EFFECTS OF VERBAL LEARNING ADJUNCTS ON E.E.G. RELATIVE POWER AND TYMPANIC TEMPERATURE AS RELATED TO RECALL AND COMPREHENSION OF PROSE

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Abstract

A study was conducted to examine the role of imagery (induced and imposed) during learning on brain hemispheric processes and on recall and comprehension performance.

Sixty undergraduate subjects were randomly divided into three groups and given an adapted chapter on psychopathology from Introductory Psychology textbooks. Before studying the textual material, one group was given a paste up of pictures, selected from Introductory Psychology textbooks depicting the various mental disorders. The second group was given instructions to generate self created imagery about the mental disorders. The control group was given some irrelevant material (from a text on genetics) to occupy them for the same duration as the other two groups. Brain waves and tympanic temperatures were monitored during the learning phase. Recall and comprehension test scores were subsequently taken.

The results show the facilitation of recall performance by pictures (imposed imagery) but not for the self created imagery (induced imagery). Analysis of the E.E.G. power spectrum shows a likely engagement of the right cerebral hemisphere commensurate with learning with pictures but not for the induced imagery. Analysis of the tympanic thermal responses shows no indication of hemispheric differences between conditions although a directional trend was observed. Questions concerning the reliability of the thermal indicator, the various forms of pictures and forms of induced imagery possible to ameliorate learning and the various means of assessing performance were raised. The general conclusion was that pictures may assist verbal learning by possible engagement of the right cerebral hemisphere. Discussion of future related research possibilities is given.

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Effects of Verbal Learning Adjuncts on E.E.G. Relative Power and Tympanic Temperature as Related to Recall and Comprehension of Prose

Chapter I. Analysis of Research Problems and Hypotheses

Introduction

The general problem investigated in this project concerns the brain neurophysiological responses to using purported enhancers as adjuncts to verbal learning and whether these brain responses can be elicited by such adjuncts (adjuncts are presentations which are purported to influence the learnability of given material). The other issue of concern was which type of adjunct produces most effect on brain responses and whether this/these correspond(s) to the one(s) which induce superior learning. This project thus has practical significance - the study of the dynamics of cognitive processes underlying verbal learning mechanisms and theoretical significance - the elucidation of underlying neurophysiological processes.

According to Wittrock's (1977, 1980) theory of generative processing in verbal learning (interhemispheric enhancement and complementarity of functioning) the brain functions optimally and learns best if the material being learned is presented in such a way as to invoke activity in both of the cerebral hemispheres (Bogen, 1977; Mykel & Daves, 1979; Caterino, 1979; Tomlinson- Keasy & Kelly, 1979;

Baird, 1979). Wittrock suggests that learning by reading verbal material invokes left hemisphere activity but not necessarily the right hemisphere to any significant degree. Other researchers argue that learning verbal material engages primarily the left hemisphere. In order to engage additionally, the right hemisphere a concomitant holistic, simultaneous, or pictorial presentation of the subject matter is required. Wittrock further states that this dual representation of material being learned facilitates the acquisition processes and elicits superior recall and comprehension.

The idea of interhemispheric enhancement is compatible with some psychological representational processes assumed to be involved in the learning of verbal materials. For instance, Paivio's (1977, 1980) theory of imagery proposes a "dual coding hypothesis" (C.f. Bugelski, 1974; Bower, Clark, Lesgold, & Winzenz, 1970; Kintsch, 1975; Delin, 1969, etc.). This theory suggests that verbal and imagery information are represented and processed in separate cognitive systems. The imagery system is activated by pictures while the verbal system is activated by linguistic stimuli. According to Paivio, interconnectedness refers to the fact that verbal information can be transformed into nonverbal information and vice versa and the activation of both systems elicits superior recall. Paivio (1975) has recently elaborated his theory to include neurological (interhemispheric) considerations.

Although much of Paivio's work dealt with word pairs and pictures there is considerable suggestion that this enhancement in performance via dual coding may also apply to the learning of textual material (Kintsch, 1975; Buzan, & Dixon, 1974; Lorayne & Lucas, 1974). Paivio (1980) suggests that mental images serve as visual aids representing knowledge in memory and cites experimental evidence that these images can be used as learning and memory enhancers in numerous tasks and thus be used as an informational base for cognitive operations as aids to new learning (Denburg, 1977).

Some researchers have shown that pictures and other illustrations may have helpful effects on memory (Kosslyn, Holyoak, & Huffman, 1976; Nelson & McEvoy, 1979; Weaver & Stanny, 1978; Paivio, 1978; Srivastava, 1978, etc.) and there have been various suggestions that pictures can operate as advance organizers to summarize the studied verbal material. Other studies have not shown such positive findings perhaps due to the nature of the pictures used as adjuncts. The extent to which they capture comprehensively the full complexity of information provided in the textual material, variations in their salience, etc, has not been shown.

Buzan (1976, 1980) provides evidence that diagrammatic illustrations (patterned notes) sometimes in conjunction with pictures, can be very helpful in improving recall and comprehension of textual material. He proposes that such devices enable the learner to use both sides of his brain (Buzan, 1974, p.4) and has even developed programs to teach individuals to create their own picture-diagrams to represent various bodies of knowledge.

Wittrock (1967, 1974, 1975); Wittrock, Marks & Doctorow (1975) and Wittrock and Lumsdaine (1977) do not exclusively specify that the coding necessarily be pictorial to activate the right hemisphere, but that other forms of holistic encoding could also accomplish this, and adjuncts such as induced imagery, advance organizer and taxonomic organization provide vehicles to the integration of information. Hence, there might be a possibility that such holistic (right hemisphere) encodings could be activated via such verbal learning adjuncts as imagery instructions (induced imagery), picture diagrams, (imposed imagery) or taxonomic organization. Related variables from the educational psychology literature such as advance organizers (Ausubel, 1960, 1962, 1977) or adjunct questions (Rothkopf, 1970) might also accomplish this. This is especially plausible in light of the fact that induced imagery, picture diagrams and taxonomic organization have frequently been reported in the research literature as enhancers for verbal learning, and that Wittrock's (1978) theory of generative learning specifies these methods as enhancers of recall and comprehension. In pilot studies I have replicated some of the above findings (i.e. see Carsley, 1981, 1982 for the enhancing effects of imagery and taxonomic organization on learning). But there remains the question as to whether this enhancement occurs by virtue of invoking the right brain hemisphere as would be suggested by Wittrock, or by some other means.

According to Ornstein (1973) there may be a number of kinds of stimulation that could invoke the right brain hemisphere during verbal learning although each method could do so in a slightly different manner. Ornstein also provides empirical evidence showing differential hemispheric activity dependent upon the nature of the presentation of the material being studied (e.g. discrete vs. continuous or verbal vs pictorial).

The objective of this study was thus to investigate which, of some of the most commonly considered in the literature, enhancing techniques maximize such engaging of the whole brain (both hemispheres) and whether such enhancing technique(s) correspond to that which induce(s) superior recall and comprehension of the verbal material learned.

Psychological Representation Processes

Induced imagery. The body of literature on visual induced imagery seems to deal with giving subjects instructions to visualize, in the mind's eye, vivid (Montague & Carter, 1973) and active images depicting the content of what is being learned (Levin & Devine-Hawkins, 1974). There is, however, controversy in the literature concerning whether adult students benefit from being given a mnemonic strategy such as "imagery instructions", and researchers such as Rohwer (1968, 1973) suggest developmental changes during mid childhood and adolescence. Given a learning task some data indicate that the late middle childhood subject may not likely be able to mediate associations (by elaboration) between words to be remembered. Rohwer (1973) claims that it would probably not occur to such a child to picture memorable interactions between word referents and to create a story. In other words this individual would not spontaneously elaborate despite the fact that he may profit from such elaboration and indeed seems to when explicitly instructed to do so. On the other hand, Rohwer (1973) maintains that the tendency to do exactly that (pictorial elaboration) does develop during adolescent years, at least among higher ability subjects (Rohwer & Levin, 1971), thus suggesting that instructions to elaborate may not be necessary for adolescent subjects or at least only be needed as minimal prompts. Hence, adolescents may not improve with such instructions since the instructions would only be telling them to do something which they already do.

Data reported by other researchers (Bower & Winzenz, 1970; Bull & Wittrock, 1973; Delin, 1969; Mueller & Jablonski, 1970; Wood, 1967, Bugelski, 1974) demonstrate the significant beneficial effects of instructing adolescents to use pictorial elaboration. These researchers instructed groups of college students to learn lists of words (serially) by linking the items together into a story with vivid imagery. This method is reported to have helped people learn the lists faster and make fewer errors in recall. In Bugelski's (1974) experiment, for instance, college students who used the pictorial elaboration technique recalled an average of three times as many words in order as did the students who did not receive instructions to do so. Levin (1973), working with fourth and fifth graders found the effect of narrative prompts varies with the number of sentences comprising the narrative generated and the particular order.

Lorayne and Lucas (1974) describe a method of applying imagery to enhance learning and recall of prose material. It consists of forming, in the mind's eye, vivid personally memorable pictures representative of the content of what one is reading. Abstract words or ideas are pictorally represented by concrete images that can stand for them and the series of personal images should be made as vivid and interactive as possible. Since Kintsch (1975) has shown that the learning dynamics for prose are essentially the same as for word lists, this technique was expected to improve recall of prose material. It was also expected to improve comprehension (Levin, 1972, 1973). The learning of prose material such as that in an Introductory Psychology text would thus be expected to be amenable to enhancement via these kinds of adjuncts (induced imagery).

<u>Pictures and diagram illustrations</u>. These refer to the presentation to the learner of concomitant pictorial stimuli or combined pictorial, diagrammatic and synthetic verbal stimuli. There is ample evidence demonstrating the beneficial effects of such pictorial presentations as adjuncts to learning textual material (Levin & Lesgold, 1978). Some findings, however, have not always demonstrated such positive effects. Some reported that self generated imagery may surpass picture presentation (imposed imagery) as a verbal learning adjunct, and that, in some cases, pictures might distract from the reading task. This may well be tempered, however, by the fact that, generally, recall of pictures has been found to surpass recall of words at all age levels (Parker, 1981; Rohwer, 1973; Peloquin, 1979).

It was found by Chmielewska (1975) that lecture plans incorporating a pictorial mode were most effective, even more than questions or other statements in increasing the "scope, durability and conciseness" of content understanding and recall by students. Stone and Glock (1981) studied the effect of illustrations as adjuncts to text on procedural information in 90 university undergraduates and reported positive findings and suggested that certain types of information are more effectively presented in combination with pictorial illustrations (Schallert, 1980). Others, however, such as Duchastel (1980) reported a lack of enhancement of retention of verbal material presented in conjunction with illustrations, and suggest that refinements to the theory need be specified.

However, an important issue they seem to have ovelooked is the nature of the illustrations and the extent and manner in which they capture the content of the verbal material. Using 12 and 13 year olds, Haring (1978), however, obtained pictorial facilitation of immediate and delayed recall with story-like verbal material and, also using undergraduates, Stopher and Kirsner (1981) suggested that depending upon whether unique or shared concept combinations are involved, the study of pictorial items positively influenced retention of sentences with which they shared a concept. The work and teachings of Buzan (1976, 1980) suggested that combined diagrammatic and pictorial presentation before a "to be learned" body of information can significantly enhance comprehension and recall. In The Human Brain, Wittrock, Beatty, Bogen, Gazzaniga, Jerison, Krashen, Nebes & Teler, (1977), described similar methods of pictorial representation which purport to enhance learning and memory.

In a review of the literature, Levin (1981) proposed that methods combining pictures with key words are the "up and coming" mnemonic of the 80's for improving learning and memory. He refered to their "proven effectiveness", "versatility", "adaptability to student differences", and "potential to foster creativity and logical thinking". Levin (1973) found positive outcomes of pictorial mnemonics using children. Others too have obtained similar results using pictures. Purkel and Bornstein (1980) found that pictures (or imagery) enhanced recall of sentences in children. Rusted and Coltheart (1979) investigated the effects of pictures on memory of new words and prose passages in 9 to 12 year olds, good and poor readers. They found that the pictures signficantly improved recall and that there was no interaction with reading ability. The pictures, however, were found to have no effect on recognition or pronunciation. Also using children Murphy and Wood (1981) found that pictorial information significantly improved task performance. Borys (1978) found that experimenter supplied pictures helped recall of prose in retarded adolescents. Bender and Levin (1978) obtained similar results with retarded 10-16 year old children. Using undergraduates, Snodgrass asnd Asiaghi (1977) found that learning with pictures could help concept comprehension in a recognition test. Dragone, Brown, Krane and Krane (1980) found evidence of hypermnesia (increment in recall over multiple recall attempts) when word lists were presented with pictures. Similarly, Parker (1981) found beneficial effects of pictures but mostly for "recency items". Pictures have been found to also facilitate paired associate learning in children and adolescents especially if the pictures were such as to elaborate the pairs of stimuli. Some critics have argued that pictures may have only marginal effects, and others who have not obtained positive outcomes, argue that pictures do not help and in some cases can distract (e.g. Samuels, 1977; Willows, 1978; and Thomas, 1979). However, it seems that the pictures used in these various studies may not be equivalent or even comparable insofar as their nature and the effects they can be expected to produce.

There have been many studies comparing the effects of pictures (imposed imagery) to those of subject generated imagery (induced imagery) and the findings have been contradictory. There seems to be lack of agreement about how these effects change with age and about the different focus of the studies. For example some studies present the picture as targets of study and use words as labels, others focus on the verbal learning and use the picture as adjuncts. So, different outcomes might be attributable to the nature of the task required and how it relates to the adjunct or learning enhancer provided. An integration of findings obtained in the research, however, seems to suggest that pictures are generally better remembered than words over all ages.

Concerning the controversy about whether imposed imagery is better than induced self generated imagery in verbal learning, a synthesis of the research reveals complex interactions. In general, self generated (induced) imagery may be more advantageous. Various authors have explained this as being due to the more personal nature of self generated imagery and the attendant greater likelihood of producing better associative links. Others have found only slight overall differences or none (Purkel, & Bornstein, 1980) between these two forms of imagery (Snodgrass & Asiaghi, 1977) and ascribe the superiority of all forms of imagery to superior sensory and meaning codes. It would, however, seem that the nature of the verbal material to be learned might also be an important determining factor often overlooked. If one were concerned with developmental differences the age variable might also interact in a complex way. Since hemispheric specialization has been shown not to be complete until adolescence (Tomlinson - Keasey, Kelly, & Burton, 1978) and there may be fairly wide individual differences insofar as the nature of and order of lateralization for various tasks (Turner & Miller, 1975) it is not surprising that inconsistent findings were found concerning the age changes in response to pictures and induced self generated imagery. There is, however, agreement that lateralization is complete in most individuals by adolescence (Wittrock, 1980; Springer & Deutsch, 1981). Hence work carried out to study these problems with adults might yield more stable findings due to considerable and differing developmental variability.

In using presented pictorial stimuli to enhance the verbal textual material, the nature of these stimuli is thus an important, perhaps critical, consideration in determining whether the stimuli can have the desired enhancing effect. If the pictorial stimuli provide sufficient conceptual details to capture the equivalent to the text and induce further elaboration of this material, it seems likely that they might have an enhancing effect on comprehension and memory. Not any kind of picture, however, can be expected to have an impact on the learner, and the kinds of pictures used need to be tailored to the subject matter. Picture-diagram stimuli which allow rehearsal (Irvin, 1976) and provide additional facilitation and content clarification (Levin, et al, 1977), perhaps by making an elaboration of the material, would be expected to enhance learning perhaps by activating significant areas from both brain hemispheres (Tomlinson - Keasy, Kelly & Burton 1979).

Measures of learning performance. Mayer's work and other experiments that endeavor to test the effects of various learning conditions, or strategies, upon verbal learning performance often concern themselves with different measures of performance. Some examine the effects of various manipulations upon verbatim memory, others consider thematic recall, others consider reading improvement and others comprehension. Sets of conditions which maximize a given measure of verbal performance may not necessarily be the same ones that would maximize another aspect of performance. In other words, depending upon desired outcomes specific learning conditions may elicit different results. Yet, Kintsch (1975) maintains that there is "a striking continuity between memory for word lists and memory for text" (p. 169). He further suggests that the parallels between list learning and the results of research with texts may be indicators of a "common process" and that the study of textual material can be built upon the solid base of facts and the relatively advanced theoretical understanding which exists in list learning research. Thus, Kintsch's (1974) theory of episodic memory for list learning is said to be extendable to text memory. Kintsch (1975) assumes that the "encoding and storage operations in memory are basically the same whether the material to be learned consists of word lists or prose paragraphs" (Kintsch 1975, p. 269). With word lists, Kintsch asserts, processing is necessarily restricted to lower levels of analysis. Syntactic and semantic processing is possible only in a very limited way. Text comprehension on the other hand, involves complex processes at the syntactic and semantic levels, and a need for multiple memory representation arises. Kintsch's (1974) broad theory brings together specific submodels and a wide variety of empirical results by means of a few key concepts and processing assumptions. His theory seems logical and may have overemphasized the similarity between word lists and prose, and does not specify the degree of divergence of word lists from various kinds of prose (i.e. story vs. technical prose, etc.).

Since, assuming Kintsch's (1977) theory to be tenable, the presentation of material by way of definitions has approximately equal effect upon comprehension and memory (Anderson & Kulhavy, 1972), comprehension and recall seem like the most educationally relevant variables to study. Comprehension and recall would, however, not be orthogonal. If the theory that superior students already use organizing and mediating strategies is tenable as well as Ausubel and Fizgerald's (1962), one would expect that those who do not use these strategies already (on the basis of the above rationale with low grade-point-average) would be maximally helped by instructions to do so.

A test of the effectiveness of induced imagery and picture diagrams for the learning of material already reasonably organized such as a chapter on "Psychopathology" from a first year college Psychology text was expected to shed light on the processes (Pirozzolo & Wittrock, 1981) involved as well as provide some clarification concerning when each of these techniques might most beneficially be used in teaching.

Other related variables

Although there are other structural and/or process variables, such as note taking, taxonomic organization, advance organization, symbolic cues around words, questions and other mathemagenics which have been proposed as enhancers of learning, only fragmented knowledge about their function exists. The suggestion that these might invoke possible increase in involvement of the right cerebral hemisphere is interesting. Taxonomic organization of textual material is analogous to list blocking in the learning of word lists. It is a hierarchially arranged organizational summary of the material. Wittrock and Carter (1975) and Ornstein (1970) reported positive effects of taxonomic organization providing a proper hierarchy is used. Material can be provided with organization in a number of other ways, for instance, according to Ausubel (1960, 1977), an early proponent of assimilation theory and developer of the concept "advance organizer", an advance organizer consists of an adjunct presented before the learned material which links the new material to known knowledge. Many other researchers such as Wittrock (1980) have also concluded that advance organizers may improve comprehension of prose passages.

Richards (1959) used specialized symbols placed around text words to cue analytic behaviors during reading and reported positive effects. Smith and Kulhary (1974) examined the influence of adjunct rules and objectives upon recall without consistent findings. Whereas Rothkopf (1972) reports increases in performance by the use of objectives, others have failed to find such effect. Adjunct rules are also ambiguous with respect to whether they enhance learning or not.

Rothkopf (1970) describes any activity that determines and influences the nature of the learning process a "mathemagenic". He also (1966, 1969) provides evidence that questions, before or after a prose text may predictably influence direct and indirect retention which was also supported by Frase (1968). The suggestion is that such adjuncts shape inspection behaviors during reading. Questions, however, can be provided in various ways. For instance, they can be asked during instruction about every important point students should master or they can be more general. They can be spaced in different ways (e.g. after a passage, before a passage, interspersed between paragraphs) but generally, the closer they are to the target information, the better. Response modes (i.e. mulitple choice vs short answer items) also elicit different outcomes. The most accepted theory seems to be that post generations reinforce learning responses by invoking appropriate reading skills in the way of inspection behaviors consistent with objectives implicit in the questions. Pre-questions are reported to influence retention of specific verbation recall whereas post questions facilitate more general conceptual learning as related to a "transfer type" learning.

Although the type of materials used were reported to have negligible effect upon the influence of questions given the suggestion of Donald (1980), it seems clear that insufficient attention may have been given to this point.

Questions may thus be motivational. They may also have arousal and associative outcomes and consequences of the questions for learning and remembering and knowledge about questioning may have important implications for education.

Findings from empirical research studies without thoughtful conceptualizations, without explicit responsibility for developing theory of instruction and without contribution to knowledge about instruction (Wittrock 1967, p. 1) seem to characterize much of the research, so far, in educational psychology. The present study counteracts these deficiencies by focusing upon the reportedly most potent learning adjuncts and relating their effect to Wittrock's emerging theory of interhemispheric brain engagement. Although Wittrock's theory suggests other possible enhancers the present study did not investigate these but focused on imagery instructions and pictorial diagrams only.

Brain Neurophysiological Correlates of Learning

Many studies on neurophysiological correlates of learning have involved examining patterns of electrical brain activity during training. Some have involved electroencephalographs (e.g. Barratt, 1956), some brain blood flow (e.g. Franzen & Ingvar, 1975), and others brain blood temperatures (Minard & Copman, 1963) which are a reflection of blood flow and metabolic activity. The present study is primarily concerned with neurophysiological correlates of learning only in terms of electroencephalographic responses and temperature change in the brain. Therefore, reported studies involving these and related aspects of the brain activity only are examined in the following sections.

General cerebral function. The Cerebral Cortex can broadly be divided into two sections: one for reception and the other for execution. The parietal, occipital and temporal lobes seem mainly concerned with reception, perception and interpretation whereas the frontal lobes generally seem concerned with execution or action.

The post central gyrus in the parietal lobe and its adjacent areas of the superior and inferior parietal lobules are responsible for the reception of somatosensory data and its interpretation, respectively. Heschl's transverse gyri in the superior temporal gyrus (temporal lobe) and the adjacent planum temporale and middle temporal gyri seem responsible for auditory reception and interpretation respectively. In the lips of the calcarine sulcus and adjacent regions of the occipital lobe lie visual reception and its interpretive areas, respectively. These visual interpreting areas also have a region that governs, via corticotectal fibers, involuntary conjugate eye movements, such as tracking an object. Some play a role in the accomodation and convergence reflex via Edinger Wesphal nuclei and ocular nuclei. The large region of confluence of the parietal, occipital and temporal lobes (around the angular gyrus and inferior parietal lobule and posterior and inferior temporal gyri) are abstract interpretive areas sometimes referred to as general associative areas because abstract interaction and synthesis of sensory modality data seems to occur here. Here, data seems to be carried in codes that are removed from and transcend the sensory impressions and these codes readily interact with data from other modalities.

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The precentral gyrus and adjacent regions of the superior, middle and inferior frontal gyri (premotor) seem involved with specific voluntary motor action and higher level motor sequences, respectively. A region in the posterior middle frontal gyrus controls voluntary conjugate gaze and may be important in reading behavior. Oculomotor and abducens cranial nerve nuclei are coordinated via the medial longitudinal fasciculus by the parabducens nucleus with information from the optic nerve, the pretectal nucleus, the superior colliculus and occipital lobe association areas. The more anterior regions of the superior, middle and inferior frontal gyri (prefrontal cortex) to the frontal pole seem involved with higher level execution such as planning, foresight and judgement. A recent study by Bogen (1983) implicates the prefrontal lobes particularly the right one in creativity, and the study by Milner (1983) implicates them in delayed free recall. P.E.T. scan findings by Ingvar (1976) suggest that the prefrontal lobes may be involved in many activities, perhaps involved in response to the limbic system.

In the opercular and triangular regions of the inferior frontal gyrus in the left hemisphere lies Broca's area, an important center in expressive language production. Covering the left hemisphere auditory association areas of the planum temporale and extending, according to some authors, to the angular gyrus, lies Wernicke's area. This region is essential for language comprehension. The arcuate fasciculus joining these two language zones also plays an essential role in language related activities.

Homologous sites of the right cerebral hemisphere function in a way generally similar to those on the left and govern functions of the opposite side of the body. Some systems, though, have bilateral innervation and uncrossed systems function ipsilaterally. Areas of the right hemisphere corresponding to the language areas of the left, however, seem to possess specialized functions and their manner of processing information may be different. Such areas of the right hemisphere appear to play a role in visuospatial and configurational functions as well as in music appreciation. Spatial orientation, color and form perception may be organized in the areas of the right cortex corresponding to Wernicke's and Broca's areas in the left. Such an area has been discovered in the superior and inferior parietal lobules and right cortical regions of the superior and middle temporal gyri and the planum temporale are also involved with music.

Of interest in the present study, however, are the general interpretive areas of the angular gyrus, inferior parietal lobule (areas involved in abstractive association sometimes referred to as "ideational language areas", "general interpretive areas", or sometimes considered part of Wernicke's area) and posterior and inferior regions of the temporal lobes which are claimed to be involved in memory (Milner, 1983).

Brain hemispheric specialization. Although each hemisphere has the potential for many functions and both sides of the brain participate in most activities (theory of mass action), in the normal person the two hemispheres tend to specialize. The left hemisphere is predominantly involved with analytic logical thinking as in verbal and mathematical functions. Its mode of operation appears primarily linear. It processes information sequentially so, implies logical thought and linear time. Sequence, order, language and mathematics, seem to be primarily left hemisphere activities.

The right hemisphere seems specialized for holistic (synchronic) functions. Its language abilities appear limited, but it seems to function in spatial tasks, imagery, facial recognition and comprehending pictures. It is believed to process information more diffusely than the left, and its responsibilities seem to demand a ready integration of many inputs at once. The right hemisphere is thus more holistic and simultaneous in its mode of operation (Ornstein, 1972).

Neurological evidence on the main functions of the two cerebral hemispheres comes mainly from people whose brains have been damaged by accident or illness, or surgery had been performed on them. The work of Penfield (1951, 1952, 1975) and Penfield and Roberts (1959) on brain stimulation has also been very enlightening. Overall findings show that subjects with lesions to the right hemisphere display deficits related to imagery, spatial comprehension and manipulation although their language function usually remains intact, whereas patients with lesions to the left hemisphere display linguistically related impairments (various forms of aphasias) or computational deficits, although their spatial or pictorial abilities tend to remain intact.

Milner, Branch, and Rasmussen, (1964) have studied the specific disorders resulting from such brain lesions. They found that lesions to the right hemisphere severely impair performance in visual and spatial mazes, produce spatial agnosia and facial agnosia, whereas lesions in contralateral homologous zones of the same extent produce no deficits for these tasks. Volpe, Ledoux and Gazzaniga (1979) found the "neglect" syndrome in many patients with right hemisphere damage and various degrees of homonymous hemianopsia depending on the caudal extent of the damage. Milner, et al. (1964) also found that lesions in specific areas of the left hemisphere produce specific language disorders. Lesions (Milner, 1954, 1970) in the anterior left temporal lobe produce verbal memory deficits; lesions in the posterior left temporal lobe produce speech impairment; damage to the arcuate fasciculus produces conduction aphasia (lack of access to content of language); damage to Broca's area produces an inability to utter normal speech (expressive aphasia) though the semantic content and grammatical structure may be normal; damage to Wernicke's area produces an inability to understand both spoken or written language (receptive aphasia) (Geschwind, 1970); damage to the fibers which connect the occipital cortex to the left hemisphere results in alexia without necessarily agraphia (Geschwind, 1965) but a motor alexia can be produced by lesions in Broca's area.

Split brain studies (Sperry, 1966, 1974; Bogen, & Vogel, 1962; Gazzaniga & Sperry, 1967) collectively substantiate the findings from studies of brain lesions concerning the functional purpose of various regions of the human brain. Subtle tests of commissurotomized individuals have supported the findings concerning specialization of each hemisphere. The left hemisphere is specialized for language related functions (speaking, writing, reading, hearing and comprehending language, etc.), whereas the right hemisphere is specialized for spatially or holistically, (gestalt) related functions (form and shape recognition and comprehension, imagery and pictorial representation, figures etc.). Such tests have shown that, whereas the left hemisphere operates largely in a sequential manner, the right hemisphere operates predominantly in a simultaneous manner - it integrates diverse inputs quickly. Careful tests of these split brain patients also demonstrate the effects of isolation of the capabilities inherent in each hemisphere. For instance, linguistically related tasks sensorily sent to the right hemisphere could not be carried out. Spatial or pictorial tasks sensorily directed to the left hemisphere could not be carried out.

Geschwind (1970, 1979) has called attention to the fact that understanding of written language requires that sensory information in the visual cortex reach Wernecki's area by means of the angular gyrus and has found interesting varieties of dyslexia following lesions in these parts of the brain. Geschwind cites a patient who suddenly lost the ability to read (alexia), and along with it some ability to see in the right visual field. Postmorten examination revealed some damage to the left visual cortex (which accounts for the partial loss of vision in the right visual field), and the posterior part (splenium) of the corpus calossum which normally conveys messages from the right visual cortex to the left hemisphere (where reading functions are processed). Visual messages which were received by the remaining visual cortex in the right hemisphere could not be conveyed to Wernicke's area in the left brain hemisphere. It has also been found that widespread damage to these and neighboring areas can produce global aphasia.

Studies involving the Wada test also support such findings concerning the primary localization of functions in the human. Wada and Rasmussen (1960) demonstrated that, if the left hemisphere is temporarily anesthetized, loss of language functions result. This does not happen if corresponding parts in the right hemisphere are anesthetized. Other studies using normal adult subjects have shown that when language tasks are directed to the left hemisphere, accuracy and reaction times are better than when directed to the right one. When spatial tasks are directed (in the normal person) to the right hemisphere accuracy and reaction time are better than when directed to the left (McKeever, & Huling 1970). In addition, Durnford and Kimura (1971) in a carefully controlled experiment with normal subjects found the right hemisphere to be superior in depth perception. Depth perception obviously requires fairly complex integration and comprehension of position, size, shading, overlap, known standards, retinal disparity, perspective etc. It has also been discovered that they tend to be quicker to signal "same" to letters which are physically (pictorially) similar (EE) if the visual stimuli are directed to the right hemisphere. In contrast, these subjects are quicker to detect two letters of different shape but the same semantically (Ee) if the stimuli are directed to the left brain hemisphere (Cohen 1973). Eye movement studies (Kimura, 1966) have also supported these findings on hemispheric specialization (Bogen, Dezure, Tenhouten & Marsh, 1972; and Bakan, 1969).

Humphrey and Zangwill (1951) have found that damage to the right parietal lobe seems to interfere with dreaming. Also Bogen (1977) noted that split brain patients tend to report an absence of dreams and conclude that this may be because of the isolation of the pictorial (right) hemisphere from the verbal and thus no access of dream picture information to the verbal hemisphere. In addition, drawing capabilities and musical tasks seem localized in the right hemisphere

(Nebes, 1977). The findings of Murray & Carsley (1979) substantiate this and further suggest that the totality of interpersonal and environmental experiences created by the more successful music teachers is such as to invoke this right (minor) hemisphere of the brain. The findings of all these studies are not to say that the left hemisphere has no spatial ability at all and the right no language at all (Zaidel, 1973). It has been found that they possess a little of each but that those respective functions (Milner, 1971) reside predominantly in their specialized hemisphere.

The localization of functions in the brain appear analogous to overlapping contours of a geographical map or different intensities of waves originating from different focal points. Some functional parts of the brain or a given region of one of the hemispheres may be essential for a given function e.g. Broca's or Wernicke's area for language functions, the somatosensory strip for sensation or the borders of the calcarine fissure for vision. But there seems to be progressive overlap in function between zones in areas such as the prefrontal lobes, the middle and inferior temporal gyri and especially in areas of the angular gyrus and inferior parietal lobule. In those areas, information appears processed in codes that are not modality specific but seem to incorporate the elements of the main modalities of vision, auditory and somesthesis.

The two hemispheric functions thus seem to exist as semiindependent information processing units with some overlap of function but with different specialties. The educator Jerome Bruner

(1962) has made many references to this fact (derived from his observations and finding in educational settings). His admonitions concerning learning through experiencing and discovery suggests that the brain may be more receptive to comprehending and remembering knowledge obtained in ways that provide a more pictorial appreciation than merely reading about it.

Upon considering these findings Bogen (1977) suggests that instructional materials ought to stimulate not only the analytic and sequential functions (Mondani, 1977) of the left hemisphere but also the imaginal and holistic functions of the right, in view of the fact that it is in the latter that creativity resides (Gowan, 1979). Bogen (1983) has found the right hemisphere plays an important role in creativity. It is believed that the use and development of both hemispheres is essential to complete mental functioning and that almost any idea can be learned more thoroughly if methods involving both hemispheres are used (Milner, 1983; Bogen, 1983). Judging by the brain functioning of so-called gifted or creative geniusses of our time, it would seem that these admonitions may be correct. For instance, Einstein reported using imagery for his greatest discoveries, Darwin's theory of evolution and Mendelleiv's discovery of the atomic chart were said to have been arrived at visually and Kekule reportedly discovered the Benzene ring in dream imagery.

Brain electroencephalography (E.E.G.). E.E.G. studies of learning have examined changes in patterns of E.E.G. activity produced during learning. E.E.G. waves are summations of excitatory and inhibitory synaptic potentials of neurons. The E.E.G. represents oscillations in voltage potentials generated by cell neurons within the range of a recording electrode (Cotman & McGaugh, 1980). Evoked electroencephalographic potentials are E.E.G. waves time locked (i.e. recorded in conjunction with the presentation of) to specific stimuli. The question asked in such a study of E.E.G. correlates of learning is whether there are changes in the E.E.G. patterns that are associated specifically with the specific learning process. (i.e. evoked in the presence of learning stimuli and learned responses)

In the 1950's many studies investigated E.E.G. activity in animals during learning and reliable outcomes were found in a variety of species. Other findings in a series of studies involving humans (John, 1967, 1972) indicate that learning produces highly specific changes in the wave shapes of evoked potentials recorded from several cortical brain regions. Wave shapes appropriate to the learned behavior consistently occurred in the later learning trails. It was found that responses could be predicted by the shape of the evoked potential elicited by the specific stimuli, which would not be elicited by other different stimuli that did not yield the responses. On the basis of such findings, John (1972) suggests that information about an experience is represented by coherent activity in assemblies of cells and that "the information is read out when the appropriate stimulus activates the representation system in such a way as to cause release of a common mode of activity like that stored during the learning experience" (John, 1972).

A variety of other neurophysiological changes in brain response were found to occur during learning. For instance, during conditioning studies a large number of brain areas were found to show increased firing patterns (Thompson, 1976; Berger, Alger, & Thompson, 1976). Case studies and conditioning experiments involving humans have indicated activity in the hippocampus directly related to the learning process whether it be classical conditioning, operant learning, or long term memory formation for verbal material.

New techniques have been developed which can trace neural events which occur during different kinds of thinking (Geschwind, 1972) even though the person may not be performing any overt behavior. Associated with higher processes are changes in the cortex which can be examined by a variety of means such as E.E.G., brain blood flow, temperature, and (most recent) perhaps P.E.T. (positron emission tomography) scans. In higher level processing of information, the association areas (silent cortex) of the brain (which make up about three-fourths of the human cortex) are the ones mainly involved (Thatcher, 1977). They have been shown to subserve higher processes such as knowing, thinking, understanding and remembering. Much of the information about the functions of these association areas for various types of higher processes comes from the combined results of learning and lesion studies in higher mammals (such as the monkey), electrophysiological record studies of humans, and studies of brain damaged humans.

E.E.G. studies of various forms of learning in humans have revealed patterns of brain response in the association cortex of the frontal, temporal and parietal lobes as well as the hippocampus (John, 1972). Other more recent approaches to the study of brain states involved in higher processes use averaged evoked E.E.G. potentials (Lehmann & Callaway, 1978), Fourrier transforms of E.E.G. responses (Yeudall, 1977, Flor-Henry, Yeudall, Koles & Howarth, 1979), spectral intensities (Walter, 1968), cross correlation functions (Brazier & Casby, 1952), average alpha and whole band integrated power (Galin & Ornstein, 1972), frequency coherence functions (Davis & Wada, 1974), and average frequency (Giannitrapani, 1969).

Averaged evoked potentials can be obtained from the E.E.G. records of a subject engaged in verbal learning. Small changes which seem to be time dependent upon the stimulus material clearly emerge and seem to occur distinctively with each type of stimulus. Studies such as these appear to have quite clearly shown that the shapes of the averaged evoked potentials depend partly upon the characteristics of the modality of the presented physical stimulus and also upon the meaning of that stimulus to the individual. According to Thatcher (1979) the averaged evoked potential can supply the neurophysiological correlates of higher learning because the shape is different when different kinds of higher processes are going on in the subject's brain. This approach has been used to study the process of attention (Hillyard, Hinkey, Schwent & Picton, 1973), behavioral set and decision making (Begleiter, Porjesz, Yerre & Kissin, 1973), localization of memories (Bartlett, John, Shimokoski, & Kleinman, 1973) and hemispheric lateralization in various language and pictorial functions (Fedio, 1970; Thatcher, 1977; Ornstein, 1978).

Thatcher (1977) has used the average evoked potentials with humans in a number of studies of higher processes. In one study, he presented subjects with a series of stimuli, some of which were simple random pictorial dot displays (controls) and others which were words which yielded the same amount of retinal stimulation as the data displays (experimentals). The subjects did not know how many displays they would see and could not predict when words would be shown. Subsequent words were presented which were either synonym, antonym or neutral with reference to the first one. During all of these presentations, E.E.G. recordings from several cortical locations on both hemispheres were obtained. Because the learning of a word releases a unique pattern of neuron firings compared to that of the random dot display, the evoked potentials to the words were significantly different from those to the random dot displays. Words carry meanings and associations which the random dot displays are not likely to carry (Brown & Wallace, 1980). It was also found that the evoked potentials to the first word were smaller and less widely distributed across the brain than those to the second and subsequent words. Thatcher (1977) explained this by arguing that higher processes going on during presentation of the second and subsequent words are more involved. The reason is that it would be not only necessary to extract the meaning, but also for the subjects to compare them to the memory of the first word to determine whether they are synomym, antonym or neutral (Brown & Wallace, 1980). The evoked potentials from the left hemisphere and from the right hemisphere were different for the words compared to the dot displays. During the first word a difference emerged with the left hemisphere showing the larger evoked potential amplitude. The evoked potentials for the second and subsequent words showed even larger left hemispheric specific E.E.G. components compared to those for the first word, thus clarifying and confirming the engagement of the left hemisphere needed in processing linguistic materials. Cerebral hemispheric differences in evoked potentials as a function of verbal vs. pictorial stimuli have also been discovered by Buchsbaum & Fedio (1969) and Buchsbaum & Fedio (1970).

Even more light has been shed on the lateralization of functions during different brain processes by other researchers. Galin and Ornstein (1972) and Ehrlichman & Wiener (1980) for instance, found that if the E.E.G. is recorded from both hemispheres during the performance of verbal or spatial information processing tasks, different "brain-wave" patterns result. During verbal tasks the integrated whole band E.E.G. power in the left hemisphere was less than in the right. During spatial tasks it was less in the right than in the left. Using frequency analysis Doyle, Ornstein and Galin (1974) found that in a verbal task alpha rhythm in the right hemisphere was greater than in the left, the left showing more beta rhythm (Galin, Ornstein, Kocel & Merrin, 1970). In a spatial task alpha rhythms in the left hemisphere came out greater than in the right, the right now showing more beta rhythm. Doyle, Ornstein and Galin interpret the appearance of the greater amounts of alpha rhythm as a "turning off" of information processing in the brain area involved. "As if to reduce the interference between the two modes of operation of its two cerebral hemispheres the brain tends to turn off its unused side" (Ornstein, 1972) in a given situation calling for activity in a given side. In most ordinary activities of daily life, according to Galin and Ornstein (1972), we alternate between these two modes selecting the appropriate one. Also, they believe that the two modes of operation complement each other without readily substituting for one another. Everyday examples of this complementary function would be in simple acts such as describing a spiral staircase. For instance most people would begin using words and soon begin to gesture in the air (Ornstein, 1972). So, within most persons the two modalities appear to exist simultaneously as two semi independent information processing units with different specialities.

There is also some evidence suggesting that the modes of physiological organization may be different in each hemisphere (Shaw, O'Connor & Ongley, 1977). Semmes, Porter, and Randolph, (1974) tested the effects of various brain injuries in 124 war veterans for motor reactions, sensory thresholds and object discrimination. Their evidence suggested that the left hemisphere may be more anatomically specialized for discrete formal information processing such as that underlying logic and that the right hemisphere may be more diffusely organized as would be advantageous for orientation in space or other simultaneous (synchronous) processing of many inputs (as in pictorial processing).

Also using E.E.G. analysis, Morgan, McDonald and McDonald, (1971), Slater, (1960) and Wood (1971) have found various manifestations of greater amounts of E.E.G. electrical activity in the left hemisphere during verbal tasks and relatively greater right hemisphere activity during spatial tasks. According to Ornstein (1972) and Ornstein, Johnstone, Herron and Swencionis, (1980) some persons habitually prefer one mode over the other. He alludes to the fact that our culture, with its emphasis on training the left hemisphere (e.g. the strong emphasis on reading, writing and arithmetic in our schools and the great emphasis on serial logic in our society) may be unwittingly limiting the brain capacity of people by not providing sufficient schooling in the use of the right hemisphere. Kirsner & Brown (1981) have investigated interesting laterality relationships to memory of learned materials.

To infer the regions of the brain which partake in various higher processes the cross correlation function is often analyzed. This reveals the phase and amplitude similarities in electrical activity emanating from various E.E.G. electrodes. Workers in the area have suggested that coherence function analysis may be superior to the cross correlation for determining the functional organization of brain states (coupling between the parts). Davis and Wada (1974) have applied this coherence analysis to study brain states involved in processing simple verbal vs. spatial stimuli. Their findings emerged consistent with others. The left hemisphere was found relatively more active in verbal tasks but the right one was more active in spatial tasks.

Brain Blood Circulation and Thermodetection

The blood supply of the human cerebral cortex is provided by 3 major arteries, the two internal carotid arteries and a single basilar artery formed from the vertebral arteries. Minor communicating arteries join these to form the circle of Willis. The anterior and middle cerebral arteries (which emerge from the carotids) supply the majority of the middle, frontal and lateral zones of the brain while the posterior cerebral arteries (which emerge from the basilar) supply the more medial posterior zones.

The lateral surfaces of the brain, (pre and post central gyri, Broca's and Wernicke's area, etc.) are supplied primarily by branches of the middle cerebral arteries fanning out after they emerge from the sylvian fissure and project onto the frontal, parietal, occipital and temporal lobes. Hence they supply the lateral prefrontal, premotor, motor, somatosensory, general associative, auditory and part of the visual associative areas. The anterior cerebral arteries and their branches supply the anterior areas (frontal lobes) on the medial aspects of each cortex but also supply a bit of the lateral brain surfaces because they overlap superiorly and project laterally. The posterior cerebral arteries and their branches supply medial aspects (posteriorly) of the occipital lobes, primarily regions of the calcarine sulcus with some coverage over the inferior portions of the temporal lobes. They wrap around and also project onto the lateral brain surface. The region on the lateral cortical surfaces encompassing the farthest distribution points referred to as the "watershed area" where the middle cerebral arteries reach out toward the anterior cerebral arteries and the posterior cerebral arteries constitutes the farthest arterial supply zone of the cortex. Here the arteries give off end arteries which anastomose among themselves and supply deeper structures.

Except in instances of unilateral occlusions or other anomalies, there is not very much sharing of blood between the two cerebral hemispheres due to the direction of flow, the equality of pressure on each side and the small radius of the anterior communicating artery.

Veins corresponding to each of these arteries return blood to dural sinuses such as the superior sagittal sinus, inferior sagittal sinus, cavernous sinus, straight, transverse sigmoid sinuses and the great vein of Galen. Some of these also receive cerebrospinal fluid drainage via the arachnoid microvilli from the various subarachnoid cisterns in the brain and it all drains into the internal jugular veins to end in the superior vena cava.

As with other organs and tissues throughout the body, blood flow through the brain is a function of cardiac output and vascular resistance. Blood vessel radius constitutes the main determinant of resistance to blood flow. Since the arterioles and metarterioles are the vessels that have the smallest radius before blood enters the capillaries, they seem to constitute the major site of cerebral vascular resistance. This is particularly important since their radii are under the most precise physiological control by the smooth muscle in their walls and the precapillary sphincters in metarterioles. Mechanisms responsible for cardiovascular control thus are the main determinants of cerebral blood flow distribution. Venous return (constriction/distention), blood volume, interaction with cerebrospinal fluid, and the status of blood demand of the tissues and organs of the body are also influential in cerebral circulation but in a secondary way.

When parts of the brain increase their activity the metabolic demands for oxygen, glucose and other molecules elicit increased amounts of blood flow to the areas involved (Lassen, 1959, 1978). Flow of blood through tissues leading to the brain thus changes with metabolic activity in the brain (Ingvar & Schwartz, 1974). Because of the constant relation between the number of ATP molecules regenerated and the number of oxygen molecules used, the functional activity in particular brain tissues is directly related to the flow of oxygenated blood in these tissues. Hence, local changes in blood flow reflect local variations in the intensity of nerve cell metabolism (Ingvar & Soderberg, 1956).

There is evidence that substances such as carbon dioxide, hydrogen ions, other substances and electrolytes such as calcium ions, potassium ions, sodium ions and magnesium ions as well as adenosine as a pharmacological agent, lactic acid, adenosine phosphate compounds themselves (in biological tissues ADP and ATP), histamine, kinins, prostaglandins, norepinephrine, epinephrine, angiotensin and vasopressin may all exert influence in determining arteriolar radius and hence, distribution of cerebral circulation. In addition there seems to be some neurogenic autonomic and other control as well as other influences (e.g. temperature) upon radius and distensibility of the cerebral blood vessels.

The medullary cardiovasomotor control center, under the influence from the hypothalamus, reticular activating substance of the diencephalon, midbrain and pons and the cerebral cortex functions as a monitoring system to maintain a relative steady state in accordance with the metabolic demands of the moment. Cardiac output is thereby coordinated with arteriolar, metarteriolar and precapillary sphincter radius to maintain this. The latter appear innervated by vasomotor fibers of the locus coeruleus. Reflex control of these functions involves sympathetic trunk nerves to the heart, arterioles and veins and parasympathetic nerves to the heart from the dorsal motor nucleus of the vagus nerve.

Research suggests that pial vessels may have some sympathetic cholinergic vasodilator fibers. There are, however, more adrenergic vasoconstrictive fibers that innervate the larger pial and intracerebral vessels. However, overall, such neurogenic control seems weak because of the low responsiveness of the alpha-adrenergic receptors to norepinephrine. An important characteristic of neurogenic control of cerebral circulation is that adrenergic nerves are more effective in arterial hypertension, perhaps to limit capillary intravascular pressure and prevent disruption of the blood brain barrier.

In addition, baroreceptors such as the carotid sinus function as blood pressure sensors. Any deviations from the appropriate state for the conditions are relayed to the hypothalamus and mechanisms are initiated to reinstate the balanced condition. Chemoreceptors such as the carotid body signal any hypercapnic or hypoxic condition and induce vasodilatation to bring additional quantities of blood to the region. There seems to be a pronounced direct action of carbon dioxide on cerebrovascular smooth muscle dependent on hydrogen ion concentration and bicarbonate ion. Norepinephrine and epinephrine (from the adrenal medulla) are usually vasoconstrictive although epinephrine can produce vasodilation in some vessels. Autocoids and hormones such as vasopressin and angiotensin also produce vasoconstriction whereas kinins, histamine and prostaglandins appear to be vasodilatative. Calcium ions produce vasoconstriction while sodium, potassium and magnesium ions produce vasodilatation. Metabolites such as adenosine or hydrogen ion which increase with brain metabolic activity, ischemia or hypoxia have been shown to induce strong dilation at least in pial vessels (Kontos, 1981). Moreover, alkalosis tends to increase neuronal excitability and arterial hypercapnia may have a local hyperemic effect. Although the cerebral veins generally function as low resistance conduits for collection and return of blood to the heart and they do not appear to have significant valves some weak sympathetic cerebral venoconstriction may occur under some conditions.

The brain circulation thus seems to be neurogenically as well as chemically regulated but because of the necessity for uninterruptive supply a tight coupling seems to prevail between metabolism and blood flow. Ingvar (1976) has demonstrated activation of specific cortical areas by sensory or motor activity eliciting increases in blood volume to the activated areas. Also, engaging in more complex mental activity produced more widespread increases in cerebral blood volume due to increased metabolism (Sokoloff, 1977). This relationship occurs via vasodilator metabolites, adenosine compounds being the most likely candidates presently considered. Thus the most important cerebral blood volume regulation from the point of view of the study of cerebral function appears to be local metabolically directed regulatory mechanisms (Ingvar & Lassen, 1975).

Sokoloff (1976) and Luria (1973) have demonstrated (in animals) that the metabolic rate within very small regions of the brain changes in consistent patterns during various specific activities along with more diffused changes occuring as the general activity of the organism changes (e.g. - different arousal levels). McGeer and McGeer (1980) have summarized how local blood flow changes relate to human behaviors like listening, speech and hand movements.

Lassen, Ingvar and Skinhoj (1978) have demonstrated that various forms of stimulation alter the blood volume to different regions of the brain. For instance, various forms of linguistic stimulation can cause increases in blood volume through Broca's or Wernicke's areas; other forms of stimulation were found to produce increases in flow through the known primary regions for each function (e.g. - visual, auditory, tactile, motor etc.) Stimuli evoking more complex cognitive responses or evoking memory were found to elicit increases of flow through the association areas in the parietal and frontal lobes.

Analyses of brain activation during normal reading was found to involve several cortical regions in specific patterns (Risberg & Ingvar, 1973) with more activity recorded in the left hemisphere. Not only do increases in blood volume to specific regions occur but Risberg and Ingvar (1973) found that routines such as recall and reasoning cause, in addition to localized changes, a significant overall increase of cerebral blood flow of sometimes more than 10%. This general increase appears to be distinctly "related to the subject's effort in performing the task" (Risberg & Ingvar, 1973). Others such as Ectors (1969) and Basar (1980) have found a striking "parallism" between cerebral circulation and EEG rhythms.

Comparatively, high levels of blood flow through the brain because its metabolic rates are very high, particularly during cognitive activity (since the blood flow through the brain is proportioned according to the metabolic needs).

<u>Tympanic Temperature Change</u>

Changes in blood volume to certain brain regions have been shown to produce temperature changes (Serota & Gerard, 1938) related to the energy release of active nerve cells and to the vasomotor responses associated with such activity. When certain zones of the brain increase their activity, local vasodilation seems to occur, as in the carotid sinus reflex (Mikhailov, 1962), to allow for the increased blood demand. This increased volume of blood to more active areas also helps cool these zones. The results of studies by Hayward and Baker (1969) and Serota and Gerard (1938) show slight net reductions in the temperature of blood in vessels and surrounding tissues which supply the relatively more active brain regions. Using the method of tympanic membrane temperature monitoring of Dickey, Ahlgren and Stephen (1970), Meiners and Dabbs (1977) have demonstrated that tympanic temperature is a measure of core temperature. Also, unilateral decreases in ear tympanic temperature have been found to be associated with brain hemispheric increases in blood volume. Temperature decreases were found to be greater in the left ear during verbal tasks and in the right ear during spatial tasks. They conclude that tympanic temperature provides a simple indirect indicator of relative hemispheric functioning in a variety of tasks and can be used in studies that relate tasks to relative brain hemispheric activity. They also provide data showing that a thermistor worn as an earplug in the auditory meatus not necessarily in contact with the tympanic membrane can detect these temperature indices of hemispheric activation.

The overall review of the literature had led to the expectation that the left brain cerebral hemisphere is primarily active during the learning of written verbal material, and that methods which incorporate pictorial representations would most likely elicit changes in relative activity in the right and left brain hemispheres. Also, the weight of evidence show the right hemisphere to be responsible for processing form visualization, shapes, pictures and spatial orientations. The methods which help organizing the learned verbal material, but not using pictorial representation, may elicit some concomitant changes in relative activity in the right and left brain hemispheres. They may further elicit changes in levels of activity in a greater number of regions of both the hemispheres since their content albeit organizational is still predominantly symbolic. There may be more ways to enhance recall and comprehension than by simply invoking concomitant changes in relative levels of right brain activity, for example symbolic organization, questions, objectives, etc. as discussed earlier. The literature on induced imagery and imposed imagery suggests this. So, a general hypothesis would be that enhanced retention and comprehension can be brought about in different ways by several methods because the underlying dimensions of operation may be different; some may be pictorial but others mainly semantically associative. Finally, enhancers may be specific as to what they accomplish. It may well be that certain pictorial methods such as induced imagery may enhance primarily recall without necessarily inducing appreciable gains in comprehension. On the other hand symbolic strategies emphasizing the organization of knowledge or the discriminative linking of knowledge to existent cognitive structures may induce observable gains in comprehension without necessarily providing much enhancement in verbatim recall, as compared to other techniques involving imagery or pictures. Pictorial diagrams, however, due to their simultaneous use of organizational frameworks along with vivid descriptive images representing the verbal material to be studied, may well produce a respectable enhancement in retention (over a control group not exposed to them) and perhaps also a significant enhancement in comprehension of the material. This study was aimed at showing whether or to what extent these expectations, derived from research findings, are borne out.

The central hypothesis.

The analysis of available findings shows no apparent correlation of the findings from research on verbal learning with those concerned with the study of the brain functions. Clearly, there is a need for studies to relate the findings concerning induced imagery and pictorial diagrams to the findings concerning brain concomitants of learning as detected by brain electrophysiology, blood flow and temperature (Paivio, 1973).

Wittrock (1977) in his proposed theory of generative learning, suggested to determine whether or not (c.f. Buzan's) "methods which induce generative learning enhance the learning process by engaging more centers in the nondominant hemisphere", which tend to remain relatively dormant during verbal tasks. This is the general research issue the present study addressed. The central hypothesis of the present experiment is that the learners' performance proficiency owing to imposed and induced imagery learning adjuncts would be accompanied by corresponding higher level of right hemispheric brain activities relative to left hemispheric activities because the right hemisphere is purported to play an increasing role in the processing of pictorial materials.

In order to determine if the methods that engage relatively greater right hemisphere activity correspond to those which elicit improvements in learning as measured by recall and comprehension, obviously we need to define the methods experimentally.

Any set of data thus collected will be capable of addressing some interesting psychological question on the efficiency of learning adjuncts in terms of recall and comprehension of learning materials in addition to the findings concerned with the localizations of concomitant cognitive functions in the brain (particularly hemispheric lateralization).

Experimental expectations.

Based on the earlier analysis of previous studies, it can be expected that imagery instruction and pictorial diagrams will facilitate recall and comprehension, that pictorial diagrams will elicit superior recall and comprehension as compared to the imagery instruction condition, and finally that the pictorial diagrams and imagery instruction would be accompanied by enhanced levels of concomitant relative right hemisphere activity.

Chapter II. Methodology

Subjects and Design

The methodology utilized in this study is intimately linked to the research practice concentually validated throughout the literature. The literature generally uses induced imagery as an independent variable by providing the experimental subjects with instructions to form interactive vivid imaginal images representative of the verbal material being learned. It uses availability of pictures as an independent variable by providing the experimental subjects with actual pictures representative of the verbal material studied.

It could be argued that these conditions, while qualitatively different, may also not be equivalent in terms of providing different "dosages" of content to each experimental group and thus not be comparable experimentally. In order to render these experimental conditions parallel it would be necessary to ensure that the content inherent in each form of adjunct be the same. Even if such an enormously difficult task were possible the manipulations would no longer be generalizable or comparable to the vast body of research already existent on these adjuncts. Their qualitative nature would thus be distorted in attempts to render them quantitatively equivalent for content. So, the present study methods remained consistent with the literature (while perhaps sacrificing parallelism) and used these adjuncts in the ways they are commonly employed in Educational Psychology research.

Sixty right-handed subjects randomly drawn from a pool of volunteers of low GPA (to reduce the likelihood that they habitually use these elaborative techniques, Rohwer, 1973) from a Vancouver community college and the University of British Columbia were obtained. Right handers were chosen to ensure most probable left brain hemisphere dominance (normal lateralization of function). If a subject reported writing and doing most daily tasks with the right hand the subject was deemed to be right handed and inferred to most likely be left brain hemisphere dominant. Low GPA subjects (less than 3.5) were chosen to overcome the phenomenon Rohwer (1973) observed. He and others had found that high ability subjects (i.e. subjects who have demonstrated high grade point average) would elaborate using imagery or other organizing strategies spontaneously and did not substantially profit from experimenter induced imagery (instructions) or other mnemonic aids (since they were already performing near their maximum).

The sixty subjects thus selected were randomly assigned to three experimental conditions, 20 subjects each. The three included (a) induced imagery instruction, (b) pictorial diagrams, and (c) control conditions.

Induced imagery instruction. Based on the method of Lorayne & Lucas (1974) and Rohwer (1968, 1973), instructions to create mentally vivid images concerning the material to be learned were composed. These instructions replicated the usual instructions, for this manipulation, used in the literature but included some words from the text to be read in order that it be, to some degree, "equivalent" to the other conditions which by their nature, necessitated such material. The instructions were concentrated mainly on "how to" information. These instructions filled four 8 1/2" x 11" pages and were assembled as a poster. (See Appendix A for the actual text material in this adjunct)

Pictorial Diagrams. Based on an adaptation of the methods of Levin & Lesgold (1978); Buzan (1976, 1980) and Vernon (1980), the intrinsic logic of the material and using pictures commonly presented in popular textbooks on the topic of Psychopathology, a "picture diagram" illustration of the to be learned textual material was constructed. This picture-diagram was composed to create a 17" x 22" poster. (See Appendix A for a print of the poster used)

Control Group. A poster 17" x 22" containing irrelevant material of an instructional nature (from Genetics) was constructed so each condition is equivalent. (See Appendix A for the actual text material used).

*To enhance the salience and importance of these posters, before their exposure, each subject read some student objectives pertaining to knowledge and comprehension (Bloom, Englehart, Furst, Hill & Krathwohl, 1956) based on the ideas behind Bloom's taxonomy.

Based on the main concepts in a typical chapter on "Psychopathology" from a typical "Introductory Psychology" textbook, a chapter was created in such a manner as to cover adequate balance and give appropriate weighting to each of the mental disorders. This constituted the text material the subjects were required to learn.

Criterion Test Materials of Recall and Comprehension

The recall test consisted of asking the subjects to recall freely (Wood, 1971) as many of the mental disorders they have studied. It thus measured verbatim recall of information in the text. After the recall task the subjects were given the comprehension test. The comprehension test consisted of 15 multiple choice questions which measured understanding of the concepts in the text as defined in Bloom's Taxonomy by Bloom, Madaus & Hastings (1981). These items were chosen from a pool of items, consensually judged valid by teachers of this subject and regularly used as achievement questions for Introductory Psychology. Internal consistency reliability coefficients (Hoyt's Analysis of Variance) were calculated from previous use of these items. Reliabilities ranged from 0.73 to 0.88 in 100 item tests.

Apparatus

Electroencephalograph, signal analyzer and instrumentation F.M. recorder. A Grass Instrument Co. 8 channel (only 4 of which were used) electroencepholograph in conjunction with a Physiograph "Model Six" polygraph (E. & M. Instrument Co.) were used to monitor the E.E.G. bilaterally. Four standard E.E.G. electrodes were used at sites T_3, P_3, T_4, P_4 referenced to C_z from the International 10-20 system. (See Figure 2 for electrode locations) A "Data 6000 - Universal Waveform Analyzer" (Analogic Corporation) was used to check

Insert Figure 2 about here

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the ongoing power spectrum in real time to ensure correct signal reception as noise free and as artifact free as possible. A Model 3960 4-channel Hewlett Packard FM Instrumentation Tape Recorder was used to record the E.E.G. during each of the periods.

Thermodetector. Two Yellow Springs Instrument Co. Model 49TA Digital Temperature monitoring units were used as tympanic temperature sensors to monitor the thermal responses bilaterally. Two thermistor thermal transducers, attached to an auditory canal earphone set, one in each ear, were used to detect these responses. Specifically constructed felt paddings were used to prevent, as much as possible, the conduction of heat away from the transducers through ambient air.

Insert Figure 3 about here

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Filtering units and others. Two Krohn-Hite Co., Model 3342R "Dual Analog Filter Units" were used to provide for first order Nyquist filtering of the E.E.G. signals.

Two large darkroom timers (Dimco Gray Co., Model 165 & 171 "Gralab Universal Timers") were used. One, in the shielded isolated chamber, to help subjects pace themselves and one for the operator to keep track of time and events. A chin rest was used to prevent excessive movements that could disrupt the electrophysiological signals. An Archer Model 43-221A Transistorized Intercom System was used to provide remote communication between the operator and each of the subjects.

Computers. A PDP-11/23 MINC DECLAB computer with the RSX-11 Fortran Enhancement Package and A/D, D/A, Digital-In and Clock laboratory modules were used to carry out the E.E.G. analysis. A dedicated hard disk in addition to the "Systems" disk were used for data storage and processing manipulations. A Model 7220C Hewlett Packard plotter was used to display graphs of raw E.E.G. data, Fast Fourier Transform Magnitudes and Power Spectra. The remaining analyses were carried out using the main U.B.C. computing center (Amdahl XXY).

Software. Five computer programs were created in Fortran-77 to carry out the E.E.G. analyses. Program "ADTEST" carried out Analog to Digital sampling at the desired frequency and for the desired time intervals. Program "READREC" was used to write the values sampled in a record. Program "DISPLAY" which graphs the raw data, the Fourier Coefficients or Power Coefficients was used as ongoing check and to obtain figures. Program "DMUX" demultiplexed the signals when 4 simultaneous channels of data were processed at once. Program "POWER" calculated the Fast Fourier Transform and the power spectrum and took average powers for designated numbers of records.

Experiment Room. An electrically shielded and soundproofed laboratory-designed isolation chamber (Electrical Engineering, McLeod Building, room 257) was used to ensure proper attention to stimuli and eliminate incidence of electrical noise and other artifacts from the neurophysiological measures.

Procedure

Subjects were randomly assigned to one of the three conditions by drawing their number from a table of random numbers as they presented themselves for the experiment. Each subject first signed the disclaimer and was given general information and practice on the sequence. He/She had the electrodes from the electroencephalograph appropriately attached (at positions T_3, P_3, T_4 and P_4 and C_z based on the international 10 - 20 System) and the ear probes placed in position. Electrode impedance was measured less than 5000 ohms at each electrode location. Since reading constitutes a low artifact E.E.G. task (Ornstein et al., 1979) a verbal learning paradigm was used. Each subject was then given five minutes to study the student objectives during which time I calibrated the settings with an input signal of 10 Hz at 50 V, verified proper operation of the systems, and ensured stabilization of temperature. The poster presenting the adjunct format appropriate to his/her condition was presented by instructing the subject, over the intercom, to remove the cover and thereby expose the paste up in front of him/her and set the timer to 5 minutes. (Pre-training on these movements had been given during the provision of general information on the sequence). Each subject was thus given five minutes to study the Adjunct material in front of him/her. When this five minute period was over, each subject was instructed to set the timer for 15 minutes and studied the text material during this time. Throughout this whole period (of 20 minutes) each subject's neurophysiological responses were monitored. The 4-channel E.E.G. signals were recorded on the FM recorder and a permanent record of them kept while the temperature samples were written down every minute as per Meiners & Dabbs (1977). After this 15 minute interval I signalled, on the intercom, that this was the end of the study period. I entered the chamber, turned over the adjunct poster and took the text material. I set the timer so each subject was thus given 10 minutes to do the paper and pencil recall task and the comprehension test. When this 10 minute period was over I entered the chamber and took the tests signalling that this was the end of their time. I then scored their recall and comprehension tests to provide feedback and I explained the study to them.

Post Experimental Debriefing

I asked the subjects if they had any questions or comments, whether they had experienced any discomfort wearing the electrophysiological unit during the procedure or due to the arrangement of things or whether they had felt the room comfortable for temperature, ventilation, etc. or if they had any other complaints. I did a manipulation check to ensure that the subjects in each condition were influenced in the manner needed for the experiment and encouraged comments, criticisms and questions during every part of this debriefing period.

Methods of Observations and Measurements

E.E.G. artifact rejection. The raw data were examined using the program DISPLAY to determine obvious artifacts, signal loss or blatant extraneous electrical noise. These were edited out of the analysis by manual procedures such as recommended (or used) by Gevins and Yeager (1975). More subtle sources of noise and artifacts were fairly well controlled for by the filtering processes. The main sources of E.E.G. artifacts and extraneous noise include extracerebral sources such as eye movement artifacts (EOG), eye blinks, eye and facial muscle EMG artificats, EMG from other muscle potentials of the body neck and head, pulses and EKG (contamination of E.E.G. by cardiac activity potentials), sweating and GSR contamination, static electricity on the subject or around him/her, subject movement or object movement artifacts, cross talk between E.E.G. channels, varying electrode resistance artifacts, and other sources such as polarization of electrodes stray capacitance, respiration artifacts, artifacts associated with tremor of head or limbs and contraction or dilation of scalp skin capillaries which give rise to skin potentials as well as conductivity changes. Other sources of E.E.G. artifacts can be summarized as arising from various sources of external electrical interference. Electrostatic and electromagnetic interference from external sources in interaction with the subject or in and of themselves constitute another group of artifacts. Radio frequency interference, interference due to machine faults, power surges, switch faults, amplifier radiation or amplifier faults, polarization effects, and contact faults.

According to a study by Chen, Drangsholt, Dworkin & Clark (1983) the alpha band showed no significant artifactual change in power with various behaviors. The alpha band is not affected by explicit behavioral movements since these artifact effects are centered predominantly in the low frequency delta band and the high frequency

30–50 Hz band. Since the analog low pass Nyquist filters had a cut off at 25 Hz and the digital filters had high pass and low pass cut offs at 8 Hz and 14 Hz, these artifacts would be expected to have been excluded prior to the analyses. O'Donnell, Berkhout & Adey (1974) observed little if any EMG infiltration of the E.E.G. signals below 14 Hz except when the E.E.G. electrode was very close to a contracting muscle.

According to Gevins, Yeager, Zeitlin, Ancoli & Dedon (1977) there could be high frequency artifacts associated with EMG of over 34–44 Hz and low frequency Electro-Oculo-Gram (EOG) artifacts (Girton & Kamiya, 1973) both which would have also been rejected by the processing system. Movement artifacts would also have been minimized by the requirement that the subjects use the chin rest and that the task did not require any significant motor responses. Smiling and laughing are said to elicit increments in power artifacts whereas moving the eyes or squinting tends toward power reduction artifacts but the nature of the material was not such that would elicit these responses. Chen et al. (1983) also reported that major muscle artifacts fall in the high frequency range and that the alpha band (the one analyzed in this study) is least affected by movement of frontalis, masseter or biceps muscles. Frontalis activity is reported to affect power in the delta and theta bands only (O'Donnell et al., 1974). Chen et al. (1983) also reported that, in their studies of E.E.G. artifacts, no laterality differences were observed, however, variations were often apparent between different subjects performing the same movements.

"EMG infiltration is absent in the E.E.G. below 14 Hz even when muscles are contracted for long periods of time" (O'Donnell et al., 1974). However, when a muscle directly under an electrode contracts there can be sudden massive increase in spectral power over the entire frequency range (Johnson, Wright & Segall, 1977). Close observation of the power spectrum during the analyses did not reveal any evidence of such massive general increase in spectral power.

Eye movement potentials (EOG) are due to the action of the eye as a variable electric dipole (the cornea being positive with respect to the retina). With eye movement this corneo-retinal potential produces an interference with the E.E.G. at the same time as changes in potential at sites near the eye. These potentials are transmitted throughout the whole head but become significantly attenuated with increasing distance from the eye. These have presented a problem with studies recording the E.E.G. particularly in contingent negative variation measurements and in cross correlation studies (Hillyard & Galambos, 1970). Since these are very slowly changing potentials, a simple method is to exclude segments which show eye movement artifact. Various electrode placements are differentially affected by vertical or horizontal components of eye movement artifact. Gerton and Kamiya (1973) have devised an on line technique for subtracting eye movement artifacts from the E.E.G. which requires that vertical and horizontal EOG electrodes be attached and integrated with a Vertex to Mastoid E.E.G. recorder. Eye movement artifacts are however much more pronounced for the more frontal electrode placements. Temporal and parietal placements are said to not be too influenced by these artifacts (Cooper, Ornstein & Shaw, 1980). Temporal placements such as in this present study sometimes evoke artifacts associated with activation of the temporalis or masseter muscles (jaw muscles). These are usually eliminated by instructing the subject to relax his/her jaw lightly onto the chin rest and once eliminated do not tend to return. In four instances, during the setting up stage of the present study such admonitions were conveyed to the subjects. In addition, visual examinations were carried out of graphical displays of the FFT's and power spectra (Levy, Shapiro & Meache, 1980) to detect contamination of E.E.G. spectrum by cranio facial muscle contraction but, as stated above, there is a general lack of problem using the given electrode positions. Control for possible pulse or EKG contamination was accomplished by having the electrode board suspended above the subjects, short leads to it and no contact with the subject by the wires going from the electrodes to the amplifiers. Sweating and GSR potential artifacts were controlled for by having the experimentation area well ventilated by opening the windows and by the lack of contact anywhere on the subject except at the electrode position. Debriefing of the subjects confirmed that the room temperature remained cool enough. They had not experienced high enough levels of ambient temperature to experience sweating nor discomfort. Possible static electricity on the subject or around him/her was eliminated by having all objects touching parts of the shielded room going to ground and a special ear lobe grounding electrode to ground each subject. Since subject movements were minimal and there were no moving objects within the experimentation chamber, these sources of artifacts should have been at a minimum. Possible cross talk between channels was eradicated by having each of the leads physically very separate from the others and the use of shielded coaxial cable leads (with the shielded portion connected to its own separate ground). This procedure also eliminated possible stray capacitance effects. Possible artifacts caused by varying electrode resistance were controlled for by ensuring proper electrode impedance (less than 5,000 ohms) prior to the experimental tests and by test runs on various subjects to ensure constant contact pressure by the electrode band. The system was closely monitored throughout to ensure that no radical changes might have occurred due to electrode polarization. Possible respiration artifacts were eliminated by the very direct routing of wires from the scalp electrode positions to the electrode boards and thence to the amplifiers. Each subject had been encouraged to relax during the electrode attachment phase and since as mentioned before, the area was relatively cool, responses are not likely to have been drastic enought to induce radical departures of the E.E.G.'s. Alteration of possible external sources of electrical interference was accomplished by ensuring that the shielded room was all arranged as designed. 60 Hz interference from mains a.c. lines was rejected by the extensive shielding of all cables and by the low pass filtering at 25 Hz and at 14 Hz by the analog and digital filters respectively. Possible interference from motor generators, magnetic fields, radio frequency sources, microphonics, switches, telephones, radio and other machines were thus controlled for. Also, the possibility of radiation from noisy tubes or batteries was carefully monitored and excluded by the extensive grounding.

E.E.G. data signal processing. (a) Analog filtering and digitizing. The E.E.G. data collected on the FM Instrumentation Recorder were fed into first order Nyquist low pass analog filters. The low pass cut offs were set at 25Hz to ensure a comfortable margin for anti-aliasing. For the 20 minutes of data for each subject the four channels of E.E.G. were thus low pass filtered at 25 Hz with the Krohn-Hite 3342 analog filters and then digitized at 64 Hz using the DECLAB MNCAD module and the program ADTEST. This thereby constituted 307000 data points per subject. These filtered signals were thus fed to the Analog to Digital converter which, in conjunction with the Clock module and the program ADTEST sampled the one second signals sweeps at 64Hz. This epoch provides for multiples of 1Hz of the digitized data.

(b) Demultiplexing: One channel at a time, these data were demultiplexed using "DEMUX" to create four files each 300 data records long.

(c) Windows: The fourier transform and power spectrum algorithms essentially compute the frequency spectrum from the input block of samples (epoch) taken by quantization. The fourier transform and power spectrum assume that this epoch is infinitely repeated. When measuring a continuous signal like the E.E.G. the epoch does not usually contain a number of cycles consistent with the input E.E.G. wave since, depending on where the sampling process happens to "catch" the wave, it produces different representations of frequency components i.e. when the waveform is not periodic in the epoch, the fourier transform and power spectrum algorithms thus get computed on the basis of a distorted waveform (sampling is thus such that the epoch caught along the wave is not periodic) since sharp phenomena in the time domain are spread out in the frequency domain. The spectrum thus becomes distorted. "The missing end point of one sequence sampled is the beginning of the next period" (Harris, 1978). The finite fourier transform must be made to approximate the infinite (theoretical) one. If the wave is not periodic in the time record (E.E.G. is not periodic) power gets spread throughout the spectrum. This energy leak out of one resolution line of the fourier transform and power spectrum into the other lines of resolution is the phenomenon called "leakage in the frequency domain" because it results in a form of smearing of energy through the frequency domain. "From the continuum of possible frequencies only those which coincide with the basis will project onto a single basis vector; all other frequencies will exhibit non-zero projections on the entire basis set" (Harris, 1978) and "the discontinuities are responsible for spectral contributions (or leakage) over the entire basis set" thus "windowed data are smoothly brought to zero at the boundaries so that the periodic extension of the data is continuous." (Harris, 1978).

If the E.E.G. wave were periodic within the epoch sampled this would not happen but given the irregularity of the E.E.G. wave this leakage is likely. Also, if it were possible to obtain an infinite time record (epoch) this would also not occur. "Processing a finite duration observation imposes interesting and interacting considerations on the harmonic analysis" (Harris, 1978). But, since the continuous input from the E.E.G. is not periodic in the epoch, leakage which may be severe enough to mask small signals, (due to the discontinuities) distortion of the representation is likely to occur. Windowing provides a partial solution to this problem (Harris, 1978).

Since most of the problem seems to be at the edges of the epoch a window causes the fourier transform and power spectrum to ignore the ends and concentrate on the middle of the epoch. So, in windowing, the time record is multiplied by the window function which is zero at the ends and large in the middle. Correct choice of window provides vast improvement of this leakage since it reduces weighting of the ends whereas the center gets through fine (Harris, 1978).

For some applications such as in the case of transient waves one might want to use all the data in the time record equally and uniformly. The rectangular window, which weights all the time record uniformly and gives sharp cut off forcing the input to zero at the beginning and end might serve best since it provides least error in the means squared error sense. It is thus the closest one can get for the infinite extent.

The mean square error may be least with a rectangular window but this is not the criterion of interest in application like E.E.G.

spectral analysis. So we multiply, in the time domain, the E.E.G. waveform by a suitable window and get the power spectrum of this windowed function.

Certain spectral components of frequency invisible with a rectangular window can be seen using other windows. For measuring white noise-like signals such as the E.E.G., a window function with a more gradual roll off at the ends and a more rounded top at the center of the record might be desirable. A trade off however is necessary with respect to certain aspects of doing this. "Windows impart on many attributes of a harmonic processor" (Harris, 1978). For instance, one can end up with a spectrum of broader bandwidth than one started with (ripples on each side of the main lobe). One can also, with such a window, end up with broader than original resolution or a decreased or increased width of the main lobe. The equivalent noise bandwidth (noise power of the output of the window per unit bandwidth) needs to be considered.

There is also the processing coherent gain. Incoherent power output is the product of the proportion of variance of the noise and the sum of squared of the window function. In addition there is scalloping loss, worst case processing loss, overlap correlation, highest side lobe and side lobe fall off. All the advantages and disadvantages of these parameters have to be taken into account in reference to the data and the purpose of one's analysis when selecting a window function to apply to the given data. Many kinds of windows besides the rectagular window can be used depending on one's purpose.

Among these are the triangular window, the Hamming (Cosine family) windows, the Hamming window, the Blackman window, the Riesz (Bochner, Parzen) window, the Riemann window, the Jackson, Parzen window, the Tukey window, the Bohman window, the Hanning-Poisson window, the Cauchy (Abel, Poisson) window, the Gaussan (Wererstrass) window, the Dolph-Chebychev window, the Barcilon-Tewes window and the Kaiser Bessel and Four Point Kaiser Bessel window.

The Kaiser Bessel window is a smooth curve with ordinates zero at the ends but a window such as the Four Point Kaiser Bessel window seems optimum in giving improved accuracy and frequency domain frequency resolution. It seems to possess the best compromise in terms of positive and negative characteristics and so gives the best representation of frequency (which is the factor of interest in the present study).

Using "POWER" the digitized signals were preprocessed by multiplying by a Kaiser Bessel four point window to prevent the discontinuities due to leakage in the frequency domain as discussed above. The Kaiser Bessel window appears superior to the Cosine or Hamming windows (see Figure 4) because it

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Insert Figure 4 about here

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offers the best compromise of equivalent noise bandwidth, coherent gain, scalloping loss, highest side lobe, side lobe fall off, worst case processing loss, etc. Considering its properties, it was felt to be the best compromise of positive features for a window. After windowing the data was Fourier transformed using a 64 point FFT.

Digital filtering and average power computation. Subsequent to digital filtering, second by second power spectra were obtained for the Alpha band (8 to 14 Hz) and averaged for each second. Second by second power spectra were then averaged over 2 minutes 40 seconds and eight of these were collected and averaged over the whole 20 minutes. (See Figure 5 for sketch of signal processing system)

Insert Figure 5 about here

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Calibration. (a) Computer software scaling: Power values were calibrated by the computer routines to convert to a representation of the voltages at the input to the A/D converter rather than the digitized quantization values (scaling due to the A/D process) the computer worked with. Values of the order of V^2/Hz were thus returned by the program POWER.

(b) Applied external calibration (for the system): To these values produced by the program POWER the various system gains had to be applied to arrive at a correct μV^2/Hz value (which represents the input at the E.E.G. electrodes). The overall system block diagram starting with the E.E.G. signal at the electrode cap and leading to the PDP-11 is shown in Figure 6.

Insert Figure 6 about here

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The value of the overall averaged power presented by the program POWER took into account the quantization scaling but not the gains of the amplifier tape recorder and analog filters. To obtain the true power (representation at the E.E.G. electrodes) the values returned by the program POWER were divided by the gains G_1 through G_4. Thus the true value of power is given by:

$$\text{True Power } (\mu v^2/\text{Hz}) = \frac{\text{Computer Calculated Power}}{G_1\ G_2\ G_3\ G_4} \quad (3)$$

To process the data from a subject, each 75 4K buffers of 4 channel data collected using ADTEST needed 20 minutes per channel of data or 1200 total raw data records. To demultiplex these 20 minutes of data per channel (1200 raw data records) required 5 minutes per channel and to average the powers using POWER and windowing the data required 5 minutes per channel. The total time involved in calculating the average power for the 4 channels for each subject was plus 65 minutes. Examining displays and plots required additional time. Hemispheric averages were computed by taking the mean for the two left hemisphere electrodes and the mean for the two right hemisphere electrodes. These were used as dependent variables along with the relative right hemispheric average power ratios as per Steadman & Morgan (1974) and Doyle et al., (1974) and Matousek & Petersen (1973) and the log power ratios as per Ornstein et al. (1979) and Gasser, Bacher and Mocks (1982).

Most experts suggest transforming the absolute power values before performing statistical analyses. According to Ornstein, et al. (1979) statistical analyses ought to be computed on natural logarithmic transforms of hemispheric ratio because ratios have been found to not meet assumptions required of the analysis of variance. According to Ehrlichman & Wiener (1979) this is accomplished to make the ratios symmetrical about unity and to reduce the impact of extreme scores. According to Cooper Osselton & Shaw (1980) and Matousek and Petersen (1973) the analysis of variance needs to be carried out on square root transformed E.E.G. power values as well as the log power ratios. Matthis, Scheffner & Benninger (1981) examined the mathematical properties of E.E.G. spectral parameters and maintain that relative power parameters are robust, numerically stable etc...but do not meet the theoretical models for statistical tests. Gasser et al. (1982) however have studied various transformations of E.E.G. spectral parameters for skewness, kurtosis and Wilk's W. and conclude that relative power is not too distorted only in the Delta band. They do, however, recommend using the square root and natural log transformation of absolute power. Statistical techniques which rely on the normal distribution thus cannot be used if absolute power values are used because their empirical distribution does not follow the normal distribution in samples of healthy individuals (Gasser et al., 1982).

These deviations are ostensibly quite substantial, resulting from asymmetry and long tails in the empirical distribution. They may arise from different sources such as being inherent in the scale used, intrinsic in the biological systems generating the E.E.G., sample heterogeneity (such as unrecognized pathology in some subjects), recording techniques, or the parameters themselves (Gasser et al., 1982).

Since the ratio of right hemisphere power to left hemisphere power has been shown to give a value concordant with left hemisphere activity to right hemisphere activity and that in the present study, right hemisphere activity was of main interest I used the inverse of this ratio. The ratio can thus be taken to represent a value concordant with activity proportional to the relative right hemisphere. In right handed people the Right to Left ratio of alpha power is typically higher during tasks predicted to primarily engage the left hemisphere (verbal tasks) and the Left to Right ratio of alpha power is typically higher during tasks predicted to primarily engage the right hemisphere (i.e. spatial tasks)(Ornstein et al., 1979). Left hemisphere power is thus divided by right hemisphere power to compute a ratio of relative right hemisphere activation. This ratio of alpha power measure is said to be somewhat more stable than raw E.E.G. alpha power; computing ratios is (Ornstein, et al., 1979) analogous to normalizing the index within subjects and reflects relative hemispheric engagement concisely.

There is thus a disagreement in the literature about the method in which E.E.G. average power data ought to be analyzed. Some have done inferential tests on raw E.E.G. power averages but according to many authors, including Ornstein et al, (1979), analysis of variance carried out on raw E.E.G. power may be erroneous because of the data not meeting the distribution requirements as per the above arguments. So, it is recommended, to obtain the assumptions of inferential statistical tests that an analysis of variance be carried out on the root power and the natural logarithmic transform of the hemispheric ratios. In accordance with this, in the present study, the main analysis of E.E.G. was carried out using the natural logarithmic transforms of the ratios. These showed to be more conservative tests of the effects. A probability level of $P < .05$ was chosen as criterion for rejecting the null hypotheses for all the planned comparisons.

The two orthogonal planned comparisons were chosen "a priori" on the basis of the specific hypotheses of the study. The main consideration, in this study was experimental in nature and the logic, relevance and specific groups chosen as well as the methods and procedures were predicated on carrying out the specific contrasts chosen. The planned comparisons were conducted instead of the omnibus F test. Considering the seriousness of Type II errors - (overlooking of potentially important effects either because they are small or because of attentuation by experimental error) and that the replication process ought to provide protection from Type I errors (since independent demonstrations themselves reduce chances of spurious or inaccurate findings), in the present study I adopted a .05 alpha level for the two orthogonal planned comparisons. The two post hoc comparisons were carried out using an adjustment to the alpha level as per the Dunnett procedure when the comparisons are referenced to a control group. Since the obtained probability levels seem quite clear (no effects with the range of marginality that would make a difference) this is not a problem whichever way it is done.

<u>The meaning of average E.E.G. power changes and thermal changes</u>. The potentials recorded from the scalp E.E.G. appear to be produced within the cortex itself. The pyramidal cells appear to be the principal cellular elements contributing to the E.E.G. and it has been found that visual sensory stimuli can evoke simultaneous activation of large cortical surfaces. The E.E.G. potentials evoked by natural or artificial stimulation of afferent sensory pathways are usually composed of a potential which at first has a positive wave at the surface of the cortex with respect to a remote reference followed by a negative wave. These can be followed by later positivity. The initial positivity can be split into several constituents (Dondey & Gaches, 1974). This would undoubtedly result in enhanced average power at the area of recording electrode. The initial positive wave of the sensory evoked potentials can be supplemented by a later positivity, longer lasting, which may be caused by inhibitory post synaptic potentials. These seem to be due to inhibition of cortical neurons. These potentials are claimed to affect large regions of cortex but are mixed with spontaneous random activities which often mask them. The averaging process allows more or less attenuation of the spontaneous part of this activity. Electrical activities which arise in the cortex have been reported to diffuse away from their origin. The potential difference due to diffusion seems to depend on the intracortical

generators. Cellular columns at the cortical surface follow a somatotopic pattern. This leads to physiologically homogeneous zones being represented by groups of neighboring and synergistic columns. The glial covering constitutes a supplementary route for diffusion of currents and moderates or attenuates their intensities. This is why the E.E.G. is normally less than the 100 μV range (Dondey & Gaches, 1974). Between the cortex and the E.E.G. electrodes there is a series of electrically inactive media which interfere with the passage of currents. These are the cerebrospinal fluid, the meninges, the skull and the scalp; the cerebrospinal fluid, and meninges providing the most interference.

Within the 8 to 14 Hz range there have been established certain varieties of waves reliably related to activities as in reading (Kappa) and to problem solving cognitive function (K - complex), possible Lambda waves, Mu rhythm (7 to 11 Hz), other periodic activity up to 20 Hz, and various other undefined wave patterns associated with certain activities and conditions. The average alpha power spectrum is taken on all these waves within the alpha frequency band and is a reflection of the degree of synergistic activity along all these dimensions of brain activity.

Given that the E.E.G. is derived from neural electrical activity in the brain in an hitherto misunderstood way, some speculations can be asserted with regards to the possible meaning of the average power spectrum of the E.E.G. Given the E.E.G. as a time series, the average power spectrum can be thought of as a statistical estimate of the electrical intensity or energy coming off from the cortex at the point of a given E.E.G. electrode. From the E.E.G. waveform in the time domain the A/D conversion samples points along this waveform at a rate per unit time (in this study, 64 samples per second). In the fast fourier transform, these 64 data points sampled at intervals of time of one second are transformed into 64 fourier coefficients in the frequency domain, one each for the sine and the cosine terms. This transform is equivalent to multiplying by the cosine and sine frequencies.

Since for random data the fourier coefficients have random phases, the power spectrum is more useful. The original unit time data points yield half the number of power spectral estimates in frequency space each with two degrees of freedom (one each from the sine and cosine terms). To improve the accuracy of the estimates, one averages the power spectrum of several small subsets of data points and then averages the power spectrum from each group. Thus averaging several frequency bins provides considerably more degrees of freedom and thus considerably more accuracy of the estimated power spectrum. In about 2/3 of cases the true power spectrum can be expected to be between $\pm\sqrt{2/D}$ (D=df) of each estimate (Cooper, et al., 1980).

A complex waveform such as the E.E.G. can thus be shown to be represented by the sum of a number of sine waves of differing frequencies and amplitudes. The fourier method provides a transform of the waveform which tells the relative strengths of the different frequency sine waves that, when added together, will give the original time domain waveform. This waveform is assumed to be periodic. The fourier method is thus like multiplying the frequency components by the various cosine and sine harmonics and average the values obtained for each. This process determines which of the harmonics are present since when sine waves are multiplied the mean cross product is finite when their frequencies are the same and zero when their frequencies are different (Cooper, et al., 1980).

In fourier analysis the complex waveform is thus separated into harmonically related components the fundamental having a period equal to the epoch length. For instance, a sample of 1 second of E.E.G. can be represented by a fundamental waveform of 1 Hz and harmonics of 2, 3, 4 etc. Hz. One can thus represent a component at each frequency as the sum of sine and cosine components of the particular frequency. The power spectrum combines the sine and cosine components while giving up the information about phase (Cooper, et al., 1980). The average power spectrum is, however, not a unique description of the waveform since the same spectrum can result from quite different waveforms. Also, the average power spectrum is a manifestation of not only amplitude but also duration of certain frequencies within the band pass. It thus gives the relative intensities of sine waves that would reconstitute the signal. Thus the average alpha power spectrum gives a representation of the extent of synchronous electrical activity occurring at the particular E.E.G. electrode. This may be a manifestation of correlated activity between groups of neural ensembles indicating synchronic thinking. Holistic cognitive processing may be the mechanism underlying this E.E.G. spectral manifestation since synergistic cell activity may be involved.

The meaning of thermal changes: based on previous findings relative unilateral decreases in ear canal temperature from the initial baseline levels during cognitive tasks can be expected to reflect relatively increased blood flow to that side of the brain hence greater unilateral hemispheric utilization.

Chapter III. Results

Initially, the data collection of the present experiment yielded a set of 8 measurements for each subject, defined as follows:

(1) Two second by second integrated alpha spectral powers from the left and right brain hemispheres as per Doyle, et al., (1974) and Furst, Gardner and Kamiya (1974) averaged over 2 minutes 40 seconds and then over the 20 minute period. The histogram of the treatment means of the powers are shown in Figure 3.

(2) An E.E.G. index of relative right hemispheric activity (ratio) as per Doyle et al., (1974). The natural logarithmic transform of this ratio was also analyzed as per Ornstein, et al., 1979).

(3) Two thermal response indices (maximum decrease temperature) from the left and right tympanum areas as per Meiners and Dabbs (1977). The histogram of the treatment means of the thermal indices are also shown in Figure 7.

Insert Figure 7 about here

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(4) A temperature index of relative right hemispheric activity as per Doyle et al., (1974).

(5) Recall score.

(6) Comprehension score.

Bickel and Doksum (1981), as well as Carroll and Ruppert (1981), report that one can choose a good transformation of E.E.G. power spectral data but this is difficult or impossible to reliably do from the data. For power spectrum analysis, Matousek and Petersen (1973) and others have been using the E.E.G. square root power transformation instead of absolute power. According to Gasser et al. (1982) this transformation is superior to the absolute power values and to other root transformations. For the present purpose, it was decided to use two neurophysiological measures, E.E.G. power ratio and thermal index ratio, and two verbal response measures, recall and comprehension scores. It was found that the experimental conditions were indeed linked to the procedure. The outcome of the manipulation check showed that each condition had been influenced as required. The control group reported having read the irrelevant material and having experienced no help toward the learning. The induced imagery group reported having created their own self generated imagery. The picture group reported having examined the poster and having been helped by it.

In order to test the predictions derived from the central general hypothesis it was necessary to make two orthogonal contrasts. The first contrast (hereinafter referred to as the "Effect of Learning Adjuncts") was to compare the linear combination of mean vectors for Imagery Instruction and Pictorial Diagrams conditions with the mean vector of the control condition. The second contrast (hereinafter referred to as "Imagery vs. Picture Effect") was to compare the mean vector of the Induced Imagery condition with that of the Pictorial Diagram condition. The means and mean squared errors of the E.E.G. power ratios and tympanic temperature ratio index are reported along with those of verbal recall and comprehension scores in Table 1.

Insert Table 1 about here

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Presented also in Table 1 are natural logarithms of the relative right hemisphere activity E.E.G. ratio indices and their mean squared errors.

The means for the E.E.G. average power generally indicate a difference due to pictures. The means of the E.E.G. power ratios (also of the E.E.G. power log ratios) indicate a difference due to pictures and a possible slight difference for the Imagery Instruction condition. The means of decreases in temperature for the right and left hemispheres indicate slightly greater right hemisphere decreases for the experimental conditions than for the control condition. The means for the temperature indices of right hemisphere activity reveal a possible difference due to pictures. An examination of the means shows that the effect of pictures (imposed imagery) seems to have induced superior recall and comprehension than the effect of the two other conditions. The Imagery Instruction seems to have elicited slightly better recall and comprehension than the control condition but not always significantly so.

<u>Neurophysiological Measures - E.E.G. Power Ratio and Thermal Index Ratio</u>

A multivariate analysis was carried out taking the two neurophysiological variables as dependent variables in the logical temporal order of their occurrence. The planned orthogonal comparisons for this analysis consisted of the joint learning adjunct effect and the Imagery vs. Picture effect. The joint effect contrasted the two experimental conditions in combination with the control condition. The Imagery vs. Picture effect contrasted the imagery instruction with picture diagram condition. Step down analyses of variances were also carried out. The results of statistical analyses are shown in Table 2.

Insert Table 2 about here

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For the joint learning adjunct effect the overall multivariate analysis of variance was not statistically significant, F (2,56) = 2.219, $p <$ .1182. Neither of the step down F values associated with this tested statistically significant.

For the Imagery Instruction vs. Picture Diagram contrast effect the multivariate variance analysis was statistically significant, F (2,56) = 6.073, $p <$ .0042. This shows a reliable difference between the two forms of learning adjuncts for the effect upon the physiological variables. The step down variance analysis shows that the most of this effect can be accounted for by the E.E.G. response variable (E.E.G. step down F (1,57) = 9.903, $p <$ .0027). The thermal response variable accounts for a marginally nonsignificant portion of this contrast, step down F = 2.059 (1,57), $p <$.1569). Another post hoc multivariate test compared the picture diagram and imagery instruction conditions separately with the control condition. It showed that E.E.G. power ratio of the picture diagram was the only one distinctively different from two other treatment means, $F(1,57) = 12.356$, $p < .0009$. This set of findings in conjunction with the neural impact on the left hemispheric activities as shown in Figure 3 suggests that pictures are superior to Imagery Instruction to eliciting a neurophysiological response.

Verbal Recall and Comprehension Test Scores

The overall multivariate analysis of variance for the combined recall and comprehension scores was statistically significant. F value approximation, Roy's criterion and associated probability are given in Table 3.

Insert Table 3 about here

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The joint effect was significant, $F(2,56) = 7.997$, $p < .0009$. These findings corroborate the hypothesis of pictorial superiority. This means that the two forms of learning adjuncts combined influenced learning as reflected on recall and comprehension test scores. The step down F was statistically significant for recall. $F(1,57) = 15.813$, $p < .0002$. The fact that the step down F for comprehension score was not statistically significant indicates that the recall effect can account for pretty much of comprehension effect, $F(1,57)$ 1.0, $p < .552$. For the Imagery vs. Picture effect the F ratio was statistically not significant, $F(2,56) = 2.9549$, $p < .0603$. This means that there is no overwhelmingly reliable statistical difference between the two forms of learning adjuncts for their influence upon the combined recall and comprehension test scores. The step down F, however, was statistically significant for recall, $F(1,57) = 4,551$, $p <$ .037 for recall score, but the step down F for comprehension was not significant, $F(1,57) = 1.332$, $p < .253$. This means that the effect of this contrast can be accounted for by recall, or vice versa since the univariate analyses were significant. Another post hoc multivariate test compared the picture diagram with the control. It showed that both verbal recall and comprehension scores of the picture diagram were significantly greater than the control conditions, while the imagery instruction condition effect fell between two extremes, as can be seen in Table 1.

Relationship Between Two Neurophysiological and Two Verbal Learning Measures

A multivariate analysis of variance was also carried out taking the four measures in the logical temporal order of their occurrence, in order to determine the correlational structure of two sets of response domains, neurophysiological and verbal responses. The multivariate results for the relative right hemisphere E.E.G. log ratio, the relative right hemisphere temperature index, the recall and comprehension variables are presented in Table 4.

The planned orthogonal comparisons for this analysis also consisted of the learning adjunct effect and the Imagery Instruction vs. Picture Diagram effect. Step down analyses of variance were carried out, the results of which are shown in Table 4.

Insert Table 4 about here

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For the learning adjunct effect the overall multivariate analysis of variance analysis was statistically significant, multivariate $\underline{F}$ (4,54) = 5.066, $\underline{p} < .0012$. This shows that taken together the effect of both forms of learning adjuncts seems to influence reliably the set of four response variables. The step down analysis shows that there is the only one significant effect recall in terms of $\underline{F}(4,54) = 14.515$, $\underline{p} < .0004$. This means that recall is the only variable affected by this influence. The neurophysiological variables did not show statistically significant effects as before. When recall score was let to account for the effect, the comprehension variable had very little to account for. This means that there is little relationship between the neurophysiological variables and the verbal response variables as far as the effects of both learning adjuncts are concerned.

The Imagery Instruction vs. Pictorial Diagram contrast shows a reliable difference between the two forms of learning adjuncts for their effect on the set of four response variables, multivariate $\underline{F}(4,54) = 4.346$, $\underline{p} < .0041$. When the step down analysis was performed on the four response variables as shown in Table 4, the effect of the picture diagram vs. imagery instruction turned out to be significant first in terms of the E.E.G. power ratio, and then all other three variables did not show up any significance.

It should be noteworthy here that the earlier multivariate tests, particularly that of the learning adjuncts, and univariate $\underline{F}$ tests of the imagery instruction vs. picture effect were significant in terms of the verbal measures, as shown in Table 3. When we let the E.E.G. power ratio to account for the effect, the previously significant variance analyses for the verbal response variables are no longer shown to be significant, step down $\underline{F}$s (1,57) = 2.48 and 2.13, $\underline{p}$s < .12 and .15, recall and comprehension, respectively. This finding shows a relationship between the E.E.G. measure and the verbal measures, particularly recall measure. That is to say, the E.E.G. concomitant to learning for recall may well be a precursor to the subjects' abilities to perform well on a recall task.

The picture diagrams facilitated more of left hemisphere processing via the intermediary of the right hemisphere. Synchronous neural activity in the right hemisphere seems to have possibly induced synchronous neural activity in the left hemisphere which gave rise to superior verbal performance. These findings corroborate the central hypothesis of relative hemispheric utilization during learning with the pictorial diagram adjunct.

Chapter IV. Discussions and Conclusions

The findings obtained generally corroborate the predictions from Wittrock's theory of generative learning. Outcomes of the debriefing procedure means that the experimental manipulations performed as they had been designed to. The use of pictures seems to have enchanced learning via alteration in brain state of activity but the effect of imagery instructions remains somewhat unclear. Paivio's theory of dual coding processes is also corroborated.

Hence, the present findings shed some light on the research issue in educational psychology, brain electrophysiology and the link between the two and the meaning of this link. The findings need to be examined for not only internal validity but also external validity.

Neurophysiological Measures

Electroencephalographic indicators of brain hemisphere activity. Although the findings obtained in this study stand unique because of involving a learning component, the analyses for the E.E.G. activity associated with the tasks show that the ratios showing relative hemispheric E.E.G. activity appear generally in keeping with the results reported in the general literature involving other tasks by Doyle et al. (1974), Ornstein et al. (1979), Galin and Ornstein (1972) and Galin et al. (1978). The suggestion offered by Gevins, Zeitlin, Doyce, Yingling, Schapper, Callway and Yealer (1979) and the "evoked potential" literature that E.E.G. alpha asymmetry findings could be attributable to task related differences in efferent activity, stimulus characteristics and performance rather than cognition ought, however, to be re-examined.

There was a general overall increase in power in both hemispheres with pictorial cognitive tasks. This is consistent with the expectations from theoretical knowledge of the relationship between E.E.G. and neural activity and the empirical findings of Simpson, Paivio and Rogers (1967), Short (1953), Short and Walter (1954) and Slatter (1960) and with the reports of some critics of Galin's (1974) and Galin, Johnstone, and Herron (1978) and Doyle's (1974) studies.

Doyle's studies did not involve learning processes but compared writing letters to block designs or other perceptual or motor processes. Differential physical activity may be a factor that could have produced some hemispheric alpha blocking since an individual can be expected to exert efferent motor activity in writing with the right hand but would be expected to not necessarily use the preferred hand in doing a block design. In the present study, however, physical activity was constant for all conditions so the differences observed are purely attributable to cognitive processing differences. Also some of the literature suggests unilateral changes in the alpha power spectrum with hemispheric utilization without jumping into the beta range. This is what was observed in this study.

According to Simpson, et al., (1967), who investigated the relation between E.E.G. activity and imagery, significant results were obtained that contradicted those reported in previous investigations as well as some findings reported primarily from the Langley Porter

Neuropsychiatric Institute. Whereas Doyle et al. (1974) and Galin et al. (1978) as well as others had found decreases in right hemispheric alpha with pictorial processing, Simpson, et al., (1967) found higher alpha amplitude during visual tasks and lower alpha amplitudes during verbal tasks. Alpha amplitude is a component of average alpha power. Barratt (1956) had also found that suppression of alpha rhythm was not reliably associated with imagery. It seems, according to Paivio (1973), as if the data could also be interpreted in terms of "general activation or arousal" related to task difficulty. Visual tasks, including the kind of visually assisted learning as carried out in the present study, may be less difficult than analogous purely verbal tasks. Lesser alpha attenuation while working on a visual as compared to a verbal task could be due to the greater cognitive arousal needed to learn by the less facilitative, strictly verbal approach. Kamiya (1969) also reported that alpha amplitude was suppressed during mental effort, and Paivio (1973) reports that this alpha suppression may be related to strictly verbal processes.

The literature on proactive and retroactive inhibition and facilitation could serve as an explanation. Interpreting it in terms of difficulty, something bordering on a form of proactive inhibition may have been at work for the control group. After reading the irrelevant, perhaps, in the overall sense, confusing with respect to the learning task, information on "Genetics" the control subjects may have had a jumble of quite similar but incoherent facts in their mind. This may have interfered with their capability to recall and comprehend the text on mental disorders. The Induced Imagery group, on the other hand, would have had no proactive inhibition since the instructions to create images were couched in non complex form. On the other hand, the picture group (Imposed Imagery group) had been presented, in the adjunct, materials of a visual nature, which seemed to have assisted eventual recall of the text material. This enhancement of recall via pre studied material could be referred to as "proactive facilitation".

The fact that the picture manipulation as well as the induced imagery condition produced significant E.E.G. power outcomes for both the left and right hemispheres suggests that pictorial cognitive processing, in general, induced changes in neural acitivity in both hemispheres.

Changes in hemispheric neural activity seem correlated with alterations in verbal test score performance. Dual coding of learning materials is thus strongly suggested in the presently obtained empirical data. Tulving's notions of episodic vs. semantic memories seem also supported. One also needs to consider other findings (of Grabrow, Aronson, Green & Offord, 1979) that it is left hemisphere activation that is most affected by differential processing tasks (verbal vs. spatial). Right hemisphere E.E.G. activity seems to remain more or less the same with differential cognitive tasks which appears to be very similar to the present finding (c.f. Figure 3). So, from the point of view of brain activation the present study brings together considerable knowledge integrating it into cognitive processing theories which taken together corroborate Wittrock's generative learning theory.

The pictorial diagrams as learning adjuncts appear, however, to have induced differences in the E.E.G. power ratios in the direction predicted from previous results. The treatment effect of the pictorial diagram was manifested only in terms of the E.E.G. power ratio. In the analysis of the E.E.G. log power ratios the picture effect was statistically significant compared to the imagery instruction condition effect, which in turn was not significantly different from the control condition.

Another possible interpretation of the observed differences in average E.E.G. alpha power might be that the pictorial diagram as a subjectively experimental stimulus may have continued to exert its effect during the text learning phase as it did during the initial 5 minutes. This possible differentiation in E.E.G. average alpha power outcome had been anticipated so power spectrum data for the first 5 minutes were by computer compared to that for the last 15 minutes. Since no differences were observed for these time segments in each of the conditions they were combined and the analysis was carried out on the whole 20 minutes.

<u>Thermal indicator of brain hemispheric activity.</u> The analyses of the temperature indicator showed that task related increases in left brain hemisphere activity were not statistically significant for all comparisons involved. In this study, the subjects started off reading text materials, i.e., the objectives and instructions, and continued

all the way through in all conditions. Except for small fluctuations, no statistically significant changes in this variable due to mental activity are not big surprises in view of spurious random fluctuations, due to minute changes in environmental temperature and body temperature. These fluctuations were anticipated and accounted for by focusing mainly on task dependent departures from baseline rather than absolute amounts.

The analyses of the temperature indicator showed that task related increases in the right brain hemisphere activity were also not statistically significant. If such effect had attained statistical significance the minute change in temperature difference would have been consistent with the results of Meiners and Dabbs (1977) but much less powerful than reported by these authors. Little temperature variations attributable to the experimental treatments are most likely due to the capricious character of such temperature measurements and the difficulty in measuring temperature at such fine levels of accuracy. A future research suggestion would perhaps focus on this temperature hemisphericity variable with greater levels of environmental, instrumentation and subject control.

Neurophysiological Variables Combined

The E.E.G. neurophysiological measures emerged as distinctly more relevant than the tympanic thermal measure in this study. A high discriminability was observed for this E.E.G. ratio in all the effects tested.

<u>Verbal Performance Measures</u>

<u>Recall.</u> The analyses of recall scores reveals a reliable difference between imagery instruction vs. pictorial diagram. The pictures produced a dramatic enhancement of memory for the material studied whereas the Imagery Instruction did not. This is at variance with the literature (e.g. Willows, 1978) which, despite some findings consistent with this, generally reports either no difference between pictorial and imagery instruction or a superiority of imagery instruction over pictorial diagram, given prose materials. The explanation generally offered (e.g. Samuels, 1977) ("focal attention hypothesis") states that self generated images are more appropriate and more personally relevant than externally imposed fixed, designated pictures. This is not supported in the present study since the opposite was found. A major issue earlier raised from my reviews of the literature pertains to the general lack of studies addressing the point of different varieties of pictures and their effects as well as the point of different varieties of induced imagery and their potential effects and comparisons to the varieties of pictures.

The general statistical significance of the joint effect of both types of learning adjuncts can be accounted for primarily by the powerful effect manifested, in this study, by the pictures. Perhaps the substantial amount of information intrinsic to the pictures which was not provided by the instructions to create self generated images, may have contributed significantly to the difference. This effect was also manifested in the imagery instruction vs. pictorial diagram contrast.

Debriefing of the subjects also confirmed this surmise. In the debriefing it was confirmed that the control, induced imagery and picture conditions had triggered the desired state in the subjects, as previously described. The adjuncts were being used by the subjects in the manner designed. Those who had been exposed to the imposed imagery tended to say that the pictures were very helpful in providing mnemonics and a structure for their recall of the mental disorders, whereas, despite having constructed their own mental images, this was largely absent or only vaguely stated by those in the induced imagery condition. The hypothesis that induced imagery would equal the effect of imposed imagery is thus not supported. Differential time on task among conditions is an issue which could be raised as a possible contributor to the differential performance and neurophysiological outcomes observed between the pictorial diagram and the other two conditions. However, if this were the case, the differences between the performance of the Imagery Instruction group would have been expected to diverge more from that of the control group than it did since the former had more time on task by virtue of the organizational statement of the mental disorders provided at the beginning of their adjunct. If time on task had been of substantial relevance one would have expected a statistically significant difference between these groups. But this was not observed. A future research suggestion would be to tease out the relative dynamics of different kinds of pictures and different kinds of induced imagery for learning of various content subjects with images.

Comprehension. The analyses of comprehension scores suggest that both forms of learning adjuncts enhanced comprehension with some difference between them. The pictorial diagram significantly enhanced comprehension of the material studied while the imagery instruction did not. This finding is also somewhat at variance with the literature (e.g. Bobrow & Bower, 1969), but consistent with the hypothesis of this study which had emerged from examination of the literature taken with the specific materials used here. The pictorial materials used, which had been extracted from introductory psychology textbooks, appear to provide conceptual description of the ideas concerned and thereby seem to have contributed additional structure by which to organize the meanings. On the other hand, there seems to be a distinctive lack of the imagery instruction effect. The self-generation of imagery can only be encouraged if it is indeed desired that self-created personal images be used. Excessive instructions about which pictures or which type of pictures, to use in the creation of self-generated images can restrict the subject's freedom or disposition to indeed make up his own personal images. A follow up study to this would explore the differences between two different kinds of induced imagery in comparison to imposed imagery. One kind of induced imagery would be as used in this study, namely "how" directions on the creation of self generated images. Another kind of induced imagery would, through direction, give specific instructions on what specific images to create in the mind as applicable to the specific materials being learned. This latter would only differ from the imposed imagery condition in as much as words in textual format would be used to describe the mental pictures to be visualized. The mental pictures recommended, however, would themselves correspond to the condition provided with actual pictures. These comparisons to be explored in a subsequent separate study would carry considerable theoretical significance in an understanding of the effects of the various kinds of induced imagery and imposed imagery. This problem as applied to comprehension also seems inadequately treated in the literature to date.

The general statistical significance of both types of learning adjuncts taken jointly can be attributed primarily to the powerful effect of the provided pictures. This was confirmed also in informal post-experimental questioning. In post-experimental debriefing of subjects, this effect was however, not generally reported to have been felt as strongly subjectively, as the case for recall scores. Nevertheless, their performance on the comprehension test seemed to show that they comprehended more of the textual materials than they might have realized (Nisbett & Wilson, 1977).

Verbal Learning Test Score Variables Combined

The post hoc tests show that the effect of pictures is statistically significant upon both recall and comprehension whereas the effect of imagery instruction is not. The step down F's show that this effect is localized more upon the recall variable than on the comprehension variable. The pictures seem to have provided a framework as well as a mnemonic to reconjure during recall. The conceptual meanings also conveyed in the pictures assisted in the comprehension tests.

Imagery instruction does not seem to provide the conceptual structure needed for comprehension nor apparently the mnemonics needed for recall. There is the additional problem that despite the elaborate verification carried out to ensure that the manipulations took, there is no way to be absolutely certain, in this type of manipulation, that the subjects did indeed use self generated images nor that if they did generate images, that these would be adequate or effective for the purposes intended.

Post experimental questioning of subjects in this condition generally yielded the reply of having tried to visualize images the best they could and the general feeling that this technique was of help in learning the material. Their performance, however, did not confirm the latter.

The multivariate analysis of the verbal learning test variables decomposed into planned contrasts for a general experimental effect over control shows a confirmation of the powerful effect due to pictures thus confirming the previous assertions. The verbal learning tests multivariate planned contrast between the two experimental groups is not statistically significant. Hence, we can conclude that there is likely some difference between the experimental groups compared to each other with respect to their effects upon the verbal learning tests variables together.

Correlations of Verbal Response Variables with the Neurophysiological Responses

The multivariate analysis of the verbal response variables in conjunction with the E.E.G. power and temperature index variables for the picture effect contrast is an important one to note. The step down analysis of variance showed the E.E.G. power ratio being associated with the recall variable. These findings incorporate into and supplement well the existing nomological network of information in this area. The clear association between the verbal performance measure of recall and the E.E.G. neurophysiological indication of brain neural activity was established. The interaction between the brain hemispheres during cognitive processing for learning was demonstrated.

For the joint effect of the experimental groups the multivariate analysis of the verbal learning test variables with the temperature hemisphere indicator was statistically not significant. For the verbal learning tests taken with temperature relative right hemisphere index indicator, however, the multivariate test of the picture effect and of the general learning adjuncts used by experimental groups jointly are statistically significant. The pictures could help only during the phase of picturing. With reading text this effect may have become combined with the text processing mode hence a return back to relatively dominant left hemisphere processing may have occurred but in a different cognitive mode and brain state.

The multivariate analysis of the verbal learning test variables in conjunction with the E.E.G. power indicators of left and right hemisphere activity for the picture effect contrast was statistically significant. This is somewhat at variance with the temperature indicators of hemispheric activity. Given the tenuous nature of the temperature measure and the different processes probed by it, however, one cannot place excessive reliance on it in such a comparison. Also, there may be some processes underlying the dynamics of temperature regulation in connection with brain blood flow that may differ from processes underlying E.E.G. manifestations of electrical activity of the brain. One would also expect a lag in temperature manifestation which would not be expected to occur for the E.E.G. because temperature conduction takes longer than electrical conduction.

For the verbal learning test variables taken with E.E.G. log power ratio indicator of relative right hemisphere activity the multivariate post hoc test of the picture effect was statistically significant. The step down analysis of variance gives an indication that the variance of this contrast is mainly located in the ratio index itself. Pictures thus influenced relative hemispheric activity and verbal performance. For the induced imagery effect the multivariate test taking the power ratio indicator was not statistically significant but recall seems emphasized in the step down analysis of variance. This negates the premises of the focal attention hypothesis of Samuels (1977). Pictures did not distract from learning but quite conversely helped substantially. The multivariate general experimental effect of learning adjuncts, however, was statistically significant when taking the achievement tests with the E.E.G. power ratio. A high contribution for recall and a high contribution for the ratio indicator were demonstrated also in the multivariate test for the contrast of imagery instructions vs. pictures. For the verbal learning test variables the relative right hemisphere activity E.E.G. log ratio for the pictures thus seem to have had a profound influence. The step down analysis of variance also, shows the greater emphasis of recall over comprehension going along with the log ratios. These collectively substantiate the internal validity of the findings in this study.

This can be interepreted to mean that it may be due to the picture effect being associated with recall and the log power ratio whereas the imagery instruction having a spurious association with comprehension and the log power ratio.

The observation that the multivariate comparison contrasting the imposed to the induced forms of imagery came out statistically significant indicates that the difference between these forms of adjuncts is dependable with regard to the effect on relative right brain hemisphere activation. One can estimate from the other analyses that the pictures may have had the bulk of the effect and one can estimate from the step down analyses of the two physiological measures that the relative E.E.G. was the most sensitive in accounting for this discrimination. Upon examination of the same multivariate comparisons taking not only the neurophysiological measures but also the verbal learning test measures we find a confirmation of the above assertions with respect to the neurophysiological measures namely that the relative right hemisphere E.E.G. provides the only statistically significant step down F value for the picture diagram vs. imagery instructions effect. The fact that the relative right hemisphere thermal response variable is statistically not significant in the step down analysis could be due to the considerable random error possibly associated with this measure. The interesting part of the step down analysis, however, concerns the statistically significant joint experimental effect of learning adjuncts (i.e. effect of Imposed and Induced imageries together) upon the linear combination of the four dependent measures in the planned contrast analysis. The step down variance analyses for the neurophysiological measures are here statistically nonsignificant (though marginally so) but the step down F values reveal the strong effect of adjuncts in general, for the enhancement of recall. So, enhancement in recall, on the basis of these step down analyses, may be associated with concomitant generalized shifts in relative brain hemispheric activity.

When looking at both forms of adjuncts together the relative ineffectual effect of the imagery instructions may be masking the effect of the pictures as it comes out in the pure comparison. What we find, essentially, is that since average alpha power may reflect intensity or energy of brain activity the pictorial diagrams elicited enhanced amounts of this energy in the right brain hemisphere which, in turn, evoked enhanced activity (hence cognitive processing) in the left brain hemisphere. This enhancement of left brain hemisphere energy via enhanced right brain hemisphere energy can explain the drastic improvement in recall observed by those in the pictorial diagram condition over those in the control condition. Thus, neural activity in the brain (left hemispheric via the right hemispheric) can be taken as the concomitant to efficient learning and thus the precursor to efficient recall and performance. The imposed imagery (picture-diagram) facilitated more of left hemisphere processing via the intermediary of the right hemisphere.

A general mnemonic strategy such as induced imagery as applied in this study does not seem superior to presented pictures in eliciting superior recall or comprehension. Given that subjects with stated G.P.A. of less than 3.5 were used in this study plus the observation by Rohwer (1973) that there may be individual differences in the use of strategies depending upon academic ability it is possible that, with the kind of imagery instruction provided, the subjects could not use it or did not know how to use it.

Since the general nomological network of the literature reports a change in the ratio of right to left hemisphere average power with pictorial cognitive processing the results herein obtained fit in well with bimodal theory. The absolute amounts of average power are not specified as especially relevant but the relative right to left power is what is considered important. Gevins et al, (1979) specify the following as criteria for studies examining task related brain asymmetries in the E.E.G.: Minimal differences between tasks in stimulus properties, no differences in efferent activities, minimal differences in performance related factors, behavioral validation of the tasks, E.E.G. patterns from the left and right hemispheres presented separately and extracerebral artifacts rejected. The present study rigorously adhered to these criteria.

Crowell, (1975) cited in Swartz and Shaw (1975) found increases in power spectral density energy of the E.E.G. in the right hemisphere of children with the presentation of flashes of light patterns. It revealed increases in the region of 3 Hz to 14 Hz. "The right side of the brain may dominate in adult visual acuity because it develops that capability before the left side does" (Swartz & Shaw, 1975).

Moreover, Galin & Ellis (1975) and others have frequently stated that their findings show a hemispheric enhancement of evoked potentials with lateralized cognitive processing which is somewhat at odds with the results of general activity. "The visual evoked response is enhanced over the right posterior temporal cortex when evoked by a spatially intricate stimulus" (Vella, Butler & Glass, 1972 p. 125). "Effect of imageability on recall is related to the more extensive bilateral processing of such words" (Rugg & Venables, 1980). "When a stimulus is task relevant, the evoked potential amplitude increases as a function of increasing attention or involvement" (Galin & Ellis, 1975). "It is unclear whether the E.E.G. patterns found to distinguish complex behaviors are related to the cognitive components of the tasks or to the sensory - motor and performance - related factors" (Gevins et al, 1979).

In the present study, the tie between verbal learning and neurophysiology is thus established. Judging from the results it would seem that the recall variable has this profound association with the

E.E.G. measure of relative hemipheric activation. Such an observation clearly demonstrates that the source of efficient recall may well be relative brain hemispheric activity because the E.E.G. is likely a manifestation of this activity. The E.E.G., hence brain activity, patterns are thus clearly related to cognitive components of learning performance. The essence of Wittrock's theory is thus demonstrated in four ways. First, that there is a link between cognitive processing and neural acitivity in the brain. Second, that a relative hemispheric utilization occurs during learning. Third, that in generative cognitive processing the right brain hemisphere may play an increasing role. Fourth, that the pattern of activation throughout the whole brain, including the semantic association areas, may be different when using a generative processing strategy for learning. It is suggested that synchronous activity (syncratic, simultaneous, parallel processing, etc.) may well be the mode of neural network activity during generative processing.

Concerning task related alpha power ratios it has been found that "hemispheric processing is a function of the task processing demands and not just related to perceptual requirements" (Willis et al, 1979). "Large bilateral areas of cerebral cortex are involved in cognitive higher functions" (Gevins, et al, 1979). "Cross correlation analysis indicates a constant phase relationship between alpha waves from the two hemispheres with one or the other leading" (Hoovey, Heinemann & Creutzfeldt, 1972). Thatcher (1977, 1979) finds that the average evoked potential is larger over the right hemisphere than the left in a visuospatial task but the presentation of verbal stimuli often results in enhanced average evoked potential amplitude on the left side. No clear explanations have been offered for these average evoked potential amplitude asymmetries. "With respect to the E.E.G. studies of human short term memory and neurophysiological state," research has produced what seem to be paradoxical results as efficient performance has been associated with low states of activation (Gale, Jones & Smallbone, 1974). Taken together, the above findings in conjunction with this study show that one can expect not only quantitative changes in task related relative hemispheric processing but also concomitant qualitative changes in the waveform that may be specific to the cognitive task performed and to the performance demands in the study. Interest in this study was with the verbal learning processes associated with pictures or aroused imagery but not simply the effect of examination of pictures. So it was essential to look at the overall learning experience rather than segments of pictorial or instructional perception. This can explain the patterns of outcomes found. Moreover, overall external validity is hereby confirmed.

The general relationship between the use of pictures during verbal learning and concomitant hemispheric brain processes appears to be that the right hemisphere may play a crucial role when learning with pictures which may not necessarily occur if learning by using induced imagery. It may enable efficient processing of verbal material by the left hemisphere. A shift in the ratio from predominance of the left to predominance of the right is observed which suggests overall general qualitative changes in brain functioning occurring during learning with pictures. A lack of clear theory concerning the nature of brain functioning, however, remains. Given that amplitude and duration of given frequency components are both manifested by and intrinsic to the power spectrum, a certain indeterminancy in interpretation is to be expected. Also, whether various types of E.E.G. shifts could be possible depending on the nature of the material, tasks and whether associated efferent activity, task demands or stimulus characteristics are involved still remains to be dissected in future studies. More research is needed to tease out the finer details of the E.E.G. and associated cognitive and efferent processes involved with hemispheric processing in pictorial learning versus textual learning. A controlled study examining task dependent E.E.G. coherence changes (as per Beaumont, Mayes & Rugg, 1978) during learning various materials by means of various forms of pictorial processing would be excellent as a future project to attempt to sort out these additional points.

Conclusions

The present study found that pictorial diagrams as learning adjunct, facilitate recall even with removal of any possible differential effect of time on task (similarity between the control and induced imagery conditions precludes any such difference). The neurophysiological precursor to this facilitation may well be synchronous activation of the right hemisphere which might induce synchronous activity in the left. The locus of the experimental effect, in particular the pictorial diagrams, was observed to be in the left hemisphere in terms of the E.E.G. perhaps through the intermediary of the right hemipshere. The effect of learning adjuncts localized in the left hemisphere seems due to facilitative effects of the nature of right hemisphere activity. A clear brain neurophysiological correlate of efficient verbal recall was established. Although it had been hypothesized that imagery instructions would enhance recall by a similar concomitant brain mechanism this was not observed in the present study. A clear link of these conclusions to the procedures employed was shown to be manifested.

When college students (of g.p.a. of less than 3.5) learn a passage on mental disorders taken from introductory psychology textbooks the use of imposed imagery (pictures) appears to assist learning so it elicits better performance. It was found to enhance recall and comprehension. Instructions of how to visualize in the mind's eye, without defining which actual images to conjure up does not appear to augment recall nor comprehension over the presentation of irrelevant material. It appears, however, to induce minute changes in cognitive processing as inferred from the concomitant E.E.G. The relative superiority of pictorial diagrams over imagery instructions can be traced to concomitant activity in the brain. The pictorial diagrams appear to produce statistically observable relative engagement of the right and left brain hemispheres. The synchronous activity induced in the left hemisphere may be produced via the right hemisphere. Qualitative changes in cognitive processing are suggested during learning. The imagery instruction may also induce concomitant changes in relative hemispheric brain activity. The nature of, and content information intrinsic to the pictures, various kinds of induced imagery, and varieties of tests were suggested as having a determining effect on the performances concerned. The relationship of the kinds of imposed imagery and induced imagery to the material to be learned is also of utmost importance particularly in regard to the amount of detail provided and the concepts thereby conveyed. Also, findings of the effects of imposed and induced imagery in adults may vary from that discovered with children and adolescents in the literature.

This study did not examine the full variety of adjuncts used in educational settings nor did it examine the full complex of adjuncts proposed by Wittrock's theory of generative learning. Because this was an investigation into the effects of these adjuncts on brain correlates of learning it did not examine the interactive effects of combinations of these adjuncts jointly or with effects of other variables. The study also did not examine the full configurations of brain and physiological responses that occur during various kinds of efficient verbal learning but it focused on hemispheric brain responses only. Future studies of exact zones of the brain involved in various ways of cogitating about verbal material (which would further enlarge the scope of such understanding) might use the P.E.T. (position emission tomograph) - now being installed at U.B.C. This equipment can display a three dimensional view of the brain depicting the relative activity of specific zones in the brain during various kinds of higher level information processing (Sargent, 1980).

Contribution of this study. This study compared some of the major adjuncts used to improve learning (imagery instructions and pictorial diagrams) and determined which one(s) might best enhance recall and which one(s) best improve comprehension. Since these techniques are frequently used and have been recommended by various authors as methods of improving the teaching of subject matter, this study may contribute to educators' understanding of pedagogical benefits of alternate instruction techniques and their combinations. It thus provided information of practical value. It showed which of the above techniques are most likely to be helpful for specific purposes. So one might say, it had pragmatic value. But it is also of theoretical value in increasing our depth of understanding. It showed why some adjuncts such as the use of pictures work better (for certain purposes) than others. So far, exact explanations as to why these techniques work have been lacking or at best hypothetical. This study provides psycho-neurophysiological explanations for the dynamics of operation of these enhancing strategies. In addition to having a sort of empirical validity, such explanations have the added advantage of being grounded in the hard sciences (Neurology, Medicine, Engineering, Physiology, Biology, Physics and Chemistry) from which information can be drawn to complement and clarify the findings. It also provides the opportunity for some rapproachment and consensual validation between educational science and technology and the basic sciences.

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Figure Caption

Figure 1. Language Receptive and Execution Areas

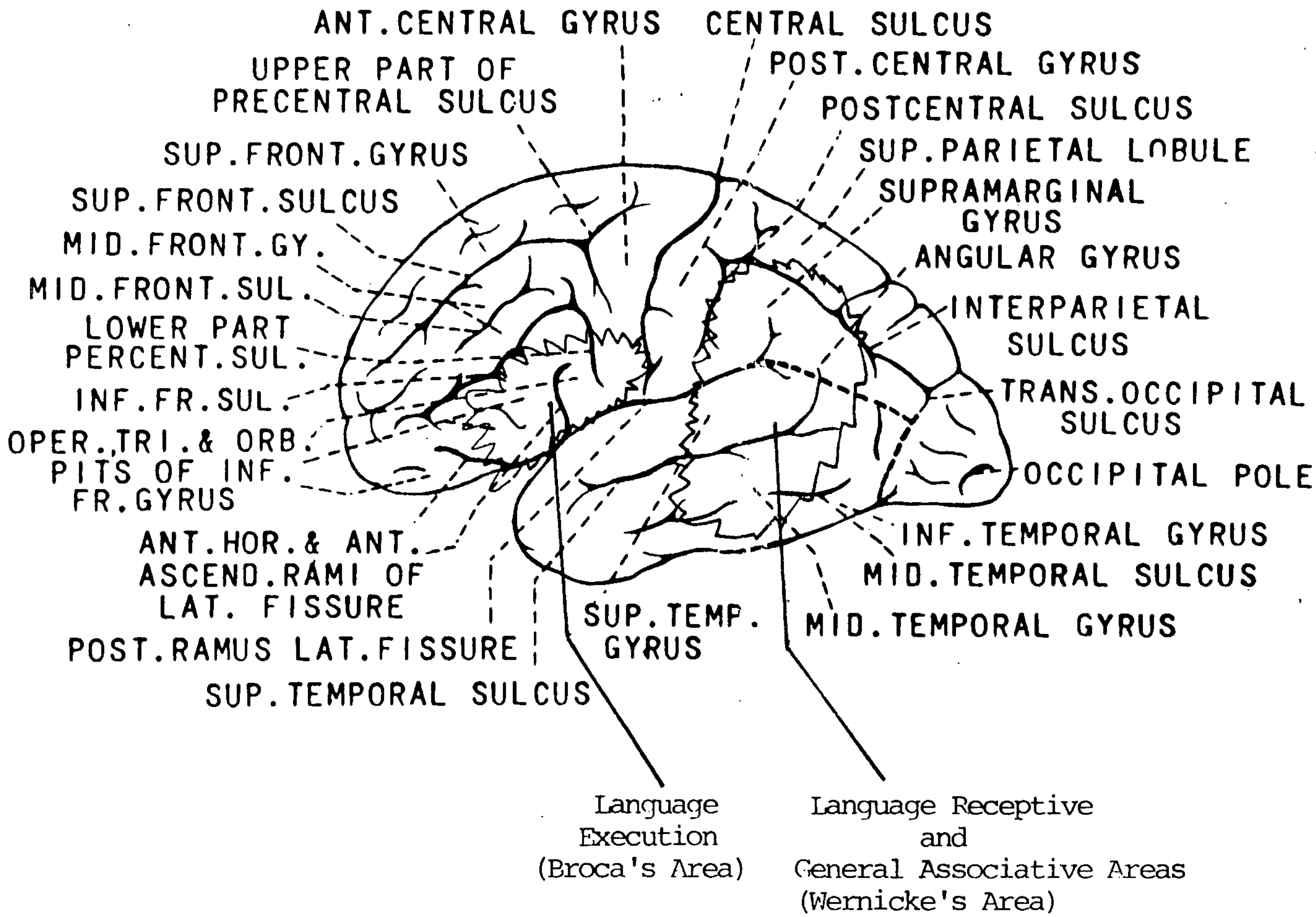
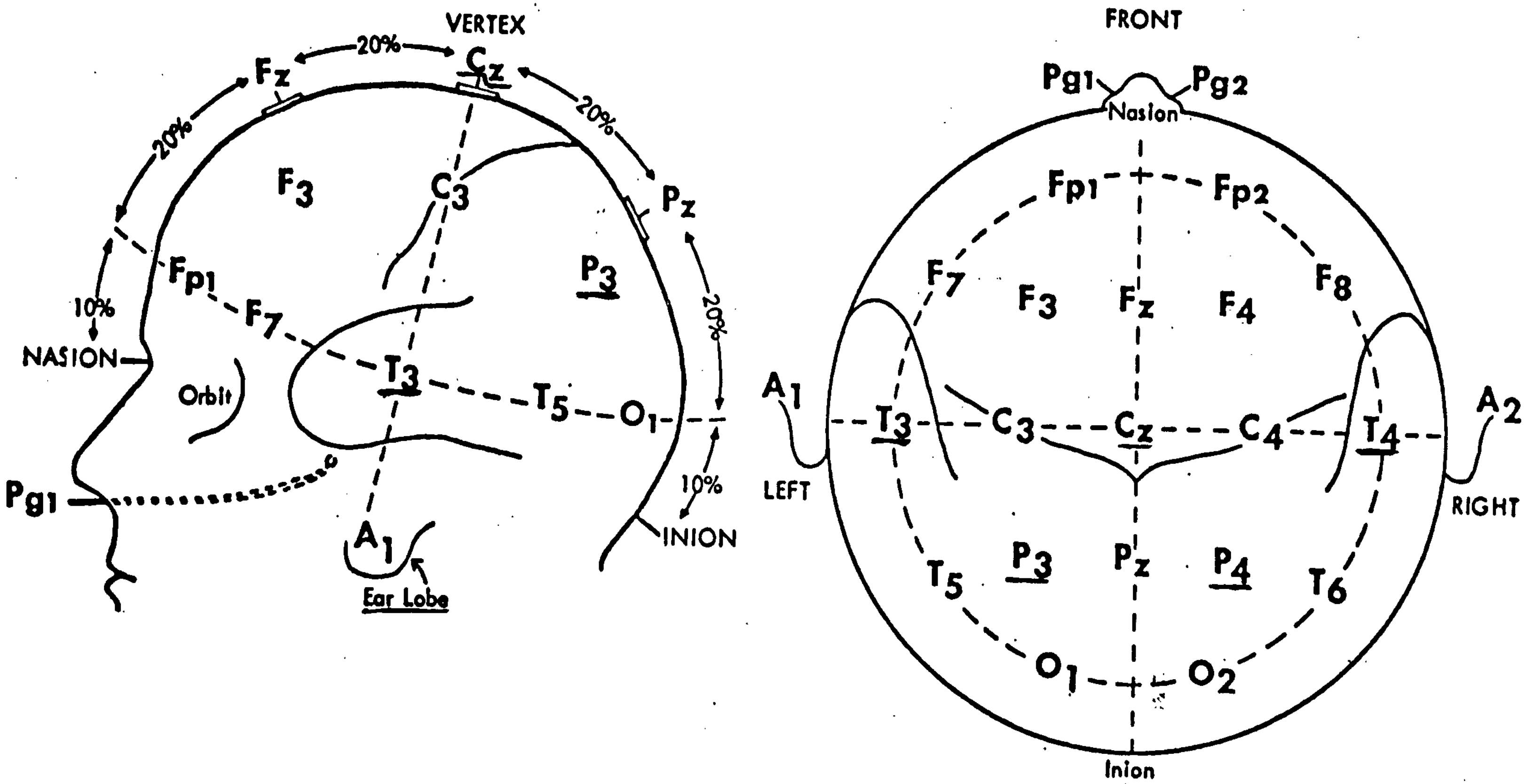


Figure Caption

Figure 2. Diagram of Electrode Positions for E.E.G.



LEFT SIDE OF HEAD

TOP OF HEAD

Figure Caption

Figure 3. Tympanic Temperature Sensing Monitor Unit

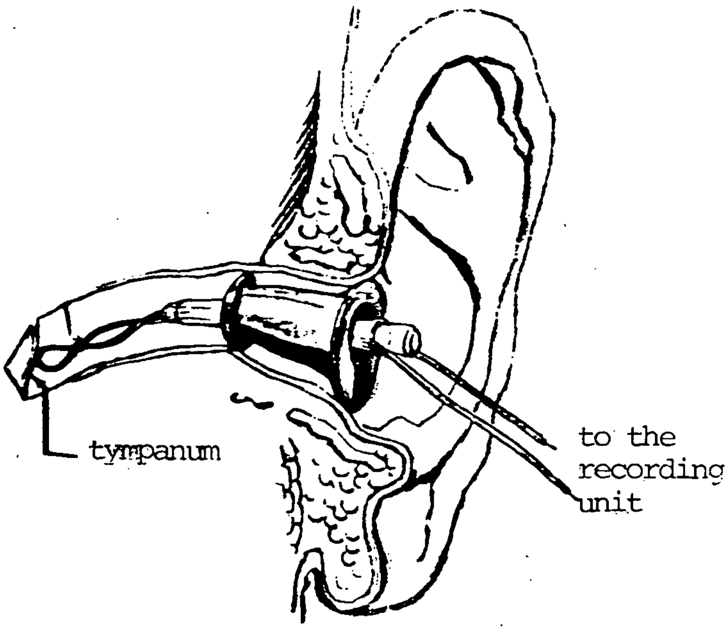


Figure Caption

Figure 4. Four point Kaiser-Bessel window compared to Hamming window

Hamming: $W_k(n) = .54 - .46\cos\left(\frac{2Pi(n)}{N}\right)$ $\quad 0 < n < N-1$

4 Point Kaiser Bessel:

$$W_k(n) = .40243 - .49804\cos\left(\frac{2Pi(n)}{N}\right) + .09831\cos\left(\frac{4Pi(n)}{N}\right) - .00122\cos\left(\frac{6Pi(n)}{N}\right) \quad 0 < n < N-1$$

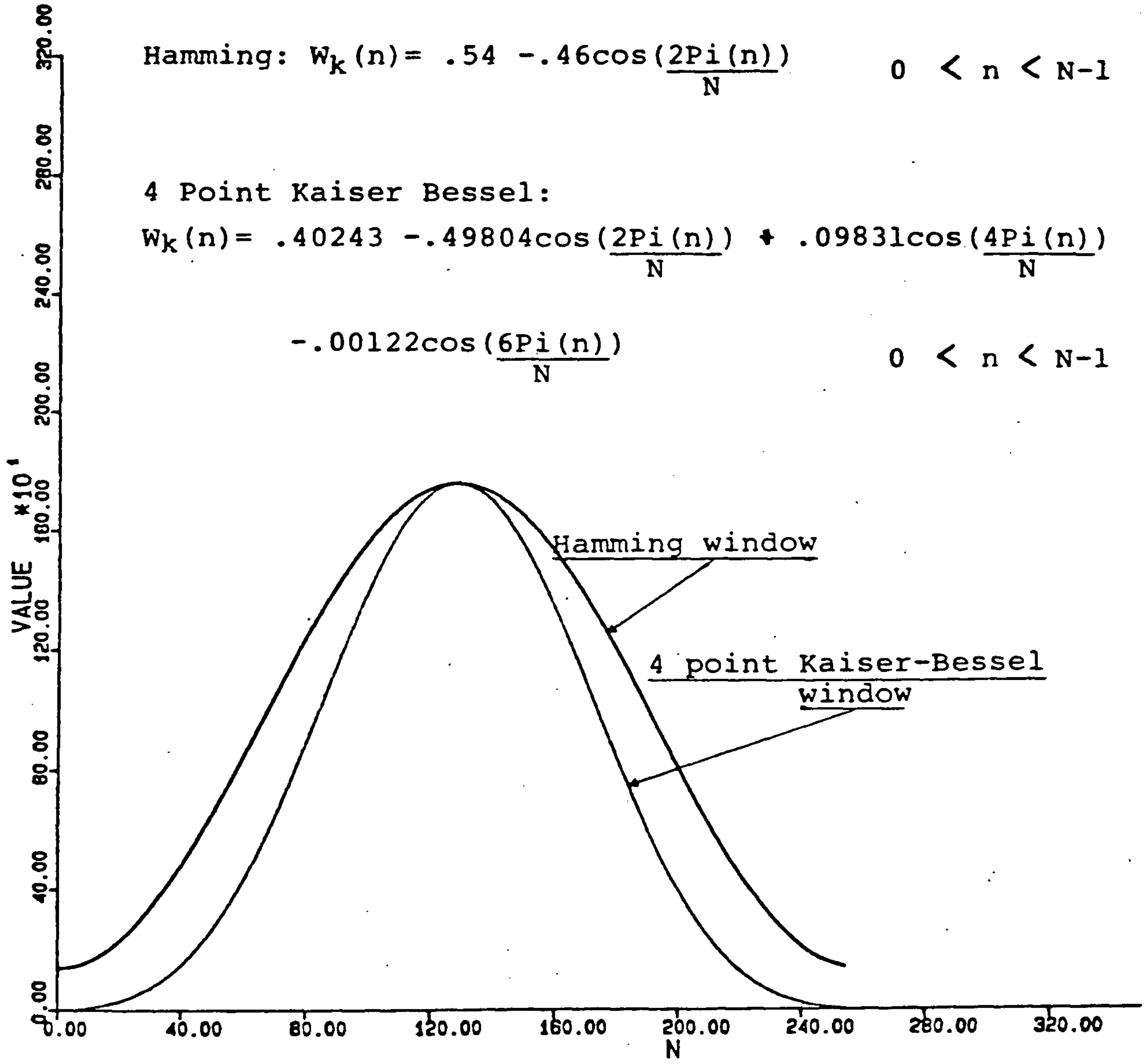


Figure Caption

Figure 5. Signal Processing System Sequence

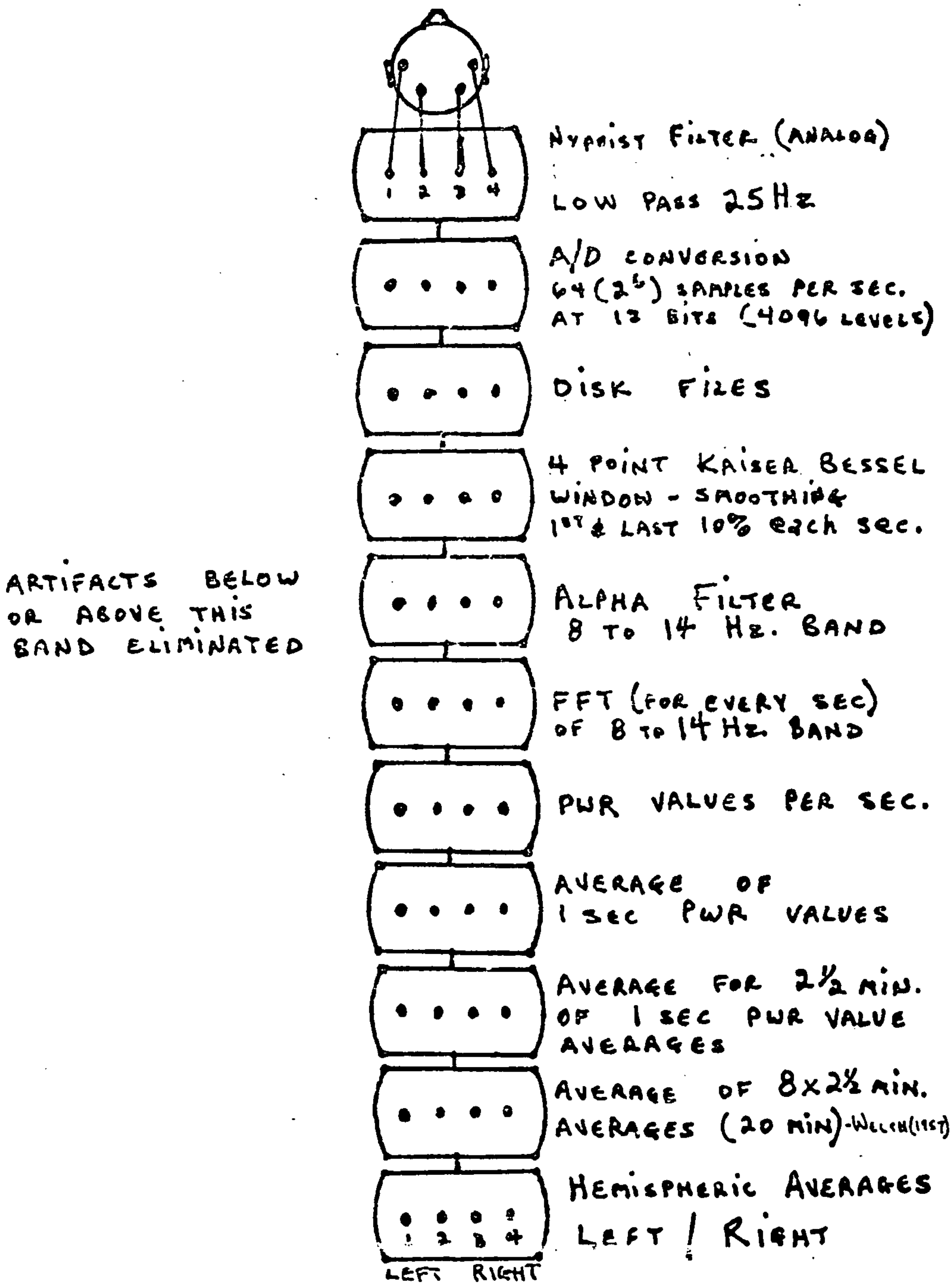
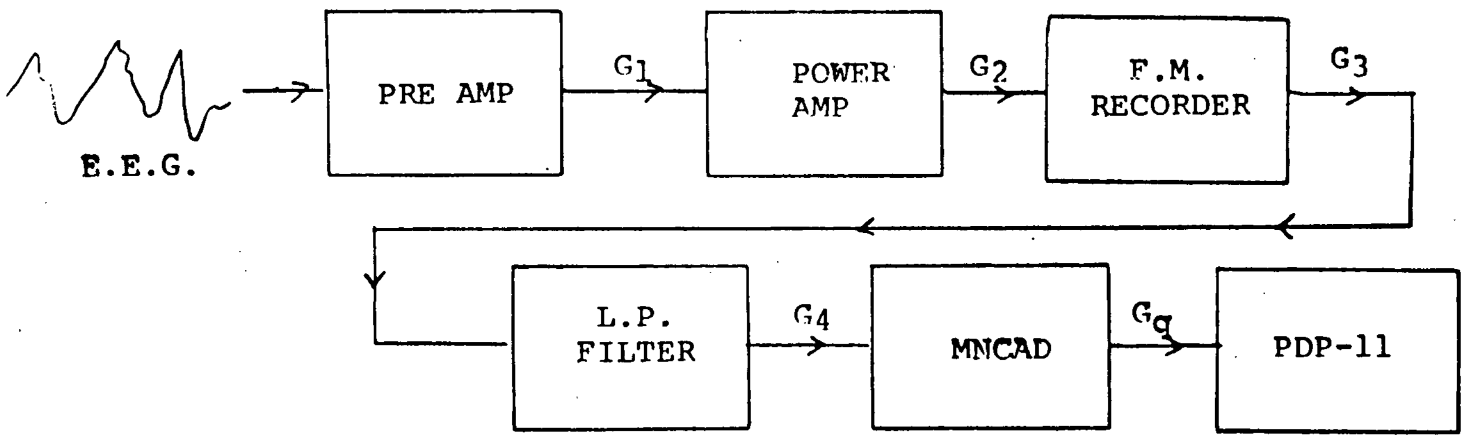


Figure Caption

Figure 6 . Block diagram of EEG to PDP-11 System Gains



G_1 Pre Amp Gain

G_2 Power Amp Gain

G_3 Gain due to F.M. Recorder

G_4 Filter Gain

G_q Quantization Gain

Figure 7

Figure Caption: BAR GRAPHS

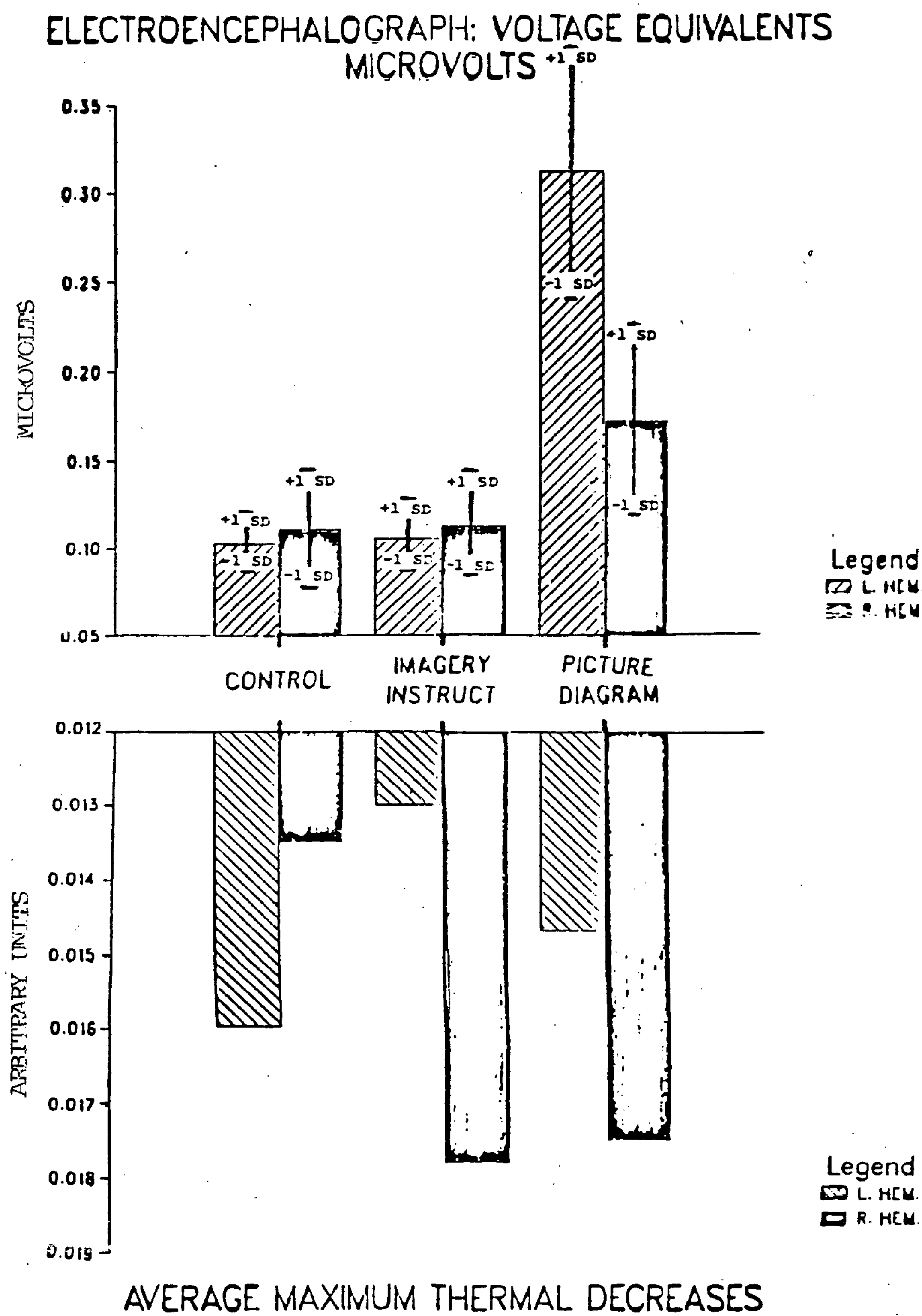


Table 1

Means and Means Squared Errors of E.E.G. Power Ratio, Log E.E.G. Power Ratio, Thermal Index Ratio, Recall and Comprehension Scores by Three Experimental Conditions (N=60)

Measure / Exp. Cond.	E.E.G. Power Ratio (Log Ratio)	Thermal Ratio	Verbal Learning Scores: Recall	Verbal Learning Scores: Compreh.
Control	0.9409 (-0.0172)[a]	1.0430	6.7000	5.7500
Imagery Instr.	0.9545 (-0.0579)	1.1450	8.6500	6.4500
Picture Diagram	1.5300 (+0.5652)	1.3765	10.4000	7.9000
MS_e	0.0460 (0.3920)	0.4650	6.7292	5.4128

a The figures in the parentheses are the natural logarithms of the E.E.G. power ratios

Table 2

Results of Multivariate Analysis of Variance on Relative Log Power Ratios of E.E.G. and Thermal Indices

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Effect of Learning Adjuncts	6.437	.0734	2.219	2,56	.1182		
Univariate		M.S.	F	df	p		
Log (E.E.G. Power Ratio		0.979	2.496	1,57	.1197	2.496	.1197
Thermal Index Ratio		0.632	1.360	1,57	.2484	1.903	.1733

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Picture vs Imagery Instruction	6.556	.1782	6.073	2,56	.0042		
Univariate		M.S.	F	df	p		
Log (E.E.G. Power Ratio)		3.883	9.903	1,57	.0027	9.903	.0027
Thermal Index Ratio		0.536	1.153	1,57	.2875	2.059	.1569

Table 3

Planned Contrasts: Multivariate Analysis of Variance Table for Two Verbal Learning Tests

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Effect of Learning Adjuncts	11.700	.2222	7.997	2,56	.0009		
Univariate		M.S.	F	df	p		
Verbal Recall		106.408	15.814	1,57	.0002	15.813	.0002
Comprehension		27.075	5.003	1,57	.0293	.359	.5516

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Picture vs Imagery Instruction	11.600	.0955	2.9549	2,56	.0603		
Univariate		M.S.	F	df	p		
Verbal Recall		30.625	4.551	1,57	.0373	4.551	.037
Comprehension		21.025	3.885	1,57	.0536	1.332	.253

Table 4

Planned Contrasts: Multivariate Analysis of Variance Two Physiological and Two Verbal Learning Dependent Variables

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Effect of Learning Adjuncts	18.068	.2729	5.066	4,54	.0012		
Univariate		M.S.	F	df	p		
Log (E.E.G. Power Ratio		0.979	2.496	1,57	.1197	2.496	.1197
Thermal Index Ratio		0.632	1.360	1,57	.2484	1.903	.1733
Verbal Recall		106.408	15.814	1,57	.0002	14.515	.0004
Comprehension		27.075	5.003	1,57	.0293	.442	.5090

Source	SCP's	Roy's Largest Root	Approx. F	df	p	Step Down F	p
Picture vs. Imagery Instruction	18.028	.2435	4.346	4,54	.0041		
Univariate		M.S.	F	df	p		
Log (E.E.G. Power Ratio		3.883	9.903	1,57	.0027	9.902	.0027
Thermal Index Ratio		0.536	1.153	1,57	.2875	2.059	.1569
Verbal Recall		30.625	4.551	1,57	.0373	2.478	.1212
Comprehension		21.025	3.885	1,57	.0536	2.133	.1500

APPENDIX A

Materials Used in the Study

STUDENT OBJECTIVES

The student:

Knows specific facts.

1. Identifies names of concepts.
2. Defines the concepts.
3. Lists mental disorders.
4. Lists characteristics of mental disorders.

Comprehends.

1. Recognizes instances of the concepts.
2. Provides examples of the concepts in his own words.
3. Distinguishes the various mental disorders.
4. Translates an abstract definition into a specific example.
5. Explains abnormal behavior in terms of mental disorders.
6. Relates mental disorders to each other.

IRRELEVANT MATERIAL

(Control Group Condition)

Darwin named the agent by which selection operates "survival of the fittest," referring by the phrase to the differential mortality of individuals within a species. His concept has since been broadened to include the selective agent of differential fertility. Differential mortality operates on individuals prior to reproductive age, and therefore determines that group of individuals who survive and may potentially produce the offspring who will constitute the next generation of a population. Differential fertility operates within this surviving group of individuals who have reached reproductive age. It refers to the differences in the contribution made to the next generation by individuals due to their inequalities in reproductive performance. Although differential mortality and differential fertility operate through separate means and on different age groups, their ultimate genetic consequences for a population are much the same.

Unlike Darwin, we now know that in any population there are genotypes that differ from one another and that the differences are due to mutation. Briefly stated, mutation provides the raw material of evolution in the form of alleles, and selection then determines the fate of these alleles in a gene pool.

Over time an advantageous mutation may eventually either displace the former allele(s) or achieve a state of equilibrium with its allele(s) through the action of opposing, balanced selective forces acting on the locus in question.

Selection may therefore operate as both a stabilizing and a dynamic force in a population. In either role it exerts systematic pressure on the gene pool so that the direction and magnitude of genetic changes are determinate in principle. As a stabilizing agent in both eliminates deleterious mutations each generation (normalizing selection) and maintains a gene pool's existing allele frequencies through time in equilibrium with the environment (stabilizing selection). Simultaneously, selection is also an important dynamic agent of evolution, changing a population's genetic composition as the environment changes (directional selection). A disadvantageous allele may be maintained at a very low frequency in a gene pool (generally 1 percent or less) by the balanced opposing forces of normalizing natural selection and recurrent mutation. An advantageous allele may increase in a gene pool and attain a frequency greater than that which can be maintained by recurrent mutation alone.

Genetic polymorphism may be transient or balanced. In the case of transient polymorphism natural selection is operating as a dynamic agent of evolutionary change. An advantageous mutant gradually displaces the normal allele(s) in the gene pool until the latter is reduced to a low frequency maintained by recurrent mutation alone. At this point, of course, by definition a polymorphism no longer exists at that particular locus, and selection is of a normalizing type. Until this point is reached, however, a polymorphism does exist. Balanced polymorphism, on the other hand, is the result of natural selection operating as a stabilizing agent.

INDUCED IMAGERY

(Imagery Instruction Condition)

Personality disorders are the addictions, the sexual perversions, the sociopathies and psychopathies. Neuroses are the phobias, the obsessive-compulsions, the hysterias and the hypochondrias. Psychoses are the manias, the melancholias, the schizophrenias and the paranoias.

Learn the next presented passage much as you normally would. However, while you are reading it, picture in your mind's eye vivid and dynamic images of the ideas presented. Imagine a story with continuity, as a series of pictures like a movie as you read through the material in terms of characteristics of the figures described and concrete pictures of them in action. Link the scenes you visualize together. Lucid images are very useful to help your mind during learning.

If bizarre, obscene or grotesque images that relate to the material come to mind as you read, do not hold back or worry about being foolish, etc. You will not be asked to disclose these. They will be kept private, to yourself. Use these more bizarre and vivid pictures to help you remember. These bizarre types of mental images strike your fancy and hold your attention. You will find them easy to remember afterwards. The more of an impression the mental image you use makes on your mind, the easier you will find it to remember the material you have studied afterwards. Outlandish images can also be very useful in making clear and memorable the memory traces of what you read.

If you come across unfamiliar or more abstract words, substitute for them with concrete things you know about. Picture these concrete ideas vividly while at the same time bearing in mind the term it is substituted for. Apply this method to names, words, facts and concepts. Look for key words as you read and build your mental picture around them. Remember the mental disorders, what they are and what they mean this way. Try to understand them by presenting to yourself these unique self generated images. In depicting their conceptual basis by imagery in your mind's eye you will find that understanding them is easy.

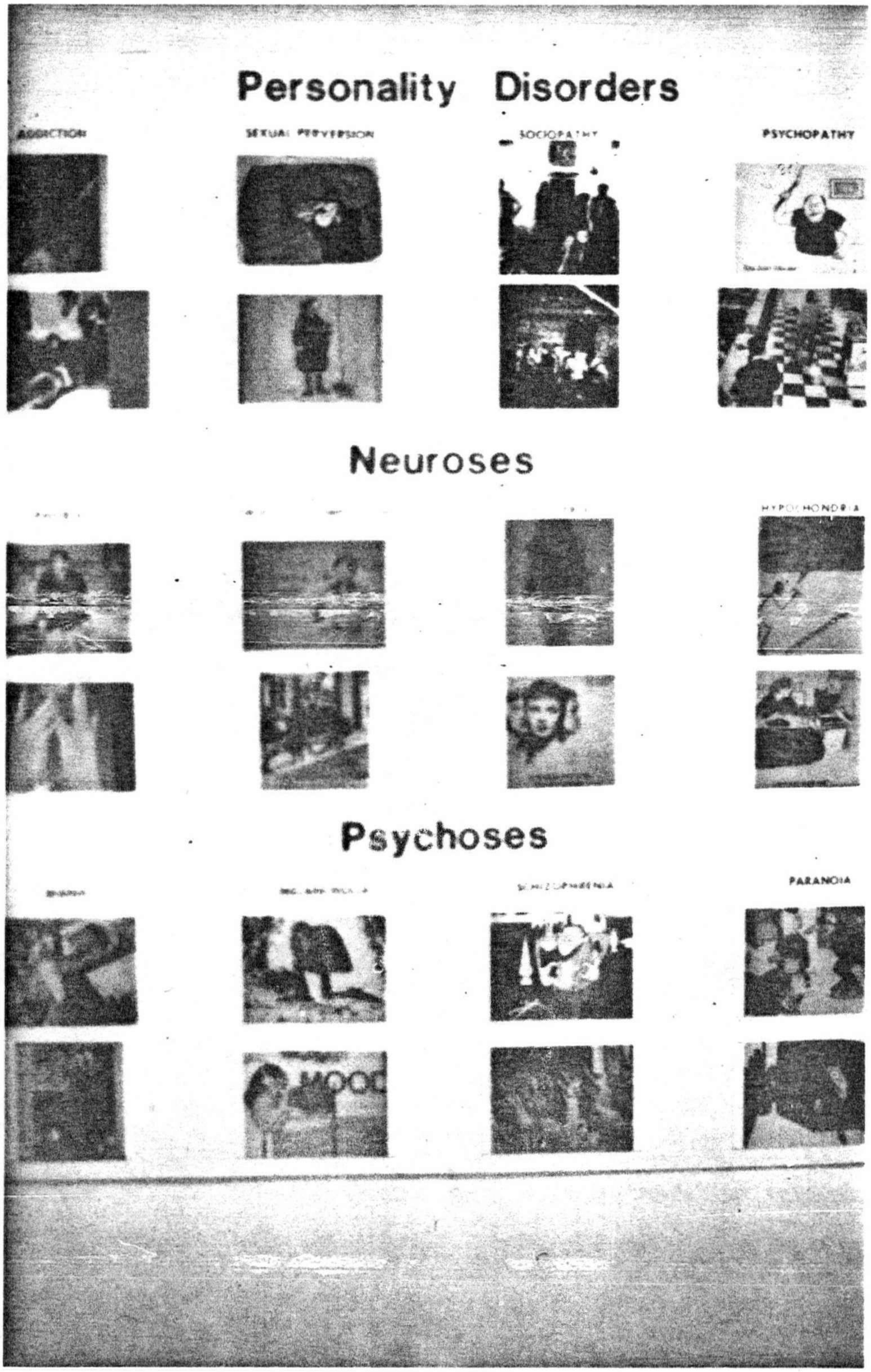
Apply this method even if it seems to slow down your reading rate. You will not have to go over the material again. As you apply this system, your proficiency will increase because when it comes time to remember something from this reading, all you will need do is bring back the images you created in your mind and you will know it. Remember to keep making a continuous pictorial story as you read every sentence.

For e.g. for pyromania, you might imagine a person, carbon character or someone you know being compelled to sneak into a house at night and set fire without anybody's knowledge. Then this person would watch the fire with fascination and revel with excitement at the panic, commotion and sight of fire trucks coming and people being awed and shocked by the flames and smoke. This individual would be pleased with himself and tickled for having created this shock effect.

Have the feeling that you can keep these private pictures you created in your mind's eye to yourself forever and that they can be re-conjured at will whenever needed. Remember that you should not only know the material you read, but also comprehend what it means.

IMPOSED IMAGERY

(Pictorial Diagram Condition)



TEXTUAL MATERIAL

MENTAL DISORDERS

Three broad categories of mental disorders each have four sub-types. The categories are personality disorders, neuroses and psychoses. Personality disorders are the addictions, the sexual perversions, the sociopathies, and psychopathies. Neuroses are the phobias, the obsessive-compulsions, the hysterias, and the hypochondrias. Psychoses are the manias, the melancholias, the schizophrenias and the paranoias.

Personality disorders are ingrained habitual patterns of character that limit an individual's functioning in a responsible way. Addictions involve dependencies upon the ingestion of particular substances. Sexual perversions are abnormal patterns of sexual desire which conflict with the practices of society. Sociopathies are disorders in which the person entertains a code of ethics which is different from that of the dominant social or legal structure. Psychopathies are disorders in which the individual has no moral values, acts on momentary impulses and does not learn from experience. Neuroses are disorders in which an individual is unable to cope with anxieties and conflicts, hence, exhibits abnormal symptoms. Phobias are persistent irrational fears of objects, places, or situations. Obsessive compulsions involve recurrent thoughts of a disturbing nature accompanied by irresistible urges to repeat stereotyped or ritualistic acts. Hysterias involve two or more personalities being entertained by an individual or bodily symptoms due to some psychic conflict. Hypochondrias involve morbid concern over one's health and exaggerations of bodily symptoms. Psychoses are severe mental diseases involving serious disruption of cognitive and emotional processes along with loss of contact with reality. Manias are characterized by excitement and elation. Melancholias involve sadness and despondency accompanied by gloomy thoughts of worthlessness and hopelessness. Schizophrenias involve a split between expressions and exigencies of reality along with withdrawal from reality. Paranoias involve bizarre delusions of persecution, grandeur or reference.

Personality disorders are characterized by deeply ingrained maladaptive patterns of behavior which frequently show a life- long history. The patient is generally unconcerned with the problem and treatment is usually obtained involuntarily. The maladjustment is usually expressed in overt behavior rather than in thought disturbances, emotional disturbances, or anxiety. The personality disorders manifest themselves in a wide variety of ways, and usually involve some form of social maladjustment. These behaviors may have diverse causes and may occur in persons with different kinds of personalities. These patterns frequently show a life-long history. In most cases these persons are unconcerned with their problems. If they obtain treatment, it is due to the insistence of their families or as a result of clashes with society or law.

Addiction is seen in psychological and/or physical dependence on alcohol, cigarettes, drugs, or gambling. Such a state can have disastrous consequences physically, psychologically, and socially. It is apparently learned and maintained because of short-term reinforcement.

Compulsive gambling is learned and maintained in a similar manner. Addictions imply illegal activities and these activities make the addict a criminal. The loss of self regulating capacities can also have disastrous physical consequences on the health of the addicted person. This stems directly from the excessive amount of foreign substance and the indirect effects of inadequate diet and contagious disease conditions. At the psychological level there is a loss of self control accompanying lowered self-esteem with a loss of interest in usual life activities and goals.

The dominant moral code of society defines a wide range of sexual perversions, such as the expression of sexual desire for children (pedophilia), and obtaining sexual enjoyment from observing sex acts and objects (voyeurism) and from the display of parts of the body in public (exhibitionism). Homosexuality is also classically defined as deviant; the statistical surveys of Kinsey indirectly have called into question the oversimplified classification of homosexuals as deviants by pointing to the extensiveness of homosexuality among males. Some deviations from the norm are clearly considered in need of control; other types of deviant sexual behavior create legal or social problems only in certain instances.

The sociopath deviates because of a moral code he holds which differs from the one endorsed by general society. It results in deviant behavior because the individual has a strong allegiance with standards which differ from those of the general social group. The sociopath has personal moral feelings, but does his dyssocial acts because he feels they are right. For instance, the young gang member or gangster may be very loyal to their own kinds but have no guilt about their violence toward society.

The psychopath represents behaviors that violate society's norms or laws. The psychopathic personality violates these codes because of an absence of internalized moral values. This individual is typically impuslive and frequently turns to crime. He is largely incapable of loyalty to other individuals, groups or social values. This individual is selfish, irresponsible and unable to learn from experience or feel guilt. This disorder stems from faulty psychosocial development in which social standards have never been introjected. The impulsive thief or murderer would be examples of this type.

In general, the various neuroses are assumed to arise when the person's conflicts are not adequately handled by the various defense mechanisms; the core of the neurosis lies at the point where anxiety has blocked or distorted the learning process so that new learning essential to adjustment cannot take place. The neurotic person's symptoms may shift from time to time, but among his shifting symptoms a dominant pattern can usually be detected. This dominant pattern probably tells us something about the nature of the individual and of his problems, just as the characteristic pattern of defense mechanisms in the individual tells us something about his personality. Some of the generally recognized forms of psychoneurotic reactions are the following.

Phobias are intense fears of objects or situations that in fact present no real danger. We are all familiar with the term "claustrophobia" and know that this term is applied to an intense fear of closed places. There are many other types of phobias, however, such as pathophobia (fear of disease), nyctophobia (fear of darkness) and hematophobia (fear of blood). Many well-adjusted people have strong fears that we would not call phobias. The fear of mice by some people, fear of water by many people, and fear of high places, for example, are not generally phobic in nature. Most of these fears are developed through unfortunate childhood experiences. Patients suffering phobias, however, are not aware of the basis of their fears, react violently to the feared object, and are often greatly inconvenienced by their fears. In many cases, the individual realizes his fear is irrational but is helpless to do anything about it. All phobias have certain features in common.

Obsessive-compulsions are characterized by obsessive and unavoidable thoughts, often unpleasant and unwelcome to the person(s), and by compulsive irrational acts, which follow from irresistible urges. The person's obsessive thoughts may have to do with fear that he is "losing his mind," that his child is "going to have an accident," that he is "going to strike someone," or they may have to do with insistent thoughts of an erotic nature. The compulsive acts frequently take the form of repetitive ritualistic behavior, such as highly routinized ways of moving, dressing, or eating. The compulsive act often appears to be "magic way" of warding off the unpleasant obsessive thought. An adolescent boy, for example, was characterized by a neurotic compulsion to wash himself repeatedly during the day, spending a great deal of his time in a series of acts relating to body cleanliness. Investigation indicated that he suffered obsessive guilt feelings from acts of masturbation, which he regarded as "unclean."

The hysterias may manifest themselves as a conversion reaction, a disorder in which the anxiety is converted into a physical malfunction, with no underlying physical or organic damage. Conversion hysterias typically occur in situations of stress and conflict. In such situations, the patient develops an organic symptom, rather than a purely psychological symptom. In other words, we might say that the psychological stress is converted into a bodily disturbance. The hysterical reaction may also involve a problem in the psychological sphere only, as in the dissociative reaction, in which the individual attempts to control anxiety by removing from consciousness those parts of the personality which are producing it. Examples of this reaction are amnesia, fugue reaction, and multiple personality. In multiple personality, the person manifests two or more completely different systems of personality, changing from one to the other for periods of a few minutes or even several years. Usually the personalities involved are quite different from one another. One may be carefree and fun-loving while the other is quiet and serious. Often, while one personality is dominant, the person cannot remember the other or how he behaved when the other was dominant.

The hypochondriac evidences a morbid concern over his health and bodily processes. Commonly found in individuals in late middle age, hypochondrias occur more often in women than in men. These people usually have many physical complaints, and their general overconcern with health keeps them on the alert for signs of new and different illnesses. Often they are avid readers of popular writings of health topics, and frequently, there is an excessive concern with excretory and digestive functions. Some patients keep charts of bowel movements and detailed information on diet, constipation, and trends in evacuation. Typically, they are always looking for new methods of treatment for their imaginary illnesses, and they provide a large market for every new patent medicine.

Psychoses are forms of mental illness that are much more severe and disabling than neuroses. The term "insanity" was formerly used to refer to such disorders, although today insanity is primarily a legal term usually used to refer to those individuals who are unable to manage their affairs properly because of a severe mental disorder. The psychotic individual's personality is generally disorganized, he is incapable of functioning socially in a normal way, and frequently he must be hospitalized. Some experts in this area believe that there is a continuity from the normal, or well- adjusted, through the psychoneuroses and psychoses. The differences are regarded as largely a matter of severity of symptoms, rather than differences in kind. Not all psychologists and psychiatrists, however, hold this position. Some feel that psychoses are fundamentally different from neuroses.

The so-called "manic", or excitable, involves a generalized excitement, elation of mood or euphoria, overactivity such as pacing back and forth, singing, and so on, and a "flight of ideas," during which the patient's conversation jumps from one topic to another with little apparent connection. With excessive elation, he becomes manic, and, if he goes too far, explodes into violent and unrestrained behavior, sometimes dangerous to others or to himself (thus the common term "manias").

The disorder, known as melancholia, occurs when the individual reacts to problems and conflicts with or spontaneously acquires feelings of hopelessness, dejection, and depression. The depression often but not necessarily results from some specific event, such as the death of a loved one, but it continues for an excessively long period of time. There is good prognosis that the patient will recover but the most serious danger is the possibility of suicide. In the depressive reaction the patient appears sad, discouraged, and inactive. The hallucinations are characteristically those of self-degradation.

Schizophrenias are characterized by a wide variety of symptoms, not all found in any one person. In general, there appears to be a peculiar distortion of the emotions and feelings; the person may seem completely insensitive to things that would normally be expected to evoke emotional response, for example, news of the death of a member of the family. His standards of conduct, dress, personal hygiene, and social relations may show severe deterioration. He may become excessively withdrawn, out of all touch with the external world, even to the point at which he may sit completely immobile for hours, during which time the limbs can be moved about by someone else and will remain in the positions in which they are placed. He may often be subject to halluciantions in which he "hears voices" or "sees visions." He may exhibit bizarre behavior, confused thought processes or chaotic speech. The patient may also experience auditory hallucinations - hearing voices talking to him from some unknown source.

"Paranoia" is a condition characterized by delusions of persecution and/or grandeur. These delusions are usually well systematized and tightly knit. The personality of this type of patient is not severely disorganized, and thus the condition is differentiated from paranoid schizophrenia. The paranoid state, second of the paranoid disorders, typically involves transitory or temporary delusions that lack the logic and systematization of paranoia. Delusions and hallucinations of a religious nature, among other symptoms, are often found in both types of paranoid disorders.

RECALL TEST

List as many of the mental disorders you have just learned as you can remember.

COMPREHENSION TEST

1. A major consequence of most addictions is the:

   a. acceleration of self-confidence feelings to unrealistic heights
   b. unreasonably high sense of self control
   c. loss of interest in usual life activities
   d. heightened orientation to many social reinforcers
   e. heightened creativity

2. Sexual perversion is to hysteria as:

   a. paralysis is to overactivity
   b. crutch is to fantasy
   c. simile is to metaphor
   d. doing is to forgetting
   e. feeling is to apathy

3. Which of the following is an example of Sociopathy?

   a. militant behavior on the part of individuals belonging to organized crime
   b. chronic anxiety about exposure to other people
   c. unrealistic fear of appearing foolish in public
   d. hearing voices
   e. having a bizarre behavioral pattern in one's repertoire

4. Psychopathy is to obsessive compulsion as:

   a. impulse is to mortality
   b. frozen is to molten
   c. reading is to speaking
   d. youth is to old age
   e. random is to repetitive

5. Individuals with personality disorders:

   a. exhibit problems similar to psychosis
   b. suffer much anxiety because they feel responsible for the troubles they cause
   c. typically perceive their problems as being related to luck or to the faults of others
   d. generally do quite well in life
   e. have the most severe kind of mental disorders

6. Neurotic disorders have been said to involve:

    a. hallucinations and delusions
    b. feelings of anxiety and inadequacy
    c. unusual sexual preferences
    d. an antisocial personality
    e. fixation upon a certain substance

7. Psychosis is to Schizophrenia as:

    a. metaphor is to simile
    b. comfort is to discomfort
    c. sex is to motive
    d. plant is to flowers
    e. blaming is to curing

8. Phobia is to Paranoia as:

    a. emotion is to beast
    b. laughter is to seriousness
    c. appropriateness is to uniqueness
    d. fear is to belief
    e. thought is to action

9. Addiction is to Mania as:

    a. symptom is to cause
    b. need is to energy
    c. lion is to beaver
    d. ego is to mother
    e. moon is to earth

10. A person who wants to believe he/she is ill when no physical illness is present is a:

    a. malingerer
    b. compulsive patient
    c. narcissistic person
    d. substance abuser
    e. hypochondriac

11. Last night your roommate went out at midnight and hit the neighbor's sheep. He told the police that the sheep appeared in the toilet bowl and said he was Satan in sheep's clothing. His symptoms reflect a case of:

    a. mania
    b. melancholia
    c. schizophrenia
    d. hysteria
    e. obsessive compulsion

12. A writer working at home changes his clothes at least five times a day. Each time he changes clothes he experiences a reduction in anxiety. He would probably be diagnosed as:

    a. phobic
    b. hysterical
    c. paranoid
    d. perverted
    e. compulsive

13. A woman who is orderly, consistent and logical in most situations also believes that she is Joan of Arc and in danger of being killed. This woman is displaying symptoms of:

    a. a hysterical nature
    b. an addictive nature
    c. a phobic nature
    d. a paranoid nature
    e. an obsessive compulsive nature

14. Intense feelings of anxiety that become displaced to objects or situations that the individual believes are responsible for his anxiety or fear are referred to as:

    a. phobias
    b. chronic anxieties
    c. acute anxieties
    d. obsessions
    e. delusions

15. Which of the following characterizes melancholia:

    a. deep sorrow following the loss of a loved spouse
    b. feelings of depersonalization after viewing an accident
    c. a strong sense of profound despondency that arises for no apparent reason
    d. the recurrence of unwanted thoughts which cannot be banished from consciousness
    e. separate identities invading the personality at different times.