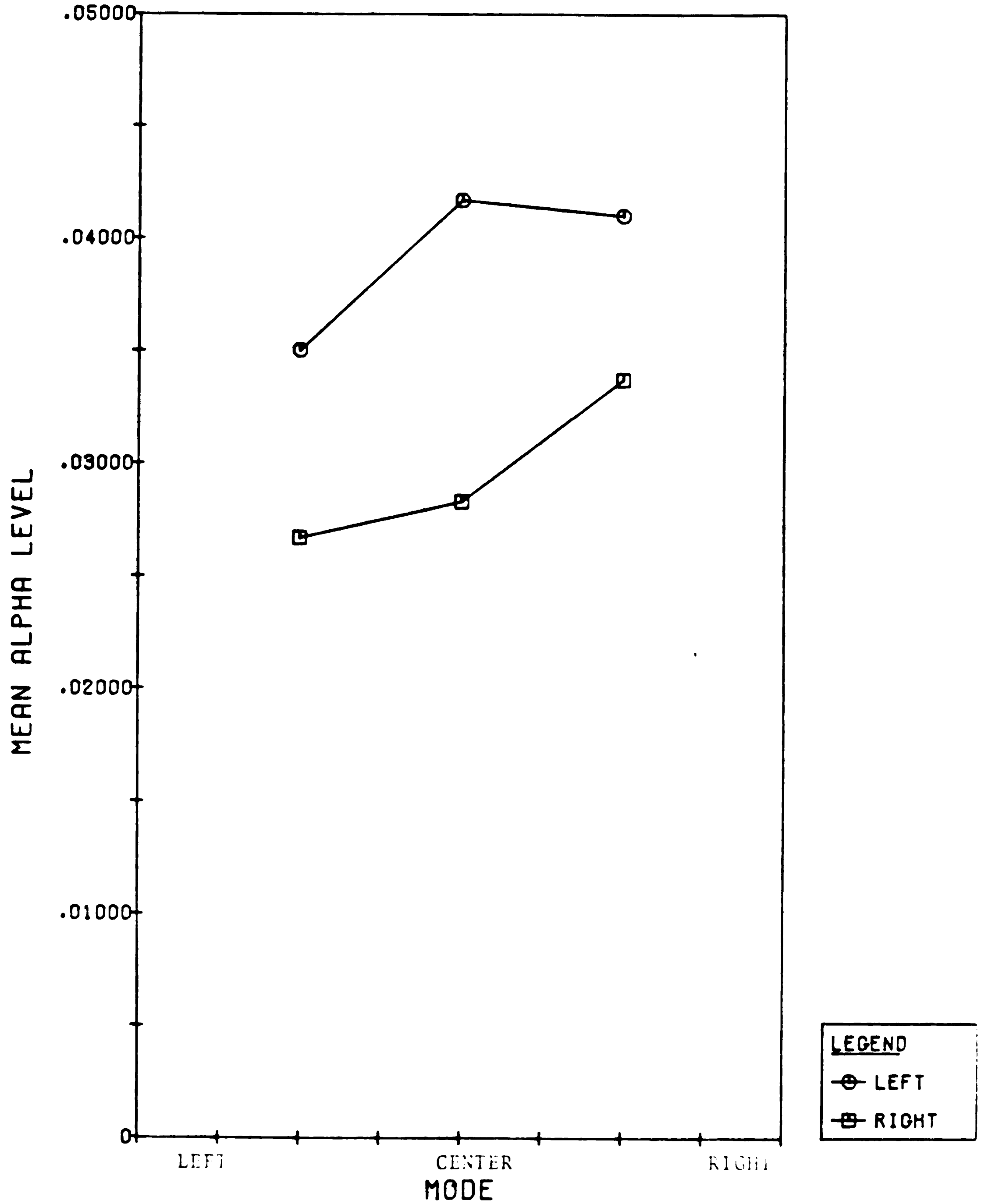


Figure 10. Plot of Side by Mode Interaction

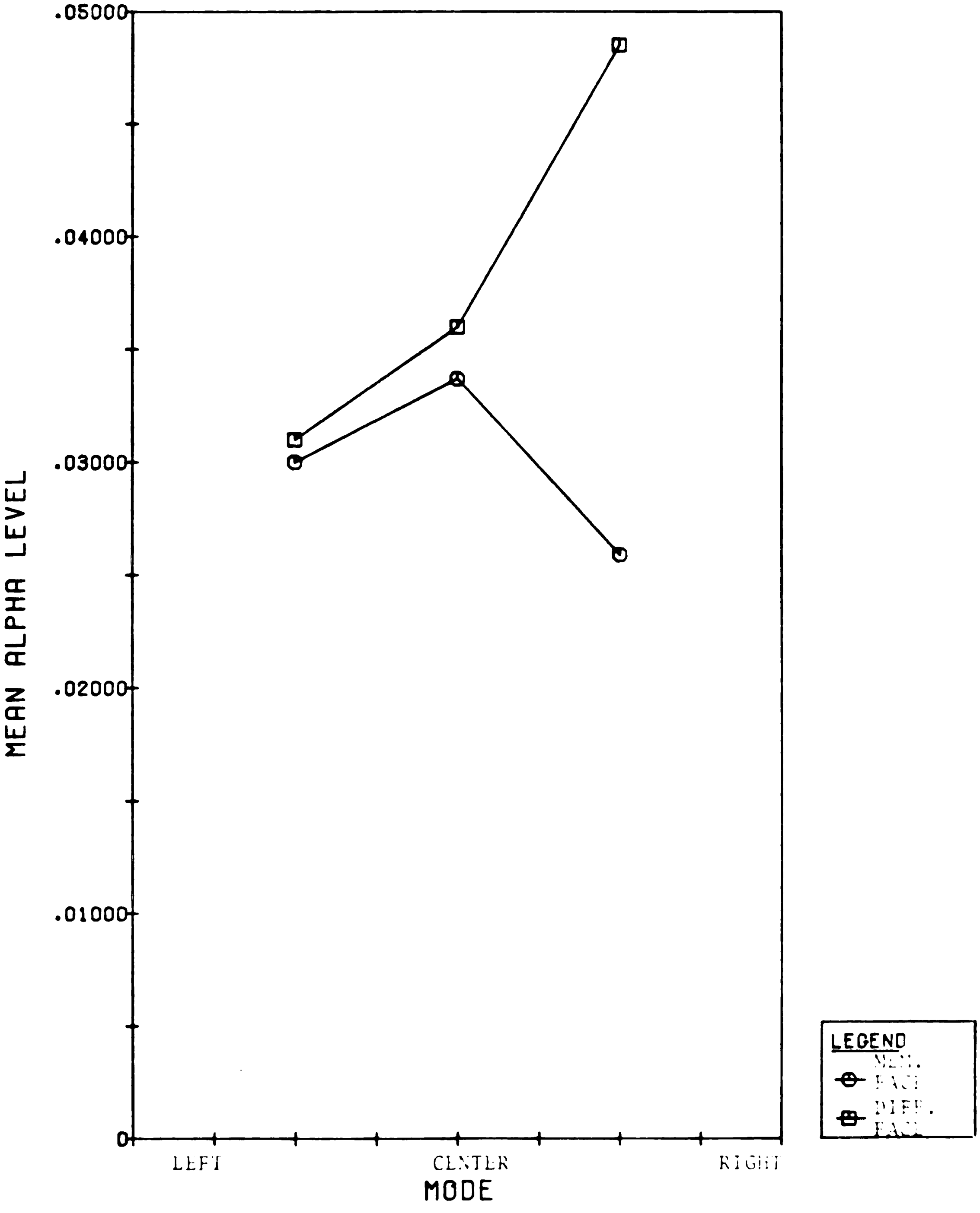


Figure 11. Plot of Stimulus by Mode Interaction.

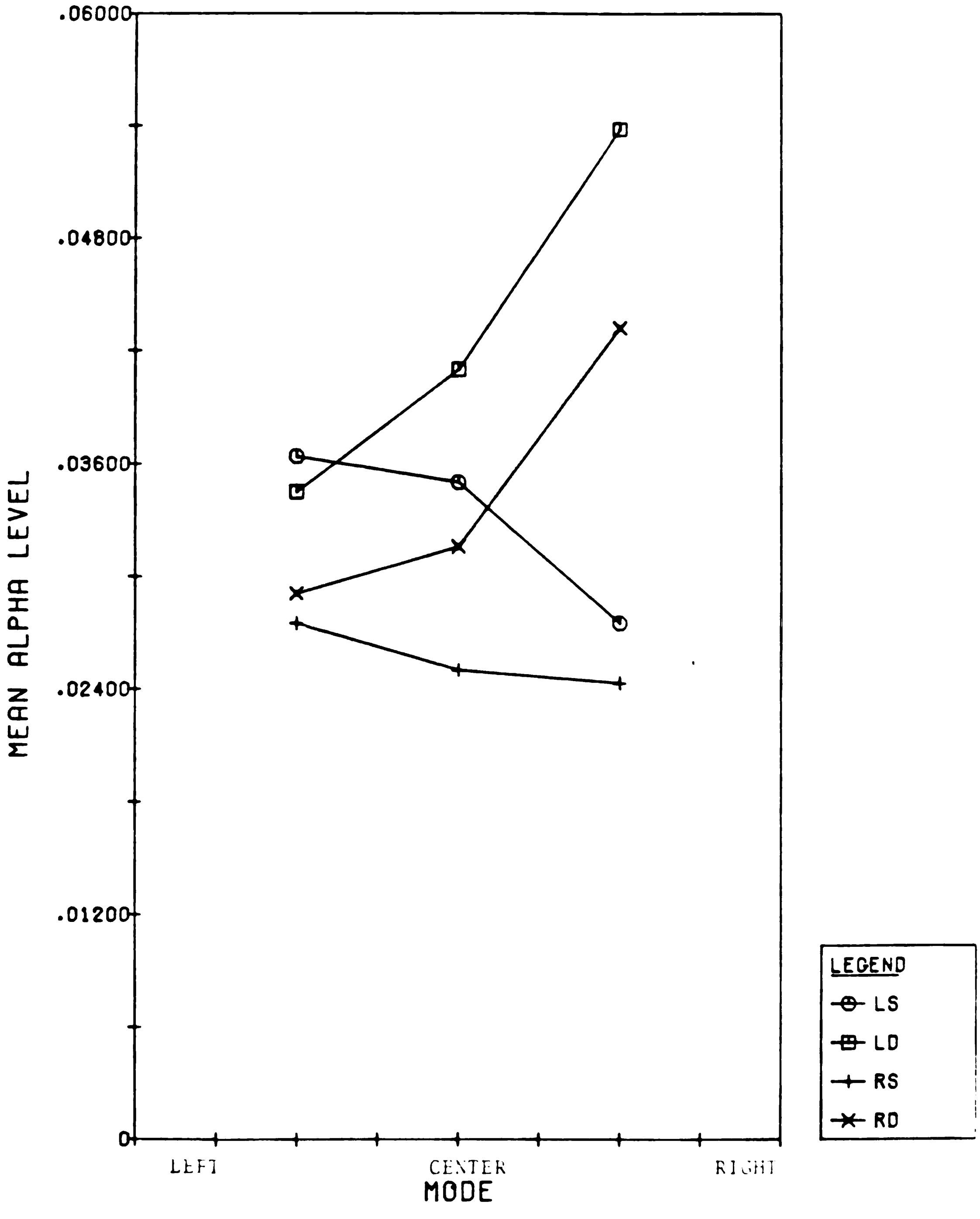


Figure 12. Plot of Side by Stimulus by Mode Interaction

interactions between the variables of hemisphere by mode of presentation (visual field) by stimulus (same or different). This means that there were no statistically significant effects of these variables on one another.

Relationship Between Bett's QMI Scores on Visual Imaging and Alpha Activity

H_0: There is no significant relationship between alpha activity in the right hemisphere and Bett's scores for visual imaging.

A Spearman Rank Correlation coefficient was computed for these two variables. The resulting coefficient was equal to .334. Data are displayed in Table 7. The correlation is plotted on Figure 13. Because of the relatively low correlation, the null hypothesis is not rejected.

Summary and Discussion

The result of the dependent t-tests for matched pairs for differences of alpha activity between left and right hemispheres when the stimulus (test faces) were presented in the left, center, or right visual fields, did not show those differences to be statistically significant at the .05 level. In comparing left and right hemispheric activity for left, center and right visual field presentation modes, no statistically significant difference was found.

TABLE 7

Comparison of Bett's Visual Imaging Score and Mean Right Hemisphere Alpha Activity

Subjects	Bett's Visual Image Score*	Mean Right Alpha Activity
1	4.6	.022
2	6.0	.013
3	5.2	.014
4	5.8	.031
5	5.2	.054
6	6.4	.035
7	6.2**	.031***

*Bett's score subtracted from 8 (total possible test score).

**Mean = 5.629, Standard Deviation = .647

***Mean = .029, Standard Deviation = .014

Inspection of the data reveals that although the mean alpha activity for the left hemisphere was consistently higher than for the right hemisphere, across mode of presentation and stimulus, no significant differences were found at the .05 level.

The dependent t-test for matched pairs between alpha activity by left and right hemisphere where the test faces were the same as or different than the memory face resulted

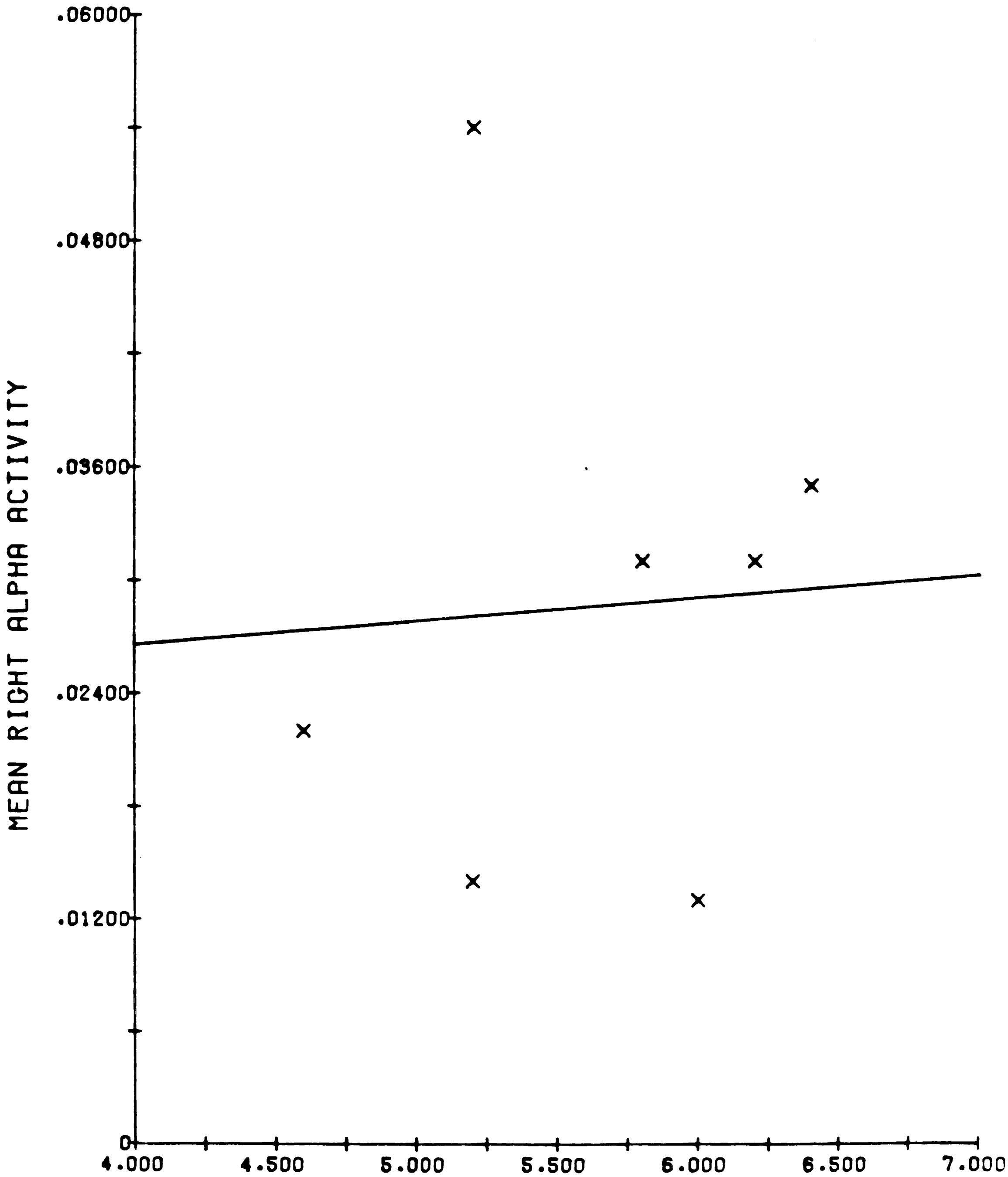


Figure 13. Bett's Imaging Score with Right Alpha Activity

in no significant differences between hemispheres. Although differences did not achieve a .05 level of significance, the mean alpha activity in the left hemisphere was higher than the right regardless of the sameness or difference of the stimulus face. However, since differences were not found to be significant at the .05 level, the null hypothesis was not rejected.

The three-way ANOVA test of sources of variance in alpha activity by side (hemisphere), by stimulus (same or different), by mode of presentation (left, center or right visual field), did not reveal any significant interactions, neither first nor second order, between these factors at the .05 level. It is worthy to note that the F-value for the differences attributed to the side (hemisphere) and also for stimulus, did not show any statistical significance at the .05 level which supports the results from earlier analysis.

TABLE 8

Summary of Results

Research Hypothesis	Statistical Hypothesis	Statement of Rejection/ Non-Rejection
There will be no significant difference between left and right alpha activity when test faces are presented in the left visual field.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces are presented in the central visual field.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces are presented in the right visual field.	$H_0=\mu_0-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces, in comparison with the memory face, are the same as the memory face.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.

Table 8 (cont'd.).

Research Hypothesis	Statistical Hypothesis	Statement of Rejection/ Non-Rejection
There will be no significant difference between left and right alpha activity when test faces, in comparison with the memory face, are different than the memory face.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces are presented in the left visual field.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces are presented in the central visual field.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant difference between left and right hemispheric activity when test faces are presented in the right visual field.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.

Table 8 (cont'd.).

Research Hypothesis	Statistical Hypothesis	Statement of Rejection/ Non-Rejection
There will be no significant difference between left and right hemispheric alpha activity when test faces, in comparison with the memory face, are the same as the memory face.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq0$	Null not rejected.
There will be no significant difference between left and right alpha activity when test faces, in comparison with the memory face, are different from the memory face.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq0$	Null not rejected.
There will be no significant interaction effect between hemisphere and stimulus for alpha activity.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq0$	Null not rejected.
There will be no significant interaction effect between hemisphere and mode of presentation for alpha activity.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq0$	Null not rejected.

Table 8 (cont'd.).

Research Hypothesis	Statistical Hypothesis	Statement of Rejection/ Non-Rejection
There will be no significant interaction between stimulus and mode of presentation for alpha activity.	$H_0=\mu_1-\mu_2=0$ $H_1=\mu_1-\mu_2\neq 0$	Null not rejected.
There will be no significant interaction between hemisphere by stimulus by mode of presentation for alpha activity.	$H_0=\mu_1-\mu_2-\mu_3=0$ $H_1=\mu_1-\mu_2-\mu_3\neq 0$	Null not rejected.
There will be no significant relationship between alpha activity in the right hemisphere and the Bett's scores for visual imaging.	$H_0=\rho xy=0$ $H_1=\rho xy\neq 0$	Null not rejected.

CHAPTER V

SUMMARY AND CONCLUSIONS

This chapter presents a summary review of the study with a discussion of the conclusions drawn and implications for future research. The introduction summarizes the purpose, the need and procedures of the study. The second section presents the conclusions drawn from the analysis of the data. The third section discusses these conclusions in light of the findings of related studies by other investigators. In the final section, implications and recommendations for further research in this area are presented.

Introduction

This study was conducted to investigate experimentally the phenomenon of lateral, hemispheric specialization in normal, adult humans. The literature describing this physiological human characteristic and its psychological implications was presented. As was related in the review of literature, few studies have been conducted to relate this phenomenon to information processing in human learners. With an increased interest in the investigation and measurement of cognitive, information processing within the field of instructional psychology, an experimental design was proposed which utilized the collection of EEG recordings as a dependent variable. Because of the interest and need for understanding of the psychological principles upon which to base the design of graphic, visual instruction, a visual iconic stimulus protocol was developed to test normal subjects for laterality. Lateral differences in information processing were operationally defined as a reduction of the alpha wave spectral band in the activated hemisphere.

To test for lateral differences, a sample of ten, normal adults were given a facial recognition test via a two-channel Scientific Prototype Tachistoscope. The test was constructed of thirty test faces, of which six were the same as the "target" face. The target face was presented initially to each subject via the blank channel of the tachistoscope in their central, normal, visual field for three minutes. Subjects were read a standard set of instructions which requested that they memorize the face. Following this, they were told to close their eyes between trials and to open them when they were tapped lightly on the shoulder by the experimenter. Upon opening their eyes, they were requested to look to the center of their visual field in which a small "x" was displayed via the blank t-scope channel. Inter-trial periods averaged ten seconds. When their eyes were open a test face was presented for a period of 160 milliseconds in either their far right, far left, or central visual field. Presentations were randomized, with the target face appearing a total of six times. Subjects were not required to make verbal or manual responses, but were asked to be aware of the test face's difference or sameness to the target.

EEG recordings were gathered and referenced for each of the thirty trials. Baseline recordings were sampled with eyes open and closed for each subject. Subsequent to the data collection and experimental treatment, each subject was asked to complete a short-form version of the Sheehan's test of imaging ability, the "Bett's QMI Vividness of Imagery Scale". This test was selected for its construct validity and test-retest reliability to investigate relationships between imaging ability and hemispheric laterality in processing the visual information of the stimuli.

Four hypotheses were tested in this investigation. The initial ratios and means by subject and trial indicate a directionality of processing of the test faces by the right hemisphere. However, a statistical test of differences between test groups showed no significant differences at the .05 level.

Conclusions

Therefore, the following tentative conclusions are proposed.

1. There is an apparent, consistent reduction in

alpha power in the right hemisphere when subjects are presented the target face in either the left, center, or right visual fields. The trend of this reduction of alpha activity seems to indicate a right hemisphere processing of the stimulus independent of mode of presentation. However, since the statistical tests indicated this was not significant at the .05 level, this conclusion remains tentative pending replication.

2. The "sameness" or "difference" of the test face to the memorized face seems to have no impact on which hemisphere was processing the information. The right hemisphere had reduced alpha activity whether or not the test faces were the same or different.

3. The Bett's QMI Vividness and Imagery Scale showed that the subjects for this investigation were all medium to high in overall imaging ability. The scores on this test did not appear to correlate highly with the observed alpha ratios. Further, although the differences between subjects and between trials did not support the rejection of the first three null hypotheses, a Spearman Rank Correlation was performed. An observed correlation of .334 did not achieve significance required at the .564 level, therefore, it would appear that information processing as measured by alpha activity does not correlate very highly with the ability to generate vivid, visual images, as measured by Bett's QMI questionnaire.

Discussion

Previous evidence of laterality of hemispheric function has come from studies of clinical, neurological cases, "split-brain" research, and a number of behavioral (i.e., response time or other manual tasks) investigations. EEG studies investigating cognitive functioning and lateral hemispheric differences in alpha activity have generally found support for the assertion that the right hemisphere is specialized for visual-spatial tasks (such as mentally reconstructing block designs). Similarly, these studies have indicated that the left hemisphere is primarily activated in performing cognitive tasks requiring logical, sequential information processing (such as mentally composing a letter). However, the findings of the current study cannot be interpreted as evidence of significant lateral, hemispheric differences for the particular task (i.e., the recognition of pictures of human faces) investigated. It should be noted that results from other EEG studies do not present unequivocal support for the notion that cognitive tasks result in clear-cut, lateral differences in alpha activity.

For example, a recent study by Gevins, Doyle, et al. (1979) replicated some of the earlier experiments by Galin and Ornstein (1972). Among their hypotheses was the question of whether some of the differences found in the earlier investigation might have been due to muscle movement involved with the response tasks. They found that when manual tasks were controlled for in the experimental design, there were no significant differences between left and right hemispheric alpha activity. By using a "multivariate pattern recognition" analysis technique the authors found that:

> When limb movements are not required, and when stimulus characteristics and performance-related differences between tasks are relatively controlled, logical and spatial cognitive operations can be discriminated only very weakly on the basis of spectral intensity measurements of the background EEG. Furthermore, evidence of interhemispheric lateralization of these tasks was all but absent. (p. 667).

Their findings, though utilizing a different stimulus protocol (i.e., Koh's block designs, mental composition of letters, and serial math tasks) and a different analysis of the EEG data (i.e., multivariate pattern recognition versus Fourier transformation) than the present study, indeed do suggest that further research in this area is required.

The results of the current study seem to indicate that the information processing associated with the perception and recognition of human faces is not a clear-cut, hemispherically specialized function. Although this study avoided possible EEG contaminations due to muscle artefacts resultant from response tasks (i.e., no motor response was required of the subjects), there still were no statistically significant differences in alpha spectral power between the two hemispheres.

One possible explanation of the lack of statistically significant differences may be that the two second epoch was too long to represent the period of actual information processing associated with facial recognition. For instance, it may have been the case that the hypothesized difference did occur, but only during the period of time immediately succeeding the presentation of the stimulus (i.e., less than a second). If this were the case, during the latter part of the two second epoch, alpha activity may have increased in one or the other hemisphere due to some other function unrelated to the facial stimulus. It would follow in this event, that measure of alpha power differences would be contaminated by extraneous mental activity.

Implications and Recommendations

Further study of EEG correlates of cognition and information processing tasks are required before definitive answers to the questions of lateral specialization can be obtained. To improve the design of future research in this area, the following recommendations are presented:

1. Increased sample size would allow more precise statistical testing of EEG data collected. The current study (with an N = 10) indicated that a possible difference in alpha activity between hemispheres and with same versus different stimulus characteristics occurred, but did not show these differences to be statistically significant. In this study, those differences could have been due to chance.

2. It is recommended that this study be replicated with a modified data collection technology. The use of a DC, FM tape recorder to collect EEG signals would allow rapid and cheaper access to the basic frequency data. The analysis of the wave forms would be greatly facilitated by the automated conversion of the wave forms from the analog to digital data (as contrasted with the time consuming and costly digitizing by hand method).

3. To test the possibility that differences do occur, but during a shorter epoch (i.e., a second's duration) a period of one second is recommended as the epoch length to be analyzed. With the use of a computer tape recorder system, the shorter epoch could be analyzed more easily and efficiently than the EEG strip chart recording method.

Another recommendation for future studies of this type would be the use of the Bett's QMI as a control. Sampling subjects with a broader range of imaging ability may provide a better spread of scores to correlate with alpha power spectra. In the present study, the relative homogeneity of the subjects (as reflected in the range of scores on the Bett's QMI, 4.6-6.2) and the somewhat small number of subjects may have reduced the potential for finding statistically significant variance.

Summary

This researcher feels that this area of research is worthy of more and better studies in the future. The availability of more facilitative technologies and increased theory construction in the area of lateral hemisphericity would prove beneficial to the fields of instructional technology and development. As an applied discipline, instructional design should be concerned with accessing the best scientific information available concerning questions of cognition, learning, and information processing. Experimental studies which investigate cognitive functions of the human brain can be conducted with the aid of appropriate research media and content experts. In studying first hand the neuropsychological variables of cognition, instructional technologists may accelerate the availability of theoretical guidelines for instructional applications of the potentially powerful visual information processing concepts. Moreover, it seems important that the field of instructional development not be content to wait for other disciplines to supply these guidelines.

This study was conducted as part of a team effort to develop a research system for investigating lateral differences in neural information processing. The strength of working as a group resulted in carefully considered decision-making, collaborative problem-solving, and analysis of methodology. The networking of resources, literature, professional contacts, individual talents, and time, was considered by this researcher to be a useful model for future investigators in this field. The acquisition of research skills by this group provided an opportunity to investigate more complex variables than would be possible by more conventional, individual efforts.

APPENDICES

APPENDIX A

THE BETT'S QMI VIVIDNESS OF IMAGERY SCALE

APPENDIX A

THE BETT'S QMI VIVIDNESS
OF IMAGERY SCALE

NAME: ______________________________ DATE: ______________

ADDRESS: ___________________________ TELEPHONE: _________

Instructions for Doing Test

The aim of this test is to determine the vividness of your imagery. The items of the test will bring certain images to your mind. You are to rate the vividness of each image by reference to the accompanying rating scale, which is shown at the bottom of the page. For example, if your image is "vague and dim" you give it a rating of 5. Record your answer in the brackets provided after each item. Just write the appropriate number after each item. Before you turn to the items on the next page, familiarize yourself with the different categories on the rating scale. Throughout the test, refer to the rating scale when judging the vividness of each image. A copy of the rating scale will be printed on each page. Please do not turn to the next page until you have completed the items on the page you are doing, and do not turn back to check on other items you have done. Complete each page before moving on to the next page. Try to do each item separately, independent of how you may have done other items.

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience. ....Rating 1

Very clear and comparable in vividness to the actual experience. ....Rating 2

Moderately clear and vivid. ....Rating 3

Not clear or vivid, but recognizable. ....Rating 4

Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

An example of an item on the test would be one which asked you to consider an image which comes to your mind's eye of a red apple. If your visual image was moderately clear and vivid you would check the rating scale and mark "3" in the brackets as follows:

Item		Rating
5	A red apple	(3)

Now turn to the next page when you have understood these instructions and begin the test.

Think of some relative or friend whom you frequently see, considering carefully the picture that rises before your mind's eye. Classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
1.	The exact contour of face, head, shoulders and body.	( )
2.	Characteristic poses of head, attitudes of body, etc.	( )
3.	The precise carriage, length of step, etc., in walking.	( )
4.	The different colours worn in some familiar costume.	( )

Think of seeing each of the following, considering carefully the picture which comes before your mind's eye; and classify the image suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

5.	The sun as it is sinking below the horizon.	( )

<u>Rating Scale</u>

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of each of the following sounds, considering carefully the image which comes to your mind's ear, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
6.	The whistle of a locomotive.	( )
7.	The honk of an automobile.	( )
8.	The mewing of a cat.	( )
9.	The sound of escaping steam.	( )
10.	The clapping of hands in applause.	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of "feeling" or touching each of the following, considering carefully the image which comes to your mind's touch, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
11.	Sand	( )
12.	Linen	( )
13.	Fur	( )
14.	The prick of a pin	( )
15.	The warmth of a tepid bath	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of performing each of the following acts, considering carefully the image which comes to your mind's arms, legs, lips, etc., and classify the images suggested as indicated by the degree of clearness and vividness specified on the Rating Scale.

Item		Rating
16.	Running upstairs	( )
17.	Springing across a gutter	( )
18.	Drawing a circle on paper	( )
19.	Reaching up to a high shelf	( )
20.	Kicking something out of your way	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of tasting each of the following considering carefully the image which comes to your mind's mouth, and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
21.	Salt	( )
22.	Granulated (white) sugar	( )
23.	Oranges	( )
24.	Jelly	( )
25.	Your favorite soup	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of smelling each of the following, considering carefully the image which comes to your mind's nose and classify the images suggested by each of the following questions as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
26.	An ill-ventilated room	( )
27.	Cooking cabbage	( )
28.	Roast beef	( )
29.	Fresh paint	( )
30.	New leather	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

Think of each of the following sensations, considering carefully the image which comes before your mind, and classify the images suggested as indicated by the degrees of clearness and vividness specified on the Rating Scale.

Item		Rating
31.	Fatigue	( )
32.	Hunger	( )
33.	A sore throat	( )
34.	Drowsiness	( )
35.	Repletion as from a very full meal	( )

Rating Scale

The image aroused by an item of this test may be:

Perfectly clear and as vivid as the actual experience.	....Rating 1
Very clear and comparable in vividness to the actual experience.	....Rating 2
Moderately clear and vivid.	....Rating 3
Not clear or vivid, but recognizable.	....Rating 4
Vague and dim.	....Rating 5
So vague and dim as to be hardly discernible.	....Rating 6
No image present at all, you only "knowing" that you are thinking of the object.	....Rating 7

International Matematics and Statistics Library

(IMSL) FTREQ Program Format

```
      -PROGRAM-F1019(OUTPUT,TAPE1,TAPE2)
       DIMENSION IND(6),XIND(2),XYHV(6),X(256),ACV(60),FREQ(61),PS(61)
       DIMENSION DATA(270,2),NAME(3),POWER(5),FRQ(5)
       COMMON XCOV(122)
       DIMENSION XSPECT(1),AMPHAS(1),XFER(1),COHER(1)
       INTEGER EXPR,SUBJ,TRIAL,LEAD,COUNTER
       EQUIVALENCE (XSPECT(1),XCOV(1)),(AMPHAS(1),XCOV(1)),(XFER(1),XCOV(1
      +)),(COHER(1),XCOV(1))
       DATA IND/0,256,0,60,0,0/
       DATA XIND/.390625E-2,0.0/
       DATA ENDD/0/
       DATA NAME/3HSUE,4HJOHN,5HTERRY/
10     DO 15 I=1,540
15     DATA(I)=0.0
       I=1
20     READ(1,25)ID,EXPR,SUBJ,TRIAL,LEAD,COUNTER,(DATA(I,J),J=1,2)
25     FORMAT(I5,T1,I1,2I2,I1,I4,2(2X,F8.3))
       IF(I.NE.1)GO TO 26
       LID=ID
26     IF(EOF(1).EQ.0.0)ENDD=1
30     IF(ID.NE.LID)GO TO 35
       IF(I.EQ.1)GO TO 31
       IF(I.NE.1.AND.DATA(I,1).GT.DATA(I-1,1)) I=I+1
       GO TO 32
31     I=I+1
32     IF(I.LE.270)GO TO 20
       PRINT *," MORE THAN 270 DATA POINTS"
35     BACKSPACE 1
       I=I-1
       ID=IX=1
       T=XIND(1)
40     IF(DATA(ID,1).EQ.T)GO TO 55
       IF(DATA(ID,1).LT.T.AND.DATA(ID+1,1).GT.T)GO TO 45
       ID=ID+1
       GO TO 40
45     IF(ID.GT.1.AND.ID.LT.I)GO TO 50
       X(IX)=RLGRINT(1,DATA(ID-1,1),DATA(ID-1,2),T)
       IX=IX+1
       GO TO 60
50     X(IX)=RLGRINT(2,DATA(ID-1,1),DATA(ID-2,2),T)
       IX=IX+1
       GO TO 60
55     X(IX)=DATA(ID,2)
60     IF(ID.LT.I) GO TO 40
       CALL FTFREQ(X,IND,XIND,XYHV,ACV,FREQ,PS,XCOV,XSPECT,AMPHAS,XFER,CO
```

```
      +HER,IER)
       IF(IER.EQ.129)STOP "IND VAL OUT OF RANGE"
       IF(IER.EQ.130)STOP "XIND VAL OUT OF RANGE"
       IF(IER.EQ.67)PRINT *," ************* WARNING ************* PS ES
      +IMATE < 0 --- SET TO 0"
       CALL SUM(PS,FREQ,POWER,FRQ)
       PRINT 65,NAME,EXPR,SUBJ,TRIAL,LEAD,(FRQ(II),POWER(II),II=1,5)
65     FORMAT(2X,*POWER SPECTRUM FOR *,A10,* SUBJECT *,I2,* TRIAL *,I2,*
      +LEAD *,I2/5(2X,2F20.10/))
      PRINT(2,65) NAME,EXPR,SUBJ,TRIAL,LEAD,(FRQ(II),POWER(II),II=1,5)
      IF(ENDD.EQ.0)GO TO 10
      END
      FUNCTION RLGRINT(NORD,X,Y,P)
      DIMENSION X(NORD,2)
      N=2*NORD
      RLGRINT=0.0
      DO 10 I=1,N
      RNUM=DENOM=1.0
      DO 5 J=1,NORD


      IF(I-J)1,5
1     RNUM=RNUM*(P-X(J))
      DENOM=DENOM*(X(I)-X(J))
5     CONTINUE
10    RLGRINT=RLGRINT+(RNUM/DENOM)*Y(I)
      RETURN
      END
      FUNCTION RECODE(FREQ)
      DIMENSION FMAX(5)
      DATA FMAX/4.,7.,13.,35.,60./
      IF(FREQ.LT.0)GO TO 99
      DO 10 I=1,5
10    IF(FREQ.LE.FMAX(I))GO TO 15
15    RECODE=I
99    STOP "BAD FREQUENCY"
      RETURN
      END
      SUBROUTINE SUM(PS,FREQ,POWER,FRQ)
      DIMENSION PS(61),FREQ(61),POWER(5),FRQ(5)
      DO 10 I=1,61
      FREQ=RECODE(FREQ)
10    CONTINUE
      J=1
      DO 20 I=1,5
      POWER(I)=0.0
15    IF(FREQ(J).NE.I)GO TO 20
      POWER(I)=POWER(I)+PS(J)
      J=J+1
      GO TO 15
20    CONTINUE
      RETURN
      END
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```

APPENDIX B

(IMSL) FFTREQ PROGRAM FORMAT

PROTOCOL FOR EEG RECORDING AT MICHIGAN STATE UNIVERSITY

EXPLANATION OF FOURIER TRANSFORMATION

PROTOCOL FOR ELECTROENCEPHALOGRAPH RECORDING AT MICHIGAN STATE UNIVERSITY

Special Diagnostics Laboratories

Beckman Accutrace 16

All EEG's recorded at the following settings unless otherwise indicated on the record:

Chart Speed-30 mm/sec.

60 Hz Filter-Off

Hi-frequency Filter-70Hz

Master Sensitivity-7.5 mV/mm

Time Constant-.16 seconds
(Lo linear filter-1Hz

Calibration voltage-50mV

Electrode Placement- International Ten/Twenty System

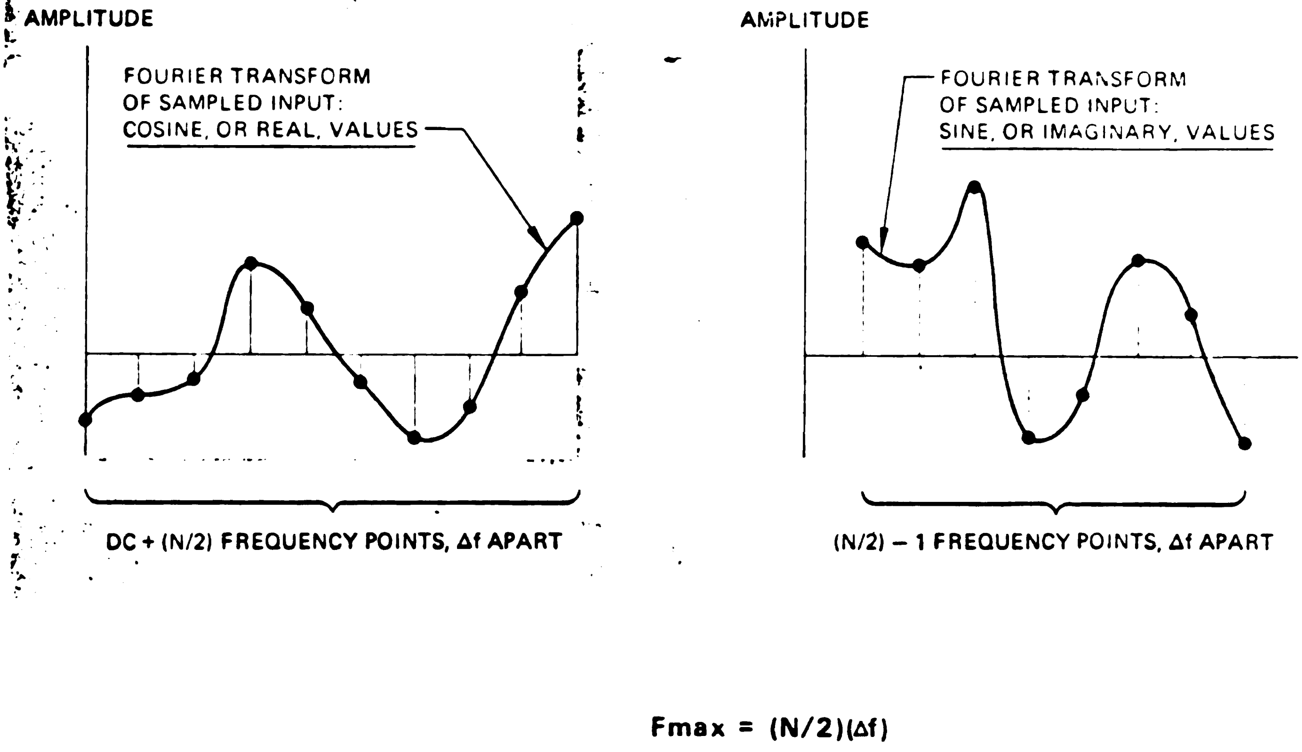

Fig. 2-4 Frequency Domain.

Frequency Domain

Once we perform a Fourier transform, there is a similar set of parameters in the frequency domain, as shown in Figure 2-4.

Δf—the number of Hz between frequency points, or, as more familiarly known, the frequency resolution. Origin of display is $0\Delta f$ (DC component, on real (cosine) displays only); next point is $1\Delta f$ (fundamental frequency); next point is $2\Delta f$ (first harmonic); next $3\Delta f$ (second harmonic), etc. Frequencies between the harmonics will not show. To make them show, a smaller Δf must be used (but there are limits to this, as explained on page 2-6). Δf on the ADC panel is called ΔFREQ.

N/2—the number of frequency points: this is half the block size, or N/2, because the frequency information is broken down into two displays; real or magnitude (depending on MODE switch setting), and imaginary or phase (depending on MODE switch setting).

F_{max}—the maximum frequency of the display, or in other words, the bandwidth. (MAX FREQ on the ADC panel.) From Figure 2-4, it can be seen that:

maximum frequency = no. of frequency points x frequency resolution

$$F_{max} = N/2 \times \Delta f$$

The time and frequency domains are related as shown in Figure 2-5.

sample interval = reciprocal of 2 times the maximum frequency

$$\Delta t = \frac{1}{2F_{max}}$$

frequency resolution = reciprocal of total record length

$$\Delta f = \frac{1}{T}$$

This means that changing one parameter will change the others.

Table 2-1 summarizes the equations above, and is also given in the Fourier Analyzer operating manual so that the user can obtain the best trade-off on the parameters he is interested in.

For example, suppose the user must have a 1 Hz frequency resolution (Δf) and at the same time wants a 5 kHz maximum frequency (F_{max}). He goes into Table 2-1 at line 3.

$$\Delta f = 1$$

In the last column, he sees that the equation relating frequency resolution (Δf) and maximum frequency (F_{max}) is:

$$F_{max} = (N/2)\ \Delta f$$

So:

$$5000 = (N/2) \times 1$$

$$N = 10,000$$

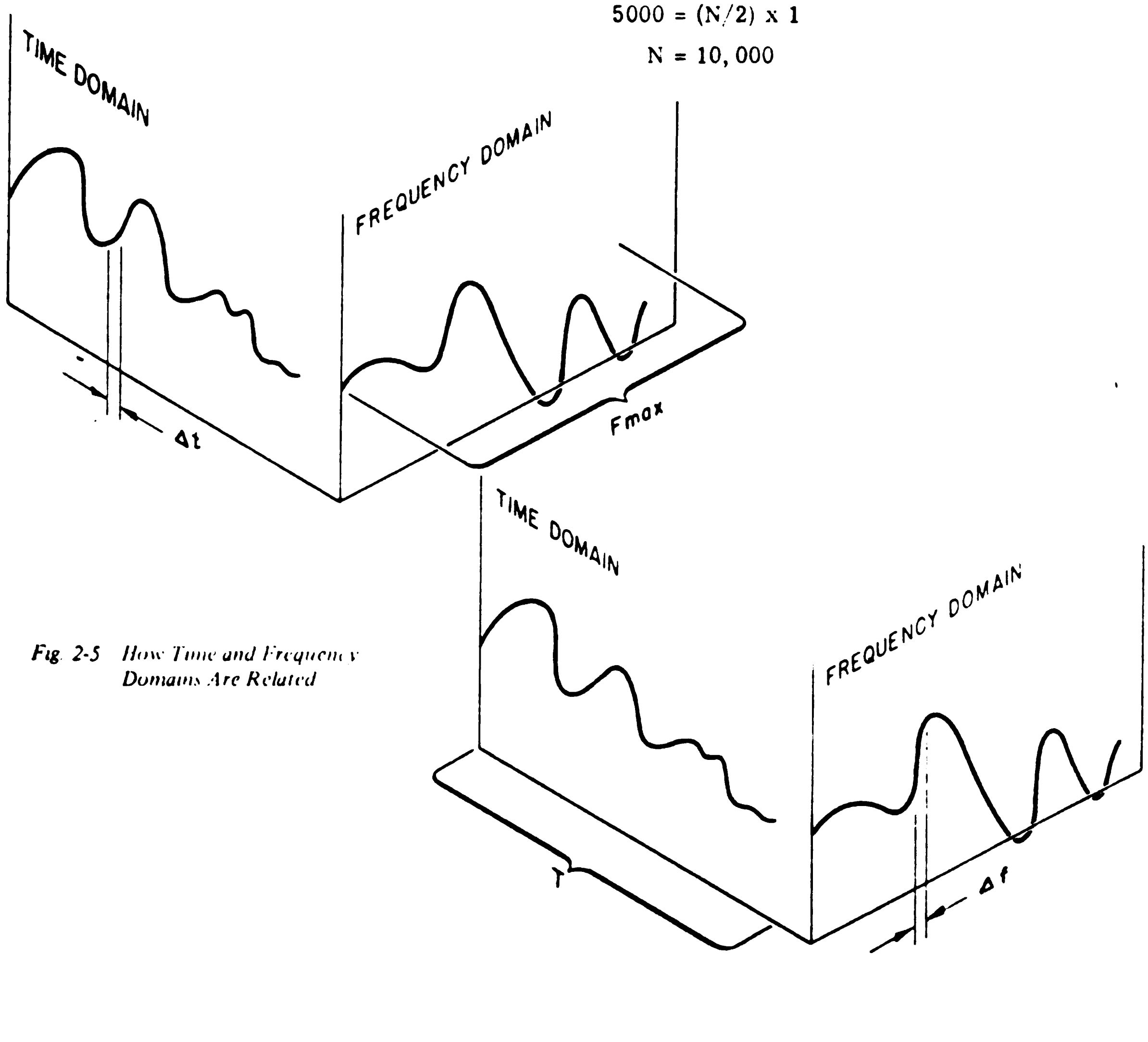

Fig. 2-5 How Time and Frequency Domains Are Related

But the largest block size in the 8K Fourier Analyzer is 1,024, and in the 16K is 4,096. So a block size of 10,000 is impossible. Something has to give. Suppose the user is willing to settle for a lower maximum frequency. Assuming he has an 8K machine, he will enter the largest block size available, 1,024, in the F_{max} equation, because this will give him the largest possible F_{max}:

$$F_{max} = 1,024/2 \times 1$$

$$F_{max} = 512 \text{ Hz}$$

If the user wants a 1 Hz resolution on an 8K machine, he must settle for a 512 Hz maximum frequency. Of course, if he needed the 5 kHz maximum frequency, he could have obtained it at the expense of some frequency resolution.

This is the kind of manipulation of ADC parameters which the user must be able to do. The parameters are set with the SAMPLE MODE and MULTIPLIER switches on the ADC, plus the BLOCK SIZE key on the Keyboard.

Table 2-1. Selecting Values for Data Sampling Parameters

Choose convenient round number for parameter shown.	Chosen parameter automatically fixes the value of parameter below, because of relationship in parentheses.	Then make either of the remaining two parameters (can't be both) as close as possible to the desired value by choosing N* in the relationships shown.
1. Δt	$F_{max}\left(F_{max} = \frac{1}{2\Delta t}\right)$	$T\ (T = N\Delta t)$ $\Delta f\left(\Delta f = \frac{1}{N\Delta t}\right)$
2. F_{max}	$\Delta t\left(\Delta t = \frac{1}{2F_{max}}\right)$	$T\ (T = N\Delta t)$ $\Delta f\left(\Delta f = \frac{1}{N\Delta t}\right)$
3. Δf	$T\left(T = \frac{1}{\Delta f}\right)$	$\Delta t\left(\Delta t = \frac{T}{N}\right)$ $F_{max}\left(F_{max} = \frac{N}{2} \cdot \Delta f\right)$
4. T	$\Delta f\left(\Delta f = \frac{1}{T}\right)$	$\Delta t\left(\Delta t = \frac{T}{N}\right)$ $F_{max}\left(F_{max} = \frac{N}{2} \cdot \Delta f\right)$
*N, the data block size, is always a power of 2.		

FOURIER SERIES

We know that time functions are often conveniently interpreted by the analysis of their frequency content. This approach is derived from the work of French mathematician Jean Baptiste Fourier. Fourier discovered that periodic time functions can be broken down into an infinite sum of properly-weighted sine and cosine functions of the proper frequencies. The mathematical statement of this discovery is:

$$x(t) = a_o + \sum_{n=1}^{\infty} a_n \cos\left(\frac{2\pi nt}{T}\right) + b_n \sin\left(\frac{2\pi nt}{T}\right) \qquad (4\text{-}1)$$

where T is the period of x(t), that is, x(t) = x(t + T)

When the coefficients a_n and b_n are calculated using the equations derived by Fourier, the amplitude of each sine and cosine wave in the series is known. Equivalently, when the coefficients a_n and b_n are known, the magnitude and phase at each frequency in x(t) is determined, where

$$\sqrt{a_n^2 + b_n^2}$$

is the amplitude at the frequency $f_n = (n/T)$, and $\tan^{-1}(b_n/a_n)$ is the corresponding phase.

THE FOURIER TRANSFORM

The Fourier Series is a useful tool for determining the frequency content of a time-varying signal. However, the Fourier Series always requires a periodic time function. To overcome this shortcoming, Fourier evaluated his series as he let the period of the waveform approach infinity. The function which resulted is known as the Fourier Transform. The Fourier Transform Pair is defined as:

$$S_x(f) = \int_{-\infty}^{\infty} x(t)\, e^{-i2\pi ft}\, dt \qquad \text{(Forward Transform)} \qquad (4\text{-}2)$$

$$x(t) = \int_{-\infty}^{\infty} S_x(f)\, e^{i2\pi ft}\, df \qquad \text{(Inverse Transform)} \qquad (4\text{-}3)$$

Where $e^{\pm 2\pi ft} = \cos(2\pi ft) \pm i \sin(2\pi ft)$, is known as the kernel of the Fourier Transform.

$S_x(f)$ is called the Fourier Transform of x(t). $S_x(f)$ contains the amplitude and phase information at every frequency present in x(t) without demanding that x(t) be periodic.

From the foregoing discussion of Fourier Series and Transform analysis, one sees that both of these techniques may be viewed as mathematical filtering operations.

THE DISCRETE FINITE TRANSFORM

The Fourier Analyzer utilizes a digital computer to calculate Fourier transforms of time-varying voltage signals. We will examine the results of computing the Fourier transform digitally, considering the forward transform,

$$S_x(f) = \int_{-\infty}^{\infty} x(t)\, e^{-i2\pi ft}\, dt \qquad (4\text{-}4)$$

In order to implement the Fourier transform digitally, one must convert the continuous input signal into a series of discrete data samples. This is accomplished by sampling (measuring) the input waveform, x(t), at certain intervals of time. We will assume that the samples are spaced uniformly in time, separated by an interval Δt. In order to perform the integral (4-4), the samples must be separated by an infinitesimal amount of time (i.e., $\Delta t \rightarrow dt$). Due to physical constraints on the analog-to-digital converter, this is not possible. As a result we must calculate

$$S_x''(f) = \Delta t \sum_{n=-\infty}^{n=+\infty} x(n\Delta t)\, e^{-i2\pi fn\Delta t} \qquad (4\text{-}5)$$

Where $x(n\Delta t)$ are the measured values of the input function.

Equation (4-5) states that, even though we are dealing with a sampled version of x(t), we can still calculate a valid Fourier transform. However, the Fourier transform as calculated by (4-5) no longer contains accurate magnitude and phase information at all of the frequencies contained in $S_x(f)$. Rather, $S_x''(f)$ accurately describes the spectrum of x(t) up to some maximum frequency (F_{max}) which is dependent upon the sample spacing, Δt. The determination of F_{max} is discussed further on page 4-4.

In order to calculate $S_x''(f)$, we must take an infinite number of samples of the input waveform. As each sample must be separated by a finite amount of time, one would have to wait forever for the calculation of $S_x''(f)$ to be completed. Clearly then, we must limit our observation time in order to calculate a useful Fourier transform. Let us assume that the input signal is 'observed' (sampled) from some zero time reference to time T seconds. Then we have

$$\boxed{T/\Delta t = N} \qquad (4\text{-}6)$$

Where N is the number of samples, and T is the "time window".

We see that restricting the observation time to T seconds is equivalent to truncating equation (4-5). As we no longer have an infinite number of time points, we cannot expect to calculate magnitude and phase values at an infinite number of frequencies between zero Hz and F_{max}. Equivalently, the truncated version of equation (4-5) does not produce a continuous spectrum. This discrete finite transform (DFT) is given below.

$$S_x'(m\Delta f) = \Delta t \sum_{n=0}^{N-1} x(n\Delta t)\, e^{-i2\pi m\Delta fn\Delta t} \qquad (4\text{-}7)$$

Only <u>Periodic</u> functions have such a 'discrete' frequency spectra. Therefore, equation (4-7) requires that our input function be periodic with period T. Conversely, equation (4-7) assumes that the function observed between zero and T seconds repeats itself with period T for all time. This assumption is made whether or not x(t) is actually periodic. It is apparent that the discrete finite transform, as calculated by (4-7), is actually a sampled Fourier Series.

Note that there are N points in the time series and that, for our purposes, the time series always represents a real-valued function. However, to fully describe a frequency in the spectrum two values must be calculated (i. e., the magnitude and the phase, or the real and imaginary part at the given frequency). As a result, N points in the time domain allow us to define N/2 complex quantities in the frequency domain.

If F_{max} is the maximum frequency present in the spectrum, then

$$\boxed{F_{max} / (N/2) = \Delta f} \tag{4-8}$$

where Δf is the separation of frequencies (referred to as resolution) in the frequency domain.

SHANNON'S SAMPLING THEOREM

Shannon states that it requires slightly more than two samples per period to uniquely define a sinusoid. In sampling a time function, this implies that we must sample slightly more than twice per period of the highest frequency we wish to resolve. Translating Shannon's theorem into an equation:

$$\boxed{F_{max} < \frac{1}{2\Delta t}} \tag{4-9}$$

For convenience, equation (4-9) will be written:

$$\boxed{F_{max} = \frac{1}{2\Delta t}} \tag{4-10}$$

When using equation (4-10) one should remember that the maximum frequency which can be accurately resolved is $F_{max} - \Delta f$.

Substituting (4-10) into (4-6) and employing (4-8) gives:

$$\Delta f = F_{max}/(N/2) = (1/2\Delta t)/(N/2) = 1/N\Delta t = 1/T$$

or

$$\boxed{\Delta f = \frac{1}{T}} \tag{4-11}$$

Equation (4-11), as a direct result of Shannon's Sampling Theorem, is a physical law.

FREQUENCY AMPLITUDE

Let A_n denote the peak amplitude of an input sinusoid of frequency f_n. In the Fourier Analyzer, the discrete Fourier transform is implemented such that the amplitude calculated for this f_n is $A_n/2$. Thus, the frequency amplitudes calculated by the Fourier Analyzer must be multiplied by a factor of 2 in order to display peak amplitudes. Similarly, these amplitudes are multiplied by $\sqrt{2}$ in order to display RMS values.

APPENDIX C

SUBJECT CONSENT FORM

SUBJECT DEMOGRAPHIC INFORMATION FORM

INSTRUCTIONS TO SUBJECTS

APPENDIX C

SUBJECT CONSENT FORM

1. I have freely consented to take part in a scientific study being conducted by ____________________ under the supervision of: ____________________ Academic Title: ____________________.

2. The study has been explained to me and I understand the explanation that has been given and what my participation will involve.

3. I understand that I am free to discontinue my participation in the study at any time without penalty.

4. I understand that the results of the study will be treated in strict confidence and that I will remain anonymous. Within these restrictions, results of the study will be made available to me at my request.

5. I understand that my participation in the study does not guarantee any beneficial results to me.

6. I understand that, at my request, I can receive additional explanation of the study after my participation is completed.

7. To my knowledge, I have no history of psychological disorder or epilepsy.

8. I understand that this is not a Clinical Center project. Therefore, I am not considered a Clinical Center patient.

Name: ______________________________ Date: __________

Signed: ______________________________
(Parent or guardian, if not 18)

Instructional Development & Technology
College of Education

SUBJECT DATA FORM

____
Code Number

1) Age ________ (in years) 2) Sex ___ 3) Handedness ___ (R/L)

4) Eye Dominance ___ (R/L) 5) What is your "native" language _______

6) Do you speak another? ______ (Yes/No) 7) Sheehan Scores ___________

8) Level of Education (in years) ___ 1-5 ___ 6-10 ___ 11-15 ___ 16-20 (check one)

9) Field of Study/Specialization (Please print) ___________________________

10) Have you ever participated in a study which used an EEG recording? ______ (Yes/No)

11) If yes to #10, please describe __________________________
____

12) Have you ever studied or practiced Transcendental Meditation or related relaxation techniques? ______ (Yes/No)

13) If yes to #12, how long?

______ 2 weeks ______ 1 month ______ more than 1 month ______ one year ______ more than one year

14) Have you ever been involved in a study which used a tachistoscope (t-scope) such as the one in this study? ______ (Yes/No)

15) If yes to #14, please describe briefly __________________
____

16) Have you ever participated in a psychological experiment which involved imagery, or visual perception tests? ______ (Yes/No)

17) If yes to #16, please describe briefly __________________
____

INSTRUCTIONS TO THE SUBJECT

1. Before EEG collection (facial recognition experiment)

A. Here is a picture of a face I would like you to look at and commit to memory. After you have had a few minutes to study the face I'm going to show you a number of pictures of faces. Some of the faces will be the same as the one you have memorized, and others will not be the same. Just be aware of whether they are the same or different.

B. Presentation of faces: The faces will be presented quickly--for less than a second. They will appear in either the right, left or center of your normal visual field. Close your eyes after the face appears. When I ask you, open your eyes and fix your attention on the small "x". The order of which side will show the face next is randomized, so don't try to anticipate where the next face will be presented. Your best strategy is to look at the middle (a small "x" will be superimposed on the visual screen) and let your eyes naturally view the face as it is shown.

C. We'll do a few practice trials to make sure that the procedures are "OK" and that our equipment is working. Remember to close your eyes as soon as you see the face appear and re-open them as soon as I tap you on the shoulder. OK, let's try a few faces.... (Experimenter taps subject and triggers the t-scope stimulus. Re-explains procedure as required. Attempts to relax the subject).

D. Things to remember: It is important that you remain relaxed. If you are tense, our results will be less helpful than if you just pretend this is a game situation. Try to remain comfortable and relaxed.

APPENDIX D

ALPHA SPECTRUM AND MEANS BY SUBJECT, BY HEMISPHERE, BY MODE OF PRESENTATION, BY STIMULUS

APPENDIX D

ALPHA SPECTRUM AND MEANS BY SUBJECT, BY HEMISPHERE, BY MODE OF PRESENTATION, BY STIMULUS

Subject	Same as Memory Face			Different than Memory Face		
	Left	Center	Right*	Left	Center	Right
1	.020	.007	.030	.120	.127	.007
	.106		.051	.017		.025
Left*	.009			.034		
Means	.045	.007	.04	.057	.127	.016
	.007	.010	.011	.066	.038	.010
	.067		.019	.010		.014
Right	.007			.014		
Means	.027	.010	.015	.03	.038	.012
2	.005	.004	.020	.009	.012	.011
	.006		.006	.016		.007
Left	.004			.006		
Means	.005	.004	.013	.010	.012	.009
	.006	.005	.020	.125	.018	.031
	.012		.005	.011		.010
Right	.005			.019		
Means	.007	.005	.012	.018	.018	.020
3	.009	.005	.021	.021	.015	.038
	.059		.012	.042		.014
Left	.016			.015		
Means	.028	.005	.016	.026	.015	.026
	.008	.004	.010	.012	.009	.025
	.038		.007	.020		.026
Right	.017			.019		
Means	.021	.004	.008	.017	.009	.025

Appendix D (Cont'd)

Subject	Same as Memory Face			Different than Memory Face		
	Left	Center	Right*	Left	Center	Right
4	.075	.011	.012	.011	.046	.096
	.018		.014	.023		.019
Left	.036			.022		
Means	.043	.011	.013	.018	.046	.057
	.034	.013	.007	.010	.046	.063
	.022		.008	.012		.012
Right	.033			.027		
Means	.029	.013	.007	.016	.046	.037
5	.048	.085	.027	.017	.126	.13
	.039		.007	.009		.032
Left	.048			.034		
Means	.045	.085	.017	.02	.126	.081
	.060	.089	.088	.018	.028	.012
	.041		.021	.023		.047
Right	.088			.044		
Means	.063	.089	.054	.028	.028	.029
6	.055	.042	.018	.021	.034	.057
	.055		.027	.069		.042
Left	.085			.106		
Means	.065	.042	.022	.068	.034	.049
	.018	.047	.007	.020	.031	.121
	.051		.016	.051		.025
Right	.039			.067		
Means	.036	.047	.011	.046	.031	.073
7	.025	.042	.029	.065	.015	.091
	.020		.020	.028		.005
Left	.018			.036		
Means	.021	.042	.024	.043	.015	.048
	.035	.029	.028	.083	.010	.061
	.030		.027	.022		.016
Right	.035			.045		
Means	.033	.029	.027	.05	.010	.038

Appendix D (Cont'd)

Subject	Same as Memory Face			Different than Memory Face		
	Left	Center	Right*	Left	Center	Right
8	.014	.089	.023	.055	.056	.011
	.064		.019	.063		.062
Left	.074			.044		
Means	.050	.089	.021	.054	.056	.036
	.037	.019	.034	.052	.088	.036
	.084		.050	.039		.041
Right	.011			.080		
Means	.077	.019	.042	.057	.088	.038
9	.016	.022	.059	.023	.026	.115
	.021		.008	.014		
Left				.017		
Means	.018	.022	.033	.018	.026	.115
	.013	.013	.042	.016	.026	.099
	.047		.010	.015		
Right				.013		
Means	.03	.013	.026	.014	.026	.099
10	.033	.043	.117	.065	.053	.165
	.044		.035	.018		.032
Left	.055			.010		
Means	.044	.043	.076	.031	.053	.098
	.011	.021	.074	.017	.022	.103
	.032		.008	.020		.020
Right	.033			.009		
Means	.025	.021	.041	.015	.022	.061

*Left, Center, Right refers to visual field presentation; Left and right refers to hemisphere. Blank spaces indicate missing data.

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