40Hz. ACTIVITY IN MBI, LLD AND NORMAL CHILDREN: A COMPARATIVE EEG STUDY

A Dissertation

Presented to

the Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

By

Georgia A. Laxton

December, 1976

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ABSTRACT

EEGs were recorded on three groups of children classified as Normals (N=22, mean age=10.08, mean IQ=102.32), Language-Learning Disability (LLD, N=29, mean age=9.91, mean IQ=99.36) and Minimal Brain Injured (MBI, N=25, mean age=10.63, mean IQ=90.56) by the Aldine School District during resting and performance of verbal and nonverbal tasks. Mean errors for the Verbal-Visual (VV) task were 2.41 for Normals, 4.62 for LLDs and 6.12 for MBIs. Mean errors for the Verbal-Auditory (VA) task were 1.91 for Normals, 5.34 for LLDs, and 6.94 for MBIs. Mean errors for the Tactile-Kinesthetic (TK) task were 3.86 for Normals, 5.38 for LLDs, and 5.12 for MBIs. Normals performed better than both learning disability groups on all tasks but no differences were found between the LLDs and MBIs.

Computer analysis of the P_3-C_z and P_4-C_z leads divided the EEG into four 23% 1/3 octave bands centered at 30, 40, 50, and 70Hz. Activity of interest was 40Hz. with 30 and 50Hz. serving as control frequencies and 70Hz. used as a muscle detector. Normals had increases during the VV task in both leads in 40 and 50Hz. activity, during the VA task in both leads in 40Hz. activity, and during the TK task in the P_4-C_z lead in 40Hz. activity. MBIs had increases during the TK task in the P_3-C_z lead in 40 and 50Hz. activity. LLDs had increases during the VV task in P_4-C_z in 50Hz. activity and decreases in 30Hz. activity in both leads during the VV task and in P_3-C_z during the VA and TK tasks.

Subgroups were formed using psychoeducational test data from school records and behavioral and EEG comparisons were made between the subgroups and between the subgroups and Normals. Hyperactivity, WRAT (Reading, Mathematics, and Spelling), and WISC Performance variables were not as effective as WRAT Reading subtest, WISC Verbal and the Bender-Gestalt test in predicting the degree of 40Hz. deficit as measured by the number of subjects showing 40Hz. increases within a subgroup compared to Normals.

Findings were discussed in terms of "focused arousal," right-left hemisphere processing differences, the delayed maturation hypothesis, and prognosis for improvement resulting from 40Hz. conditioning as a treatment for learning disabilities. LLDs were selected as the group most likely to benefit from 40Hz. conditioning.

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CHAPTER I

STATEMENT OF THE PROBLEM

Children with learning deficits make up a sizable portion of the school population, therefore, much time and effort has been spent to remedy the situation. While it may be a simple task to go into a classroom and pick out the children who are failing, the reason or reasons why they are failing and how to help them become successful students are very complex. Causes of failure could be emotional problems, mental retardation, lack of motivation, deprived preschool environment, sensory deficits, neurological deficits, brain damage, etc.

One segment of the underachieving population has been classified as Minimal Brain Injured (MBI), Minimal Brain Damaged (MBD), or Minimal Cerebral Dysfunction (MCD). Reference to brain injury has come from studies of actual structural damage that have discovered various types of verbal and nonverbal impairments in function (Hix, 1971; Kinsbourne, 1971). The decrements have, in some cases, been very similar to those shown by learning retarded children on psychological tests. Effects on both lower and higher order processes have been demonstrated (Kinsbourne, 1971). Impairment of brain processing, however, need not be the result of structural damage; functional inadequacies (delayed development, over or under reactivity, failure to integrate between different brain areas, for example) could account for cognitive deficits just as well. Indeed, functional difficulties have been postulated because of the improvement that has occurred over time and/or in conjunction with drug treatment (Hix, 1971; Klonoff & Low, 1974; Satterfield, 1973).

Electroencephalographic (EEG) recordings of the brain have been related to cognitive functioning (Butler & Blass, 1974; Doyle, Ornstein, & Galin, 1974; Dolce, 1974; Galin & Ornstein, 1972; McKee, Humphrey, & McAdam, 1973, are a few of the more recent studies), therefore, the EEG has been one of the tools used in the diagnosis of learning disability children. Hix (1971) did a thorough review of the literature and reported that the median incidence of EEG abnormalities among children with scholastic problems classified as MBD-MCD was 57% compared to 10% among normal achieving children. Types of abnormalities described were "(1) posterior slow waves, (2) positive spikes (6-7/sec and 14/sec), (3) abnormal alpha block responses, (4) abnormal CNV responses, (5) disturbed inter-regional relationships, and (6) disturbed inter-hemispheric relationships" (Hix, 1971, p. 55). Recordings were made under varying conditions such as resting, eyes open or closed; sleeping; during and after hyperventilation; in conjunction with photic driving; and, in some cases, while the subject was engaged in a simple level of cognitive processing. Clearcut relationships between the type of EEG abnormality and specific expressions of learning disability as expressed in "soft" neurological signs and psychoeducational tests were few. More recent studies (Dyment, Lattin, & Hebertson, 1971; Gerson et al., 1972; Hartlage & Green, 1971, 1972, 1973) obtained essentially the same results. Several factors could account for the lack of direct evidence between certain types of EEG abnormalities and specific mental dysfunctions. 1. The abnormalities observed might be a function of a general state created by or causing underachievement. 2. Some of the proposed EEG abnormalities may not be abnormalities. 3. The measures used may be too gross. 4. The abnormalities may be labile and would only be present during the mental activity in question.

Hix (1971) conducted a study that related a specific brain wave frequency band (23% octave filters centered at 40Hz.) to a problem solving situation among normal and MBI children. EEGs were recorded during resting, visual perceptual tasks, verbal-visual tasks, and verbal-auditory tasks. Controls showed increases in the 40Hz. band in the occipital area, but not in the 31.5Hz. or the 50Hz. band, over resting in the verbal-visual task. MBIs made significantly more errors than Controls on the verbal-auditory and verbal-visual tasks. Subjects were matched for age and IQ.

Based on Hix's findings and previous studies (Hix, 1969; Sheer & Grandstaff, 1970; Sheer, 1975) that related 40Hz. to cognitive processing it is predicted that 40Hz. will reflect differences in problem solving behavior between normal and learning disability children. Further, superior performance on the behavioral tests will be accompanied by increases in 40Hz. activity during testing when compared to a resting situation.

Learning disability children are a heterogeneous group and, therefore, not all children with learning disabilities may be manifesting brain dysfunction in information processing. Recording the EEG while cognitive processing is in progress appears to be a promising effort but is both time consuming and costly. Recent biofeedback studies (Sheer, 1975) have indicated that EEG conditioning might be one method of encouraging the brain to function properly. If 40Hz. EEG activity could be related to learning deficits as defined by standard psychoeducational tests diagnostic procedures would be simplified and treatment would be facilitated. Psychoeducational tests that related to 40Hz. deficits could be used to identify children that would benefit from conditioning and possibly even the brain areas where conditioning was needed most. By subgrouping the learning disability children using the psychoeducational tests available from the school district, the present study will attempt to establish the above mentioned relationships.

CHAPTER II

REVIEW OF THE LITERATURE

I. Definition of Learning Disability Child

The National Advisory Committee on Handicapped Children defined children with learning disabilities as follows:

> Children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written language. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. They do not include learning problems which are due primarily to visual, hearing, or motor handicaps, to mental retardation, emotional disturbance. (UPHS, 1969)

II. Evidence of Brain Dysfunction

From the definition it is obvious that learning disabilities come in all shapes and sizes. The children classified as learning disabled have been described as hyperactive, perceptual motor impaired, emotionally labile, poorly coordinated,having short attention spans, easily distracted, perseverative, impulsive, having disorders of memory and thinking, having reading, writing, spelling and arithmetic deficits, having disorders of speech and hearing, and having equivocal neurological and electroencephalographic (EEG) irregularities (Clements, 1966, p. 13). Although no one label appears to be applicable in all cases, a recent review by Bryan (1974) concluded that three basic facts were indicated by the data:

(1) The learning disabled have trouble paying attention.
(2) The learning disabled have difficulty using language.
(3) The learning disabled can not process complex auditory and visual presentations as well as their peers.

It was also noted that in most studies comparing learning disability children to normally achieving children, the learning disabled usually had the lower intelligence scores. Bryan's own research (1974) suggested that perhaps 25% of learning disabled children could be considered educable mentally retarded (EMR). Other studies included learning disabled children who had severe hearing losses, epilepsy, subdural hemotomas, encephalitis, etc. To suggest subtle brain malfunctions when such overriding factors were present would be very difficult. Therefore, any study designed to demonstrate defects in information processing by the brain would necessarily not include children with the severe types of impairments or retarded intelligence levels mentioned above.

To better understand how brain damage could differentially affect learning ability some discussion of how the brain processes information is necessary. That the left hemisphere generally subserves verbal functions and the right hemisphere nonverbal functions has been demonstrated by studies of structural damage (Milner, 1974; Kinsbourne, 1971), dichotic listening tasks in normal subjects (Kimura, 1964; Milner, 1974), and studies of patients who have had commissure section (Milner, 1974; Sperry, 1974). However, the idea of two separate, independently working systems is not supported, instead researchers talk of complementary specialization where one side takes a larger role than the other depending on the task (Teuber, 1974). Milner (1974) reported an example of the complicated interaction between the two hemispheres in the tactile mode. The stimuli were irregular wire figures bent into flat shapes and presented to one hand at a time behind a screen. A matching-to-sample procedure was followed in which one of the patterns was felt by the subject with one hand and then after a variable delay four more patterns were presented to be touched by the same hand, only one of which was the same as the first. Commissurotomized patients consistently did better with the left hand demonstrating the superiority of the right hemisphere for nonverbal material. However, patients with unilateral cortical excision for epilepsy, intact commissures and no sensory defects were able to perform the task proficiently with either hand and no training. Considerable training was required for successful performance by the commissurotomized patients even with the left hand. Milner suggested that either separation of hemispheres may have reduced functional efficiency or the left hemisphere normally participated in tasks of this kind.

EEG studies have contributed to the idea that each hemisphere plays a larger part depending on the task. Alpha suppression has been the most popular method of investigation. The usual procedure is to use tasks that have been demonstrated as right or left hemisphere tasks by the previously mentioned methods. Recordings are then made under rest, verbal, and nonverbal conditions. A ratio of right over left hemisphere EEG is computed and inferences are made depending on the size of the ratio and upon which side contributes the most to the change. Suppression of alpha (9-12Hz.) on the left side more than the right was found for arithmetic computation (Butler & Glass, 1974; Doyle, Ornstein, & Galin, 1974) and various linguistic tasks (Doyle, Ornstein, & Galin, 1974; Galin & Ornstein, 1972; McKee, Humphrey, & McAdam, 1973). Suppression of alpha on the right side more than the left side was found for spatial (Doyle, Ornstein, & Galin, 1974; Galin & Ornstein, 1972) and musical tasks (Doyle, Ornstein, & Galin, 1974; McKee, Humphrey, & McAdam, 1973). Parietal leads usually gave the most consistent results.

In a slightly different study Dolce and Waldeier (1974) recorded bipolarly between parietal and parietal-occipital leads on the same side of the head during resting, reading, and arithmetic trials. Not only did suppression of alpha on both sides of the brain accompany mental activity but the EEG showed a more complex organization among the fast frequencies. Differences in beta (13-20Hz. and 20-30Hz. bands) between the two hemispheres and within each hemisphere were not found during reading, resting eyes open, or resting eyes closed, in a study done by Provins and Cunliffe in 1972. Recordings were from parietal and parietal-occipital areas. Similarly, Hix (personal communication) recording in the post-parietal-occipital area of normal children found no difference in the 26-35Hz. band between resting (eyes open) and a visual-verbal task for the right or left side but noted a significant increase over resting in the 36-44Hz. band on the right but not the left side.

Taking into consideration the lesion, split brain, dichotic listening, and EEG research it would appear that both hemispheres are participating in information processing in the intact brain but one side may be playing a more important role depending on the nature of the task. Complementary specialization is, at present, the best conclusion from the data. However, the amount and nature of the contribution of each hemisphere is not yet clearly defined.

Some of the most fruitful data that has added to our information about the functions of different areas has been the lesion study research. Kinsbourne (1971) in an extensive review separated the different types of lesions into cognitive subcategories. The topics most relevant to the present study were attention, language, and spatial performance. Memory was not treated separately but was integrated into each subject matter where relevant. Breakdowns in selective attention did not appear to be characterized by focal lesions in any particular location.

Language disorders were generally characterized by left hemisphere damage, unless, of course, speech had developed in the right hemisphere. Milner (1974), using a sodium Amytal injection procedure that caused a temporary inactivation of the affected hemisphere, reported that 92% of the right handers, 69% of the left handers, and 30% of the left handers with early left hemisphere damage had speech represented in the left hemisphere. While the tendency for speech to develop on the left side is strong, possible contributions by the right side to verbal tasks can not be excluded. Patients who had cerebral commissurotomy showed impairment on strictly verbal learning tasks (reported as a personal communication from Zaidel & Sperry to Milner, 1974).

Lesions on the left side seem to interfere in different ways with verbally mediated material. Left frontal lesions impaired performance on tasks that required the suppression of previously presented verbal materials (Milner, 1974), and left temporal lobectomies impaired the learning and retention of verbal material (Milner, 1974; Kinsbourne, 1971). Direct evidence of verbal impairment after damage to the parietal lobes has not been noted (Kinsbourne, 1971; Milner, 1974). Indirectly Kinsbourne (1971) described a syndrome related to left parietal disease which he termed as the inability to use "spatio-temporal order information to establish superordinate categories" (p. 331). Such subjects had difficulty ordering information appropriately for the operations of verbal labeling and arithmetic.

Damage to the right hemisphere seems to cause handicaps similar to the left hemisphere types but is related more to nonverbal material. As reported by Milner (1974) right frontal lesions resulted in impairment on recency tasks and right temporal lobectomies resulted in impairment of learning and retention of information but the impairments involved tasks that did not lend themselves easily to verbal coding (faces, melodies, abstract paintings, for example), while only slight impairment occurred on similar verbal tasks.

Left and right parietal lesions affect spatial performance but in different ways (Kinsbourne, 1971). While left parietal damage appeared to result in oversimplifications of the figure being copied or substitution of a similar figure already in the subject's repertoire, right parietal damage resulted in correct copying of the individual components but an inability to place them in the appropriate spatial relationships to each other. Left side damaged patients appeared to construct the figures in random sequence rather than in a manner that indicated prior analysis of the figure into its main components while right side damaged patients showed appropriately organized sequences of drawing, at least up to the point where angle distortion or line overshooting unbalanced their whole performance. Kinsbourne characterized the left parietal deficit as a deficit in spatio-temporal ordering, and the right sided deficit as possibly a problem of visual retention of position which he considered could cause impairment even of a direct copying task.

Indications that learning could be affected by brain damage that was not necessarily structural have come from the improvement on behavioral tests and EEG symptoms reported by various investigators (Satterfield, 1973; Douglas, 1974; Burnett & Struve, 1971; Hughes, 1971) after drug treatment. Douglas (1974) postulated that the main effects of stimulant drugs (most commonly used with learning disability children) were on attention and impulse control. She found that hyperactive children while receiving the drug tended to make more correct responses and fewer incorrect responses on continuous performance tasks. Children who exhibited learning problems along with petit mal epilepsy showed improvement on both EEG symptoms and scholastic performance when treated with anticonvulsant medication (Hughes, 1971).

Some researchers have suggested that learning disability children may be manifesting delayed development in brain maturation (Hughes, 1971; Klonoff & Low, 1974; Satterfield, 1973; Zislina, Opolinskiy, & Reidiboin, 1972). Learning disability children who had both soft neurological signs and abnormal EEGs showed more scholastic improvement to methyl phenidate treatment than did learning disability children who had only one symptom or neither symptom suggesting an underlying neurophysiological basis for their disorder. Examination of the neurological and EEG findings revealed that poor coordination and excessive slow wave activity were, respectively, the most common symptoms. Testing under drug free conditions revealed both longer latencies and smaller amplitudes in the cortical auditory evoked responses of the learning disability children as compared to normal children matched for age. Because the observed data were commonly associated with children at earlier stages of development Satterfield concluded that a theory of delayed maturation was supported.

III. EEG Relationships to Learning Disabilities

Because the present study compares the EEG relationships between learning disability children and normally achieving children the EEG evidence will be treated separately in two parts. The first part will consider learning disability and EEG relationships in general and the second part will review efforts to relate the EEG to specific types of performance deficits.

A. Incidence of EEG Abnormalities

A comprehensive review by Hix (1971) reported a median incidence of 57% EEG abnormalities among children with learning problems versus a median incidence of 10% in normal controls. While a number of types of abnormalities were described, posterior slow waves, positive spikes (6-7/sec and 14/sec), abnormal alpha block responses, abnormal Contingent Negative Variation (CNV) responses, disturbed inter-regional relationships, and disturbed inter-hemispheric relationships, in most cases the anamolies were not related to specific performance deficits but were presented as evidence of abnormal brain pathology. The most common abnormalities reported were slow waves and positive spikes.

Hughes (1971) and Myklebust (1973) extensively studied a group of children drawn from the third and fourth grades between the ages of 8 and 11 years. The EEG sample (606) included only those children who had passed tests in vision, audition, and anxiety and had a WISC IQ of at least 90. A learning quotient (LQ, Myklebust, 1968) was used to categorize the subjects as borderline (LQ of 85-89) underachievers or learning disability (LQ less than 85) underachievers. Briefly, the LQ was a measure of discrepancy between actual school achievement and expected school achievement based on mental ability, age, and school experience. Each underachiever had a matched control of the same age and sex taken from the same classroom. A battery of psychoeducational tests, ophthalmological exams, neurological exams, and EEG assessments was given to the subjects. Both bipolar and monopolar (referenced to the ear) EEG recordings were made in accordance with the International 10-20 system of electrode placement. EEG assessments included recording during wakefulness (with five minutes of hyperventilation), sleeping (induced with chloral hydrate), and photic stimulation (ten-second periods of repetitive flashes at 9-10 different frequencies from 1-30 flashes per second). Alpha activity was judged on the basis of rhythmic organization, amplitude development, and frequency. Abnormal EEGs, noted in 36.6% of the sample, were slow waves, sharp (epileptiform) waves, positive spikes, and extreme spindles. The most common abnormalities were slow waves (51.4%) and positive spikes (47.3%). Slow waves were judged mild in degree in 83% of the records, were observed most often in the occipital areas, and second most often in the temporal areas. When the two groups of underachievers were compared to their own control groups only the borderline group (47.7%) showed more EEG abnormalities than its control group (31.2%). Slow waves accounted for most of the difference. Examination of alpha rhythm revealed no differences in frequency but both the borderline and learning disability underachievers showed more fair to poor organization of rhythmicity and fair to poor amplitude development than their control groups. Hyperventilation and photic driving did not discriminate between the underachievers and controls when the underachiever groups were considered separately. An attempt was made to predict whether a child would be an underachiever on the basis of the EEG. Combining the two underachiever groups resulted in significant differences for rhythmic organization and amplitude development of alpha and left sided depression of photic driving between the underachievers and their controls. Using the presence of at least one of these three types of abnormalities as a basis for placement in the underachiever group, 79% of the abnormal records were correctly placed in the underachiever group which accounted for 62% of the entire underachiever group.

Myklebust (1973) reported that, while the psychoeducational data were the best discriminators between the underachievers and controls, the fact that the underachievers showed a significant number of abnormal brain patterns, even though they were not a clinically chosen population, indicated that the EEG was a valuable tool of assessment. Further, neurological signs followed a pattern similar to EEG signs indicating the presence of brain dysfunction. At first the presence of more EEG abnormalities among borderline than learning disability children was puzzling, however, Hughes hypothesized that the positive EEG signs might be a symptom of the reactivity of the central nervous system to the learning deficit. His explanation would predict a better prognosis for improvement among the borderline underachievers since the learning disability underachievers would be manifesting fewer symptoms of central nervous system reactivity indicating that no correction of the learning problem was occurring. An alternative explanation could be that the borderline underachievers were showing a developmental lag in central nervous system maturity while the learning disability group's problems were of a different nature, perhaps behavioral.

A developmental study by Klonoff and Law (1974) investigated both neuropsychological and EEG correlates among children who were classified as having Minimal Cerebral Dysfunction

(MCD) by a psychiatrist. To be included in the experimental group MCDs had to manifest at least two out of three signs of motor impairment, intellectual impairment, or personality disturbances commonly described as symptomatic of MCD children. Children who had only personality disturbances or a history of seizures were not included. A control group matched for age and sex was used for the neuropsychological data but no EEG assessments were made on them. Each MCD child had an initial assessment and a repeat assessment one year later. Two MCD groups were used, 9 years or older and under 9 years of age. No IQ differences were found between the two MCD groups.

EEG recordings were made under conditions of hyperventilation (3 minutes) and sleep (induced by chloral hydrate) using both bipolar and monopolar recordings according to the International 10-20 positions. One electroencephalographer rated all the recordings as normal, borderline, minimal abnormal, moderately abnormal, or markedly abnormal. Among the younger MCD group initial examination revealed 30% of the tracings unequivocally normal, 30% borderline, and 40% unequivocally abnormal. The most common abnormality was diffuse slowing with very few records demonstrating spike foci, positive spikes, asymmetries, or focal slowing. A year later 51% of the records were unequivocally normal with only two patients showing more abnormalities than in the initial examination. Diffuse slowing was still the most common finding but decreased to 41% whereas spike foci went from an initial 4% to 22% and asymmetries went from an initial 11% to 24%. The older MCD group had 68% normal records, 5% borderline, and 27% unequivocably abnormal records on initial examination. Spike foci (16%), diffuse slowing (16%), and asymmetries (8%) accounted for most of the abnormalities. Only a 5% improvement of normal records was shown on reexamination which was accounted for by the disappearance of all spike foci. Not only did the younger MCD group show more EEG abnormalities and subsequently more improvement than the older MCD group, the younger MCD group also exhibited greater neuropsychological impairment and subsequently more improvement than the older MCD group. The author suggested that either the etiology of the two groups might be different, brain dysfunction in the younger and behavioral disorder in the older, or that reconstitution of a developmental lag might take place within a critical time frame, i.e., it had to take place by a certain age. The relative stability of neuropsychological and EEG data between initial and reexamination in the older MCD group indicated a poor prognosis for improvement.

B. Relationships Between EEG Abnormalities and Behavioral Deficits

Three psychoeducational tests that have been widely used to study children with learning problems are the Wechsler Intelligence Scale for Children (WISC), the Wide Range

Achievement Test (WRAT) and the Bender Visual-Motor Gestalt Test. Gerson, Barnes, Manning, Fanning and Burns (1972) studied 128 children who had learning disabilities but were not severely retarded. No correlations with the WISC and EEG abnormalities (excess theta, sharp waves, and slow waves) were found but those who had abnormal EEGs also had numerous gross deviations on the Bender-Gestalt Test. Positive spikes and occipital slow waves were not correlated with any subtest nor combination of subtests in the study done by Hughes (1971). However, the presence of EEG abnormalities appeared to correlate with several combinations of deficiencies, namely, reading and arithmetic, auditory reception and written language, and auditory reception and reading. Children who had epileptiform sharp waves demonstrated deficits in the combination of reading, spelling, and arithmetic.

One set of researchers (Hartlage & Green, 1971, 1972, 1973) tried to relate the locus of EEG abnormalities to WISC and WRAT performance. EEG abnormalities reviewed were slowing, asymmetries, spikes, sharp waves, abnormal complexes, and poorly organized rhythm. Subject groups were classified as left hemisphere abnormal, right hemisphere abnormal, diffusely abnormal, and normal EEG. None of the WRAT subtests and only one WISC subtest, the Coding subtest, discriminated between the subgroups. Coding subtest scores differentiated between normal and right hemisphere abnormal, right hemisphere and diffusely abnormal, and left hemisphere and diffusely abnormal. The authors considered the one significant finding as probably artifactual.

Children with reading deficiencies have been given a significant amount of attention in the literature. Whether reading is more right than left side or vice versa has not been established. Kinsbourne (1971) suggested that at least nine variants could result in reading difficulties. They were termed as follows: "failure to discriminate form, sequence, orientation; to retain form, sequence, orientation, or to retain the verbal associates of form, sequence, orientation" (p. 335). In a study that compared poor and good readers enrolled in grades 5 through 7 Yeni-Komshian, Isenberg, and Goldberg (1975) presented visual stimuli to the right and left visual half fields. Poor readers performed significantly worse than good readers in the left visual half field implying either a right hemisphere deficit or a problem of transmission from the right to left hemisphere.

The incidence of EEG abnormalities was found to be higher in poor than good readers in recordings from the parieto-occipital and parietal-post-temporal regions by Goldberg, Marshal, and Sims (1973) and Tuller and Eames (1973), but no one abnormality appeared to be characteristic of the poor reading group. Wuehl (1973-74) divided disabled readers into three EEG groups, abnormal with 14 and 6/sec positive spike patterns, abnormal other, and normal. The abnormal other group showed less reading retardation than the other two EEG groups. Hughes (1971) did not find significantly more abnormalities among poor readers compared to normals in either the borderline versus normal or learning disability versus normal groups. However, nonverbal deficiencies were correlated with temporal slow waves and borderline subjects with nonverbal deficits had more abnormal EEGs than their normal controls.

A spectral data analysis technique was used in a study comparing normals to reading disability children labeled dyslexics (Sklar, 1972; Sklar, Hanley, & Simmons, 1972). Bipolar EEG recordings between the parietal-occipital, occipital-temporal, fronto-parietal, and fronto-temporal areas on each side were made during rest, eyes closed; attentive, eyes open; performing mental arithmetic; reading word lists; and reading text. Band width was 1-32Hz. The analysis successfully discriminated between the control and experimental group in all test situations but the best discriminator was in the parieto-occipital area during the rest, eyes closed phase. The dyslexic children had more energy in the 3-7Hz. and 16-32Hz. bands while normals had more energy in the 9-14Hz. band. During reading normals tended to have more energy in the 16-32Hz. band than dyslexics. Coherence during reading tended to be higher in the same hemisphere for dyslexics but higher between symmetrical regions across the midline for normals.

Hyperactivity, frequently named as a symptom in learning disability children, was studied by Grunewald-Zuberbier, Grunewald, and Rasche (1975). Two groups of behavior problem children comparable on age, intelligence and educational level were divided on the basis of motor restlessness. The groups represented two extremes of activity, restless and impulsive versus quiet and behaviorally better controlled. Neurological impairments and EEG abnormality signs were not present except for two children who showed slight EEG abnormalities and none of the children were or had been receiving drug treatment immediately prior to the experiment. Monopolar recordings were made from O_1, C_3 and P_3 referenced to the contralateral ear during a classical conditioning task where tones and lights were paired. Subjects were told to press a key when the light stimulus appeared. The tone always preceded the light at intervals varying from 5 to 20 seconds. Under resting conditions the hyperactives showed a lower arousal spectrum of the EEG with higher alpha and beta waves and a smaller number and lower mean frequency of beta waves. The range of EEG analysed was from 7-22Hz. During conditioning hyperactives exhibited both a smaller amplitude reduction to the tone and a quicker recovery of amplitude after the light presentation. Mean keypressing times to light presentation were shorter and mean reaction times longer for the hyperactives. The evidence indicated that the hyperactives were underaroused or underarousable in the experimental situation. It was suggested by the authors that motivational (anxiety) and attentional (inability to sustain concentration) factors may have been the basis for the performance differences.

Verbal-auditory (VA) and verbal-visual (VV) reasoning was investigated by Hix (1971) among MBI and normally achieving children. Subjects were matched for age and IQ. Bipolar EEG recordings in the post-parietal-occipital areas were made while the children were performing arithmetic, rhyming, and object discrimination tasks. Power spectral functions for 23% 1/3 octave bands centered at 31.5, 40, and 50Hz. were generated and hand planimetered to obtain power estimations for each band. Muscle corrections were made based on a band centered at 70Hz. and muscle artifact periods were either eliminated or statistically corrected. Both the behavioral data and the EEG results successfully discriminated between the MBIs and normals. During the VV task the 40Hz. band in the normals, but not in the MBIs, increased in power during the stimulus period when compared to prestimulus resting baselines while the 31.5 and 50Hz. bands remained stable. Since recording was essentially from the occipital area, the expectation that the Verbal-Visual task would show the best relationship to the EEG findings was borne out. Implications for 40Hz. as a "consolidation rhythm" (Sheer & Grandstaff, 1970; Sheer, 1975) were discussed by Hix relative to the behavioral and EEG results. Sheer (1975) proposed that 40Hz. reflected "a state of circumscribed cortical excitability or focused arousal which is 'optimal' for consolidation in short term store" (p. 358).

CHAPTER III

METHODS AND PROCEDURES

Subjects

The subjects were 76 males from the Aldine Independent School District classified by the school district as Normal (N=22), Language-Learning Disability (LLD, N=29) and Minimal Brain Injured (MBI, N=25). To be placed in a learning disability group by the school, a child first had to be having problems in the classroom to such an extent that a teacher referral was made for a psychological evaluation. Both psychoeducational tests and medical evaluations were made. Each child was initially classified by the school as an LLD on the basis of the psychoeducational evaluations but if the examining physician stated that the child showed symptoms of brain dysfunction the classification was changed to MBI. Only those learning disability children (based on the school records) who had "(1) low normal to normal IQ, (2) no hard neurological signs, (3) no primary sensory or motor deficits, (4) achievement level below chronological age and mental age, and (5) no primary emotional maladjustments" (Hix, 1971, p. 123) were used in the study. Because the LLD classification had just taken effect at the beginning of the present study the average age of the LLDs was slightly younger than that of the MBIs. Mean ages were 10.08 years (SD=.81) for the Normals, 9.91 years (SD=1.02) for the LLDs and 10.63 years

(SD=1.47) for the MBIs. Mean IQs (Otis-Lennon Mental Abilities Test, WISC Verbal Score or Slosson Intelligence Test) were 102.32 (SD=4.64) for the Normals, 99.36 (SD=8.32) for the LLDs and 90.56 (SD=9.95) for the MBIs.

Using the available data from the psychoeducational tests as a basis the learning disability children were divided into subgroups for further EEG comparisons. Standard scores were used when available. When the score was given as mental age it was divided by chronological age and when the score was in the form of grade level at which the child was said to be operating, the score was divided by the grade level the child should have obtained according to his chronological age. WISC verbal and performance and all other intelligence test scores are standard IQ scores. WISC subtest scores are standard scores. WRAT scores are grade level at which the child is operating divided by expected grade level according to chronological age. Bender-Gestalt scores are mental age divided by chronological age. Nine subgroups were formed; Hyperactives (N=14, Mean age=10.36, Mean WISC Verbal IQ=87.64), Nonhyperactives (N=11, Mean age=10.97, Mean WISC Verbal IQ =90.36), Poor Readers (N=21, Mean age=10.80, Mean WRAT Reading subtest score=.50, Mean WISC Verbal IQ=86.67), Adequate Readers (N=10, Mean age=9.88, Mean WRAT Reading subtest scores=1.10, Mean WISC Verbal IQ=99.20), Low WRAT Scorers (N=17, Mean age=11.00, Mean WRAT score=.50, Mean WISC Verbal IQ=84.88), Low Performance Scorers (N=8, Mean age=10.63, Mean

WISC Performance IQ=88.40, Mean WISC Verbal IQ=87.80), Adequate Performance Scorers (N=10, Mean age=10.51, Mean WISC Performance IQ=102.00, Mean WISC Verbal IQ=85.75), Low Verbal Scorers (N=15, Mean age=10.84, Mean WISC Verbal IQ=83.40), Low Bender-Gestalt Scorers (N=14, Mean Age=10.59, Mean Bender-Gestalt Score=.74, Mean WISC Verbal IQ=88.14). The size of the sample and availability of data prevented the formation of comparable subgroups of learning disability children in all categories. Only the comparable learning disability subgroups were mutually exclusive because the purpose of the study was to relate the EEG to specific types of learning problems (not children) and it is recognized that most learning disability children have multiple deficits.

Experimental Apparatus and Procedures

Testing took place at the University of Houston laboratory. Subjects were given the Harris Test of Laterality Dominance, either before or after EEG recording, and the Hix Visual-Auditory-Tactile (VAT) Test (Hix, 1971) during EEG recording. A comfortable reclining chair was provided, with a supporting pillow for the neck, during resting and problem solving conditions.

The experimental chamber was an electrically shielded, semi-soundproof room next to the recording area. Opposite the child was a table containing a 15" x 15" white easel for the visual displays. The experimenter sat at the table during verbal-auditory and verbal-visual testing. Two push buttons were supplied, one to start the trial (held by the experimenter), and the other to stop the trial (held by the subject). Pressing the start button activated the EEG recorder and a tape transport for putting the EEG on magnetic tape. Activation of the response button by the child turned everything off. Subjects were told to press the response button when they thought they knew the correct answer but not to give the answer out loud until after the button had been pressed.

Two sections of the Hix VAT (Verbal-Visual and Verbal-Auditory) were described in detail by Hix (1971). Some revisions were made and the new stimuli for the Verbal-Visual (VV) tasks were presented in a Master's Thesis by Johnson (1975) and for the Verbal-Auditory (VA) tasks in Appendix A of the present study. Stimuli for the Tactile Kinesthetic task may be found in Appendix B of the present study. The Tactile Kinesthetic (TK) task was developed as an assessment tool for nonverbal abilities. Stimuli were presented in three forms. One set of stimuli consisted of small circles glued to a board, the second set was made of continuous lengths of wire glued to a board, and the third set was grooved out of the boards. For the third set a stylus was used by the subject to trace the figures. Formboards were all of uniform size and shape. The TK stimuli consisted of both freeform and standard geometric figures that varied on dimensions that were considered difficult to verbalize.

Before the behavioral testing began approximately eight minutes of muscle artifact free (determined at this point by visual inspection of the records) EEG recording was done while the child sat resting with his eyes open. In some cases a resting period was also recorded at the end of a session. Each major section (VV, VA, TK) of the behavioral test contained a block of 15 trials which was broken down into groups of five trials each. One practice trial was given before each set of five trials in the VV and VA tasks and two practice trials were given before each set of five trials in the TK task to determine if the instructions for each test were understood. Tests were similar for the VA and VV tests except in one case the problems were presented visually and in the other presented orally. The order of presentation was varied for the VV and VA tasks but the TK task was always presented last.

In the first set of trials for the VV task the subject was shown a picture containing four common everyday objects and was asked to tell the experimenter which object did not belong with the rest. For the second set the subject was shown a picture of an object and asked to give the experimenter a word that rhymed with the object. The third set of stimuli consisted of strings of objects between which were "+" and/or "-" signs and at the end of which was an "=" sign followed by a word that categorized the objects. For example, if the objects were pigs, cows, and dogs then the word after the equal sign was animals. The subject was asked to tell how many "animals" there were after all the additions and/or subtractions were completed. Essentially the same procedure was followed for the VA task except that all stimuli were presented orally by the experimenter.

TK task stimuli were presented to the subjects in a large black box. One side of the box was open so that the experimenter could easily see and manipulate the stimuli. The other side, bottom, and top were solid except for a small hole covered with flaps through which the subject could put an arm. No visual contact with the stimuli was allowed the subject. The procedure was as follows: 1. Two stimuli were placed inside the box. 2. The subject was told to put his arm through the hole. 3. The experimenter explained to the subject that he would be feeling, with his fingers only, two different shapes and after he had felt both shapes he was to press the response button and then tell the experimenter if the two shapes were the same or different. If the stimuli were grooved out the experimenter explained that the subject was to trace the shape with the stylus placed in his hand. The subjects were cautioned not to lay their full hand down but to use only their fingers. 4. The experimenter placed the subjects' fingers at the starting point marked on each board and allowed the child to explore each figure for no more than seven seconds. 5. The subject pressed the response button and gave his answer.

Answers were recorded by the experimenter with no comment as to their correctness. The same reinforcement was given to all children, a toy at the end of a session for participation. Total time of the recording session was usually about 30 minutes and time of day was generally between 9:00 A.M. and 3:00 P.M.

EEG Recording

Grass cup silver-silver chlorided electrodes were attached to the scalp in placements corresponding to the standard International 10-20 System (Jasper, 1958). Recordings were bipolar with all leads F_3, F_4, P_3, P_4, O_1, and O_2 referenced to C_z. Grass Model 7P511 EEG amplifiers in a Grass Model 78 polygraph amplified and wrote out the signals on standard EEG paper. A low pass setting of 10 and a high pass setting of .3 allowed a frequency range from 10Hz. to 100Hz. to pass through. An Ampex SP300 tape recorder was used to record the EEG on magnetic tape for computer analysis.

Data Analysis

EEG analysis was made via a computer developed for the University of Houston Laboratory. The theoretical basis for the analysis procedure was discussed thoroughly in studies done by Hix (1971), Sheer (1975) and Johnson (1975) and, therefore, will not be detailed in the present paper. EEG channels P_3-C_z and P_4-C_z were analyzed. Twenty-three percent

1/3 octave filters with center frequencies at 30, 40, 50, and 70Hz. were built into the computer. The 30 and 50Hz. bands served as control frequencies for the 40Hz. band and the 70Hz. band served as a muscle artifact detector. When 70Hz. was present no analysis took place in the other three bands ± 100msec on either side of the muscle burst.

Printout scores from the computer represented the amount of 30, 40, and 50Hz. activity that was present during a trial for each EEG lead, the number of seconds a trial lasted, and the number of seconds of muscle time (70Hz.) in the trial. While amplitude was a factor in determining the counts, the relationship was relative. Potentiometer settings, determined initially by the amplification factor at the EEG machine, were set the same for 30, 40, and 50Hz. but less stringently for 70Hz. Setting the potentiometer determined the minimum amplitude a frequency must have to establish a count. When at least three cycles of the frequency were above the minimum amplitude established one count was registered. Each subject served as his own control because of the wide variation of EEG levels and muscle activity.

CHAPTER IV

RESULTS

EEG and Behavioral Test Results for MBIs, LLDs and Normals

Parametric data for the Hix VAT, age, and IQ are presented in Table 1. Scores on the Hix VAT are mean number of errors for each major subtest. The Normals performed better (Table 2) than the LLDs on the VV (M diff=2.21, $t=3.80$, $p<.001$), VA (M diff=3.43, $t=5.90$, $p<.001$), and TK (M diff=1.52, $t=2.98$, $p<.05$) tasks. No differences were found between Normals and LLDs for age and IQ. The Normals performed better than the MBIs on the VV (M diff=3.71, $t=5.72$, $p<.001$), VA (M diff=5.01, $t=6.78$, $p<.001$) and TK (M diff=1.26, $t=2.12$, $p<.05$) tasks. No differences were found for age but the MBIs had lower IQs (M diff=11.86, $t=5.18$, $p<.001$) than the Normals. LLD error scores were lower than MBI scores on all three Hix VAT subtests but the differences were not significant. MBIs were older (M diff=.72, $t=2.02$, $p<.05$) and lower in IQ (M diff=8.80, $t=3.40$, $p<.01$) than LLDs.

Within group comparisons (Table 2) on the three subtests demonstrated that Normals performed better on the VV (M diff=1.45, $t=3.45$, $p<.01$) and VA (M diff=1.95, $t=4.24$, $p<.01$) tasks than the TK task, while MBIs performed better on the TK (M diff=1.80, $t=2.22$, $p<.05$) than the VA task. No within group differences on the Hix VAT subtests were found for the LLDs.

TABLE 1

MEANS AND STANDARD DEVIATIONS ON HIX VAT, AGE, AND IQ

FOR MBIS, LLDS, AND NORMALS

		Verbal Visual		Verbal Auditory		Tactile Kinesthetic		Age		IQ	
Group	N	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
MBI	25	6.12	2.88	6.92	3.26	5.12	2.37	10.63	1.47	90.56	9.95
LLD	29	4.62	2.71	5.34	2.56	5.38	1.99	9.91	1.02	99.36[a]	8.32
Normal	22	2.41	1.27	1.91	1.48	3.86	1.57	10.08	.81	102.32	4.64

[a]N=28

TABLE 2

"t" SIGNIFICANCES ON IQ, AGE, HIX VAT,

FOR NORMALS, LLDS, MBIS

	Normals vs. LLDs	Normals vs. MBIs	LLDs vs. MBIs		Normals	LLDs	MBIs
IQ		5.18***	3.40**	VV vs. VA			
Age			2.02*	VV vs. TK	3.45**		
VV	3.80***	5.72***		VA vs. TK	4.24**		2.22*
VA	5.90***	6.78***					
TK	2.98**	2.12*					

***$p<.001$

**$p<.01$

*$p<.05$

Intercorrelation matrices were computed (Table 3) to examine age, IQ, and subtest performance relationships between each group. For MBIs all correlation coefficients were significant except for TK and age, and TK and IQ. LLDs showed a relationship between the VV ($r=.77$, $p<.01$) and VA task, the VV ($r=-.57$, $p<.01$) task and age, and the VV ($r=-.41$, $p<.05$) task and IQ, and between the VA ($r=-.58$, $p<.01$) task and age and the VA ($r=-.47$, $p<.02$) task and IQ. Normals showed no interrelationships between any of the subtests, age or IQ. Lower error scores on the Hix VAT went together with increasing age and higher IQs.

Behavioral data taken from school records together with age and Hix VAT subtests were intercorrelated for the MBIs and LLDs on the Univac 1108 using a package program titled DStat2. Because the LLDs' and MBIs' tests were somewhat different each group was analyzed separately. Table 4 contains the intercorrelation matrix for the MBIs and Table 5 the matrix for the LLDs. Means and standard deviations were also generated by the program and are presented in Tables 6 and 7. For the LLDs the VV ($r=-.59$, $p<.01$) and the VA ($r=-.62$, $p<.05$) tasks correlated with the Slosson Intelligence Test (SIT). WISC Math. ($r=-.45$, $p<.05$) and WISC Simil. ($r=-.46$, $p<.05$) correlated with VA performance and WISC Simil. ($r=-.42$, $p<.05$) correlated with TK performance in the MBIs. Negative correlations between the Hix VAT subtests and other behavioral data indicated a positive relationship between performance levels.

TABLE 3

INTERCORRELATION MATRIX ON HIX VAT, AGE, AND IQ

FOR MBIS, LLDS, AND NORMALS

Group		VA	TK	Age	IQ
MBI	VV	.49**	.41*	-.46**	-.19
	VA		.49**	-.43*	-.39*
	TK			-.14	-.15
	Age				-.19
LLD	VV	.77***	.08	-.57***	-.41*
	VA		-.18	-.58***	-.47**
	TK			.14	.10
	Age				-.07
Normal	VV	.08	.16	-.29	.06
	VA		-.16	-.25	-.04
	TK			-.02	.07
	Age				-.11

***p<.01

**p<.02

*p<.05

TABLE 4

INTERCORRELATION MATRIX ON BEHAVIORAL DATA FOR MBIS

		HIX VAT			WISC							
		VV	VA	TK	F.S.	Perf.	Verb.	Inf.	Comp.	Math.	Simi.	Voc.
HIX VAT	VV	--	.49**	.41*	-.18	-.27	-.04	-.02	.44*	-.37	-.11	-.02
	VA		--	.49**	-.33	-.07	-.38	-.11	.09	-.45*	-.46*	-.27
	TK			--	-.10	.02	-.14	-.07	.04	.02	-.42*	.03
WISC	F.S.				--	.65***	.80***	.49**	.33	.58***	.50**	.63***
	Perf.					--	.06	.01	-.27	.33	-.09	-.03
	Verb.						--	.65***	.64***	.52**	.74***	.84***
	Inf.							--	.25	.64***	.54***	.56***
	Comp.								--	-.10	.39	.57***
	Math.									--	.38	.42*
	Simi.										--	.60***
	Voc.											--

(Table continued on next page)

TABLE 4 (Continued)

	WISC						WRAT						
	DS	PC	PA	BD	OA	Cod.	Read.	Math.	Spel.	Bend. Gest.	SIT	HL	HA
VV	.19	-.19	-.03	-.05	-.20	.04	-.01	-.00	.10	-.33	.44	-.07	.40*
VA	-.19	-.35	-.20	.10	.05	.13	.01	-.32	.07	-.37	-.05	.04	.37
TK	.19	.13	-.27	.12	-.07	.25	.26	.09	.25	-.33	.27	-.03	.25
F.S.	.67***	.69***	.30	.06	.21	.31	.37	.47*	.37	.59***	.81***	.10	-.16
Perf.	.44*	.45*	.58***	.50**	.64***	.50**	.21	.06	.18	.37	.47	.18	-.14
Verb.	.55*	.55***	-.02	-.26	-.16	.06	.33	.57***	.36	.52*	.78***	.02	-.12
Inf.	.25	.21	-.01	-.03	-.14	-.00	.63***	.51**	.48*	.32	.58*	-.12	.01
Comp.	.41	.11	-.27	-.31	-.27	.05	-.07	.12	.12	.14	.42	-.05	.20
Math.	.38	.58***	-.01	.20	-.16	.06	.56***	.58***	.40	.39	.75***	.07	-.14
Simi.	-.08	.43*	.15	-.53**	-.36	-.09	.14	.51**	.11	.30	.57	.11	-.02
Voc.	.25	.58***	-.25	-.36	-.17	-.10	.34	.59***	.35	.42	.40	.00	-.12

(Table continued on next page)

TABLE 4 (Continued)

					WISC				WRAT					
		DS	PC	PA	BD	OA	Cod.	Read.	Math.	Spel.	Bend. Gest.	SIT	HL	HA
WISC	DS	--	.36	.22	.50*	.19	.34	.10	.20	.32	.36	.51	.09	-.10
	PC		--	.01	-.04	-.02	-.09	.07	.43*	.07	.24	.62*	.09	.05
	PA			--	.01	.35	.33	.07	.10	-.02	.13	.48	.26	-.25
	BD				--	.38	-.01	.11	-.17	.10	-.03	-.09	.07	-.12
	OA					--	.06	-.05	-.32	-.18	.35	-.05	.18	-.27
	Cod.						--	.30	.31	.22	.23	.35	.23	.07
WRAT	Read.							--	.55***	.85***	.54*	.54	.12	-.31
	Math.								--	.48*	.27	.61*	.38	-.20
	Spel.									--	.49*	.49	.01	-.17
	Bend. Gest.										--	.22	.17	-.42
	SIT											--	.11	.36
	HL												--	-.27
	HA													--

*p<.05

**p<.02

***p<.01

TABLE 5

INTERCORRELATION MATRIX ON BEHAVIORAL DATA FOR LLDS

		HIX VAT			WRAT						
		VV	VA	TK	Read.	Math.	Spel.	SIT	HL	Otis Lenn	HA
HIX VAT	VV	--	.77***	.08	-.24	-.17	-.19	-.59***	-.17	-.10	.09
	VA		--	-.18	-.18	-.21	-.28	-.62***	-.40*	-.04	-.14
	TK			--	.12	-.16	.16	.11	.03	.23	.29
WRAT	Read.				--	.47*	.65***	.31	-.21	.56	.01
	Math.					--	.51*	.30	.19	-.01	.10
	Spel.						--	.23	-.16	.09	-.03
	SIT							--	.18	.56*	.10
	HL								--	.07	.19
	Otis Lenn									--	.08

*p<.05

**p<.02

***p<.01

TABLE 6

MEANS AND STANDARD DEVIATIONS ON WISC
AND BENDER-GESTALT FOR MBIS

	Test	$\overline{X}$	SD	N
WISC	FS	90.12	8.96	25
	Perf.	93.36	10.05	25
	Verb.	88.84	11.67	25
	Inf.	7.52	2.39	23
	Comp.	8.57	2.97	23
	Math.	7.22	1.81	23
	Sim.	10.44	3.29	23
	Voc.	8.35	2.62	23
	DS	7.53	2.24	17
	PC	9.17	2.99	23
	PA	9.18	1.97	22
	BD	10.00	2.29	22
	OA	9.68	2.50	22
	Cod.	8.32	2.75	22
Bender-Gestalt		.82	.15	19

TABLE 7

MEANS AND STANDARD DEVIATIONS ON TESTS

COMMON TO LLDS AND MBIS

Group	Test	$\overline{X}$	SD	N
MBI	VV	6.12	2.93	25
	VA	6.92	3.33	25
	TK	5.12	2.42	25
	WRAT Read.	.58	.25	23
	WRAT Math.	.67	.27	23
	WRAT Spel.	.56	.23	23
	SIT	93.75	13.36	12
	HL	4.04	1.10	25
	HA[a]	.56		
LLD	VV	4.62	2.76	29
	VA	5.34	2.61	29
	TK	5.38	2.03	29
	WRAT Read.	.87	.28	18
	WRAT Math.	.83	.17	18
	WRAT Spel.	.70	.28	18
	SIT	100.12	8.07	26
	HL	4.31	1.00	29
	HA[a]	.07		

[a]Proportion of group diagnosed as hyperactive

According to school records, where the same tests were available for the MBIs and LLDs (Table 8), the LLDs were better at mathematics (WRAT Math., M diff=.16, t=2.27, $p<.05$) and reading (WRAT Read., M diff=.29, t=3.45, $p<.01$) than the MBIs. More MBIs were diagnosed as hyperactive (56% versus 7%, Chi-square=13.26, $p<.001$) than LLDs.

EEG results are presented in Table 9 for all three groups. When muscle time indicated that over 50 percent of a given condition had contained muscle artifact the condition was eliminated from analysis resulting in different values of "N" for some of the conditions. Trials where 50Hz. was over 50 percent of 40Hz. were also eliminated for further control of muscle artifact.

Forty Hertz activity successfully discriminated between Normals and learning disability groups for all subtests of the Hix VAT. A significant number of Normals showed increases over resting for 40Hz. activity in the P_3-C_z lead during the VV (Prop.=.75, Chi-square=4.00, $p<.05$) and VA (Prop.=.82, Chi-square=7.12, $p<.01$) tasks, and in the P_4-C_z lead during the VV (Prop.=.95, Chi-square=15.21, $p<.001$), VA (Prop.=.82, Chi-square=7.12, $p<.01$) and TK (Prop.=.78, Chi-square=5.56, $p<.05$) tasks. No difference in Normals were found for 30Hz. activity but 50Hz. activity increased over resting in the P_3-C_z lead during the VV (Prop.=.75, Chi-square=4.00, $p<.05$) and TK (Prop.=.93, Chi-square=10.29, $p<.001$) tasks and in the P_4-C_z lead during the VV (Prop.=.84, Chi-square=8.89, $p<.01$)

TABLE 8

"t" SIGNIFICANCES ON BEHAVIORAL TESTS FOR LLDS AND MBIS

Groups	WRAT Read.	WRAT Math.	Hyperactivity
LLDs vs. MBIs	3.43**	2.27*	13.26***

Note. X^2 test of significance used for hyperactivity

**$p < .01$

*$p < .05$

***$p < .001$

TABLE 9

PROPORTION OF MBIS, LLDS, AND NORMALS THAT SHOWED AN INCREASE OVER THE RESTING EEG FOR 30Hz., 40Hz., AND 50Hz. DURING THE HIX VAT

		P_3								
		VV			VA			TK		
Group[b]	N[a]	30	40	50	30	40	50	30	40	50
MBI	25	.55	.65	.50	.59	.68	.45	.47	.74*	.74*
LLD	29	.09****	.48	.61	.25*	.65	.55	.22**	.72	.72
Normal	22	.44	.75*	.75*	.65	.82***	.59	.43	.71	.93***
		P_4								
		VV			VA			TK		
		30	40	50	30	40	50	30	40	50
MBI	25	.50	.64	.59	.65	.60	.40	.40	.60	.60
LLD	29	.17***	.58	.79***	.43	.67	.48	.43	.52	.57
Normal	22	.47	.95****	.84***	.71	.82***	.47	.56	.78**	.61

[a]N may vary between conditions

[b]X^2 Test of significance

****p<.001

***p<.01

**p<.02

*p<.05

task. LLDs showed no differences for 40Hz. between resting and testing but 30Hz. activity decreased from resting in the P_3-C_z lead during the VV (Prop.=.09, Chi-square=15.70, $p<.001$), VA (Prop.=.25, Chi-square=5.00, $p<.05$) and TK (Prop.=.22, Chi-square=5.56, $p<.02$) tasks, and in the P_4-C_z lead during the VV (Prop.=.17, Chi-square=10.67, $p<.01$) task. The only difference in 50Hz. activity for the LLDs appeared in the P_4-C_z lead during the VV (Prop.=.79, Chi-square=8.17, $p<.01$) task where an increase over resting activity was noted. For the MBIs increases over resting were found for 40Hz. activity in the P_3-C_z lead during the TK (Prop.=.74, Chi-square=4.26, $p<.01$) task and for 50Hz. activity in the P_3-C_z lead during the TK (Prop.=.74, Chi-square=4.26, $p<.01$) task.

EEG and Behavioral Test Results for Normals and Learning Disability Subgroups

Nine subgroups were formed from school test data; Hyperactives, Nonhyperactives, Poor Readers, Adequate Readers, Low WRAT Scorers, Low Performance Scorers, Adequate Performance Scorers, Low Verbal Scorers, and Low Bender-Gestalt Scorers.

Nonhyperactives and Hyperactives were subgroups of the MBI group. Nonhyperactives scored better than Hyperactives (Tables 10 and 11) on the VV (M diff=2.32, t=2.11, $p<.05$) and the VA (M diff=2.45, t=2.15, $p<.05$) tasks. No differences were found for any of the other variables.

Poor and Adequate Readers were chosen on the basis of

TABLE 10

MEANS AND STANDARD DEVIATIONS ON BEHAVIORAL TESTS FOR LEARNING DISABILITY SUBGROUPS

Group		Hyperactives (N=14)		Nonhyperactives (N=11)		Poor Readers (N=21)		Adequate Readers (N=10)		Low WRAT Scorers (N=17)	
Test		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HIX VAT	VV	7.14	2.77	4.82	2.71	6.24	2.88	4.30	2.30	6.53	2.83
	VA	8.00	4.08	5.55	1.13	6.90	3.40	5.20	2.49	6.88	3.39
	TK	5.64	2.34	4.45	2.46	4.62	2.09	5.40	2.32	4.53	1.94
WISC	Perf.	92.14	11.06	94.91	8.87	92.38	11.37	--	--	92.41	11.95
	Verb.	87.64	9.72	90.36	14.09	86.67	9.68	99.20[a]	8.66	84.88	8.53
	Inf.	7.54	2.30	7.50	2.64	6.65	1.90	--	--	6.53	1.97
	Comp.	9.08	2.81	7.90	3.18	8.60	2.60	--	--	8.24	2.54
	Math.	7.00	1.96	7.50	1.65	6.60	1.50	--	--	6.65	1.54
	Sim.	10.38	3.07	10.50	3.72	10.20	3.32	--	--	10.24	2.86
	Voc.	8.08	2.29	8.70	3.09	7.90	2.51	--	--	7.65	2.50
	D.S.	7.56	2.74	7.50	1.69	7.07	1.79	--	--	6.85	1.82
	P.C.	9.31	3.17	9.00	2.91	8.85	3.20	--	--	8.88	3.31
	P.A.	8.75	2.38	9.70	1.25	9.32	2.21	--	--	9.25	2.27
	B.D.	9.75	2.63	10.30	1.89	9.79	2.46	--	--	9.69	2.55
	O.A.	9.08	2.54	10.40	2.37	9.63	2.29	--	--	9.50	2.42
	Cod.	8.50	3.03	8.10	2.51	7.84	2.77	--	--	7.69	2.96
WRAT	Read.	.51	.21	.67	.27	.50	.15	1.10	.25	.48	.15
	Math.	.62	.27	.72	.27	.61	.22	.90	.17	.57	.15
	Spel.	.52	.26	.60	.20	.49	.18	.83	.29	.44	.14
	Bender Gestalt	.76	.11	.88	.16	.79	.12	--	--	.78	.13
	H.A.[b]	1.00	--	.00	--	.52	--	.00	--	.59	--
	Age	10.36	1.64	10.97	1.30	10.80	1.50	9.88	.79	11.00	1.44

(Table continued on next page)

TABLE 10 (Continued)

Group		Adequate Performance Scorers (N=8)		Low Performance Scorers (N=10)		Low Verbal Scorers (N=15)		Low Bender-Gestalt Scorers (N=14)	
Test		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HIX VAT	VV	5.75	3.41	6.20	2.90	5.93	2.79	6.71	2.58
	VA	6.13	3.64	7.40	2.88	7.20	3.91	7.36	3.50
	TK	4.75	2.25	4.70	2.31	4.47	1.81	5.86	2.21
WISC	Perf.	102.00	3.59	88.40	8.30	94.33	10.00	93.00	10.09
	Verb.	85.75	14.62	87.80	9.96	83.40	8.32	88.14	10.03
	Inf.	6.38	1.77	6.90	2.38	6.60	1.24	7.36	2.59
	Comp.	7.75	2.92	8.50	3.06	7.60	2.20	8.86	2.63
	Math.	6.25	1.39	7.20	1.93	6.80	1.57	6.86	1.92
	Sim.	9.75	3.99	10.00	3.20	9.07	2.81	10.29	3.02
	Voc.	8.25	3.45	8.20	2.39	6.93	1.98	8.36	2.56
	D.S.	7.86	1.86	6.50	1.76	7.31	1.75	7.75	2.56
	P.C.	9.00	3.12	8.60	3.03	8.40	3.25	9.00	3.26
	P.A.	10.50	1.20	8.10	1.45	9.47	2.00	8.93	1.98
	B.D.	11.00	1.51	9.20	2.90	10.00	2.45	9.86	2.25
	O.A.	11.63	1.77	9.00	2.36	10.07	2.28	9.29	2.76
	Cod.	8.75	2.31	6.80	1.55	8.00	2.85	7.79	2.49
WRAT	Read.	.51	.03	.57	.31	.49	.15	.54	.21
	Math.	.65	.23	.56	.25	.52	.19	.57	.28
	Spel.	.49	.11	.55	.29	.48	.19	.53	.22
	Bender Gestalt	.78	.13	.84	.18	.79	.12	.74	.08
	H.A.[b]	.25	--	.50	--	.60	--	.64	--
	Age	10.51	1.98	10.63	2.82	10.84	1.64	10.59	1.84

[a]Includes both WISC Verbal and SIT scores.

[b]Proportion of group diagnosed as hyperactive.

TABLE 11

"t" SIGNIFICANCES ON BEHAVIORAL TESTS BETWEEN LEARNING DISABILITY SUBGROUPS AND NORMALS

	Group / Test	Hyperactive vs. Non-Hyperactive	Poor Readers vs. Adequate Readers	Low Performance vs. Adequate Performance	Hyperactive vs. Normal	Nonhyperactive vs. Normal	Poor Readers vs. Normal
HIXVAT	VV	2.11*			5.99***	2.80***	5.63***
	VA	2.15*			5.34***	7.74***	6.16***
	TK				2.51**		
WISC	Perf.			4.30***			
	P.A.			3.76***			
	O.A.			2.61**			
	Cod.			2.14*			
WRAT	Read.		6.00***				
	Math.		4.14***				
	Spel.		3.09***				
	Age		2.24*			2.12*	
	IQ		3.62***		5.28***	2.74**	6.72***

(Table continued on next page)

TABLE 11 (Continued)

	Group / Test	Adequate Readers vs. Normal	Low Performance vs. Normal	Adequate Performance vs. Normal	Low Verbal vs. Normal	Low WRAT vs. Normal	Low Bender-Gestalt vs. Normal
HIXVAT	VV	2.45*	3.99***	2.72**	4.57***	5.64***	5.81***
	VA	3.87***	5.72***	3.17***	4.99***	5.65***	5.51***
	TK						2.94***
WISC	Perf.						
	P.A.						
	O.A.						
	Cod.						
WRAT	Read.						
	Math.						
	Spel.						
	Age					2.36**	
	IQ		4.40***	3.15***	8.02***	7.62***	4.96***

Note. IQ may be Otis Lennon, SIT, or WISC Verbal.

***$p<.01$

**$p<.02$

*$p<.05$

the Wide Range Achievement Test (WRAT) subtest, the requirement being a score less than or equal to .85 for the Poor Readers and a score greater than or equal to .90 for the Adequate Readers. Most of the Poor Readers were MBIs while most of the Adequate Readers were LLDs. Behavioral test differences between Poor and Adequate Readers were (Table 10, 11) on WRAT Reading (M diff=.60, t=6.00, $p<.01$), WRAT Mathematics (M diff=.29, t=4.14, $p<.01$), WRAT Spelling (M diff=.34, t=3.09, p<,01), age (M diff=.92, t=2.24, $p<.05$) and IQ (M diff=12.53, t=3.62, $p<.01$).

Low WRAT Scorers (WRAT Mean=.50, Mean age=11.00, WISC Verbal IQ=84.88, and WISC Performance IQ=92.41) were placed in the Low WRAT group if they scored less than or equal to .85 on each of the WRAT subtests.

Low and Adequate Performance Scorers were chosen by the WISC Performance subtests. Since WISC Picture Completion (P.C.) correlated with WISC Verbal IQ (Table 4, r=.55, $p<.01$) it was eliminated and WISC Picture Arrangement (P.A.), WISC Block Design (B.D.), WISC Object Assembly (O.A.) and WISC Coding (Cod.) were used to define the subgroups. Subjects who were placed in the Adequate Performance subgroup could score less than nine on no more than one subtest, or nine on no more than two subtests, with at least 10 on the remaining subtests. Subjects who were placed in the Low Performance subgroup had to score below 10 on at least three out of the four subtests or less than or equal to seven on at least two of the four subtests. Low and Adequate Performance Scorers differed on WISC Performance IQ (M diff=14.60, t=4.30, p<.01) WISC P.A. (M diff=2.4, t=3.76, p<.01), WISC O.A. (M diff=2.63, t=2.61, p<.02) and WISC Cod. (M diff=1.95, t=2.14, p<.05). Both groups were essentially MBIs.

WISC Verbal subtests were used to define the Low Verbal subgroup excluding WISC Digit Span (D.S.) which correlated with WISC Performance IQ (r=.44, p<.05). Subjects who were included in the Low Verbal subgroup (WISC Verbal IQ=83.40, WISC Information Mean=6.60, WISC Comprehension Mean=7.60, WISC Mathematics Mean=6.80, WISC Similarities Mean=9.07, WISC Vocabulary Mean=6.93, WISC Performance IQ=94.33, and Mean age=10.84) had to score below ten on at least four of the five WISC Verbal subtests and were essentially MBIs.

Low Bender-Gestalt Scorers (less than or equal to .85 on the Bender-Gestalt) had a mean Bender-Gestalt score of .74, WISC Verbal IQ of 88.14, WISC Performance IQ of 93.00, mean age of 10.59, and all but one were MBIs.

Comparisons between the subgroups and the Normal group are shown in Table 11. All subgroups performed worse than Normals on the VV and VA tasks but only two subgroups, Hyperactives (M diff=.78, t=2.51, p<.02) and Low Bender-Gestalt Scorers (M diff=2.00, t=2.94, p<.01) did worse on the TK task. All subgroups except the Adequate Readers had significantly lower IQs than the Normals. Nonhyperactives (M diff=.89, t=2.12, p<.05) and Low WRAT Scorers (M diff=.92, t=2.36,

$p<.02$) were the only two subgroups who were older than the Normals.

Increases in 30, 40, and 50Hz. activity over resting are presented in Table 12. Results reflected the pattern of the main groups. Poor readers showed increases in the P_3-C_z lead for 40Hz. (Prop.=.88, Chi-square=9.00, $p<.01$) and 50Hz. (Prop.=.81, Chi-square=6.25, $p<.02$) lead during the TK task, and in the P_4-C_z lead for 30Hz. (Prop.=.80, Chi-square=5.40, $p<.05$) during the VA task. Adequate Readers showed a decrease in the P_3-C_z lead for 30Hz. (Prop.=.13, Binomial Test, $p<.05$) and an increase in the P_4-C_z lead for 50Hz. (Prop.=.88, Binomial Test, $p<.05$) during the VV task. Low WRAT Scorers had increases in the P_3-C_z lead for 40Hz. (Prop.=.82, Chi-square=9.31, $p<.01$) and 50Hz. (Prop.=.85, Chi-square=6.23, $p<.02$) during the TK task. Low Verbal Scorers had increases in the P_3-C_z lead for 40Hz. (Prop.=.82, Chi-square=4.45, $p<.05$) during the TK task.

To see if the proportion of increases in one hemisphere as compared to the other hemisphere might reflect which side played the greater part in processing information for a particular task Chi-square comparisons were made between the two hemispheres for each task and across tasks within each hemisphere for 40Hz. activity (Table 13).

Comparing activity in the two hemispheres on the VV task for the Hyperactives and Nonhyperactives showed that the Hyperactives had a different pattern of increase (Chi-square=

TABLE 12

PROPORTION OF MBI AND LLD SUBGROUPS THAT SHOWED AN INCREASE IN 30Hz., 40Hz., AND 50Hz. ACTIVITY OVER THE RESTING EEG

		P_3								
		VV			VA			TK		
Groups	N	30	40	50	30	40	50	30	40	50
Hyperactives	14	.40	.50	.60	.58	.75	.58	.33	.78	.78
Nonhyperactives	11	.70	.80	.40	.60	.60	.30	.60	.70	.70
Poor Readers	21	.56	.67	.61	.65	.71	.41	.50	.88***	.81**
Adequate Readers	10	.13*	.25	.50	.38	.63	.50	.33	.67	.83
Low WRAT Scorers	17	.57	.64	.64	.69	.77	.46	.46	.92***	.85**
Adequate Performance Scorers	8	.43	.57	.29	.43	.57	.14	.50	.67	.67
Low Performance Scorers	10	.50	.50	.50	.57	.57	.29	.38	.75	.75
Low Verbal Scorers	15	.54	.62	.54	.62	.69	.31	.55	.82*	.73
Low Bender-Gestalt Scorers	14	.50	.40	.50	.40	.60	.40	.40	.70	.60

(Table continued on next page)

TABLE 12 (Continued)

		P_4								
		VV			VA			TK		
Groups	N	30	40	50	30	40	50	30	40	50
Hyperactives	14	.38	.69	.77	.64	.55	.55	.30	.60	.60
Nonhyperactives	11	.67	.56	.33	.67	.67	.22	.50	.60	.60
Poor Readers	21	.53	.68	.63	.80*	.60	.47	.39	.56	.61
Adequate Readers	10	.25	.50	.88*	.38	.63	.25	.43	.71	.57
Low WRAT Scorers	17	.50	.69	.69	.75	.58	.50	.29	.57	.57
Adequate Performance Scorers	8	.57	.57	.43	.67	.67	.50	.43	.43	.43
Low Performance Scorers	10	.33	.56	.67	.71	.57	.14	.38	.50	.63
Low Verbal Scorers	15	.50	.57	.57	.73	.55	.45	.38	.46	.54
Low Bender-Gestalt Scorers	14	.38	.69	.69	.64	.36	.36	.36	.45	.55

Note. N may vary between conditions.

***$p<.01$

**$p<.02$

*$p<.05$

TABLE 13

TABLE OF X^2 SIGNIFICANCES OF 40Hz. ACTIVITY BETWEEN LEARNING DISABILITY SUBGROUPS AND NORMALS

Groups	P_3 vs. P_4			Across Conditions	
	VV	VA	TK	P_3	P_4
Hyperactives vs. Nonhyperactives	7.40***			8.91***	
Nonhyperactives vs. Normals	6.41**				
Poor Readers vs. Normals			5.50*		
Poor Readers vs. Adequate Readers			4.64*	8.91**	
Adequate Readers vs. Normals				13.47***	
Low Bender-Gestalt vs. Normals		4.26*	5.01*		
Low WRAT vs. Normals			5.42**		
Adequate Performance vs. Normals			4.06*		
Low Verbal vs. Normals			7.11***		

***$p<.01$

**$p<.02$

*$p<.05$

7.40, $p<.01$). Hyperactives had a right greater than left side pattern, similar to the Normals, while Nonhyperactives had a left greater than right side pattern. Nonhyperactives differed from the Normals (Chi-square=6.41, $p<.02$) in the same direction. Further investigation revealed that the proportion of increases on the right side was smaller (Fisher Exact Probabilities Test, $p<.02$) for Nonhyperactives than Normals.

During the VA condition the Low Bender-Gestalt group showed a left side greater than right side pattern of increase which differed (Chi-square=4.26, $p<.05$) from the Normals who showed the same amount of increase for both hemispheres. The right side showed a smaller proportion of increase (Fisher Exact Probabilities Test, $p<.02$) in the Low Bender-Gestalt Scorers than the Normals.

Subgroups in the TK condition who showed a left side greater than right side pattern of increase differing from the right side greater than left side pattern in the Normals were Poor Readers (Chi-square=5.50, $p<.05$), Low Bender-Gestalt Scorers (Chi-square=5.01, $p<.05$), Low WRAT Scorers (Chi-square=5.42, $p<.02$), Adequate Performance Scorers (Chi-square=4.06, $p<.05$) and Low Verbal Scorers (Chi-square=7.11, $p<.01$). Adequate and Poor Readers differed on the TK task (Chi-square=4.64, $p<.05$) with Adequate Readers demonstrating the same pattern of increase as the Normals.

The across tasks differences for 40Hz. activity between

Adequate Readers and Normals (Chi-square=13.47, $p<.01$) could be accounted for by the smaller proportion of increase (Fisher Exact Probabilities Test, $p<.04$) in the Adequate Readers in the P_3-C_z lead during the VV task. While no across conditions differences were found in the P_4-C_z lead the Adequate Readers again had a smaller proportion of increase than Normals in the VV (Fisher Exact Probabilities Test, $p<.04$) task. Poor and Adequate Readers differed in the across tasks comparisons in the P_3-C_z (Chi-square=8.91, $p<.02$) lead and Hyperactives and Nonhyperactives differed in the P_3-C_z (Chi-square=8.91, $p<.02$) lead.

Taking the 40Hz. deficit as measured by the proportion of subjects showing increases in each lead for each task (Tables 9 and 12), the LLDs showed a smaller proportion of increases than Normals during the VV task in the P_3-C_z (Chi-square=3.99, $p<.05$) lead and the P_4-C_z (Fisher Exact Probabilities Test, $p<.01$) lead, and fewer MBIs than Normals showed increases during the VV task in the P_4-C_z (Fisher Exact Probabilities Test, $p<.02$) lead.

Low Performance and Adequate Performance Scorers demonstrated a smaller proportion of increases in 40Hz. compared to Normals in the P_3-C_z lead during the VA (Fisher Exact Probabilities Test, $p<.02$) task and in the P_4-C_z lead during the VV (Fisher Exact Probabilities Test, $p<.04$) task. Low Verbal Scorers had smaller increases in the P_4-C_z leads during the VV (Fisher Exact Probabilities Test, $p<.013$) task.

Poor Readers showed a smaller increase than Normals in the P_4-C_z lead during the VV (Fisher Exact Probabilities Test, $p<.04$) task. Low Bender-Gestalt Scorers showed smaller increases than Normals in the P_3-C_z lead during the VV (Fisher Exact Probabilities Test, $p<.01$) task.

In general, most of the MBI subgroups reflected the smaller proportion of increases in the P_4-C_z lead during the VV task shown by the MBI group. Two subgroups, Low Bender-Gestalt Scorers and Adequate Readers, reflected the smaller proportion of increases shown by the LLDs in the P_3-C_z lead during the VV task. While the Adequate Readers were mainly LLDs the Low Bender-Gestalt Scorers were mainly MBIs. The Low Bender-Gestalt was the only subgroup to show a deficit in the P_4-C_z lead during the VA task. Low and Adequate Performance Scorers were the only two groups who showed a deficit in the P_3-C_z lead during the VA task.

CHAPTER V

DISCUSSION

Following procedures used in previous 40Hz. studies (Hix, 1971; Johnson, 1975) the 30 and 50Hz. bands were used as controls. If increases were significant in 30 and 50Hz. then the effect could be attributed to 40Hz. activity. Muscle control was accomplished by several methods described in the data analysis section. In the Normals the VV task was the only condition where both 40 and 50Hz. showed significant increases. Large amplitude bursts could affect more than one band in the same manner. However, the 70Hz. control should have eliminated any such large bursts which would only have occurred if muscle artifact was present. Significant increases in 50Hz. were not invariably accompanied by significant increases in 40Hz. indicating that muscle was being controlled. Hix's (1971) data used the same (VV) task and got significant increases in 40Hz. without 50Hz. increases.

The behavioral and EEG results for the LLDs and MBIs appeared to parallel those of the group studied by Hughes (1971) and Myklebust (1973). Where comparisons were available the LLDs usually scored better than MBIs on psychoeducational tests. In the school's program of special education MBIs were placed in special classes all day while LLDs usually received only one to four hours of special education. From the school's program and behavioral data the MBIs appeared to be more educationally handicapped than the LLDs. EEG results indicated that the LLDs were showing more abnormalities than the MBIs. LLDs had a decrease in 30Hz. and a larger degree of deficit than MBIs in the left hemisphere while LLDs and MBIs together showed a deficit in the right hemisphere. No comparisons were made on neurological data because school records were not as detailed as those of Myklebust. However, not all MBIs had soft signs because, before the LLD classification went into effect, to receive state aid a learning disability child had to be diagnosed as an MBI. Also, while medical examinations were routinely done on LLDs, detailed neurologicals were being discouraged which may have resulted in children with some types of soft signs being included in the LLD group.

Differences were found for age and IQ between the three groups. Looking only at the LLDs and Normals no differences were found for age and IQ. For the LLDs and MBIs age and IQ were related to VV and VA tasks performance but not for the Normals. It is very unlikely, due to the magnitude of the differences on the VA and VV tasks, that the IQ differences were large enough to make a significant contribution. Higher IQs for the LLDs and a younger age than the MBIs offset each other and probably did not affect Hix VAT results differentially. Hix's (1971) study found the same results on the VV and VA tasks with children matched in pairs for age and IQ.

Age and EEG differences between MBIs and LLDs appeared to coincide with the Klonoff and Low (1974) study that found more EEG abnormalities and more improvement a year later in the younger learning disability children. While improvement was not measured in the present study a theory of delayed maturation would be consistent with the findings.

On the Hix VAT MBIs showed the low verbal-high performance pattern that has been reported in the literature (Ackerman, Peters, & Dykman, 1971a) while Normals showed a high verbal-low performance pattern. Ackerman et al. (1971a, 1971b) studied a group of 82 elementary school boys with learning disabilities. Learning disability subjects with subaverage Bender-Gestalt scores had significantly lower scores on WISC Information and Arithmetic subtests; but Normals with subaverage Bender-Gestalt scores did not differ from Normals with average Bender-Gestalt scores on any WISC subtests. Low WISC Verbal scores were more reliably associated with serious reading disabilities than were low WISC Performance scores. Table 4 of the present study showed a high intercorrelation between WISC Verbal, Bender-Gestalt, WRAT Reading and WRAT Math scores in the MBIs. Normals did not show intercorrelations between VV, VA, TK, Age and IQ but MBIs and LLDs did. The high interrelationship between performance on the different tests for the learning disability groups suggested an underlying factor affecting verbal learning in a general way. The lack of focused arousal represented by 40Hz. appeared to be the relevant variable.

For both MBIs and LLDs the EEG results during the VV task were very effective as discriminators from the Normals. Not only did the learning disability groups not show increases in either lead in 40Hz., but the MBIs, LLDs, and all but three subgroups, Hyperactives, Low Bender-Gestalt Scorers, and Low WRAT Scorers, had a more severe degree of deficit in 40Hz. in the P_4-C_z lead. In the P_3-C_z lead the LLDs, Low Bender-Gestalt Scorers, and Adequate Readers had a larger deficit. The right hemisphere deficit appeared to be more prevalent. As mentioned in the review Poor Readers performed worse than Normals when visual numbers and words were presented to the right hemisphere (Yeni-Komshian et al., 1975) which tended to support the present findings.

Neither the MBIs, LLDs, nor learning disability subgroups showed 40Hz. increases in the VA task but three subgroups, Low Performance Scorers, Adequate Performance Scorers and the Low Bender-Gestalt Scorers, showed a larger degree of deficit with the first two subgroups showing more deficit in the P_3-C_z lead and the Low Bender-Gestalt Scorers showing more deficit in the P_4-C_z lead.

Results from the TK task are difficult to interpret. Degree of deficits did not appear to be a significant factor. MBIs increased in 40 and 50Hz. on the left side which was repeated in the Poor Readers, Low WRAT, Low Verbal, and Adequate Performance subgroups. Normals increased in 40Hz. only on the right side. Milner (1974) noted that patients who had intact brains did better on a bent wire pattern discrimination task than split brain patients. Some form of compensation may have been operating. It may also be that the same right side deficit that was noted in the VV task was responsible for the poorer behavioral performance of the MBIs (compared to Normals) on the TK task but the different nature of the TK task (more performance oriented) allowed for better performance than that of the verbal tasks. The TK task may not be purely nonverbal or integration between the two hemispheres could be the contributing factor.

Three comparative subgroups were formed from the learning disability children, Hyperactives versus Nonhyperactives, Low versus Adequate Performers, and Poor versus Adequate Readers. Hyperactives and Nonhyperactives differed in right-left increase patterns on the VV task. Hyperactives showed a pattern similar to the Normals. Neither the Hyperactives nor Nonhyperactives had significant increases in 40Hz. for any condition but Nonhyperactives showed more of a deficit in the P_4-C_z lead during the VV condition. Poorer performance by Hyperactives than Nonhyperactives in the VV and VA tasks but essentially the same EEG results would appear to imply not only a focusing of attention problem but a general attentional and an additional motivational factor in the Hyperactives mentioned by Grunewald-Zuberbier et al. (1975).

Poor and Adequate Readers showed right-left side pattern differences in the TK condition with the Adequate Readers reflecting the pattern of the Normals. Essentially the two subgroups were MBIs (Poor Readers) and LLDs (Adequate Readers) and as such followed the patterns of the main groups on EEG and behavioral data, therefore, no new information was added in the subgrouping procedure.

Low and Adequate Performance subgroups were not different on the Hix VAT or EEG results. Both groups had low verbal IQs. The size of the subgroups was small and may have accounted for the lack of results. A better separation would have been Low Performance-High Verbal versus High Performance-Low Verbal but the subjects were not available.

Tendencies for the right or left hemisphere to play a larger role were indicated but the differences were not significant. The Normals tended to show more processing on the right side for the VV and TK tasks, the MBIs tended to show more processing on the left side, while LLDs looked like Normals on the verbal tasks and MBIs on the TK task. The results support a process of integration between the two hemispheres over differential processing for the tasks involved.

The problem of who would benefit most from 40Hz. conditioning was approached by forming subgroups of learning disability children based on the available psychoeducational data. LLDs and MBIs are also subgroups but were diagnosed as such by the school. In none of the subgroups did all subjects show 40Hz. deficits. Hyperactivity, WRAT (all three subtests taken together) and WISC Performance variables did not appear to be good predictors of degree of 40Hz. deficit while WISC Verbal, WRAT Reading and Bender-Gestalt variables did. Poor reading and low verbal scores seemed to be most related to right hemisphere deficits while the other variables included deficits on both sides. Ackerman et al. (1971b) found reading and verbal deficiencies closely associated.

If the problem is one of delayed maturation and, as Klonoff and Low (1974) suggested, a critical time period is involved, the best prediction for improvement from 40Hz. conditioning would be for the LLDs since they were younger. If, as Hughes (1971) suggested, some learning disability children are manifesting central nervous system reactivity to their learning difficulties, the LLDs would again be the best candidates. Perhaps the answer is not one of eventual improvement, which would be predicted without treatment for the less educationally handicapped, but of quality of improvement, i.e., a shorter period of learning difficulties would result in less of a handicap or perhaps no handicap at all. As such 40Hz. conditioning would be of benefit if it were a faster method of treatment.

CHAPTER VI

SUMMARY AND CONCLUSIONS

EEGs were recorded on three groups of children classified as Normals, LLDs, and MBIs by the Aldine School District during resting and performance of verbal and nonverbal tasks. Normals performed better than both learning disability groups on all tasks but no differences were found between the LLDs and MBIs.

Computer analysis of the P_3-C_z and P_4-C_z leads divided the EEG into four 23% 1/3 octave bands centered at 30, 40, 50, and 70Hz. Normals had increases during the VV task in both leads in 40 and 50Hz. activity, during the VA task in both leads in 40Hz. activity, and during the TK task in the P_4-C_z lead in 40Hz. activity. MBIs had increases during the TK task in the P_3-C_z lead in 40 and 50Hz. activity. LLDs had increases during the VV task in P_4-C_z in 50Hz. activity and decreases in 30Hz. activity in both leads during the VV task and in P_3-C_z during the VA and TK tasks.

Subgroups were formed using psychoeducational test data from school records and behavioral and EEG comparisons were made between the subgroups and between the subgroups and Normals. The following conclusions were drawn from the data.

1. Learning disability children compared to Normal controls showed a 40Hz. deficit in the parietal area during performance of verbal and nonverbal tasks.

2. When grouped as to degree of learning disability LLDs (the less educationally handicapped) demonstrated more EEG abnormalities than MBIs.

3. A theory of delayed maturation manifested by the lack of "focused arousal" could be considered an explanation for the findings.

4. Right hemisphere deficits appeared to be more severe than left hemisphere deficits in the verbal tasks.

5. Differences in right-left hemisphere patterns of processing indicated that the MBIs might be having an integration problem between the two sides.

6. EEG activity in the Normals suggested that both hemispheres played active roles in information processing during the Hix VAT.

7. Hyperactivity, WRAT, and WISC Performance did not appear to be good predictors of degree of 40Hz. deficit while WRAT Reading subtest, WISC Verbal IQ and the Bender-Gestalt test did.

8. LLDs would probably benefit most from 40Hz. conditioning.

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APPENDIX A

Verbal Auditory Tasks

Verbal Auditory Arithmetic

I'm going to read an arithmetic problem to you. Listen carefully to the whole problem and then make the computation. Make sure you understand the problem before you try to compute the answer. You will have to do the computation "in your head." Shall we try one for practice?

If you earned $1.25 one day and $2.50 the next day, how much money would you have earned? (Ans. $3.75)

Do you understand? (yes, no) If no, try: If you had 10 oranges and you ate 3 oranges, how many would you have left? (Ans. 7) If yes...... Okay, let's start the game!

(1) If you had 11 race cars and you bought 5 more, how many race cars would you have? (Ans. 16)

(2) If you had 9 oranges and you ate 3, how many oranges would you have left? (Ans. 6)

(3) If you had 28 marbles and you gave 2 to your brother and 3 to a friend, how many marbles would you have left? (Ans. 23)

(4) If books are 50¢ each, how much will 4 books cost? (Ans. $2.00)

(5) If one book case will hold 52 books, how many books of the same size can be placed in 3 such book cases? (Ans. 156)

Verbal Auditory Rhyming

You know what a rhyme is, of course.... A rhyme is a word that sounds like another word. Two words rhyme if they end in the same sound, like "dog" and "hog".... I will give you a word and ask you to give me a word of a certain kind that rhymes with that word. Now let's try one for practice.

I want you to -- Tell me a number that rhymes with door -- FOUR

Do you understand this game? (yes, no) If no, try fruit that rhymes with chair answer pear... If yes... Okay, let's start the game!

(1) Tell me a musical instrument that rhymes with crumb -----Drum

(2) How about a vegetable that rhymes with parrot -----Carrot

(3) Now tell me a part of the body that rhymes with sung Tongue

(4) How about a fish that rhymes with church ----- Perch

(5) And a tree that rhymes with nine ----- Pine

Verbal Auditory Categories

In this game I am going to read four words to you. One of these words will not belong with the rest. I want you to tell me which word does not belong.

Now let's try one for practice.

Dog - Cat - Tree - Horse (Ans. Tree)

Do you understand this game? (yes, no) If no, try Desk - Table - Carrot - Chair

If yes... Okay, let's start the game!

(1) Bow & Arrow - Gun - Saw - Sword (Ans. Saw)

(2) Alligator - Lizard - Snake - Bird (Ans. Bird)

(3) Hat - Clock - Shoe - Coat (Ans. Clock)

(4) Eraser - Pen - Typewriter - Pencil (Ans. Eraser)

(5) Phono record - Ball - Bus token - Dime (Ans. Ball)

APPENDIX B

Tactile Kinesthetic Tasks

CIRCLE (BROKEN OUTLINE) TEST
(TACTILE-TACTILE)

In this game, I am going to let you feel with your fingertips a raised dot pattern made by glueing little circles of wood to boards in different arrangements.

> /Place stimulus form P-1-S in box, move subject's fingertips over the dots for 7 seconds. Do not place his entire hand over the stimulus form at one time./

Just move the tips of your fingers over the dots like I am doing for you. The shapes are not always completely connected, so you should explore the form a little to make sure that you are not missing any of it. Remember, use only your fingertips.

> /Remove stimulus form P-1-S from the box and replace with response form P-1-R./

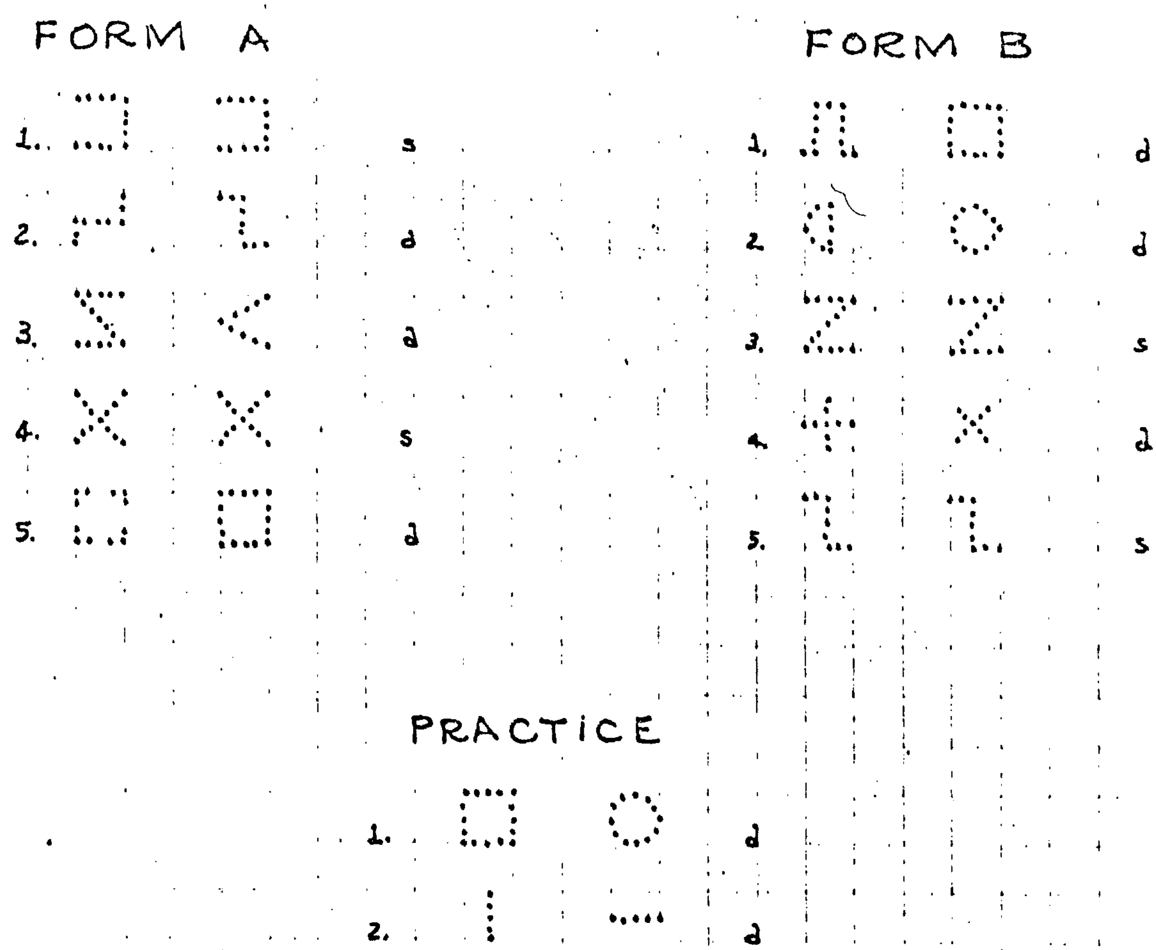
Now I have put another board with a raised dot pattern in the box. I want you to feel the dots on this second board. Use just your fingertips like you did on the first board. Are the dots arranged the same on this board as on the first board that you felt a moment ago?

> /Following the subject's response during practice, inform him of the correctness of his judgment by saying: "Yes, it is the same," or "No, it is not the same." No affirmations or corrections should be given during the test series./

> /Practice again with P-2-S and P-2-R. If subject appears to understand the task, continue with the test series./

Now that you know how to play the game, let's start! You're going to have to move your fingertips over the dots fairly rapidly, since you will be allowed to feel the dots on each board for only 7 seconds and then I will take the board away.

CIRCLE (BROKEN OUTLINE) TEST



WIRE NONSENSE FORMS
(TACTILE-TACTILE)

In this game, I am going to let you feel with your fingertip a piece of wire that has been bent into some shape and glued to a board.

> [Place stimulus form P-1-S in box and move subject's fingertip from one end of the wire, as indicated on the form, to the other end of the wire. The complete tracing of the wire should not exceed 7 seconds. Do not allow subject to place his entire hand over the stimulus form at one time.]

You may trace the wire with your fingertip only one time.

> [Remove stimulus form P-1-S from the box and replace with response form P-1-R.]

Now I have put another board with a wire form glued on in the box. Again use just your fingertip to trace this wire form just like you did on the first board. You may trace the wire form only one time. Has this second wire been bent into the same shape as the wire on the first board that you felt just a moment ago?

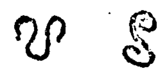
> [Following the subject's response during practice, inform him of the correctness of his judgment by saying: "Yes, it is the same," or "No, it is not the same." No affirmations or corrections should be given during the test series.]

> [Practice again with P-2-S, P-2-R and P-3-S, P-3-R. If subject appears to understand the task, continue with the test series.]

Now that you understand what you are to do, let's play the game. Remember, you can trace the wire only one time and you will have to move your fingertip along the wire fairly rapidly since I will take the board away after 7 seconds.

WIRE NONSENSE FORMS

FORM A

1.  d
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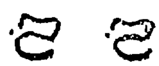
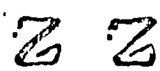
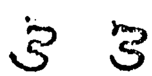
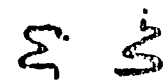
3.  s
4.  s
5.  s

FORM B

1.  d
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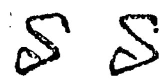
4.  s
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PRACTICE

1. 
2. 

MODIFIED SEGUIN FORMBOARD TASK
(TACTILE-KINESTHETIC)

In this game, I am going to let you feel with your fingertips a form like a circle, square, triangle, or some other form like this.

> [Place stimulus form P-1-S in box, move subject's fingertips around on the form, essentially around the edges, but not in an outlining motion, for 7 seconds. Do not place his entire hand over the stimulus surface at one time.]

Just move your fingertips around the edges like I am doing for you.

> [Remove stimulus form P-1-S from box and replace with response form P-1-R.]

Now hold this stylus in your hand like this, and I will move your hand around another form.

> [Put stylus in subject's hand. Make sure that he grasps the stylus firmly with his whole hand, as one would wrap his hand around a hammer handle. Starting at the point indicated on each form by a black arrow (the topmost point on each form), move subject's arm clockwise through the form, pausing approximately one second at each point of the course where there is a change of direction. Put subject's arm through only one complete circuit from the indicated topmost point clockwise back to the start point. Be sure that there is no finger or wrist movement, i.e., that all movement is elbow and/or shoulder movement.]

Is the shape of this second form that I have guided your hand through the same as the shape of the first form that you felt with your fingertips a moment ago?

> [Following the subject's response during practice inform him of the correctness of his judgment by saying: "Yes, it is the same," or "No, it is not the same." No affirmations or corrections should be given during the test series.]

> [Practice again with P-2-S and P-2-R. If subject appears to understand the task, continue with the test series.]

Now that you understand what you are to do, let's play the game! You're going to have to move your fingertips fairly rapidly, since you may feel the form for only 7 seconds and then I will take it away.

MODIFIED SEGUIN FORMBOARD TASK