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An Investigation of the Remediation of Learning Disabilities Utilizing EEG Biofeedback as Measured by Neuropsychological and Psychoeducational Tests, and EEG Spectral Analysis

Corinne Reed Bell

To the Graduate Council:

I am submitting herewith a dissertation written by Corinne Reed Bell entitled "An Investigation of the Remediation of Learning Disabilities Utilizing EEG Biofeedback as Measured by Neuropsychological and Psychoeducational Tests, and EEG Spectral Analysis." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Psychology.

Joel F. Lubar, Major Professor

We have read this dissertation and recommend its acceptance:

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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AN INVESTIGATION OF THE REMEDIATION OF LEARNING DISABILITIES UTILIZING EEG BIOFEEDBACK AS MEASURED BY NEUROPSYCHOLOGICAL AND PSYCHOEDUCATIONAL TESTS, AND EEG SPECTRAL ANALYSIS

A Dissertation
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Corinne Reed Bell

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This dissertation is dedicated to Jeffrey and Jennifer, my children whose intelligence, creativity, and presence in my life have provided a continuing focus for maximum achievement. Their mother gratefully acknowledges that their childhood and adolescence have been significantly altered by all efforts which have culminated in this product.

This is also dedicated to my deceased father and my two mothers. Robert N. Reed instilled in his daughter the belief of accomplishment and fulfillment of capabilities. My mother, Kathleen R. Reed, was successful in conveying the belief that "if it can reasonably be done, I can do it." Frances Bell, the informally adopted mother, provided a loving model for strength and perseverance as a mother/professional.

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ABSTRACT

The purpose of this research was to assess the feasibility of altering EEG activity in a manner which could enhance academic functioning for learning disabled (LD) students. The treatment group included four LD Caucasian males, ages 9-13. Results of treatment were measured by pre and post neuropsychological and psychoeducational evaluations, and spectral analysis EEG under three conditions: baseline, reading, and drawing. Training occurred over 31 sessions, twice weekly, utilizing EEG biofeedback. Electrodes were placed in positions T_5-F_7 or T_6-F_8 (International 10-20 System) for alternating sessions. Enhanced 8-15 Hz activity concurrent with reduced 3-7 Hz and muscle activity (>23 Hz) were targeted as desired effects.

Compared to Normal and LD Controls, statistically significant improvement was found with the LD Treatment group in reading comprehension and on the Bender Gestalt drawings. No other significant results were found among the neuropsychological or psychoeducational pre and posttesting, while a general improvement trend was noted for those treated. For the treatment group compared with controls the pre and posttreatment spectral EEGs revealed increased power in the 12-24 Hz range in left temporal and frontal areas during baseline and increased percentage power in higher frequencies for the left central and occipital areas while the children were drawing. During the reading condition, no significant differences were found for the treatment group. Biofeedback sessions were divided into three segments, prebaseline, treatment, and postbaseline. The data indicate that desired results during treatment occurred in 3 of 4 EEG frequency ranges.

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CHAPTER I

INTRODUCTION

An estimated 10% of most school populations have difficulty performing at the expected academic level (Silver, 1978). These children are typically classified into one of three categories of exceptionality: (1) mental retardation (MR), (2) emotional disturbance (ED), or (3) minimal brain dysfunction (MBD). The latter group has a variety of definitions, but commonly refers to hyperkinetic (HK) children and/or those who are learning disabled (LD).

The difficulties facing the LD child are typically described in terms of academic underachievement, or when "there is a discrepancy between potential and actual success in learning" (Myklebust, 1968, p. 1). Cruickshank (1983) describes learning disabilities as problems in acquisition of developmental, academic and social skills, and related emotional development. He considers these the result of neurologically based perceptual processing deficits which can occur during prenatal, perinatal, or postnatal periods. The learning difficulties occur in the presence of average or above average intelligence. Demonstrated difficulties can be in one or more areas such as reading, math, spelling, writing, language, etc., and are thought to be related to dysfunction in the following:

1. Visual perception

2. Auditory perception
3. Expressive language
4. Receptive language
5. Memory
6. Motor functioning
7. Concentration
8. Attention span
9. Cognitive processing (i.e. sequencing, abstract thinking, organization of information)

LD children consistently differ from each other, typically demonstrating unique combinations of deficits contributing to observable symptoms in those areas just mentioned. Heterogenous etiology of underachieving students was demonstrated by Conner (1973), as he evaluated the learning and/or behavioral disorders of 267 children, ages 6-12 years. Analysis of test scores yielded groups of five major factors (I.Q., achievement, rote memory, attentiveness, and impulse control) from which six types of specific profiles surfaced. Additionally, there were differences found between groups regarding responses to medication, motor development, and evoked responses to both visual and auditory stimuli. Considering the infinite combinations of symptoms and treatment responses that occur across children, it is obvious that families and educators experience confusion in understanding and accepting the performance levels demonstrated.

Further, the question is raised as to whether or not the term "learning disability is a definition of anything. This concept is typically utilized in reference to skill weaknesses in areas of expected academic competence. In contrast, relative gross motor deficits of similar etiology are not usually labeled as learning disabled, when the child is performing adequately in school. This appears to result from only limited societal demands on such capabilities. Two surveys were administered regarding the meaningfulness of the learning disability label (Tucker, Stevens, & Ysseldyke, 1983). The samples included researchers, teacher trainers, and policy-makers in the field of special education. An overwhelming majority in both surveys were adamant that learning disabilities is a viable classification and clinically identifiable. Due to the multiple combinations of deficits there are those who consider weaknesses of the labeled LD child as not being unusual, only limiting in one or more areas. Ames (1983) asserts that the LD diagnosis has been applied too loosely to numbers of children who are simply underachievers. Myklebust (1983) emphasizes that just because there is disagreement regarding definition, is no reason to discount the existence of learning disabilities. It has been suggested that research could be better refined by treating and comparing LD groups with certain symptoms exclusive of others (Mann, Davis, Boyer, Metz, & Wolford, 1983).

As there is confusion about the definition of learning disabilities, likewise there are contradictions regarding diagnosis. Significant discrepancies among professionals have been reported as to how test data would be interpreted (Ysseldyke &

Algozzine, 1983). They report previous research wherein data from normal students were interpreted as that of a LD student as well as the reverse. Cruickshank (1983) infers that programming is probably worthless without adequate diagnosis.

Teachers, parents and peers frequently view these students as disinterested and the children perceive themselves as failures. Thus, social maladjustment and low self-esteem result which further complicate diagnoses and treatment plans. Poremba (1975) discusses the connection of juvenile delinquency with learning disabilities, quoting various studies demonstrating that 25-75% of court offenders and/or incarcerated adolescents have some history of organic brain dysfunction or school underachievement.

Etiological factors, which continue to be debated, underlie theoretical approaches to diagnostic and treatment methodology. The following will include discussions of etiological theories regarding learning disabilities, diagnostic procedures, treatment techniques, and rationale for the current study.

Etiology

While LD children are specifically under investigation in the present research, the difficulty in differentiating between LD and HK children must be acknowledged. Research by Lahey, Stempniak, Robinson, and Tyroler (1978) found HK and LD children to be relatively different. However, Silver (1975) reports that 38% of LDs are hyperactive and 94% of HKs demonstrate learning disorders.

It is apparent from these statistics that common symptoms are frequently shared between the two groups which creates complications in making differential diagnoses for treatment and research purposes. Therefore, it is difficult to find a body of literature that offers a clear picture, clearly delineating either group. Thus, both syndromes will be discussed concurrently.

In regard to hyperkinesis, Kinsbourne and Swanson (1979) discuss Kinsbourne's previous writings in reference to three views of the underlying causes of hyperkinesis: (1) a deficit, (2) a delay, or (3) a difference. Important to note is that many professionals align their assertions, and/or etiological understanding of learning disabilities, as well as hyperkinesis, with one of these views.

The Deficit Model

This refers to the idea of specific brain damage as the causal factor resulting in inability to develop particular skills and the manifestation of hyperactive behavior. Kinsbourne and Swanson's literature review reports examples of known brain-damaged children and adults who exhibit hyperactive behavior. However, Werry (1968) reports numerous studies which indicate that attempts to trace HK symptoms to brain-damaging events have led to conflicting results. Basically, when brain-damaged children have been compared with controls, research has failed to show hyperkinesis occurring more frequently in the former, than in the latter. This is generally consistent in the literature with the exception of several studies reported by

Werry and Sprague (1970), which establish that damage to several areas of the brain can produce significant changes in activity levels. Therefore, it might be considered that the presence of hyperkinesis does not necessarily imply that brain damage has occurred, but when it does occur, an increase in activity level and/or learning problems are more likely to result.

In discussing organicity as an etiological factor, Ross and Ross (1976) cite Stewart and Old's writings which provide an estimate of less than 10% of HK referrals having histories indicating brain damaging events. They further point out that the occurrence of birth process complications is no greater among HK children than among the general population. In a comparison of neurological, EEG, and perinatal abnormalities in HK and neurotic children, Werry, Minde, Guzman, Weiss, Dogan, and Hoy (1972) found no difference in frequency of prenatal, perinatal, or postnatal events that might have contributed to organic damage. However, it was noted that the birth weights of the HKs were slightly lower than those termed neurotic. In pediatric literature, it is now accepted that lower birth weights are predictive of an infant being considered high-risk.

Most fundamentally, Cruickshank (1984) asserts that "all learning is neurological." He emphasizes that the neurological system is utilized by all sensory modalities and that no learning can occur without involvement of the nervous system. Therefore, when a perceptual disorder is present, including processing of information, a neurological deficit can be assumed. Secondarily, Cruickshank addresses conditioning as part of the learning process, while remaining clear that if neurological functions are not intact, adequate conditioning cannot occur.

The Delay Model

This model, which is often used as an explanation for HK and LD, is frequently described as maturational lag. Kinsbourne and Swanson (1979) refer to Werry's notion that HKs may have a delay in cognitive development contributing to specific deficiencies. Such a delay could obviously contribute to a child having difficulty learning at the expected level. Buschbaum and Wender (1973), based on their research with visual and auditory average evoked responses (AERs), contend that immaturity is present in HKs, both clinically and experimentally, which supports the developmental delay theory. When Zambelli, Stamen, Maitinsky, and Loiselle (1977) presented selective attention tasks to adolescents and recorded auditory AERs, their observations of clinical symptoms were further supportive of this model. The two previously mentioned studies may be questionable as they both utilized auditory stimulus without screening for auditory dysfunction, recruitment, or perception.

While the delay model is accepted by many practitioners and investigators, there is contradictory information. Shouse and Lubar (1977) treated four HK subjects with operant conditioning of sensorimotor rhythm (SMR) on and off methylphenidate. This treatment design was based on the premise that conditioned increases in the SMR are accompanied by enhanced voluntary motor inhibition. With success in three of the four subjects decreasing activity level and increasing SMR, the authors concluded that the effects of maturation were minimal.

Substantial support for the maturational lag comes from the general notion that hyperactivity disappears and that learning problems are frequently compensated for in adolescence. Too frequently, little thought is given to the possibility that hormonal changes might be responsible for improved functioning. Further, numerous studies cited by Kinsbourne and Swanson (1979) provide information suggesting that the symptoms carry over into later years. Dykman and Ackerman (1976) report their previous support for a neurodevelopmental lag thesis based on specific research findings. After reviewing numerous follow-up studies and completing their own, they have since doubted their original contentions as they noted indications of MBD symptoms lagging into mid-adolescence. However, it should not be ignored that many of the observed symptoms could be learned behaviors having become a part of overall adaptive behavior patterns. Obviously, the pertinent question regarding the delay model is: If there is a lag, why do LD and HK symptoms continue in some individuals through adolescence?

The Difference Model

This model conceptualizes a difference between HKs and normals. Kinsbourne & Swanson (1979) find this the most useful, considering the basic differences in individual personality styles, temperaments, physiological functioning, etc. Wender and Wender (1978) assert that "in virtually all instances hyperactivity is the result of an inborn temperamental difference in the child. How the child is treated and raised can affect the severity of his problem but it cannot cause the problem" (p. 21).

The contention that hyperkinesis is a result of basic temperament differences relates to numerous areas of investigation. One most frequently considered is the idea that some children exhibit reduced central nervous system (CNS) arousal, while a group showing increased CNS arousal has been identified. Lubar and Shouse (1977) discuss this distinction as they describe two types of HK children. There are those with a low-aroused CNS in which the overactivity is thought to reflect over-compensatory, self-stimulating behavior that serves to activate an abnormally sluggish system. Then there are those with a high-arousal CNS who are presumed to exhibit excessive activity that would be commensurate with the over-excited state of the nervous system. Pertinent to this particular study is an assertion by Chalfant and Sheflin (1969) that children with specific learning disabilities have CNS processing dysfunctions which directly interfere with certain types of learning.

Silver (1971) discusses the CNS arousal issue in terms of arousal System I, the ascending reticular activity system (RAS) and arousal System II, the limbic system. Reporting the work of several investigators, Silver states

> the two arousal systems are functioning in an integrated fashion; each suppressing the activity of the other. This reciprocal inhibition allows for the two systems to be in a state of dynamic equilibrium. An imbalance in one would affect the functioning of the other (p. 127).

System I dysfunctioning is thought to contribute to hyperactivity, distractibility, and short attention span, and in turn creates dysfunction in System II. This results in perceptual and learning problems and other LD symptoms. Silver infers that the balance or imbalance of these interacting systems could partially explain the neurological basis for an LD syndrome. Perseveration might be an example of malfunction of inhibiting mechanisms.

A review of psychophysiological studies involving only heart rate (HR) and skin conductance (SC) indicated that an attentional deficit exists with LD children (Dykman, Ackerman, Holcomb, & Boudreau, 1983). They differentiate between involuntary (automatic) and voluntary (effortful) attention. LD children do not necessarily differ from normal achievers on involuntary attention tasks, while HR and SC vary significantly when sustained voluntary attention is required. Methylphenidate has been found helpful in normalizing this trait. The authors conclude that there is a selective attention deficit in LD children. A lack of efficiency in switching from an involuntary to a voluntary attention mode is indicated, in addition to the problem LDs have with sustaining effortful attention. It is hypothesized that the resistance to switching is related to a mechanism in the diencepholon which controls changing from involuntary to voluntary attention. Research has led to the belief that LDs are physiologically more passive and difficult to arouse. The likelihood of too much inhibition in non-hyperactive LDs is suggested (Dykman et al., 1983).

A second area of investigation which relates to the difference model is a possible biochemical basis for hyperkinesis. Silver (1978) cited studies suggesting that hyperkinesis may be related to an abnormal balance in metabolism of the monoamines (serotonin, norepinephrine, and dopamine) most likely in the ascending RAS. It is thought that there are low cortical levels of norepinephrine, with a consequent deficiency in the inhibitory system. As amphetamines are chemically similar to norepinephrine, the intake of these drugs can facilitate increased levels of the neurotransmitter.

Genetic transmission could also be considered with this model and has been explored in numerous studies. Familial factors are strongly indicated by two studies of the frequency of psychiatric problems and childhood MBD in the relatives of patients with MBD. Cantwell (1972) administered psychiatric examinations to parents of 50 HK children and 59 normals. The results were in agreement with a similar study by Morrison and Stewart (1971) which suggested that significant differences between the groups of control and HKs were in higher prevalence of sociopathy, alcoholism, and hysteria. While incidence is high, these studies suffer from use of "non-blind examiners," in addition to questions regarding environmental factors which could conceivably induce the symptoms in HK and LD children.

In an attempt to answer the environmental question, Morrison and Stewart (1973) studied relatives of adopted children, which indicated no excess of psychopathology among adoptive parents as compared with biologic parents of HK children. Another approach to the genetic question is the utility of twin studies. Lubar and Shouse (1977) point out that the Lopez (1965) twin research is inconclusive due to a disproportionate number of fraternal twins being of unlike sex. However, adverse developmental effects are being considered in relation to the impact of toxicity and maternal emotions on the fetus in utero. Extensive knowledge is now available that chemicals and foods ingested by the mother during pregnancy have direct effects on the outcome of the child. For example, it has been frequently reported that smoking mothers have a larger number of low birthweight infants.

Regarding neurological differences of LD children, hemispheric differences are strongly considered. Obrzut and Hynd (1984) are convinced that reading-disabled children have specific brain cortical anomalies. They discuss the work of Drake (1968) who reported the first autopsy of an LD child. This revealed "an abnormal convolutional pattern in both parietal lobes." Also, the fibers in the corpus callosum were found to be thin. In a later autopsy Obrzut and Hynd reported that symmetrical temporal lobes were found in a dyslexic, when in normals the left one is usually larger. In this case the left hemisphere was abnormally developed in many ways. These authors believe there is clear evidence supporting neurodevelopmental abnormalities impacting on the cortical regions important to learning.

In contrast, a study was made of computerized tomography (CT) scores for 32 LD children who had been determined to have subtle asymmetric differences (Dencklo, LeMay, & Chapman, 1983). Radiologists who had no knowledge of neurological history found only five of the CT scans indicative of structural abnormalities. Ventricular size was found abnormal in only one of the 32 subjects.

It appears that of the three models discussed that the idea of delay, or maturational lag, has only limited support and is highly theoretical. Developmental delay seems to be a misnomer. Perhaps an immaturity in functioning does exist for some, but children frequently do not "catch up," as a delay would imply. Practitioners find numerous adolescent students who have been LD and/or HK as youngsters, and whose deficits (reading and other basic skills) continue into the secondary school years with intellectual functioning being average or above. The idea of a deficit or difference being etiologically responsible for the abnormal functioning of these youngsters appears to be more logically based and acceptable. In fact, it appears that a delay or deficit in functioning would represent a difference in children with observed limitations, compared with others.

While numerous cases of hyperkinesis and learning disabilities cannot be directly related to an occasion of brain damage, there are occurrences of known brain damage which are followed by learning problems and overactivity. The unknown factor with all infants is the amount of brain trauma that occurs before or during birth, either from intrauterine conditions or from minor head injuries. Most likely, such incidences, along with genetic and social factors, are explanation enough for the difference notion as a cause of the problems in question. While Wender's notion of "inborn temperamental differences" is much too limiting, as it places the problem of hyperkinesis in the emotional realm, the difference model appears most logical when one considers the reality of inborn individual differences for a multitude of reasons. For example, as has been previously pointed out, birth weights of HK children and high-risk infants are often lower.

Further, regarding overlap of deficits and differences, when brain damage occurs it is likely that in many cases a biochemical imbalance, such as Silver (1978) discussed, will result. He points out that this phenomenon is most highly suspected in the RAS. This is one of the brain areas pointed out in the Werry et al. (1970) discussion of former studies regarding change in activity level resulting from brain damage.

Perhaps for purposes of clarity it is helpful to consider specific models of probable causality. However, in reviewing the deficit, difference and delay notions, at once it can be seen that they should not be considered discrete and without overlap. Neither alone completely explains the etiology of problems presented by either LD or HK children.

Diagnostic Procedures

Effective diagnostic methods for making differential diagnoses of hyperkinesis and learning disabilities are limited. The identification of learning disabilities usually begins with teachers and/or parents observing school underachievement and/or a high rate of distractibility. While other symptoms may be noted, such as dominance confusion, directional problems, or difficulty telling time, school underachievement is frequently the beginning point for diagnostic assessment. Psychoeducational assessment batteries which are commonly administered for suspected MBD children, typically consists of a combination of the following:

1. Intelligence tests (Wechsler Scales, Stanford-Binet, McCarthy Scales of Children's Abilities, etc.).
2. Tests of perceptual-motor development (Bender-Gestalt or Developmental Test of Visual Motor Integration).
3. Projective drawings (Human Figure Drawing or House-Tree-Person, administered for information regarding developmental, fine-motor, and emotional status).
4. Achievement tests (Woodcock-Johnson, Spache Reading Diagnostic Scales, Wide Range Achievement Test, etc.).

In addition, when considered necessary by the examiner, other tests for specific functional deficits are administered. Examples include the Wepmen Test of Auditory Discrimination and Peabody Picture Vocabulary Test for receptive language. Further, when more detailed and extensive diagnostic information is desired, the Halstead-Reitan

Battery, The Quick Neurological Screening Test, The Luria-Nebraska Battery for Children, or other instruments which yield neuropsychological information, can be utilized. In addition, electroencephalograph technology is currently being developed and refined for purposes of differential diagnoses with LD children. The following will include description and discussion of diagnostic techniques pertinent to this study.

Intelligence--The Wechsler Scales

Numerous instruments which measure intelligence are available, while diagnosticians for school age children typically prefer the Wechsler Intelligence Scales for Children-Revised (WISC-R), which is David Wechsler's revised edition of the WISC. This is particularly true for children ages 6-16, suspected of learning disabilities. This instrument is often favored over other intelligence tests as the Wechsler Scales provide numerous measures which can be interpreted in different ways, making it possible to ascertain skill deficits and strengths. There are 12 subtests, 6 classified as Verbal and 6 as Performance. The cumulative data yield a Verbal Intelligence Quotient (VIQ) and a Performance Intelligence Quotient (PIQ), which together formulate a Full Scale Intelligence Quotient (FSIQ).

Each subtest utilizes a mixture of expressive, receptive, and cognitive modalities. Strengths and weaknesses can frequently be determined by observing trends among subtests requiring similar abilities. Analysis of this type refers to subtest scatter, or high and low peaks on the WISC-R profile. Further, the similarity or difference in VIQ and PIQ provides additional diagnostic information. A better overview can be obtained by integrating both variance among among subtest scores and VIQ and PIQ difference.

Verbal IQ and Performance IQ. The difference in PIQ and VIQ can be significant in determining major deficit areas, such as in receptive and/or expressive language with a low VIQ. Wikler, Dixon, and Parker (1970), in a study attempting to determine psychometric, neurological, and EEG differences in learning and/or behavior disordered children, found that HKs had more difference in PIQ and VIQ than non-HKs. Subject selection in this study is questionable as some were chosen based on academic skills alone. Differences have also been found in children classified as emotionally disturbed. They perform significantly higher on Performance than Verbal subtests (Dean, 1978; Nahas, 1978).

Wells (1973) explored the Verbal Performance discrepancy question with a group of 8 year olds experiencing academic difficulties. Statistics reflected that the higher VIQ group (VIQ higher than PIQ), when compared with the higher PIQ group, scored significantly higher on the Reading subtest of the WRAT and the Illinois Test of Psycholinguistic Abilities. Research with LD children (ages 9-14), in which a number of perceptual and achievement tests were administered, resulted in the higher VIQ group performing significantly better than the higher PIQ group on verbal and auditory perceptual tasks (Rourke, Young, & Flewelling, 1971). The higher performance group demonstrated significantly better skills on tasks requiring visual-perception skills.

While the various studies discussed support of the VIQ-PIQ discrepancy as a useful diagnostic tool with learning disordered children, there are contradictions in the literature. A review and analysis of diagnostic findings in a study of LD children, ages 6-15, did not yield patterns which would support utilizing the VIQ-PIQ difference as a diagnostic measure for learning disabilities (Rice, 1970). Research since continues to show a similar trend (Vance, Gaynor, & Coleman, 1976).

However, if the deficit model discussed in the previous section is to be considered plausible, Reitan's (1981) presentation of his own research suggests that the VIQ-PIQ difference is important in regard to diagnosing and localizing brain damage. Thirteen of 14 subjects with diagnosed lesions of the left hemisphere had lower verbal scores and 15 of 17 with right hemispheric lesions had lower performance scores. Similar results were found in an additional study of 32 patients with known brain damage. Research with 108 LD subjects referred for reading difficulties investigated the hypothesis of a left hemisphere lag. Parts of the WISC were used with other tests which were categorized as left or right hemisphere tasks. One hundred and five subjects performed best on tests attributed to left hemisphere functioning (Harness, Epstein, & Gordon, 1984).

While it would not be appropriate to utilize a significant VIQ-PIQ discrepancy as an isolated indicator, research strongly suggests the validity of considering it as one indicator within a total diagnostic profile. Numerous studies reflect that in children learning problems, PIQ is more often higher than VIQ (Anderson, Kaufman, & Kaufman, 1976; Feeler, 1975; Griffiths, 1977, Smith, 1978). The Anderson et al. (1976) study reported a mean VerbalPerformance discrepancy of 12.5 points (S.D. = 9.5 points)

Utility of subtest scatter. Variance among subtest scores must be statistically significant before importance can be assigned as an indicator for diagnosing learning disabilities. The WISC-R Manual presents research indicating that a meaningful variance between any two subtests would range from 2.35-3.45 points (mean subtest scaled scores = 10), depending on the subtests being considered and the age of the child. In contradiction, Kaufman's research (1976) indicated that with normal children, the mean range of scatter is 6 to 7 points. Selz and Reitan (1979) point out the importance of considering the relationship of FSIQ with subtest scatter. They devised a scoring system for the adolescent version (ages 9-14) of the Halstead-Reitan Neuropsychological Test Battery, which includes a formula for measuring the severity of scatter as it relates to FSIQ.

Numerous researchers have found subtest scatter to be pertinent in diagnosing LD children (Gajar, 1978; Gross & Wilson, 1974; Laufer, 1979; Safer & Allen, 1976; Silver, 1978). Gajar (1978) found LD children to be distinguishable from emotionally disturbed and educably mentally retarded groups (EMR) by high subtest scatter.

Profiles of EMR students will tend to reflect little scaled score variance. The following sections discuss two methods which utilize subtest scatter for diagnostic purposes.

1. Recategorization of subtests into meaningful groups is found useful by many investigators and diagnosticians. Bannatyne (1968) developed a model of three categories which has been widely used in WISC research, and has since evolved to five categories. Initially he included: (1) Spatial, composed of Block Design, Object Assembly, and Picture Completion; (2) Conceptual, which included Vocabulary, Comprehension and Similarities; and (3) Sequential, utilizing Digit Span, Coding, and Picture Arrangement. Rugel's (1974) review of WISC profiles produced information which supported Bannatyne's model and encouraged him to add a fourth category of Acquired Knowledge which was based on scores from Arithmetic, Information, and Vocabulary. At the same time, based on Rugel's work, Bannatyne found Arithmetic to be more important to the Sequential category than Picture Arrangement, and therefore made these changes in his recategorization scheme. Vance and Singer (1979) added the fifth category of Distractability which included Arithmetic, Digit Span, Coding, and Mazes. After testing 98 students in 10 learning disability classrooms they found that 71% of the subjects ranked lowest in performance on Distractability and none ranked highest.

In viewing methods utilizing subtest scatter for diagnosis of LD children, the most logical approach might be similar to that of Vance, Wallbrown, and Blaha (1978). They researched WISC-R scores of children with reading deficits and found five types of profiles that occur in approximately 75% of reading disabled students. It was reported that successful prescriptive teaching techniques had been tailored to the five profile types.

2. Patterning of subtest scores is often researched, in attempts to develop profiles typical of different types of handicaps. However, results in the literature vary to the extent that only limited consistent information is available. The difficulty in this approach would relate to the varied skill deficits found among LD children. Rugel (1974) utilized Bannatyne's (1968) recategorization system in reviewing 25 studies reporting patterns of subtest scores. He found that LD's generally performed best on Object Assembly, Block Design, Picture Completion, and Picture Arrangement. Lowest scores were present on Arithmetic, Digit Span, and Coding.

Later research reflects inconsistencies in WISC-R patterns to the extent that no fully reliable profile seems to be available (Huelsman, 1970; Vance et al., 1976). In considering the research results and Rugel's summary, consistent difficulties with LDs appear to be related to memory, auditory comprehension, and attention span, while more success seems to be found on tasks which are spatially oriented and relative to environmental awareness. Performance on the Coding subtest is most frequently found to be low throughout the literature (Ackerman, Dykman, & Peters, 1976; Bradley, Battin, & Satter, 1979; Huelsman, 1970; Millich & Lonly, 1979; Rugel, 1974; Vance et al., 1976). Reitan asserts that of the Wechsler subtests, Coding is the single most important indicator of overall integrity of cortical functioning. Therefore, Coding, as compared to the other subtests, has become an important diagnostic factor (Reitan, 1981).

The research reveals that most clinicians learn from experience that the best diagnoses are obtained from a comprehensive overview, utilizing various approaches to available data. This is especially true with LD children, considering the multiple combination of possible skill deficits, and that remedial programs must be individually designed. In a review article of WISC-R research Kaufman (1983) finds no empirical evidence supporting utility of subtest scatter for making a differential diagnosis. Subtest scatter has not been found to be significantly greater with LD children than with normals. However, the research summary reveals that the Verbal-Performance dichotomy is significantly greater for LDs, compared to normals. Based on available research Kaufman (1983) finds encouragement that variance among subtests can be constructively utilized in regard to determining strengths and weaknesses. Doing so can be an asset to making treatment plans. Multiple studies support the efficacy of using recategorization models (such as Bannatyne's).

Tests of Perceptual Motor Development

Impaired visual-perception is thought to be a major factor in reading and math disabilities, as well as in such tasks as telling time. A visual-perception disorder frequently causes children to reverse and rotate letters and words, and experience general difficulty with symbols. The Bender-Gestalt Test is frequently used in regard to these functions. It consists of nine 2-dimensional geometric designs which the subject is requested to copy on blank paper. Accurate reproductions not only require adequate visual-perception abilities, but also well developed visual-motor and fine-motor skills (Frostig, 1968; Laufer, 1979). Therefore, inaccurate drawings may be reflective of motor encoding as well as visual perception deficits. However, with consistent rotations of 90°-180°, an examiner would find it difficult to discount a visual-perception deficit. With young children, Beery's Test of Visual-Motor Integration is frequently considered more appropriate, as it provides structure. The designs are presented inside squares, with attached blank squares for reproductions. Additional diagnosit information can be obtained by using both simultaneously, in order to determine how the child functions with or without structure.

Further information regarding visual-perception disorders can be obtained from observations, such as with the Block Design subtest of the WISC-R, when there are apparent rotations or confusion in copying these three dimensional designs. Other diagnostic instruments are also available, as well as geometric designs being included in intelligence tests such as McCarthy Scales of Children's Abilities, and the Wechsler Preschool and Primary Scales of Intelligence. These tests are designed for younger children.

Achievement Tests

In order to measure levels of academic functioning, achievement tests are typically used. The WRAT is commonly utilized as a screening instrument to obtain measures in spelling, math, and word recognition. This test yields standard scores, grade levels, and percentiles. With LD children, standard scores are especially helpful in determining discrepancies between expected and functional levels.

The Spache Reading Diagnostic Scales provides only grade level measures for both word recognition and comprehension. The comprehension portion is administered both orally and silently. In the Knox County School System (TN), school psychologists and resource teachers found the Spache to reflect reading comprehension approximately one grade level above actual student performance, compared to grade levels of textbooks. Other more comprehensive achievement tests are now more frequently used, such as the Woodcock-Johnson.

Neuropsychological Measures

Diagnoses based on the traditionally administered psychometric batteries have been criticized due to erroneous conclusions resulting from an additive approach in utilizing isolated data such as scaled scores. The Reitan-Indiana Neuropsychological Battery, which evolved from tests developed by Halstead (1947) and Reitan (1955, 1966), presumably overcomes that deficit as the results are compiled in an integrative fashion. The Reitan subtests compare various abilities that relate to differential functioning of specific brain areas and permit comparisons of hemispheric functioning. Thus, a more accurate assessment of brain dysfunction can be made, with results providing more reliable information in regard to localization and etiology (Filskov & Goldstein, 1974; Reitan, 1964). As in most tests related to brain functioning, skill in interpretation, familiarity with the tests, and sound knowledge are important factors. The reliability of this battery has been well-demonstrated (Reitan & Davison, 1974; Vega & Parsons, 1967). A significant correlation between the Reitan battery and electroencephalograms (EEG) was found in research by Klonoff and Low (1974).

Historically, research and utility of this battery centered around adult populations. The Halstead Impairment Index (Halstead, 1947) has been found to be a reliable criterion in determining if organic involvement is present. This index was originally based In 10 subtests, each of which is independently judged as pass or fail. A failure of 40% of the subtests or greater would be considered significant. In addition to this measure, further information is obtained from the same and other subtests to assist in determining location, etiology, and degree of dysfunction.

Distinctly objective methods for analyzing results of this test battery have been implemented. Computerized systems of analysis (Finkelstein, 1977; Russell, Neuringer, & Goldstein, 1970) were developed with cross-validation research between these systems and the Impairment Index, indicating that the utility of the computerized systems was questionable (Anthony, Heaton, & Lehman, 1980). The Halstead Impairment Index was found to be equally reliable in diagnosing the presence or absence of organic involvement.

In regard to children, a more recent system of analysis for the Halstead Neuropsychological Test Battery for Children has been devised (Selz & Reitan, 1979). The scoring system utilizes 37 rules which resulted from analysis of test protocols of pilot subjects (Selz, 1978), and applies to children, ages 9-14. Each of the 37 items is given a weighted score of 0-3, with 0 representing no difficulty and 3 representing greatest difficulty. This is true except for items on the Aphasia Screening Test, which are scored pass/fail in assigned values of 0, 1, 2, or 3, in accordance with the level of significance an individual item is given, regarding its value in predicting brain damage.

In researching these rules, Selz and Reitan found three distinct groups which differed significantly beyond the .001 level. As subjects were tested, 73.3% were correctly classified. Neuropsychological test scores of 75 previously documented normal, LD, and brain damaged (BD) children are presented in Table 1, with 25 subjects utilized in each group.

Table 1. Reitan Neuropsychological Test Scores for LD and BD Children

Group	Range of Scores	Mean	Standard Deviation
Controls	1-25	10.60	6.62
LD	8-43	24.44	9.61
BD	11-74	40.60	18.51

These results provided differential diagnostic score categories of 0-19 for normals, 20-35 for LD, and 36 or greater for BD. Reitan (1981) concluded that LDs perform more like the normal subjects on tests of lower level functions, and more like brain damaged subjects on higher level functions. He further encouraged clinicians to utilize sensitivity, interviews, and experience in drawing conclusions. For example, a child could score within the LD range and the data could be taken at face value. However, a recent change in functioning might indicate a growing lesion or some other form of pathology, and should not be ignored.

The neuropsychological assessment approach can be considered an important asset in diagnosing learning disabilities. In the Selz and Reitan (1979) research, neurological examinations of the LD children yielded what appeared to be normal functioning, while test results reflected dysfunction in higher level cognitive processes. Therefore, it seems plausible that the classic LD child is lacking discernible structural damage, while functional neurological impairment can be present which interferes with higher level processes. In the majority of cases, this type of dysfunction can be diagnosed neuropsychologically when other methods fail to produce definitive results.

Electroencephalography

Electroencephalogram (EEG) recordings are obtained through scalp electrodes which transmit electrical activity of the cortex. The electrically amplified patterns are mechanically drawn on paper, providing data that can be examined and analyzed. The four major frequency patterns include: (1) Delta, 1-3 hz (deep sleep); (2) Theta, 4-7 hz (beginning sleep stages); (3) Alpha, 8-13 hz (relaxed awake stage); and (4) Beta, 14 or greater hz (alert).

Interpretation of EEGs relies on recognition of signs which are considered abnormal. Clear-cut abnormalities can be denoted with occurrence of the following:

1. paroxysmal spike-wave discharges
2. paroxysmal polyspike complexes
3. repeated focal spiking or slowing
4. amplitude asymmetries greater than 50%
5. marked and diffuse dysrhythmias.

The following abnormalities are considered questionable signs in regard to diagnosing from EEGs. Doing so requires keen clinical skills, with data being interpreted in light of other signs and symptomatology. They are as follows:

1. 14 and 6 per second positive spikes
2. occipital or posterior temporal slowing
3. nonfocal sporadic sharp waves
4. excessive slowing or amplitude
5. mild diffuse dysrhythmias

In an attempt to provide substantial normative data, Matousek and Peterson (1973) administered EEGs to 400 normal children and 160 adolescents. Their results revealed specific age dependent differences and appear to be valid. However, utilizing this information has limitations as John (1977) found that EEGs of 9 year olds in the United States vary from those reported by Matousek and Petersen. This suggests differences according to cultures and that similar domestic information is needed.

The traditional EEG is administered during an approximate 30 minute time period and requires an extensive and cumbersome amount of paper. A considerable amount of time and skill is needed for accurate interpretation which is highly subject to error, due to disagreement in clinical interpretation. However, EEGs are relatively reliable in diagnosing structural lesions, tumors, and seizure activity. The Fast Fourier power spectral analysis is a more advanced and accurate method which reflects the entire EEG on a single page, allowing for easier interpretation. The Fast Fourier system utilizes bandpass filters. The filter is built around operational amplifiers and with its component parts, operates as an analog computer. The software performs the Fast Fourier Transform which reduces signals to "pure sinusoids and cosinusoids and their relative amplitudes or power" (Lubar & Culver, 1978). All of the functions of the system are internally managed by the computer, with EEG signals sampled at a high speed. Data sampling is repetitive and averaged in a sophisticated manner over a preprogrammed time period (epoch). Statistical accuracy is a function of the number of epochs averaged and epoch length (Lubar & Culver, 1978). For the purposes of this research, data acquisition occurred over epoch intervals of 16 seconds.

Comparing spectral analyses with conventional EEGs, data validity is enhanced as the filters utilized screen out electrical noise that would otherwise cause artifacts. One needs to be aware that clinical interpretation can still be confused by artifacts from eye movements.

John (1977) has made considerable contributions in this area, utilizing a standardized set of EEG recordings and average evoked potentials. These measures reflect sensory, perceptual, and cognitive processes. Norms are being developed for John's Neurometric Battery (NB) with the expectation that specific cognitive deficits in LD children can be diagnosed. Preliminary results show that NB measures are sensitive indices with LD children as well as differentiating among defined LD subgroups. Of special interest is the fact that the data can be collected in two minutes of transmission time. Once refined and appropriately normed, it seems that NB measures will clearly differentiate learning disabilitis as a primary disorder when other symptoms are present, such as emotional factors, which tend to interfere with differential diagnoses.

Conflicting research results suggest that the utility of EEG measures in diagnosing MBD is questionable. The following will provide a summary of the available literature in respect to EEGs with both LD and HK children, though these groups cannot be considered mutually exclusive.

Learning disabilities and electroencephalography. EEG abnormalities found in LD children are largely those of the previously mentioned questionable type. Additionally, Schain (1970) reports 5-10% occurrence of definite abnormalities. Hughes (1976) reviewed multiple studies in which reported EEG abnormalities in LD children ranged from 25% to 95%.

With all data combined, an average of 45$ incidence was reported in Hughes (1976) summary. These data reflect results from a larger population and would likely be a more accurate report of the extent to which EEG abnormalities exist in LDs, than the results from Schain's single (1970) study.

This assertion is heightened by John's (1977) more precise EEG recordings which indicated that 49 out of 50 LD children have one or more EEG abnormalities. A more recent study at The University of Tennessee included 103 males, ages 7-12 (Lubar, Bianchini, Calhoun, Lambert, Brody, & Shabsin, 1985). Sixty-nine of the students had been classified LD by their school system. Fast Fourier Transformation of EEG recordings on all subjects revealed that for 95% of the LDs there was increased power in the 4-8 Hz and 6-10 Hz frequency bands. Other EEG frequencies did not distinguish LD from normal subjects.

Myklebust and Boshes' (1969) research, as reported by Hughes, presents contradictory information. They found that EEGs of academically borderline children were significantly more abnormal than normal controls, while there was no significant difference between LDs and normals. Age variance is probably an important factor contributing to the varied results. EEG abnormalities were found by Klonoff and Low (1974) to be more prevalent in 2 to 9-year-old children with minimal cerebral dysfunction (MCD) than MCD children ages 9-15 years. Too frequently, research efforts include children from both age groups.

A large body of EEG research with LD children describes the specific abnormalities found to be present. The following will categorize this information by abnormality.

1. Posterior slow wave activity. This appears to be most prevalent with LD children: Knott, Muehl, and Benton (1965) found 70% occurrence in the parieto-occipital area with LDs utilizing spectral analysis. Only 10% incidence was found in research with dyslexics by Hughes and Park (1968). These 10% were also found to have the most reading difficulty and visual perception problems. Hughes (1976) found temporal rather than occipital slowing to be more prominent, being bilateral with one half of the borderline group while left temporal with the LD group. John found no examples of temporal slowing alone. It should also be noted that John found frontal slowing in 68% which could interfere with impulse control, a common problem with LDs. Occipital slowing has been found to correlate significantly with poor visual perception (Hughes & Park, 1968; Pavy & Metcalfe, 1965).

2. Diffuse slowing. Gubray, Elles, Walton, and Count (1965) found diffuse slowing to be common in their study of apraxia and agnosia. Electroencephalograms of 50% of MBD children in research by Capute, Neidermeyer, and Richardson (1968) registered diffuse slowing. It is suggested that this phenomenon is related to delayed maturation, which was previously mentioned as a major causal theory for learning disabilities. Isolated examples such as this help clarify why there is general confusion in understanding the etiology of the problem.

3. Asymmetry. Shabsin (1980) observed that LD children appear to utilize their right hemispheres when processing verbal tasks. This is important to note as verbal mediation and language tasks are thought to occur in the left hemisphere. This could imply attempts at compensating with a hemisphere not structurally suited to the task, which

might explain the ongoing reading and expressive language difficulties that are often observed in LD children. Shabsin's observation could also explain Hughes' report of left temporal slowing with LDs. John (1977) found asymmetries in his work. Lubar et al. (1985) research revealed that the 4-8 Hz activity in the right hemisphere, while children are working puzzles, could be a significant factor to aid in discriminating LD from normal children.

Hughes (1971) suggested that bilateral slowing rather than asymmetrical slowing might allow for better academic performance. He found that students with the former perform at a higher level than those with the latter. Spectral analysis with dyslexics (subgroup of LDs) and normal (Sklar, Hanley, & Simmons, 1973) found normals to have higher coherence between the same regions across hemispheres, while the dyslexics had higher coherence between regions within the same hemisphere. Hughes (1971) suggests that left rather than right hemisphere problems are more likely to be found on an EEG, as children with low verbal versus performance skills will be more likely to have EEG abnormalities.

4. Alpha blocking. In his spectral analysis research, Sklar et al. (1973) also found that while normals in a resting state demonstrated more activity in the alpha range of the parieto-occipital area, dyslexics had more activity in the Beta and Theta ranges. Low alpha is believed to be associated with attentional deficits which are common with LD children. During baseline periods, Shabsin (1980) also found Alpha blocking with LDs.

5. Positive spikes. Electroencephalograms of children with visual perception problems have often shown positive spikes in the bilateral occipital or parietal lobes (Roberts, 1966). In utilizing his NB system, John (1977) found positive spikes to be significantly greater in LDs than normals. Other research (Hughes, 1971) suggests that this may be true among adolescent normals, while clinical significance with younger children should be considered.

6. Sharp waves or eleptiform discharge. While this pattern has been found to disappear with maturation (Prodescu, Roman, Costiner, Christian, & Oancea, 1968), it appears to be related to certain LD characteristics. LD children with attention deficits were found to display this pattern (Stevens, Sachdev, & Milstein, 1968). One-third of subjects in two studies (Gubray et al., 1965; Paine, 1962) with EEG abnormalities had sharp waves. Considerably fewer (6%) were noted by Hughes (1971).

Hyperkinesis and electroencephalography. The Werry et al. (1972) research revealed no distinct difference in abnormal EEGs of HK, neurotic, and normal children. This suggests that in clinical diagnoses, EEG abnormalities would not necessarily differentiate hyperkinesis as the primary disorder. However, others have found that EEG's of HK's yield more Alpha waves, smaller amount of Beta waves, and higher Alpha and Beta amplitudes (Grunewald-Zuberbier, Grunewald & Rasche, 1975). After investigating EEG abnormalities in HK children it has been suggested that EEGs would be indicated only in cases where other symptoms persist such as seizure disorders

(Safer & Allen, 1976; Wikler et al., 1970). This thinking is based on research findings that while 50% of HSs have abnormal EEGs, abnormalities are also found in 15% of normals. Hughes (1971) found that in children with no diagnosed disorders, slow waves represented 50% of EEG abnormalities. Westmoreland and Stockard (1977) found occipital and temporal slowing to be frequent in normals. Confusion persists because unexpected percentages of those free of clinical symptoms are frequently found with EEG abnormalities.

However, there are numerous findings which seduce investigators to continue searching for accurate norming procedures. For example, Satterfield (1973) reports better drug response with MBDs having abnormal EEGs and neurologicals, than those with normal EEGs and neurologicals. These results are in agreement with those of Nahas and Kynicki (1978). In contrast, others have found that HKs with normal EEGs have more effective results from medication (Burke, 1968; Gross & Wilson, 1974). This latter information may be more directly applicable, as the research involved only HK children as opposed to the broader classification of MBDs. Possible diagnostic value with sensorimotor rhythm (SMR 12-14 Hz) is suggested in the work of Shouse and Lubar (1978). They found that HKs with low CNS arousal displayed decreased SMR.

Wikler et al. (1970) found excessive slow wave activity and abnormal discharges in HK subjects. The findings of increased slow wave activity appear to be the most consistent in the literature. John (1977) reports numerous studies of MBD children with a high incidence of excessive slow waves, in addition to spikes and EEG asymmetries. These abnormalities may be related to those HK children who display LD symptoms. Knobel, Wolman, and Mason (1959) found occipital slowing in 50% of HKs. Diffuse slowing has been reported in numerous studies (Klinkerfauss, Lange, Weinberg, & O'Leary, 1965; Satterfield, 1973, Satterfield, Cantwell, Lesser, & Rodesin, 1972; Satterfield, Cantwell, Saul, & Alvin, 1974). Klinkerfauss et al. (1965) in research with 782 patients referred to the Hyperkinetic Clinic of St. Louis Children's Hospital, found abnormal slow wave frequencies to be most consistent, but guards against using this as a diagnostic aid as observed differences were non-specific. This is possibly due to the varied historical etiologies such as known neurological diseases and birth trauma vs. no known prior incidences.

Average evoked response (AER). AER refers to an advanced utilization of EEG technology which allows for a reading of electrical brain wave activity as various types of sensory stimuli are presented. The evoked response is a transient oscillation of voltage which occurs at a latency and is representative of the stimulated sensory system's central transmission timing (John, 1977). Latency, in addition to amplitude (the strength of the evoked response) is a quantifiable measure which can be averaged and recorded. This allows for more definitive information for comparison purposes, and is thus well suited for research. AER data are generally believed to be relatively accurate measures of sensory processing and change associated with learning. In addition to research utility, AER measures are believed to be an innovative and promising diagnostic method for hyperactivity and learning disabilities.

John (1977) reports that localized damage or dysfunction may be determined with visual stimuli and AERs. A high incidence of asymmetry with LD children has been found with presentation of patterned visual stimuli (John, 1977). This could relate to the prevalent visual perception problems in this population. Children with this disorder display longer latencies and higher or more variable amplitudes (Musso, 1976; Shields, 1973). Further, longer latencies (Musso, 1976) and habituation (Barnet & Lodge, 1967) have been reported in LD children. Disabled readers show reduced amplitude when trying to process difficult information (Conners, 1970; Preston, Guthrie, & Childs, 1974).

Of interest for the future is John's (1977) suggestion of more widespread utility indicating that neonatal AER waveshapes might be classified and used diagnostically, perhaps becoming a standard procedure. He contends, however, that neonatal AER latency has only limited utility. This is an important consideration as age differences have been found with amplitudes and latencies (Beck & Dustman, 1975; Satterfield & Braley, 1977).

Treatment

The most common treatment modality for LD children utilizes the classroom academic approach. In truth, there is no known "cure" which fits for the general LD population, due to wide variance of symptoms and etiology. This is frustrating for educators, because a method which works with some children, may not be effective with others. Over recent years as educators and researchers have studied the LD syndromes, one major truth has surfaced: the combinations of deficits in expressive and receptive modalities and etiological factors, vary. Therefore, a different combination of treatment approaches is required for each LD child. Research reveals that success is lacking in attempts to match specific methods with similar deficits in different children (Keogh, Major, Reid, Gandara, & Omori, 1978; Miller & Sabatino, 1977).

Most treatment for learning disorders occurs through educational systems, which utilize theoretical psychological premises. Further, medical research has provided a growing body of knowledge and treatment procedures. Treatment plans are likely to be most effective when a multimodal approach is applied. The following includes a survey of remediation alternatives in these three areas often used in combinations as well as individually.

Educational Methods

Various academic programs for LD children have been published which are well-planned and often made available in a programmed fashion. Many of these offer constructive methods and could be helpful if used in an individualized manner. Ideally, this would occur through careful diagnosis of a child's strengths and weaknesses, with a unique teaching plan developed for individual learning styles. Due to lack of funding, teacher training, and creative energy, systems too often purchase a single package by which all children are taught, regardless of unique needs.

While all sensory channels are potentially subject to impairment in LD children the auditory and visual are considered the most important sensory input modalities, with tactile abilities also being utilized for learning. Professionals debate the efficacy of teaching to strengths and ignoring the weaknesses, or working toward upgrading impaired channels. Packaged programs are often designed (or utilized) with one or the other approaches in mind. Frustration frequently results regardless of treatment plan, because too little is known about etiology of individual deficits. For example, an auditory perception problem could result from damaged tissue, hypersensitivity to stimuli, or other causes. Such differences suggest that methods and potential for improving a weak area could vary considerably.

Additionally, good research is lacking which would demonstrate the strengths and weaknesses of these tools. Frequently, research is generated by the authors or publishers, which has built-in bias. Therefore, many systems are teaching children with materials, having unproven effectiveness. Tindal (1985) reviews previous attempts to evaluate a wide range of special education programs. The article is critical as it describes the evaluations as consistently containing flaws. Complaints are made of poorly defined groups and treatments, inadequate experimental designs and inappropriate statistical procedures. Concern is presented that the weaknesses in the research have been ignored resulting in misleading results (Tindal, 1985).

Reading. Debate has occurred for decades regarding a phonetic versus a sight approach to learning reading. It has been reported that full auditory discrimination potential does not occur until the latter part of the third grade (Wepman, 1960), suggesting that initially, a visual approach would have more utility. Beyond that age level, children vary widely in their receptive skills. Therefore, it is obviously detrimental to use a single method for all children.

Multisensory approaches are considered more diverse in meeting individual needs. The Fernald (1943) method utilizes visual, auditory, kinesthetic, and tactile modalities, employing letter tracing which is faded out and allows children to write stories out of their own experience. It is believed that students will more easily recognize words which they have spoken or written. The Gillingham and Stillman (1936) method is phonetically based and simultaneously utilizes auditory, visual, and kinesthetic modalities. This provides structure, which is important with LD children, and thought to be good for those with visual perception deficits. Good research on these programs is lacking with various theoretical criticisms offered. The Gillingham and Stillman method is thought to be too structured as well as boring due to the extensive amount of time required resulting in delay of meaningful material. Dechant (1964) finds the Gillingham and Stillman program deficient in meaningful materials.

An innovative method, addressing confusion of different sounds to the same letters, is the initial Teaching Alphabet (ITA). This provides a new alphabet with a single sound assigned to each letter. Concerns have been raised regarding transition to the standard alphabet while positive results have been reported (Downing, 1978).

Arithmetic. With the combination of deficits possible for LD children, it is apparent that difficulties in arithmetic could be many and would require special instructional techniques. Lack of structure, abstraction and memory problems, confusion, and lack of meaningful content, contribute to math problems. Again, multisensory programs have been developed which make it possible for learning to occur according to unique needs.

Many LD students fail to learn math beyond the third or early fourth grade level. This frequently results from the child continuing to think in a concrete manner which interferes with more complicated abstract math processes. Receptive or expressive language difficulties are often a major block. Three-dimensional materials can be an important resource, and are made available in the Cuisenaire Program. This utilizes 10 rods of different lengths and has multiple applications for younger and older children. The Structural Arithmetic Program also provides concrete objects and is innovative in allowing students to learn by discovery of facts and by recognizing their own errors. This employs the principles whereby learning occurs more readily with direct and immediate feedback, and accompanying insight and self-correction. Such learning experiences are beneficial in bypassing problems created in math due to language deficits.

Perceptual motor training. Perceptual motor training often emphasizes visual perception to the exclusion of auditory and tactile perception. This has occurred as a result of too much attention having been given to visual perception combined with motor deficits, inferring a belief that they are the general cause of learning disabilities. As was mentioned previously, these are two of numerous skill areas in which impairments can contribute to academic problems.

Frostig's (1972) program has been widely used for perceptual motor training. She reports a .44 to .50 correlation with teacher reports of reading ability, while research of others (Hammill & Larsen, 1974; Hammill & Weiderbolt, 1973) argues that subtest or overall scores do not predict reading ability. Her program offers remediation in the following: (1) eye-hand coordination; (2) figure ground differentiation; (3) recognition of form constancy; positions in space; and (5) spatial relations. Frostig contends that learning mainly occurs through visual processes, ignoring that deficits in other channels could interfere. Others find fault with her approach, reviewing 30 studies and finding results not positive in 66% (Myers & Hammill, 1976).

The Kephart program has also received extensive attention. Treatment is prescribed from Kephart's diagnostic instrument and includes both visual perception and motor activities. This method assumes that upgrading weaknesses in these areas will automatically increase basic academic skills.

Although much attention and research have been directed toward this area, review of the literature reveals misdirection. A summary by Myers and Hamill (1976) of 200 studies found only half to have adequate controls and samples greater than 10. Methodology of the remainder was found to be questionable. In fact, the relevance of visual-perception-motor deficits to underachievement is being seriously questioned. Researchers and practitioners frequently find adequate readers with such impairments and vice versa. As a result of negative support, it presently seems that emphasis is shifting from perceptual motor training to other forms of treatment. Similar conclusions were reported in a summary article by Treiber and Lahey (1983).

Language and linguistics. In the classroom expressive language is utilized in speaking and writing. The latter ranks high in importance as it is the usual method by which students are graded in their subjects. Multiple processes are involved in both, therefore requiring varied treatment procedures when deficits are present. Frequently, children are observed who speak fluently with good syntax, while they compose written sentences in a confused order.

The receptive language modality has three important aspects. Auditory comprehension problems are common, and too often go undiagnosed. An impairment in this area assures that a child will lack understanding ofinformation given verbally. Receptive language also includes reading, which is the main area in which LD problems first become apparent. Obviously, this requires different processees from those utilized in auditory comprehension. The cognitive utility of language, or the manner in which information is processed, is a third important area in which language skills can be deficient. This is perhaps the least understood and most complicated, in terms of treatment. Cognition seems to be the mediating process, between receptive and expressive modalities.

The interaction effects of these different aspects of language functioning are often unclear, which complicates classroom management. This is especially true with teachers untrained in special education or brain/behavior relationships. Johnson and Myklebust (1967) developed a hierarchy of language development in the following progression: (1) inner language, (2) receptive language, (3) expressive language, (4) reading, and (5) writing. They assert that impairment at any one level interferes with development of the more complex tasks. Given this structure, appropriate treatment would require thorough understanding through diagnostic techniques of which processes are impaired. Important to note is that academic performance modalities (reading and writing) are last in the hierarchy. As classroom corrective measures are usually directed at reading and writing, results are poor due to overlooking deficits in the underlying processes. The Johnson and Myklebust (1967) theory obviously recommends treatment of primary impairment in order to improve secondary symptomatology.

Numerous well-planned language development programs are available. Success varies, relative to adequate diagnostic information, as well as creativity and appropriate application. For example, the Diagnostic Evaluation of Writing Skills (DEWS) is a computerized program for identifying students with special needs in written language skills, and then providing specifics regarding those language categories needing remediation (Weiner & Weiner, 1984). The DEWS design allows for individual student input and immediate feedback. Recent development of computer technology for the classroom is providing a wide array of new options for normal students, as well as those with learning deficits.

Linguistics differs from a language approach as the former emphasizes syntax and limits the importance of semantics. Syntactical emphasis is often needed, considering the confused order in which language is presented by many LD children. For the child with auditory deficits the Fitzgerald-Pugh System utilizes the visual modality in a structured approach to grammar. Both the Programmed Conditioning for Learning and the Developmental Syntax Program rely on behavioral techniques. Research adequately validating these methods is not available. Hence there are serious questions regarding their continued use.

Several psycholinguistic remediation programs have been developed based on the Illinois Test of Psycholinguistic Abilities (ITPA). These programs do not utilize sequential learning which is frequently necessary for LD children who have missed out on basics due to perceptual and other disorders. They are further criticized (Mann & Phillips, 1967) for only attending to parts of the child, rather than taking a holistic approach. Research reveals positive results in only a small portion of attempted remediation areas (Hammill & Larsen, 1974; Hammill, Parker, & Newcomer, 1975; Saudargus, Madsen, & Thompson, 1970). Further, as these programs are theoretically based on the ITPA, it is important to point out that the literature reflects inconclusive or negative results regarding predictive, construct, and concurrent validity of the 1973 edition (Hallahan & Cruickshank, 1973).

Diagnostic-prescriptive teaching. This approach primarily utilizes test data revealing specific deficits per child, with individualized teaching programs designed and implemented. Numerous attempts in this vein have utilized WISC-R profiles, making remedial methods available to fit with different subtest patterns (Banas & Wills, 1978; Jacobson & Kovalinsky, 1976; Whitworth & Sutton, 1978). More recently, Wallbrown, Vance, and Blaha (1979) presented different and distinct plans for upgrading reading skills, based on five types of WISC-R patterns.

According to Obrzut and Hynd (1983), "It has become increasingly evident that by matching the educational program to a disabled learner's needs and abilities, more progress may be seen in the remedial process" (p. 518). They discuss the value of thorough assessment, including neuropsychological tests, followed with a program tailored to unique strengths and weaknesses. Hartlage and Telzrow (1983) report that an overview of research of diagnostic-prescriptive prescriptive teaching presents a gloomy picture regarding its efficacy. However, they clearly delineate fallacies in studies an optimistic outlook for this type of remediation. The authors criticize methodological imperfections, generalizing to classroom from laboratory settings, and inadequate neuropsychological understanding of the students. These writers are hopeful for more productivity in this area and provide models for utilizing neuropsychological test data for inference of aptitudes, and matching the data to treatment plans.

Psychological Methods

In attempting to remediate learning disabilities, numerous psychologically based principles have been utilized in public schools and other settings which have varying theoretical bases. Research results provide contrasts as to the success of different orientations. Environmental strategies, behavioral techniques, neuropsychological treatment, psychotherapy, counseling, and biofeedback represent the bulk of psychological approaches in widespread use. More recently, Neurolinguistic Programming (NLP) is providing new avenues for learning disability treatment.

Environmental strategies. School environments are structured to work with groups of students with methods being used that imply that all children can function at least adequately under the same conditions. This is clearly untrue, considering various levels of success found in open vs. contained classroom settings. Ideally, numerous teaching methods would be available to meet individual needs and to gain optimal performance from each student.

Too much stimulation in open classrooms is a problem with children whose attention span is deficient. Reduction in stimulation was implemented (Strauss & Lehtinen, 1947) with brain-injured students, with improved functioning occurring rapidly. Adequate controls were lacking with the results suggesting that further investigation would be warranted. A similar study by Cruickshank, Bentzen, Ratzeburg, and Tannhauser (1961), found LD control and experimental groups improving simultaneously. Therefore, in the Strauss and Lehtinen (1947) research, other variables might have contributed to gains in performance, with low pupil-teacher ratio considered as a possible influence. Improvement in attention and increased production occurred with use of isolation cubicles (Stephens, 1977), which again suggests that improved attention span directly affects academic performance. Rost (1967) found no significant improvement in academic performance utilizing cubicles for stimulation reduction. Perhaps similar research including simultaneous treatment to change poor study habits would better produce academic gains.

Amount of stimulation relates to high structure vs. low structure in a learning setting. When structure is lacking, as in an open classroom, over-stimulation can result. Under the same circumstances, there are children who perform optimally and develop creative skills. Locus-of-Control theory supports this idea and labels these children as internal. In contrast, the external student is described as performing best under highly structured conditions (Arlin, 1975; Rotter, 1966). Academic success or failure for the internals is attributed to their own controls, while external factors re considered responsible for the latter (Rotter, Seeman, & Leverant, 1962). Bendell, Tollefson, and Fine (1980) investigated the optimum amount of structure in regard to internal/external functioning with LD students. While it would appear that LD students would function better with excessive structure, this research revealed that it was detrimental for internal LDs (by Locus-of-Control theory) to have a highly structured learning situation.

Behavioral techniques. Behavioral methodology has been utilized extensively throughout school systems in an attempt to improve academic functioning of LD students. Emphasis is typically placed on positive and negative reinforcement. Free time, extra activities, game playing, teacher or principal attention, and token economies are examples of commonly employed techniques.

Reinforcement for completion of work including planned increments for increased success have been shown to be effective (Luiselli & Downing, 1980; Smith & Lovitt, 1973). Token rewards with immediate feedback for incorrect responses have also been demonstrated as beneficial with perceptual-motor disorders (Lahey, Busemeyer, O'Hara, & Beggs, 1977). Van Houten, Morrison, Jarvis, and McDonald (1974) found success with feedback coupled with timing. Elementary pupils improved reading comprehension, vocabulary exercises, and story writing under these conditions. Increases in correct answers occurred utilizing feedback and visual displays of recorded data (Fink & Carnine, 1975; Willis, 1974).

As impulsiveness and distractibility are frequent problems with LD students, self-control can become an important factor in terms of classroom management. Training for self-control has been researched utilizing self-evaluation (Hundert, 1977; Van Houten, Hill, & Parsons, 1975; Willis, 1974) and personally chosen rewards (Ballard & Glynn, 1975; Bolstod & Johnson, 1972). Others have researched allowing the children to monitor, record, and/or graph their own behavior in regard to behavioral goals (Fink & Carnine, 1975; Johnson & White, 1971; McFall, 1970; Seymour & Stokes, 1976; Thomas, 1976; Willis, 1974). While success has been reported, the data are contaminated due to uncertainty regarding which variables truly contributed to change.

Further research regarding the distractibility problem of LD children has compared the use of drugs to behavior modification techniques. It has been demonstrated that attention span can be equally or better increased by behavioral methods, as compared to drug therapy (Christiansen, 1975; Shafto & Sulzbacher, 1977; Pelham, 1977). The importance of these results is questionable as there is no clear evidence that increase in attention span in isolation of academic tasks will improve performance (DeBoskey, 1982). However, it seems plausible that chances for academic success would increase with improved concentration skills. Methodology improvement would be important, considering the numbers of children using medication for attention span deficits and unresolved questions regarding long-term effects.

Certainly as self-control and attention span increase, classroom advantages are likely. Paquin (1978) describes four important advantages of improved self-control: (1) The techniques involved do not drain on the teacher's time as occurs with keeping points and token economies. (2) Self-control training primarily directs attention on learning, which is the main purpose of school. (3) Paquin cites evidence that increased academic performance improves behavior, which again reduces the strain on the teacher and is helpful with the child's self-image. (4) Self-motivated interest in learning is more likely to occur when impulsivity is reduced.

A different viewpoint is presented in a review of the literature (Treiber & Lahey, 1983) which discredits the efficacy of treatment directed towards changing behaviors that are considered incompatible with learning (e.g., impulsivity, attention deficits, and excessive motor activity). The authors found that numerous studies have shown that alterations in these behaviors do not produce academic gains. Further, an extensive review of "medical model" research related to treatment of process deficits indicates that secondary remediation of academic weaknesses does not occur (Treiber & Lahay, 1983). The authors' findings led them to support a focus on academic deficits and direct behavioral modifcation of the deficits. Their review of the literature and their own research have shown that short-term academic gains for LDs can be obtained when this theoretical approach is applied. Treiber and Lahey (1983) further discussed the feasibility of identifying and modifying isolated and independent units of learning behavior (e.g. reading comprehension, accuracy, speed, etc.). While the writers' conclusions in this article are well-developed, further research is needed to determine whether or not their methods will produce long-term academic gains.

Neuropsychological strategies. Until recent years, actual changes in brain functioning through training were considered impossible. Theories have since been developed supporting the belief that the neurological system develops with use. This implies that training and practice can improve the neurological condition; thus, educational procedures can make a difference. An important breakthrough occurred with Maria Montessori's work with mentally deficient children in Italy, which was initially viewed with skepticism in this country (Morrison, 1976). Her methods of training resulted in these children being functional at the level of those in the regular schools. This work has since gained respect and utility in the United States.

Montessori, a physician, viewed the problem of mental deficiency as being an educational problem rather than medical. She emphasized respect for the child and treatment of each as an individual. Mental development was viewed as evolving in conscious and unconscious stages. Montessori viewed the first three years of growth as a learning period during which the unconscious mind absorbs everything with the ability to distinguish occurring later. Sensitive periods are described which Montessori considered optimum times for acquisition of specific skills. Necessary experiences for this to occur were considered pertinent (Morrison, 1976).

Montessori emphasized the child moving about freely in a prepared environment geared to developmental learning needs. The theory in practice seems to rely heavily on learning from experiencing, sensory receptivity, and opportunity for children to absorb and integrate information at an individual pace. In the Montessori system, these principles are applied to beginning reading and writing so that these behaviors are occurring before the children are aware of what they are doing. For example, in a Montessori classroom printed words might be attached to the items which they name. This provides opportunity for the brain to absorb letter and word configurations in association with objects. Motor activities are used extensively, as Montessori believed they are beneficial to the development of concentration and attention span (Morrison, 1976). It appears that the Montessori method aims at efficient utilization of the developing neurological system in an environment designed to enhance self-esteem.

Reitan's research has provided pertinent information regarding potential for change following brain-injury (Reitan, 1981). While it has been widely believed that the earlier in childhood brain-injury occurs, the greater are the chances for recovery, as compensatory brain functioning is thought to occur. When looking at numbers of individuals who had experienced brain trauma in childhood, greater recovery was found to occur as a function of elevated ages at the time of injury. Reitan hypothesized that specific skills such as speech can be more easily trained if they have once been learned, as opposed to never having experienced speech, as with the infant. However, Reitan has produced no research regarding success or failure of specific training programs.

Standardized instruments for training or research purposes are questionable, as each brain-injury or MBD case is different.

Creativity is required of the therapist, as has been discovered by Gudeman, Golden, & Craine (1978). They have instituted a program at Hawaii State Hospital utilizing assessment with the Halstead-Reitan Test Battery, as well as the theoretical ideology in neuropsychology of A. R. Luria. Individualized programs are developed and implemented, utilizing a sequential approach in which patients are trained in the developmental steps which would occur with learning under ordinary circumstances. This program has demonstrated that recovery can occur for neurologically impaired functions that are typically considered impossible to rehabilitate. DeBoskey (1982) obtained positive results from four months of two sessions weekly in prescriptively planned remediation with LDs. Individualized activities were designed based on neuropsychological deficits found with the Halstead-Reitan Neuropsychological Test Battery including the WISC-R. With eight LD boys, ages 9-12, pre and posttesting showed significant improvement on word recognition, spelling, arithmetic, and reading comprehension, as measured by the WRAT and Spache Reading Diagnostic Scales. Academic gains were significantly greater for the treatment group, as compared with LD and normal controls. This research is different from other attempts discussed, as behaviors being remediated are more directly related to brain functioning. These results are encouraging regarding similar work for the future.

A program at the University of South Dakota is described by Golden (1979) and reportedly also recognizes and incorporates the problem of needing individualized procedures for rehabilitating brain dysfunction. With a function that has been lost or weakened, there is an effort toward recovery by teaching other areas of the brain to take over the task. Training variables are implemented that may involve reduction of stimuli, or adding stimuli may involve additional input to intact sensory modalities, which are gradually faded. Under these conditions the child is forced to perform certain tasks utilizing target areas of the brain, beginning at the individual's functional level.

The body of literature supporting neuropsychological training provides optimism regarding potential for change in brain functions previously assumed impossible. Positive implications for LD children are indicated, with further research clearly needed.

Psychotherapy and counseling. Psychologists and psychiatrists who are analytically oriented are often biased in favor of a personality or emotionally based etiology for the learning disability problem. This bias would support the idea that individual and/or family therapy could resolve the problem. However, the literature suggests that this can be helpful only as an adjunct to educational programming. Silver (1975), a child psychiatrist who specializes in learning disabilities, emphasizes the necessity of an educational setting which meets the LD child's individual needs. Therapy as the only form of treatment would not be adequate. Family therapy has been found beneficial in reducing environmental stress and increasing tolerance from parents and siblings regarding problems generated from an LD child (Guerney, 1979; Ross, 1977).

From reinforcement theory, success has occurred utilizing brief therapeutic intervention to remove the maintaining stimuli related to undesirable behaviors (Weakland, Fisch, Watslawick, & Bodin, 1974). Mediation of cognitive processes in a play therapy setting has been found helpful with attention span problems (Kissel, 1975). Building of models is utilized to increase sequential thinking, orderliness, and frustration tolerance.

Obviously, assistance can occur through counseling and psychotherapy, especially considering the reduced self-esteem and negative self-image which typically follows academic failure. However, specialized educational programming should be consistently implemented.

Biofeedback treatment. Since many believe that learning disabilities and hyperkinesis are physiological in etiology, treatment by biofeedback may be of potential utility. Lubar and Shouse (1977) describe biofeedback as

> a methodology for acquiring learned control over internal processes. Essentially, biofeedback is operant conditioning of autonomic, electrophysiological, and neuromuscular responses. The procedure usually involves making an extroceptive stimulus contingent upon some clearly delineated change of an internal response, resulting in control of the targeted response (p. 204).

Normal subjects have been successfully trained to control Alpha rhythm from the central area of the brain (Potolicchio, Zukerman, & Cherniogovskaya, 1979). This is promising in regard to what could be accomplished with LDs and HKs. At the present, most research regarding biofeedback treatment of MBD has emphasized the HK syndrome.

Due to the motoric involvement of hyperkinesis, it is considered probable that through muscular relaxation the motor activity can be decreased, resulting in more "normal" behavior patterns. Therefore, the most frequently researched biofeedback techniques with HK subjects utilize training of muscular activity levels (or electromyogram [EMG]).

The biofeedback approach with HKs reported by Shouse and Lubar (1977) and Lubar and Shouse (1977) utilizing SMR training refers to "EEG activity associated first with enhanced peripheral motor inhibition and second with changes in CNS arousal measures" (Lubar & Shouse, 1977). Relative to the amount of research which has occurred with biofeedback and HKs, the learning disabled syndrome has received minimal attention. Research in this area presently includes EMG training and EEG training of 40 Hz activity. Due to the overlap of symptoms of hyperkinesis and learning disabilities, and considering the frequency to which attention span deficits occur in both, the literature related to both disorders will be discussed. The following will include reported methodologies to date in EMG and EEG training of hyperkinesis, and the available investigations regarding biofeedback techniques with LD children.

1. EMG, biofeedback, and relaxation training with hyperkinesis. As muscular relaxation is the primary goal of EMG biofeedback training, it is a probable consideration that relaxation training (RT) might

accomplish similar results. Braud (1978) investigated this possibility with 15 HK subjects, including 12 males and 3 females (11 Caucasian, 3 Negro, and 1 Mexican-American), 6 of whom were taking Ritalin throughout the study. The subjects were divided into three groups: (1) EMG training for decreased frontalis muscle activity for two 30 minute sessions per week for six weeks, with pre and post baselines recorded; (2) RT for the same time periods utilizing tapes of Jacobson Progressive Relaxation Techniques; and (3) no treatment. The HK groups were compared with 15 non-hyperactive children not matched for sex, race, or age. Pre and post testing included Digit Span and Coding, WISC, Visual Sequential Memory, subtest of the Illinois Test of Psycholinguistic Ability (ITPA), and the Bender Gestalt Test, three behavior rating scales completed by parents, and EMG activity levels. Additionally, behavior ratings were made at home, thrice weekly, and EMG levels were measured weekly.

This study yielded positive results, with significant improvements for LDs in all measured areas, compared to controls. However, the EMG group did not surpass the RT group except for reduced EMG activity. Externally, the two groups would appear the same. These results must be viewed as tentative, considering the problems with this study. First, subject selection was questionable due to the heterogeneity regarding medication, sex, age, and ethnic background. Placement in groups by random selection did not control for these factors with the exception of sex.

Second, if a full psychological battery (i.e., full WISC and academic testing) had been administered, more differences might have been demonstrated.

Anderson (1976) made a different comparison utilizing four groups of HKs (N=9); (1) EMG training, (2) RT, (3) EMG and RT, and (4) no treatment. This comparison provides an opportunity to determine if muscular relaxation can be facilitated by the use of two simultaneous treatments as opposed to a single treatment. The fact that this more extensive design yielded no significant alterations in classroom behavior casts further doubt on the previously discussed study.

Haight, Jampolsky, and Irwine (1976) attempted to test the utility of simultaneous treatment with two groups, one with EMG training and the other with both EMG and RT. There were eight males, ages 11-15, who received nine 45 minute relaxation sessions in three weeks, with four of the subjects receiving an additional 20 minutes of EMG training. While no significant decrease in EMG activity level was found, behavior and attention span improved. As symptoms of hyperkinesis frequently decrease in adolescence, the age factor in this study might have interfered with EMG changes. Also, as the period of time for training was unusually brief, gains in behavior and attention span might have had a placebo effect. The lack of controls in this study further questions the validity of these findings.

2. <u>EMG biofeedback and counseling with hyperkinesis.</u> An investigation questioning the effects of counseling with EMG training included 30 HK male and female subjects, ages 6-11.5 (Johnson, 1977). They were divided into three groups: (1) EMG training plus counseling, (2) EMG training only, and (3) controls receiving an equal amount of time with the experimenter. Eleven sessions were completed over a four week period with pre and post testing including Porteus Maze, Behavior Rating Scale, and EMG levels. Both experimental groups demonstrated decreased EMG levels and improved behavior, with the EMG plus counseling showing the highest gains in behavior. This study is encouraging, although heterogeneity of sex and ages of subjects is of concern.

3. <u>EMG and EEG biofeedback with hyperkinesis.</u> A unique comparison was made to determine if psychological, cognitive, and behavioral characteristics were differentially affected as a result of EMG or EEG biofeedback training (Patmon & Murphy, 1978). Twenty-eight male and female HKs were divided into four groups: (1) increased EEG frequency feedback, (2) decreased EEG frequency feedback, (3) decreased EMG activity feedback, and (4) no treatment. Groups 1 and 2 were instructed to keep white noise on and group 3 was instructed to decrease clicks. EEG activity was measured in 30 second intervals of average frequency and amplitude with upper threshold set as baseline for the increase group. EMG activity was measured in 30 second intervals of average activity. Shaping

procedures were used to increase the difficulty of the task as the subject became more successful (Patmon & Murphy, 1978).

Pre and post measures were taken on frontalis EMG, EEG frequency and amplitude, Digit Span and Coding (WISC-R), resource teacher's behavior checklist, and parents' rating on the Werry-Weiss-Peters Behavioral Scale. Examiners, parents, and teachers were blind to the training procedures. The EMG group was the only one showing no increase in EMG levels while there were improvements in behavior and attention span (Digit Span). The decreased EEG group's only demonstrated improvement was the reading subtest of the WRAT. Increased cortical arousal, reduced muscular tension, and no behavior improvements were found with the increased EEG group.

These results are questionable for several reasons. The subjects were not screened for auditory loss, perception, or discrimination. Such deficits would interfere considerably with effectively attending to the white noise and clicks used for feedback. White noise would be especially difficult for a child with a figure-ground discrimination problem. Also, as previously mentioned, adolescent and mixed sex populations may not necessarily be a wise choice. In terms of measures, Digit Span alone is an inadequate measure of attention span and WRAT reading scores only measure word recognition, excluding comprehension. As both of these tasks are rote by nature, repeated administration in one month (the length of the project) could be affected by memory. This design could offer useful information if it could be replicated utilizing a younger, homogeneous sample with more adequate testing.

Tansey and Bruner (1983) attempted to differentiate between EMG and EEG biofeedback in regard to efficacy of both forms of treatment. A 10-year-old hyperactive boy was treated with three weekly sessions of EMG biofeedback, and subsequent 20 weekly sessions of SMR training. Target symptoms included an attention deficit disorder with hyperactivity, a reading disorder, and ocular instability. Reduction in motoric activity and improved attention span occurred after three SMR sessions. Improvement in reading and the ocular disorder was found following SMR biofeedback training. Symptom reduction remained with follow-up sessions over a 24 month period. While this report is limited by being a single case study, difference in effect of the two treatment forms should be noted.

EMG biofeedback only and hyperkinesis. Other studies have been reported, investigating EMG biofeedback training without comparisons to other treatments. Hampstead (1979) divided 12 HK subjects into two EMG training groups and one control group. The subjects were referred to a child guidance center with HK symptoms and were subsequently diagnosed by a multidisciplinary team. Hampstead termed the subjects developmental HKs while requiring three historical indicators suggestive of organicity. This appears to be contradictory in addition to the fact that research has demonstrated prevalence of hyperkinesis without preceding events such as birth trauma or postnatal illness. Also, subjects with symptoms of mild psychopathology were rejected. Children with diagnosed hearing deficits were ruled out, but again, no screening for auditory perception was made in a study utilizing only auditory feedback.

The treatment was presented in A-B-A-B-A form, with A being no feedback for eighty 30 second training trials. The same treatment was presented to the second experimental group with the exception of seven minutes less time per session and the second B phase providing verbal feedback regarding the EMG activity. Significant differences were shown in EMG activity between A and B phases with a steady decline in all phases. Behavior rating scales correlated with EMG except for one subject which was one of two children taking Ritalin throughout the study. All subjects decreased EMG activity and improved in three out of five psychological tests administered pre and post (Digit Span and Coding, Bender-Gestalt, Beery Developmental Test of Visual Motor Integration, and Frostig Developmental Test of Visual Perception). Hughes, Henry, and Hughes (1980) also obtained improvement in academic performance and activity level of three subjects through EMG reduction in frontal muscular tension. Maintenance occurred after biofeedback was discontinued.

Jeffrey (1976) compared an HK EMG feedback training group utilizing 20 second interval measures with an HK no treatment group. The results were positive suggesting that HK children can be trained to relax and remain in a relaxed state for short periods of time. Studies previously mentioned based results on pre and post testing measures which mostly emphasized visual-motor and attention span deficits. This study offers a broader spectrum of measures including the Bender-Gestalt, (full) WISC-R, ITPA, Torque Test, and the Quick Neurological Screening Test.

Results of a single subject (6½-year-old Male) EMG biofeedback training experiment yielded improvement in behavior, psychosomatic symptoms, and attitude (Braud, Lupin, & Braud, 1975). Training was provided twice a week for three weeks and once a week for five weeks with requests to practice at home. Test behavior from pre to post testing improved considerably from a three day test period with crying episodes, to one four hour test period with 3-5 minute breaks. On the final testing there was no crying or hyperactive behavior, with considerable gains on test results. These gains could possibly be due to no disruption from emotional factors. While the results may be valid it should be noted that behavioral rating methods are subjective and that emotionality was reportedly measured with no explanation as to how this was done.

An additional study of EMG training with HKs is also a single subject design utilizing four boys, ages 8-12 (Baldwin, Benjamins, Meyers, & Grant, 1978). These researchers present an argument that previous studies fail to demonstrate a direct relationship between EMG and HK or tension. This failure is attributed to use of subjective parent and teacher questionnaires only to measure behavior and inadequacy of control. In order to provide more objective measures, they implemented a behavioral observation system (adopted from Lubar & Shouse, 1976). However, the observations were taken in the experimental setting which is not likely representative of classroom or at-home behavior.

Training was provided in 20 one hour sessions over a 10 week period, with two weeks of baseline, three weeks of frontalis EMG training, one to two weeks of reversal with false feedback, and EMG training resumed. The sessions involved 30 minutes of EMG training, 10 minutes of study time, and 20 minutes with a math tutor. Subjects were asked not to discuss the nature of training with parents or teachers which implies there was no outside encouragement for practice. EMG activity decreased while behavior in the laboratory deteriorated with no significant change at home. The undesired negative results could be due to the amount of time quiet behavior was required in addition to no enhancement with practicing relaxation at home.

EEG biofeedback and hyperkinesis. Shouse and Lubar (1977) eliminated many of the methodological problems in their study utilizing 12 6-12 year-old HK males, diagnosed by pediatricians and medicated on Ritalin prior to the time of the study. The diagnosis was further confirmed utilizing Stewart's Teacher Questionnaire (TQ) with six symptoms required, including overactivity and short attention span. The subjects were divided into two groups based on CNS arousal indices (amplitude of auditory evoked responses, incidence of sensorimotor rhythm, slow wave EEG, and basal galvanic skin response) and somatomotor activity indices (EMG measures, Stewart's TQ, and behavioral assessment in classroom). The experimental group of four was distinguished due to indices suggesting a low-arousal syndrome. The remaining eight subjects were used as an HK control group. Normal controls were selected from the classrooms of the HKs and were matched for age, sex, and IQ.

All measures were initially obtained during Phase I (no drug) and Phase II (drug only) baseline periods. Phase III included SMR training and drug with Phase IV reversing training with drug. Phase V was a repetition of III with Phase VI eliminating the drug with SMR training only. Training was over a seven month period with results indicating increased SMR, motor inhibition, and CNS arousal in three of the four experimental subjects. One subject was dropped after six months of unsuccessful training. Except for the GSR measure, the three remaining subjects were physiologically and behaviorally nondistinguishable from normal controls. The authors question the inability to produce changes in the one subject suggesting the difference may be related to short attention span and being excessively distractible (Shouse & Lubar, 1977; Lubar & Shouse, 1977). Considering the success with three subjects, this one difficulty is more likely related to initial screening as opposed to treatment methodology.

6. EEG biofeedback with learning disabilities. Sheer (1975) presents experimental data to reinforce the body of literature suggesting that LD children show a deficit in 40 Hz activity when presented problem-solving material. He stresses the difficulty of obtaining reliable, consistent EEG recordings in this low

amplitude, fast frequency part of the EEG spectrum which overlaps with the muscle spectrum. Sheer has developed a refined technique for operant conditioning of the 40 Hz EEG signal, while eliminating the potential muscle artifact.

Adult subjects were seated in front of a screen and asked to turn on as many slides as possible. Muscular and EEG activity were recorded and if either moved above or below the set threshold, the slide projector would not trigger. 40 Hz EEG, muscle, and Beta bursts were counted automatically. Ten subjects were asked to increase brain waves while five were requested to decrease activity. The increase group showed significant difference on 40 Hz and Beta activity, with no difference on the muscle recordings. The decrease group recorded a difference only on the 40 Hz EEG. Follow-up comparisons reflect the "effect of individual differences in motivation level when subjects attempt to maintain voluntary control over their own brain rhythm on the basis simply of instructional set" (Sheer, 1975).

Six LD children with varying degrees of hyperactivity were treated in a clinical setting for 10 to 27 months with EEG biofeedback (Lubar & Lubar, 1984). Training was directed towards increasing 12-15 Hz SMR or 16-20 Hz beta activity and decreasing EMG and 4-8 Hz activity. The biofeedback was combined with academic training and spatial tasks aimed at increasing attention spans. Results included improved academic grades and achievement test scores with all six children following treatment. In addition, at the time these results were published, none of the subjects was taking medication for hyperactivity.

7. EMG and relaxation training with learning disabilities. An attempt to improve skills in LD children utilized a technique similar to those reported with the hyperkinetic children (Russell & Carter, 1978). Sixteen students labeled LD by a diagnostic unit were compared with 15 normal controls, nine mentally retarded, and 25 with undiagnosed learning problems. The training sessions included 10 minutes of passive relaxation, handwriting exercises using audiotapes, and 10 minutes of EMG training with electrode leads attached to the flexor muscles of the preferred forearm. A visual display feedback system was utilized. Results indicated that LDs made gains on the Slosson Intelligence Test (SIT), Gray Oral Reading Test, Bender-Gestalt test, Auditory Memory Test, Handwriting Quality Test, and WRAT Reading. This appears to be a reasonable comparison, although it is important to note that subjects were not described and likely not matched across groups, and that the SIT is questionable as a valid test of intelligence. Also, the four week period for training might be considered brief.

Pairing of EMG training and RT was also utilized in attempting to change (1) attention to task, (2) impulsivity, and (3) locus of control, among 32 LD students, ages 8-11. The group was split into 16 normals and 16 controls. Success was reported in behaviors 1 and 2, while no effect on 3 was found. The accuracy of these results is weakened by a single pre and post measure utilized for both attention to task and impulsivity. In addition, only three sessions for each child were provided and no information regarding long-term maintenance was obtained (Omizo & Williams, 1982).

Medical Approaches

Learning disabilities is an area which has been offered limited assistance from the medical field. There has been frustration as physicians continue attempting to be helpful with limited success, especially in treating the broad spectrum of symptoms which typically exist. Primarily, drug management has been utilized, in addition to rehabilitation units in medical centers often working towards improved sensory integration. Currently, the most expansive area of medically oriented research is in the field of nutrition. While much of this work is occurring in medical circles, a large part of nutritional research is being pursued by the fields of biochemistry and nutrition.

Psychotropic drugs. Treatment for learning disabilities with medication is currently controversial as the side effects are frequently undesirable and other means of improving functioning are available. According to Conrad and Insel (1967), clinicians report 30% effectiveness with drugs, while research indicates 70% positive results. Primarily drug treatment refers to stimulants while other various psychotropic medications are utilized, including caffeine. Many would say that those responding positively to stimulants are possibly hyperactive.

It is becoming apparent that drugs alone are not an adequate course of treatment, and should be accompanied by additional academic and psychological therapies (Schaefer & Millman, 1977). However, Ross and Ross (1976) indicate that drug therapy has become the most commonly used means for increasing attention span and a child's ability to stay on task.

Nutritional management. Increasingly, recognition is being given to effects of nutrition on learning problems. Often, children are diagnosed as learning disabled, when in fact, dietary changes are found to be helpful in remediation. However, it is difficult to overcome the problems with nutritional treatment with a child who has experienced learning problems for the first four or five years of school. Formative academic years are important relative to specific stages of development. There is uncertainty regarding the possibilities of recovering losses from not having learned sequentially, or during critical learning periods.

Additionally, if nutritional problems are discovered at grade six, for example, well-developed lack of motivation and low self-esteem could interfere with progress. More specifically, most children of these circumstances would be functioning several grade levels behind in one or more areas. With "failure" as part of the self-image, catching up is frequently difficult. The following includes some of the prominent dietary concerns discussed in the literature.

1. Allergies. Learning problems and hyperkinesis are frequently considered to be caused by food allergies. Controlled studies are lacking while Taub (1975) and others report improvement through avoiding certain foods. The Feingold diet aroused hope when it was suggested that a diet free of colorings and additives would be helpful for the HK and LD children. Follow-up research has found this approach to be successful with only a small percentage of children (Silver, 1975). Articles reporting extensive reviews of primary research on the Feingold diet strongly support Silver's report (Kavole & Forness, 1983; Mattes, 1983). In an assessment of these reviews Rimland (1983) reports that the conclusions drawn are at best of only marginal value, probably incorrect, and may perhaps be damaging. Rimland argues that although numerous studies were completed, they were inadequate and/or inappropriately accommodating of Feingold's basic premises or intentions. His article suggests that meaningful research on this question remains to be done.

2. Hypoglycemia. Cott (1971) supports the negative effects of hypoglycemia on learning while having no data to support his hypothesis. Later research has since shown that this blood sugar irregularity can cause memory problems, loss of concentration, confusion in thought processes, aphasia, impulsivity, and an endless list of physical and emotional syndromes, which resemble behaviors typical of the LD child (Charlton-Seifert, Stratton, & Williams, 1980; Cheraskin, 1976; and Lapp, 1981).

3. Trace elements. Extensive clinical treatment has been attempted with positive results reported (Cheraskin, 1976), in regard to deficiencies in trace elements such as zinc, iron, copper, calcium, sodium, etc. Increases in lead levels have been reported in correlation with learning deficits, lower IQ scores, and mental retardation. At the 1981 conference for the National Association for Children with Learning Disabilities, a full day pre-conference workshop was held regarding the impact of trace minerals and nutrition on learning. Sound and varied research from international sources was presented, positively intimating the interaction of ingested nonmedical substances and learning.

Sensory integration therapy. This treatment approach from Jean Ayres (1964, 1969) is being utilized in medical centers and by occupational therapists, as well as by psychologists. This work focuses on sensory deficits related to problems with the brain stem being unable to organize auditory and visual processes properly. These two sensory modalities are considered essential for optimal learning in regard to receptive processes. Exercises are utilized to help regulate sensory input to the vestibular and somatosensory systems, which presumably assists with intersensory integration as well as increasing adequacy in functioning across hemispheres (Ayres, 1974).

Sapir and Wilson (1978) present an optimistic attitude regarding Ayres' work. They suggest that increased control over motor and perceptual functioning can occur with her program, which results in improved self-esteem. Ayres' research (1974) revealed significant improvement in LD children following treatment. DePauw (1978) views this treatment as being successful with both auditory and visual processes. This is significant, considering that these are the two major receptive modalities for learning.

Much criticism and deteriorating interests with the Ayres program has occurred among professionals. This is probably due to discouraging reports of results, with Ayres complaining that occupational therapists attempt to utilize her methods while not being properly schooled in regard to the exact process, as it was designed to be used.

Optometric therapy. Optometric training has been commonly recommended as a treatment method for LD children. It is typically considered when visual perception disorders have been suspected. Treatment is directed at functional as opposed to structural deficits in vision in the hope that visual efficiency can be enhanced (Keogh & Pelland, 1985). Methods of training include sensory, motor and perceptual activities as well as the use of lenses, biofeedback, visual imaging, etc.

Controversy has surrounded this treatment among vision specialists and those in referring positions. Keogh and Pelland (1985) made an attempt to resolve the confusion by reviewing publications in optometry, opthamology, education and psychology. The intent of the article was to define optometric therapy and to determine for whom it is appropriate and its efficiency. Consensus regarding content of such treatment and appropriate candidates was found to be limited. Little empirical evidence that would support effectiveness was discovered. Future research with sound methodology and appropriate controls was recommended.

These authors (Keogh & Pelland, 1985) report that in 1984 a policy statement was made by the American Academy of Pediatrics, the American Academy of Ophthamology, and the American Association of Pediatric Ophthamology and Strabismus. This statement clearly denied effectiveness of vision training programs for LD children. Considering the results of the literature review (Keogh & Pelland, 1985), such a policy statement is not surprising.

Rationale for Present Study

LD and HK children have been discussed in regard to etiology, diagnostic procedures and treatment. Etiological causes have been categorized into three models: (1) deficit, (2) delay, and (3) difference. Most research and treatment modalities would fit into one of these categories. It has been pointed out that the difference model appears most logical, as a delay or deficit would represent a difference. Further, an overlap among the three contradicts either model being solely acceptable.

Diagnostic procedures presented include tests of (1) intelligence, (2) perceptual motor development, (3) achievement, and (4) neuropsychological functioning. In addition, diagnosis utilizing EEG technology was discussed. Emphasis has been placed on different ways in which the results can be viewed and the importance of intelligently integrating the obtained data.

Treatment has been discussed in regard to (1) educational methods, (2) psychological methods, and (3) medical approaches. The most important consideration is that a treating specialist see the necessity of combining methods and individually tailoring a plan to meet each LD child's unique differences.

The literature supports the hypothesis that EEG patterns for LD children differ from others. Further, clinical results and observations have suggested that LD students improve academically when 8-15 Hz activity is increased through EEG biofeedback. Therefore, at the time this study was initiated, it was believed that laboratory investigation would be beneficial to future research and treatment possibilities.

It was hypothesized that reduction in muscle activity (>23 Hz) and low frequency activity (4-7 Hz) concurrent with enhancing 8-15 Hz activity, would be beneficial to academic gains. This is supported by research findings that alpha blocking is common with LD children.

If such a treatment modality could be developed and refined, the strain on existing methods which are frequently inadequate would be reduced. Further, the range of treatment choices would be increased which would provide for improved individual multimodal plans.

CHAPTER II

METHODS

Subjects

This research included nine learning disabled and ten normal Caucasian male children between the ages of 9 and 13 from the Knoxville, Tennessee area. The LD children had a mean age of 10 years 9 months when treatment began. The mean age of the normal children was 10 years 8 months. The socioeconomic status of all subjects was lower-middle to upper-middle class.

The LD children met the following criteria before they were considered appropriate for participation in the study:

1. Diagnosed as learning disabled via psychological assessment administered by the system-employed school psychologists.
2. Actively participating in the public school resource programs.
3. Not receiving therapy or any other special services outside the school system.
4. Free of known seizures, hyperkinesis, brain trauma, speech pathology, or other handicaps, and on no psychotropic medications.
5. Full Scale IQ score of the WISC-R low-average or above.
6. Scoring in the LD range (between 20 and 40) on the Selz and Reitan (1979) scoring system for the Halstead-Reitan Neuropsychological Battery.

The LD population was initially comprised of 16 students who met the above criteria. Using the Selz and Reitan score these subjects were paired based on the severity of the neuropsychological score. There were eight in each group after they were randomly assigned to either the treatment or control group. In the early stages of the study two of the treatment subjects and three of the LD control subjects withdrew even though they had originally agreed to follow through if chosen. Moreover, several weeks after the study began one of the six remaining treatment subjects discontinued his participation in the biofeedback therapy thus leaving five treatment subjects. Towards the end of the data collection period, one child moved but promised to return for the postevaluation sessions. Extensive efforts to locate him were nonproductive. Thus, the study ultimately included four treatment and five control LD subjects. Among those that completed the project, the mean age of the LD treatment group was 10 years 11 months whereas the mean age of the LD control group was 10 years 8 months.

Criteria for the normal controls included no physical or academic problems and WISC-R scores within the low average or above range of intelligence. Their neuropsychological scores, utilizing the Selz and Reitan scoring system, fell between 0 and 19.

Both LD groups (treatment and control) participated in school resource programs throughout the study. No other forms of treatment were made available to the LD control group.

Pre and Postevaluation Procedures

Electrophysiological Measurements

The 19 subjects that remained in the study through its entirety were administered pre and posttreatment EEGs at the Neuropsychological Laboratory at The University of Tennessee, Knoxville (UTK). The Grass instrument Co. No-E5SH silver disk electrodes were held in place with electrode paste and were applied to each of the 16 scalp locations. The eight bipolar pairs of electrodes (F_3-F_7, F_4-F_8, C_3-T_3, C_4-T_4, O_1-P_3, O_2-P_4, T_5-F_7,and T_6-F_8) were placed at International 10-20 System positions. A pair of submental muscle electrodes attached to the ear provided EMG monitoring.

For the EEG recordings each subject sat in a sound attenuated electronically shielded room in a reclining lounge chair. The student was presented with three distinctly different tasks (each twice) for a five-minute time span. The tasks were baseline, reading and drawing. The three tasks were recorded once for the left and once for the right hemisphere with the order of the hemispheres and tasks randomly selected. During baseline the subject was asked to sit with eyes open and in a relaxed state. For the reading interval he was asked to read silently from narrative material at his achievement level. The drawing task consisted of copying the designs from the Developmental Test of Visual-Motor Integration.

Whenever movement that might interfere with the recorded EEG occurred, a red light on a panel in front of the child was illuminated. The parameters of EMG activity that were considered to interfere were of 50 uV or greater.

A 32K word, 16 bit Digital Equipment Corporation PDP 11-04 computer with 16 channels of A to D conversion was used to analyze the data. Only one channel could be analyzed on-line by the computer; thus, the other three were recorded using a Teac R-7 FM tape recorder. For analysis each channel had to be played back individually. The PDP computer offered on-line Fast Fourier Spectral analytic transformations of all the channels and also produced pictorial and quantitative spectral arrays of the EEG utilizing tables and graphs.

Neuropsychological and Psychoeducational Measures

A pre and post comprehensive psychological and neuropsychological test battery was administered to the LD and Normal children by two examiners who were not connected with the study as researchers and who did not know the group to which each student belonged. The battery consisted of the following tests: Wechsler Intelligence Scale for Children-Revised (WISC-R), Wide Range Achievement Test (WRAT), Spache Diagnostic Reading Scales, Bender Gestalt Designs, and the Halstead-Reitan Neuropsychological Battery.

a. WISC-R. This individual intellectual measure was utilized for two reasons. It is considered helpful in delineating the skills and deficits of children with learning disabilities. Also, it is a required component of the particular neuropsychological battery chosen for this study. All 12 subtests were administered.

b. WRAT. This quick achievement test includes three distinct academic scores yielding a grade level equivalent, standard score, and percentile rank based on chronological age. The reading score measures word recognition skills. Spelling is comprised of the child's ability to reproduce the word with a written response. The third measurement is arithmetic which involves, for the age level of these subjects, written computational skills.

c. Spache Diagnostic Reading Scales. Since the WRAT reading subtest only includes word recognition, it was necessary to measure reading comprehension, utilizing another instrument. The Spache provides a measurement for both oral (instructional level) and silent (independent level) reading which assesses the child's ability to answer questions about what he has just read. The word recognition subtest of the Spache was not given.

d. Bender Gestalt Designs. The copying of these nine designs provides a measurement of the students' motor age level, utilizing Koppitz' scoring system (Koppitz, 1963).

e. Halstead-Reitan Neuropsychology Battery. This particular battery was chosen as opposed to others such as the Luria Nebraska based on the extensive research data base for use with children in the 9-14 age range (Klove, 1974). Also, the Selz and Reitan scoring system for this battery can effectively delineate normal vs. LD vs. brain-damaged children.

The battery itself consists of 11 parts that were administered to all subjects. A brief description of each follows:

1. Category test. One hundred and sixty-eight stimulus figure slides are presented on a screen. An answer panel which contains four levers that are numbered 1 to 4 is located below the screen. The child is told that he should inspect each stimulus figure as it appears and push one of the four levers based upon which of the four numbers best relates to the slide. The bell rings if the response is correct and there is a buzzer if incorrect. This is a concept formation test which measures higher level functioning in regard to concept formation, abstracting abilities, and reasoning. This test is considered to be the best single indication of the ability to function independently without supervision.

2. Tactual Performance Test (TPT). A modification of the Sequin-Goddard formboard is used. The subject is blindfolded and then asked to fit differently shaped blocks into their proper spaces, first with the dominant hand only, then with the nondominant hand, and finally using both hands. The time recorded for each hand provides a comparison of the right and left hemispheres, while the time score for the test is based on the total time needed to complete the three trials. After the board is removed the blindfold is taken off and the student is asked to reproduce a drawing of the board. This drawing is scored according to how many shapes are remembered (Memory) and the number of shapes drawn in the correct location (Localization). Performance on this test requires tactile form discrimination, kinesthesis, coordination of movement of the upper

extremities, manual dexterity, visual spatial skills, and congruency in functioning of right and left cerebral hemispheres.

3. Speech-sounds Perception Test. This test consists of 60 oral nonsense words presented four at a time in a multiple choice format. It is played on a tape recorder with the examinee required to underline the written syllable that matches the one spoken on the tape. Close concentration, auditory discrimination, and phonetic ability are needed for this task.

4. Seashore Rhythm Test. This is a subtest of the Seashore Test of Musical Talent whereby the examinee has to differentiate between 30 pairs of rhythmic beats which are sometimes different and sometimes the same and are displayed on a cassette tape. Alertness, sustained attention, and auditory discrimination and comprehension are required.

5. Finger Oscillation Test. This test is a measurement of finger-tapping speed within a 10 second interval. The subject is measured for both the dominant and non-dominant index finger. This task is one of motor speed. The two scores can be compared in viewing symmetry of the two cerebral hemispheres.

6. Trail Making Test. This test consists of two parts (A and B). Part A is a dot to dot task with the numbers 1 to 15. Part B consists of 15 circles numbered 1 to 8 and lettered A to G. The subject is asked to connect the circles alternating between numbers and letters and proceeding in ascending order. The child is told of errors and asked to correct them as they are made. The

score is the number of seconds required to complete the Test. Trails A and B require visual planning, motor speed, a good attention span, and ability to integrate information visually.

7. Sensory Imperception. This is a series of tests which determines the accuracy with which the subject can perceive bilateral sensory stimulation after it has been determined that his perception of unilateral stimulation is adequate. There are separate tests for tactile, auditory, and the visual sensory modalities.

8. Tactile Finger Recognition. This test measures the ability of the child to identify individual fingers on both hands as a result of tactile stimulation of each finger while blindfolded. Four trials are used for each finger resulting in a total of 20 trials on each hand. The number of errors on each hand is used in determining bilateral hemispheric differences.

9. Finger-tip Number Writing. This procedure requires the child to identify numbers written on the finger-tips of each hand without the use of vision. The results can also be used for hemispheric comparisons.

10. Tactile Form Recognition. The subject is asked to identify small plastic shapes when placed in the right or left hand, again without visual cues. A visual recognition response is required rather than a verbal response. The time utilized for recognition, for the right versus the left hand, is compared and again hemispheric differences can be noted.

11. Halstead-Wepman Aphasia Screening Test. This test includes 32 verbal and/or motoric items that provide a rough measure of 12 varying neuropsychological deficits. They are listed in the Selz and Reitan scoring system as follows: constructional dyspraxia, dysnomia, spelling dyspraxia, dysgraphia, dyslexia, central dysarthria, dyscalculia, right left confusion, auditory verbal dysgnosia, visual-number dysgnosia, visual letter dysgnosia, and body dysgnosia.

Treatment

No training procedures were administered to the five LD and ten normal controls between the pre and post EEGs and psychoeducational and neuropsychological evaluations. However, the LD controls continued in their public school resource programs, as did the treatment subjects.

The treatment group participated in 31 30-minute sessions twice weekly. EEG biofeedback was administered in the Neuropsychological Laboratory at The University of Tennessee, Knoxville. This treatment program was supervised and directed by Dr. Joel F. Lubar. The following will include a description of the equipment and treatment setting, and procedures implemented during sessions.

Equipment and Treatment Setting

An EEG biofeedback machine produced by Computer Products Unlimited Company was utilized which was specifically designed for this project. This equipment employed a data acquisition and analysis device with six feedback lights in a display panel. Feedback lights were controlled by a series of active bandpass filters with 48 db/octave rolloff.

Corresponding to the respective display lights were 3-7 Hz, 8-15 Hz, 16-20 Hz, and >23 Hz. The voltage level for each filter was programmable by a microprocessor, allowing individual criteria to be set for each child per session. There were small blue or red lights activated by activity in each frequency range. There was a larger green light activated each time brain wave activity entered the targeted 8-15 Hz or 16-20 Hz range. At the end of each baseline and training segment, a series of numerical (LED) displays reported percentage of time brain wave activity was present in the different frequency ranges. A frequency count was provided for the number of criterion light bursts registering entry into the 8-15 or 16-20 Hz range. These bursts were accompanied by high frequency beeps.

The biofeedback machine was connected to the subjects by silver disk electrodes (Grass Instrument Co. No-E5 SH electrodes) which were secured to the scalp by electrode paste. Subjects were seated in a recliner in upright position in a sound attenuated room with continuous white noise. The room was relatively bare with exception of basic equipment and a two-way mirror.

Treatment Procedures

For each session two electrodes were attached in scalp positions F7 and T5 or F8 and T6 (International 10-20 System). Selection of sites was based on sessions alternating between right and left hemispheres. The intention was to balance effectiveness of training between hemispheres.

Each session was divided into three segments: prebaseline (BI), treatment (Tr) and postbaseline (BII). Baseline segments were 4+ minutes each and actual treatment was 20+ minutes. Following each segment the examiner entered the room and manually recorded data from LED displays in regard to the following:

1. Percentage time that brain wave activity was in 3-7 Hz frequency range.
2. Percentage time that activity was in 8-15 Hz or 16-20 Hz range; 16-20 Hz criterion was used for only one subject (see below).
3. Percentage time that activity was greater than 23 Hz.
4. Number of criterion light bursts for each occurrence of activity, entering target range of 8-15 Hz or 16-20 Hz.

At the beginning of each training segment subjects were instructed to relax, to be verbally quiet and still, and to activate the criterion burst light as frequently as possible, and that the accompanying "beeps" would occur as additional reminders of success. They were further told to keep lights off which represented muscle activity (>23) and undesirable low frequency activity (3-7 Hz). During baseline segments subjects were only instructed to be quiet and still at which times visual and auditory feedback were removed. Pennies were used as positive reinforcement initially for each criterion burst and then gradually changed to a ratio of one penny per ten bursts as learning increased. This transition was made without resistance. Additionally, bonus pennies were given for obtaining a set number of bursts per session, with exact number specified relative to current success of the individual. An important aspect of the training program was increasing the level of difficulty for activating criterion bursts and for keeping the lights off which represented >23 and 3-7 Hz activity. On occasion, the difficulty level had to be temporarily decreased in order to assure the opportunity for reinforcement in each session. This was important to maintaining the interest of each subject. Settings remained constant during each individual session.

After the twentieth session equipment problems occurred which required an alternate temporary course in order to be able to continue treatment free of interruption. Therefore, the decision was made that subjects would be reinforced only for percentage of time that brain wave activity was below 23 Hz. This was thought to be a positive adjunct to training as it encouraged reduction of muscle activity. This procedure was utilized for sessions 21 through 24 with the original protocol subsequently resumed until the end of the training phase.

EEG tracings were produced and observed intermittently throughout each session. This provided immediate feedback to the experimenter and was an aid in determining if problems were occurring with subjects or equipment. Observations of abnormal EEG activity were noted on the tracings of one of the subjects (SP) during the pilot sessions. The decision was then made to direct training towards 16-20 Hz activity, as opposed to 8-15 Hz. Subsequently, EEG tracings normalized. When later attempts were made to revert to 8-15 Hz training, abnormal tracings were again observed. Therefore, 16-20 Hz training was emphasized throughout the study with this subject only.

CHAPTER III

RESULTS

Neuropsychological Data

Wechsler Intelligence Scale for Children-Revised (WISC-R)

Table 2 shows the mean intelligence quotients (Verbal, Performance, and Full Scale) for the three groups of students. As can be seen in Table 2, all three groups showed an average gain in the three IQ scores. Tukey's Wholly Significant Difference (WSD) Test (Myers, 1979) was the method of multiple comparison used to evaluate the magnitude of difference between pairs of means of the subtests.

Table 3 shows the mean change score differences for each of the three student groups for the Verbal, Performance, and Full Scale IQ. Using the .05 level of significance (p<.05 q 3, df 16=3.65), and the appropriate η'' to compare one group against the other (η''4.44 Treatment vs. LD Control; η''=5.71 Treatment vs. Normal Control, and η''=6.67 to compare LD Control vs. Normal Control), none of the pairwise comparisons reached significance.

Table 4 presents the mean pre and post subtest scores from the WISC-R for all three groups. It can be noted that all subtest scores except for Digit Span increased for the Treatment and Normal Control groups and all subtest scores except for Similarities and Comprehension increased for the LD Control group. Table 5 shows

Table 2. Mean IQ Levels on the WISC-R Treatment, LD Control, and Normal Control Students

	Pretest	Posttest
	Treatment (n=4)	
Verbal IQ	98.75	103.00
Performance IQ	106.50	121.00
Full Scale IQ	102.25	112.00
	LD Control (n=5)	
Verbal IQ	90.80	96.00
Performance IQ	100.60	112.80
Full Scale IQ	95.00	103.80
	Normal Control (n=10)	
Verbal IQ	117.80	119.10
Performance IQ	114.50	120.20
Full Scale IQ	118.10	122.20

Table 3. Mean (($\overline{X}$) and Standard Deviation (S) of the IQ Change Score Differences for Treatment, LD Control, and Normal Control Students

	Treatment (n=4)	LD Control (n=5)	Normal Control (n=10)
		Verbal IQ	
$\overline{X}$	4.25	5.20	1.30
S	5.62	7.40	6.58
		Performance IQ	
$\overline{X}$	14.50	12.20	5.70
S	8.02	10.55	7.51
		Full Scale IQ	
$\overline{X}$	9.75	8.80	4.10
S	3.40	8.11	6.05

Table 4. Mean Pre and Post WISC-R Subtest Scaled Scores for the Treatment, LD Control, and Normal Control Groups

	Treatment (n=4)		LD Control (n=5)		Normal Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Information	10.00	10.50	8.40	9.60	13.70	14.10
Similarities	10.75	12.25	9.60	9.20[a]	13.70	13.80
Arithmetic	7.75	9.00	6.80	8.00	11.00	11.20
Comprehension	12.50	12.50	12.00	10.04[a]	14.30	14.50
Vocabulary	9.50	10.25	7.00	9.00	13.90	14.30
Digit Span	8.75	8.50[a]	8.60	10.00	10.90	11.80
Picture Completion	12.25	14.50	12.00	12.40	13.10	13.60
Picture Arrangement	10.50	13.75	11.00	14.20	12.40	13.40
Block Design	11.75	12.00	11.60	12.40	12.10	12.30
Object Assembly	12.25	14.50	9.80	12.80	12.00	13.40
Coding	8.50	11.50	6.60	9.60	12.00	12.20
Mazes	10.50	11.50	10.00	10.00	11.10	12.70
All Subtests	10.42	11.73	9.45	10.60	12.52	13.11

[a]Mean subtest scores decrease.

Table 5. Mean ($\overline{X}$) and Standard Deviation (S) of the WISC-R Subtest Scaled Change Score Differences for the Treatment, LD Control, and Normal Control Students

	Treatment (n=4)		LD Control (n=5)		Normal Control (n=10)	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Information	.50	1.29	1.20	1.30	.40	2.07
Similarities	1.50	2.38	- .40	2.51	.10	2.47
Arithmetic	1.25	2.75	1.20	1.30	.20	2.90
Comprehension	.00	1.15	-1.60	2.70	.20	2.04
Vocabulary	.75	2.22	2.00	.71	.40	1.71
Digit Span	- .25	2.63	1,40	3.58	.90	2.13
Picture Completion	2.25	1.50	.40	3.05	.50	1.78
Picture Arrangement	3.25	3.10	3.20	3.70	1.00	2.49
Block Design	.25	1.89	.80	1.30	.20	2.53
Object Assembly	2.25	1.71	3.00	3.87	1.40	3.66
Coding	3.00	2.45	3.00	3.74	.20	1.32
Mazes	1.00	1.63	.00	2.45	1.60	2.37
All Subtests	1.31	1.52	1.15	1.90	.59	1.15

the mean change (pre to post) score differences for all subtests. It can be noted that for four out of the twelve subtests (Similarities, Arithmetic, Picture Completion, and Picture Arrangement) the Treatment group showed a larger mean change score than either the LD Control group or the Normal Control group. However, using Tukey's WSD, none of these pairwise comparisons reached statistical significance at the .05 level.

Selz and Reitan Score

Table 6 shows the mean pre and post Selz and Reitan scores for all three groups. These scores represent an overall degree of neuropsychological impairment with 0-19 classified as normal, 20-35 classified as learning disabled, and above 36 classified as damaged. It can be noted that the Treatment group showed a similar degree of improvement on post testing as compared to the LD Control and that both of these showed a greater degree of improvement than the Normal Control group. The mean change score differences are presented in Table 7. Using Tukey's WSD, no pair-wise comparison reached statistical significance.

Halstead-Reitan Neuropsychological Battery

Eight of the 37 Selz and Reitan variables were chosen to be analyzed separately. The Category Test, Tactual Performance Test Total Time, Tactual Performance Test Memory, Tactual Performance Test Localization, Finger Tapping dominant hand, and Seashore Rhythm Test were included because they are six of the seven

Table 6. Mean Selz and Reitan Scores for Treatment, LD Control, and Normal Control Students

	Treatment (n=4)	LD Control (n=5)	Normal Control (n=10)
Pretest	26.75	31.00	11.30
Posttest	20.75	23.20	10.10

Table 7. Mean Change Score Differences in the Selz and Reitan Score

	Treatment	LD Control	Normal Control	
$\overline{X}$	-6.00	-7.80	-1.4	
s	3.37	5.12	6.45	
n	4	5	10	
df	3	4	9	Σ df=16

variables that comprise the Halstead Impairment Index for the adult battery. The seventh variable of the Impairment Index, the Speech Sounds Perception Test, was not included due to the fact that it is not administered to those reading below a fourth grade level. Several of the LD children were below this required level of reading. Trails A and B were the other two variables chosen. These are also included in the adult battery and are considered to provide valuable diagnostic information.

Category test. Table 8 shows the mean pre and post Category scores and Table 9 shows the mean change scores for all three groups. It can be noted that all groups showed improvement in the desired direction which was to display a reduced number of errors. Tukey's WSD indicated that there were no statistical differences between these pairwise comparisons.

Tactual Performance Test total time. One would hope to see a reduction in the total time required to complete the formboard with each separate hand and both hands together. Table 10 reveals that the mean change score was greater for the LD Control group as compared to the Treatment group and the Normal Control group; however, these differences were not statistically significant using Tukey's pairwise test.

Tactual Performance Test memory. The students were required to draw from memory as many as possible of the six designs

Table 8. Mean Pre and Post Reitan Test Scores for the Treatment, LD Control, and Normal Control Groups for 8 Selected Subtests

	Treatment (n=4)		LD Control (n=5)		Normal Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Category*	42.50	24.50	51.20	41.00	36.80	21.70
TPT Total Time*	352.50	292.50	526.20	339.20	521.00	458.70
TPT Memory	4.25	5.25	5.20	5.40	5.20	5.10
TPT Localization	2.75	5.00	3.20	5.00	4.30	3.90
Finger Tapping	37.50	38.30	32.43	32.40	38.54	41.54
Seashore Rhythm	22.00	21.50	20.00	20.60	25.90	26.70
Trails A*	18.75	16.25	17.60	15.80	14.40	11.00
Trails B*	57.50	43.75	49.00	45.20	36.50	29.80

*A decreased score is desirable for these individual tests whereas an increase is desirable for the other tests.

Table 9. Mean Change Score Differences in the Category Test Scores

	Treatment	LD Control	Normal Control	
$\overline{X}$	-18.00	-10.20	-15.10	
s	13.51	11.97	11.40	
n	4	5	10	
df	3	4	9	$\Sigma df=16$

that they had felt while assembling the formboard blindfolded. Table 8 shows the mean pre and post responses. It can be noted that the Treatment group started at a mean of 4.25 correct responses and improved to a mean of 5.25. The LD Control group, however, started at a higher level with a mean of 5.20 and thus only increased to a mean of 5.40. The Normal Controls started off with a mean equal to the LD control children and then decreased slightly in performance to a mean of 5.10. The mean change scores appear in Table 11. Tukey's pairwise comparisons revealed no significant differences between these pairs.

Table 10. Mean Change Score Differences in the Tactual Performance Test Total Time

	Treatment	LD Control	Normal Control	
$\overline{X}$	- 60.00	-187.00	- 62.30	
s	114.16	206.16	275.80	
n	4	5	10	
df	3	4	9	Σdf=16

Tactual Performance Test Localization

When the student was drawing the designs of the formboard from memory he was to place them as best he could in the correct location so that a score of 6 would have represented a perfect localization

Table 11. Mean Change Score Differences in the Tactual Performance Test Memory

	Treatment	LD Control	Normal Control	
$\overline{X}$	1.00	.20	- .10	
s	.82	.45	1.20	
n	4	5	10	
df	3	4	9	Σdf=16

score. Table 8 shows that the mean scores increased from 2.75 to 5.00 for the Treatment group and from 3.20 to 5.00 for the LD Control group. The Normal Control group's localization score decreased from 4.30 to 3.90. Table 12 indicates that this mean change score was greater for the Treatment group than the LD Control group and that the change for the LD Control group was greater than for the Normal Control group. Statistical analysis with Tukey's WDS revealed that the differences were not statistically significant for the Treatment versus LD control group but it did reach significance for the Treatment versus Normal Control and for the LD Control versus Normal Control groups.

Finger Tapping Test. The number of taps with the dominant hand was compared for each pair of groups. Table 8 shows the mean pre and post scores and Table 13 shows the mean change score differences. The Normal Control group was the only group that showed the desirable faster score. There were no statistical differences between the group using a multiple comparison approach.

Table 12. Mean Change Score Differences in the Tactual Performance Test Localization

	Treatment	LD Control	Normal Control	
$\overline{X}$	2.25	1.80	- .40	
s	1.26	1.10	1.07	
n	4	5	10	
df	3	4	9	Σdf=16

Table 13. Mean Change Score Differences in the Finger Tapping Test (Dominant Hand)

	Treatment	LD Control	Normal Control	
$\overline{X}$	.80	- .03	3.0	
s	6.54	4.12	4.89	
n	4	5	10	
df	3	4	9	Σdf=16

Seashore Rhythm Test. The student is required to compare 30 pairs of rhythms and indicate if they are alike or different. A score of 30 would be a perfect response. It can be noted in Table 8 and Table 14 that these scores changed minimally from pre to post testing for all three groups. Statistical significance between the pairs of groups was not obtained.

Table 14. Mean Change Score Differences in the Seashore Rhythm Test

	Treatment	LD Control	Normal Control	
$\bar{X}$	.50	.60	.80	
s	.58	2.79	2.39	
n	4	5	10	
df	3	4	9	$\Sigma df=20$

Trails A. The score on this test represents the number of seconds required to complete a dot to dot task. Table 8 shows that all three groups reduced their time from pre to posttesting. It can be seen in Table 15 that the Treatment group displayed a greater reduction than the other two groups. Analysis with Tukey's WSD did not yield statistical differences between any of the group's pairs.

Trails B. A reduction in the number of seconds required to complete this task was desirable. Tables 8 and 16 indicate that all three groups reduced their speed with the Treatment group showing the greatest reduction. Tukey's pairwise comparison test revealed no statistical differences between these pairs of groups.

Table 15. Mean Change Score Differences in the Trails A Test

	Treatment	LD Control	Normal Control	
$\overline{x}$	-2.50	-1.8	-3.4	
s	7.33	3.19	3.95	
n	4	5	10	
df	3	4	9	Σdf=16

Table 16. Mean Change Score Differences in the Trails B Test

	Treatment	LD Control	Normal Control	
$\overline{x}$	-13.75	- 3.80	- 6.70	
s	16.09	18.93	15.81	
n	4	5	10	
df	3	4	9	Σdf=16

Psychoeducational Data

Wide Range Achievement Test (WRAT)

All three sections of the WRAT were administered to all three groups as a measurement of academic gains over the experimental period.

Word recognition. Table 17 shows the mean raw scores in word recognition (reading) for the pre and posttest data. It can be seen that all three groups showed an increase during this specified period of time. The mean change scores are seen in Table 18. Examination of this table indicates that the Normal Control group improved slightly more than the LD Control group and that the Treatment group had a larger difference than either of the control groups. Using Tukey's WSD none of the groups were found to be statistically different from each other.

Table 17. Mean Scores on the Wide Range Achievement Test for the Treatment, LD Control, and Normal Control Students

	Pretest	Posttest
	Treatment (n=4)	
Reading	57.50	63.00
Spelling	34.75	38.00
Arithmetic	32.00	36.75
	LD Control (n=5)	
Reading	51.20	54.40
Spelling	33.40	34.80
Arithmetic	28.80	30.20
	Normal Control (n=10)	
Reading	77.50	81.40
Spelling	51.30	53.00
Arithmetic	38.50	40.20

Table 18. Mean Change Scores in Word Recognition on the Wide Range Achievement

	Treatment	LD Control	Normal Control	
x	5.50	3.20	3.50	
s	3.70	1.48	2.55	
n	4	5	10	
df	3	4	9	df=16

Spelling. The mean scores for spelling increased from pre to post testing for all three groups (see Table 17). Table 19 shows that the mean change scores were similar for the two control groups but the Treatment group showed a greater change than the other two groups. Statistical analysis showed that the pairwise comparisons between the Treatment group and the LD Control group and between the Treatment group and the Normal Control group were not statistically significant at the .05 level.

Arithmetic. As with reading and spelling, the mean raw scores for arithmetic also increased from pre to post testing for all three groups (see Table 17). It can be seen in Table 20 that the Normal Control group increased more than the LD Control group and that the Treatment group increased more than either control group. Using Tukey's multiple comparison test, the Treatment group was not found to be statistically different from the LD Control group and from the Normal Control group. However, in both cases the critical values

Table 19. Mean Change Scores in Spelling on the Wide Range Achievement Test

	Treatment	LD Control	Normal Control	
$\bar{X}$	3.25	1.40	1.70	
s	2.22	2.61	1.77	
n	4	5	10	
df	3	4	9	$\Sigma df=16$

Table 20. Mean Change Scores in Arithmetic on the Wide Range Achievement Test

	Treatment	LD Control	Normal Control	
$\bar{X}$	4.75	1.40	1.90	
s	3.10	1.14	1.66	
n	4	5	10	
df	3	4	9	$\Sigma df=16$

were very close to the obtained differences. The difference between the LD Controls and the Normal Controls did not yield a statistical difference.

Spache Diagnostic Reading Scales

The Spache Diagnostic Reading Scales were used to obtain a measurement of comprehension in reading as opposed to word recognition measured by the WRAT. The level of greatest difficulty that the child reads with 85% comprehension is considered the oral or instructional level. The silent or independent level is the one of greatest difficulty that the child reads with 60% comprehension. The scores obtained are grade level equivalents that do not have raw scores associated with them. The change scores were ranked and Tukey's WSD was utilized in analyzing the obtained ranks. This procedure is reported as appropriate by Conover and Iman (1981).

Table 21 shows the mean change oral reading grade equivalent scores in ranks. It can be noted that the Treatment group improved more than the LD and Normal Control groups, and that the LD Control showed greater gains than the Normal Control group. Using Tukey's pairwise test, the Treatment group was found to be statistically different from the Normal Control group. However, the differences between the Treatment and LD Control groups as well as between the LD Control and Normal Control groups did not reach statistical significance at the .05 level. Examination of Table 22 reveals that the mean change silent reading grade equivalent scores were not significantly different from each other.

Bender Gestalt Designs

The Koppitz scoring system (Koppitz, 1963) was utilized in evaluating each student's production of the Bender Gestalt Designs. Table 23 shows that the mean error scores decreased for the Treatment group from pre to post testing; however, the mean error scores for both the control groups remained relatively unchanged. The mean

Table 21. Mean Oral Reading Grade Equivalent in Ranks for Treatment, LD Control, and Normal Control Students on the Spache Diagnostic Reading Scales

	Treatment	LD Control	Normal Control	
$\bar{X}$	15.75	11.20	6.80	
s	2.72	5.89	4.22	
n	4	5	10	
df	3	4	9	$\Sigma df=16$

Table 22. Mean Change Silent Reading Grade Equivalents in Ranks for Treatment, LD Control, and Normal Control Students on the Spache Diagnostic Reading Scales

	Treatment	LD Control	Normal Control	
$\bar{X}$	13.13	12.80	7.35	
s	5.44	4.06	4.44	
n	4	5	10	
df	3	4	9	$\Sigma df=16$

change scores for all groups are depicted in Table 24. Using Tukey's WSD, both the comparison of the Treatment versus the LD Control and the Treatment versus the Normal Control showed statistically significant differences at the .05 level. There was no difference between the two control groups using the pairwise comparison technique.

Table 23. Mean Pre and Post Bender Gestalt Errors for the Treatment, LD Control, and Normal Control Groups

	Treatment (n=4)	LD Control (n=5)	Normal Control (n=10)
Pretest	2.50	4.40	2.10
Posttest	1.75	4.40	2.00

Table 24. Mean Change Bender Gestalt Scores for Treatment, LD Control, and Normal Control Students

	Treatment	LD Control	Normal Control	
$\overline{x}$	- .75	0	- .10	
s	2.22	1.22	1.10	
n	4	5	10	
df	3	4	9	Σdf=16

EEG Data

LD Children Versus Normal Children

An important area of investigation involved the electrophysiological data, looking at the differences between the LD and Normal children in regard to raw power and percentage power prior to intervention. An analysis of variance was performed on the EEG data for the three groups in both hemispheres.

Significant results at the .05 level or less are displayed in Figure 1 which reports the differences between the LD and Normal children before treatment on two EEG measurements: total spectral power and percent power. These measurements were recorded during three separate conditions: baseline$^{(B)}$, reading$^{(R)}$, and drawing$^{(D)}$. When the symbols B, R, and D are accompanied in the figure by a plus sign (B+, R+, or D+), this indicates that the LD students had larger scores than the Normals for a specific location and frequency band. If the symbols are accompanied by a minus (B-, R-, or D-), the Normal children had larger scores than the LD subjects. It should be pointed out that this study contained a larger initial sample of 16 LD students in addition to the four that were treated by EEG biofeedback. Analysis of pre-evaluation electrophysiological measures reflected in Figure 1, therefore, include 20 LD students and 10 normals.

The left side of Figure 1 displaying total spectral power reveals that in both the right and left frontal areas the LD subjects have significantly more slow wave activity than the Normals. This greater power for the LD children also occurs in the higher frequencies but not in the intermediate frequencies. The greater power in the 12-24 Hz bands for the LD children occurred during baseline, reading, and drawing tasks.

On the right side of Figure 1 is represented the percentage of power for the different frequencies. It can be noted that the LD subjects reveal more power in the left temporal and frontal

POWER

LOCATIONS	All	0-4	4-8	8-12	12-16	16-20	20-24	24-28	6-10
C_4T_4									
O_2P_4									
F_8F_4	R+	R+			D+	B+ D+ R+	B+		
F_8T_6									
C_3T_3						D+			
O_1P_3									
F_7F_3		D+				B+			
F_7T_5									

PERCENTAGE

LOCATIONS	0-4	4-8	8-12	12-16	16-20	20-24	24-28	6-10
C_4T_4								
O_2P_4		R-						
F_8F_4				D+				
F_8T_6								
C_3T_3					D+	D+	D+	
O_1P_3				D+	D+	D+	D+	
F_7F_3				B+				
F_7T_5				B+				

FREQUENCY (Hz)

KEY

R - Read
D - Draw
B - Baseline

LD > N = +
LD < N = -

Figure 1. Power and Percentage EEG Comparisons for Eight Locations Between 0-28 Hz for LD and Normal Children

positions in the 12-16 Hz band during baseline. Moreover, the LD children, in the drawing condition, have a greater percentage power in the higher frequencies for the left hemisphere in the central and occipital areas. There was only one location where the Normal subjects had larger percentage of power compared with the LD; this was at 4-8 Hz in the occipital and parietal area of the right hemisphere.

Treatment, LD Controls, and Normal Controls Compared in Spectral Power

A comparison of these three groups in regard to spectral power for pre and post conditions was obtained by first getting change scores. Guilford and Fruchter (1973) report that planned comparison analyses are a more powerful statistical test than doing sets of t tests pre and post; thus the EEG data were analyzed in this manner. The significant raw power changes from pre to post conditions for the EEG of all three groups are displayed in Figures 2, 3, and 4.

Figure 2 indicates that for the left hemisphere central location the Normals show an increase in slow and intermediate activity for the baseline condition. In the right hemisphere the LD Controls displayed less power in the lower frequencies for the occipital-parietal area. It can be noted in Figure 3 that during reading the Normal children show greater overall power in both the low and high frequencies for the right frontal region. Moreover, the Normals also show an increase in the higher frequencies over

LOCATION		All	0-4	4-8	8-12	12-16	16-20	20-24	24-28	6-10
Right Hemisphere	C_4T_4									
	O_2P_4	L-	L-	L-						
	F_8F_4						L+			
	F_8T_6								N+	
Left Hemisphere	C_3T_3	N+		N+		N+	N+			L+
	O_1P_3	N-	N-							
	F_7F_3									
	F_7T_5					N+	L-			

Low ← FREQUENCY (Hz) → High

KEY

T - Treatment
L - LD Control
N - Normal Control

\+ = Post > Pre
\- = Post < Pre

Figure 2. Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Baseline Power.

LOCATION		All	0-4	4-8	8-12	12-16	16-20	20-24	24-28	6-10
Right Hemisphere	C_4T_4								L+ N+	N+
	O_2P_4			T+						T+
	F_8F_4	N+		N+	N+		N+	N+		N+
	F_8T_6					N+		N+	N+	
Left Hemisphere	C_3T_3									N+
	O_1P_3									
	F_7F_3									
	F_7T_5									

Low — High

FREQUENCY (Hz)

KEY

T - Treatment
L - LD Control
N - Normal Control

+ = Post > Pre
- = Post < Pre

Figure 3 . Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Reading Power.

LOCATION		All	0 -4	4 -8	8 -12	12 -16	16 -20	20 -24	24 -28	6 -10
Right Hemisphere	C_4T_4		T+				L+	L+	L+	
	O_2P_4									
	F_8F_4		T+	N+	N+	N+				N+
	F_8T_6					L-				
Left Hemisphere	C_3T_3									
	O_1P_3									
	F_7F_3					N-			N-	
	F_7T_5							L-	L-	

Low — High

FREQUENCY (Hz)

KEY

T - Treatment
L - LD Control
N - Normal Control

+ = Post > Pre
- = Post < Pre

Figure 4. Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Drawing Power.

derivations in the temporal region. For the drawing condition, Figure 4 reveals that raw power in the right central region for the LD controls increased in the higher frequencies. In addition, for the frontal region of the right hemisphere the Normals show an increase in intermediate activity.

Treatment, LD Controls, and Normal Controls Compared in Percentage Power

The percent power for the three conditions (pre and post) was also analyzed utilizing change scores in the same manner as with the raw power data. Figures 5, 6, and 7 display statistically significant changes ($p < .05$, two-tailed) from pre to post conditions. Figure 5 shows that in the baseline condition the LD Controls show an increase in higher and intermediate frequency activity in the right central area whereas the treated LD group only showed an increase in the intermediate frequencies. The figure also reveals a decrease of very slow activity in both the Treatment and LD Controls in the right central and occipital locations. Moreover, one can see that there was increased activation of the right temporal regions for Normals.

The significant pre and post changes for the reading condition are noted in Figure 6. The Normal subjects show an increase in right temporal activity as well as an increase in right central activity for the higher frequencies. It can be noted that the Normal subjects show an increase in right side higher frequency activity

LOCATION		0 -4	4 -8	8 -12	12 -16	16 -20	20 -24	24 -28	6 -10
Right Hemisphere	C_4T_4	L-				L+			N-
	O_2P_4	L- T-	L+ T+	T+	L+ T+	L+	L+	L+	T+
	F_8F_4				L+				
	F_8T_6		T+			N+	N+	N+	
Left Hemisphere	C_3T_3		N-						
	O_1P_3		L+						
	F_7F_3								
	F_7T_5				N+				

Low — High

FREQUENCY (Hz)

KEY

T - Treatment
L - LD Control
N - Normal Control

+ = Post > Pre
- = Post < Pre

Figure 5. Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Baseline Percentage Power.

Location		0 -4	4 -8	8 -12	12 -16	16 -20	20 -24	24 -28	6 -10
Right Hemisphere	C_4T_4					L+		L+	
	O_2P_4	T- N+	T+		N+	N+	N+	N+	T+
	F_8F_4								
	F_8T_6				N+	N+	N+	N+	
Left Hemisphere	C_3T_3	L-			L+	L+			
	O_1P_3	L- N-		L+ N+	L+				N+
	F_7F_3			L+			N-		
	F_7T_5		L+						

Low — High

FREQUENCY (Hz)

LOCATION

KEY

T - Treatment
L - LD Control
N - Normal Control

+ = Post > Pre
- = Post < Pre

Figure 6. Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Reading Percentage Power.

LOCATION		0-4	4-8	8-12	12-16	16-20	20-24	24-28	6-10
Right Hemisphere	C_4T_4	N+	N-			T-			
	O_2P_4	N-	T+	N+	N+ L+	N+	N+	N+	N+ T+
	F_8F_4								
	F_8T_6								
Left Hemisphere	C_3T_3							L-	
	O_1P_3								N+ T+
	F_7F_3	N+	N-		N-	N-	N-	N-	
	F_7T_5	N+	N-						N-

Low — High

FREQUENCY (Hz)

KEY

T - Treatment
L - LD Control
N - Normal Control

+ = Post > Pre
- = Post < Pre

Figure 7. Directional Comparisons of Treatment, LD Control and Normal Control Groups for Pre and Post Training Scores for Drawing Percentage Power.

while the LD Controls show an increase in the intermediate frequencies on the left side.

The drawing condition for percentage (Figure 7) reveals that the Normals increase in the right hemisphere for the higher frequencies occipitally whereas the treated group shows an increase in right occipital-parietal activity for the lower frequencies. In addition, the Normals show a decrease in the higher frequencies on the left side of the frontal derivations.

Biofeedback Data

For each of the 31 sessions, the treatment (Tr) phase was compared with prebaseline (BI) in order to determine the extent to which change occurred. Frequency counts were made of increases/decreases from BI to Tr in EEG activity in three frequency ranges (4-7 Hz, 8-15 or 16-20 Hz, and >23 Hz) and criterion light bursts. The frequency counts excluded sessions 21-24 during which only reduction of muscle activity was reinforced. Chi Square was utilized as a means of evaluating significance with Yates correction for continuity (Guilford & Fruchter, 1973) applied when appropriate.

Table 25 shows that at the .05 level of confidence three of the four subjects significantly increased the number of incidences of EEG activity entering the targeted frequency range (8-15/16-20 Hz) from BI to the Tr phase of the sessions. This is represented

Table 25. Summary of Significant Increases/Decreases from Prebaseline (BI) to Treatment (Tr) for all Sessions

Subject	3-7 Hz		8-15/16-20 Hz		>23 Hz		Criterion Bursts	
	.10	.05	.10	.05	.10	.05	.10	.05
*SP	-			+				+
BF								+
TC	-							+
PH	-							
Total Sessions		-		+				+

+ = Observed frequency of increased activity reached statistical significance at .05 or .10 level of confidence.

- = Observed frequency of decreased activity reached statistical significance at .05 or .10 level of confidence.

*Only S for which 16-20 Hz activity was reinforced.

by Criterion Bursts. Increase of percent time that EEG activity was in the targeted range, comparing Tr with BI is shown in Table 25 as being significant for one student at the .05 level. 3-7 Hz activity was significantly decreased from BI to Tr at the .10 level for three-fourths of the students. Reduction in muscle activity (<23 Hz) from BI to Tr did not occur significantly for any of the students.

Table 25 also shows a summary of sessions for all subjects and that the desired changes occurred from BI to Tr in three of the four categories at the .05 level. Significant reduction in muscle activity (>23 Hz) did not occur. Table 26 shows in raw frequency counts that, overall in far greater than half of the sessions, the desired effect was elicited when Tr is compared with BI.

Table 26. Percentage of Sessions for which Increased or Decreased EEG Activity Occurred from BI to Tr for All Subjects

	3-7 Hz	8-15 16-20 Hz	>23 Hz	Criterion Bursts
Decrease in activity	67%	32%	58%	23%
Increase in activity	33%	68%	42%	77%

BF was the only subject for which the desired effect was not achieved during treatment in any of the four categories. It should be noted that he was the most difficult of the four subjects in regard to maintaining attention span and interest level, and appeared the most immature by comparison.

Generalization of Training

In order to obtain information regarding possible effects of treatment on school functioning, parents were contacted by phone two months after treatment was terminated. This occurred concurrent with the end of the academic year, with the parents questioned regarding changes observed in academic capabilities of their sons. The following reports were given:

SP--Increased grades in some areas with improvement in spelling being most noticeable.

BF--More relaxed at home and in school and reported by his teacher to be less active during class periods. Handwriting had improved.

TC--Concentration during reading improved (as reported by the student) with comprehension having increased. Sentence writing was considered improved.

PH--The teacher reported to the mother that this student had improved in completion of assignments and in staying on task in class.

While these are subjective observations, it is encouraging that no negative effects or disappointments were reported in regard to possible effects of the treatment program. Parental attitudes were consistently positive. Regarding the subject that participated and moved prior to completion of the project, his mother reported improved self-confidence and decreased dependency as the project progressed. She related this to his learning to come into the University laboratory setting independently.

CHAPTER IV

DISCUSSION

In this study, if the biofeedback therapy with learning disabled children had positive results one would expect to see noticeable changes in the neuropsychological data, psychoeducational data, EEG assessments data, and EEG biofeedback data. Moreover, it might be anticipated that the statistical data for the treated LD subjects would diverge from the findings of the non-treated LD controls and become more similar to the measurements of the Normal Control children.

Neuropsychological Data

WISC-R

Based on the finding that there were no significant pairwide comparisons in the change scores for the intellectual profiles, it must be concluded that the biofeedback therapy did not have a direct effect upon intellectual test scores. It might have been anticipated that the subtest scores involving concentration (Digit Span, Arithmetic, and Coding) would have increased for the treatment group based upon the fact that they received training to increase activity in the frequency band representing higher attentional levels. However, this effect did not generalize to the psychological test results.

Selz and Reitan

The Selz and Reitan scoring system was utilized as a measurement of the severity of neuropsychological dysfunction. It was expected that for the biofeedback Treatment group, this deficit score would improve but for the two Control groups it would remain somewhat constant. The change scores from pre to post testing for the Treatment LD group as well as the LD Control group showed a noticeable improvement but not one that reached statistical significance. Very little change was noted in the overall scores of the Normal children.

The first question that comes to mind relates to the reason that the LD Control children improved as much as those receiving biofeedback treatment. One possibility is that the learning disabled students would show a greater change in neuropsychological functioning compared to Normals merely as a function of maturation and being a developmentally delayed population. One would expect that a delayed group would show greater improvement even if they did not receive intervention strategies. Most importantly, it must be remembered that the LD Control subjects continued to be involved in LD classes and as a result cannot be considered a group of learning disabled children that are not being treated. It was reasonable to have hoped that biofeedback treatment would have added to the positive effect of school intervention to the point that this improvement would reach statistical significance. The separate analyses of the eight variables from the Reitan Battery revealed that in general the Treatment group showed a greater mean change as compared to the LD Controls; however, not enough to be considered statistically significant. The fact that the Normal subjects showed very little improvement in their scores makes it evident that the growth shown by the LD children was possibly not due entirely to maturation or test-retest practice.

Psychoeducational Data

The academic gains of the WRAT shown by the LD Treatment group were all in the desired direction in comparison to the two control groups; however, none of the changes were considered statistically significant. These results do not support the hypothesis that the biofeedback therapy results in increased ability to perform academically. Generalization did not occur as would have been expected.

Silent reading levels, as measured on the Spache, were found to improve most for the Treatment group and in diminishing amounts for the LD Controls and Normals, in that order. The only comparison that was significant was between the Treatment and Normal Control groups. The previously mentioned factor, that LD children are developmentally delayed and thus more likely to improve, could also be operating here, since treatment and LD control groups did not differ.

Last, the results of the Bender Gestalt Test seem to suggest that the biofeedback therapy may have had an influence on the LD students' ability to perform perceptual motor tasks. The Treatment group improved its Koppitz score when compared to both control groups. Since spatial designs are thought to relate to the right hemisphere, one might consider the possibility that the biofeedback therapy had a greater impact on the right hemisphere than on the left.

EEG Date

LD Children versus Normal Children

The results of the pretreatment electrophysiological data in comparing Normal and learning disabled children does not correspond fully with other research which indicates that the LD subjects show greater occipital slowing (Pavy & Metcalfe, 1965) and temporal slowing (Hughes, 1971). The LD children in the present study showed greater slow wave activity in the left and right frontal areas, which supports previous research. However, they also showed more spectral power for 16-20 Hz, which has not been reported previously. It seems possible that this finding might be due to excessive muscle activity in the data. Most recently, Shabsin (1982) has noted that learning disabled children have problems relaxing when EEG recordings are made (EMG in excess of 50 uV). It might be helpful to provide relaxation training prior to electrophysiological assessment.

The percentage power data also contradicted previous results. In the drawing condition, instead of showing greater activity in the higher frequencies in the right hemisphere, greater activity for 12-24 Hz was found in the left hemisphere. This left hemisphere elevation is possibly support for the presence of hemispheric problems or cross dominance in the LD population.

Treatment, LD Controls, and Normal Controls Compared in Spectral Power

For the baseline session, the Normal children showed an increase in slow and intermediate activity in the left central location. The desired effect of increasing 8-15/16-20 Hz activity among the Treatment group during the reading task was not accomplished. Instead, the Normal subjects, without any intervention, made the type of gains one would have hoped for the treated LD. It appears that maturation of Normal children is an important consideration.

While drawing, the LD Controls increased in the higher frequencies in the right central region and this again is an unexpected result. A reasonable explanation is that this increased power is due to excessive eye or muscle movements during the assessment session.

Treatment, LD Controls, and Normal Controls Compared in Percentage Power

The findings of the percent power during baseline can be explained from a number of vantage points. The increased percentage of power for the Normals in the temporal region is probably due again to the process of maturation. The result of increased higher frequency activity for the LD Controls in the right central area might be due to increased EMG or muscle activity. On the other hand, a decrease in muscle and increase in lpha may be the reason the treated LD increased in the 4-16 Hz frequency bands.

The results in the reading and drawing conditions are generally random and do not relate to previous findings in the literature. The one expected result found is the fact that Normals increased in the higher frequencies for drawing. It was hoped that the treated LD group would show similar effects; however, they did not.

Biofeedback Data

With positive results of the EEG biofeedback treatment, it would be expected that increased 8-15/16-20 Hz activity and Criterion Bursts, concurrent with decreased 3-7 Hz and >23 Hz activity would occur over time from prebaseline to the treatment phase.

The desired effect on 8-15/16-20 Hz activity as represented by increased Criterion Bursts from prebaseline to treatment, occurred at .05 level of confidence for three of the subjects. When the data were combined for all subjects, a statistically significant increase at the .05 level occurred. This suggests positive results reinforced by some increase in percentage time that EEG activity was in the targeted range during the treatment phase, when compared to prebaseline. This occurred at the .05 level of confidence for only one student, although significance at the same level was found when sessions for all students were combined.

For three of the four subjects activity in the 3-7 Hz range decreased at the .10 level of confidence. No significant decrease occurred for the fourth student. This represents a trend in the desired direction, although success is viewed as limited. Again, comparing treatment with prebaseline, muscle activity (>23 Hz) was not decreased at a significant level.

The desired increases and decreases from prebaseline to treatment appear to have been generally accomplished, as reflected by combined data for all subjects. This is supported by significant results at the .05 levels of confidence for three of the four categories.

Generalization of Training

For all treatment subjects, parents reported positive results related to school functioning. However, improvement in schoolwork and attentional skills cannot necessarily be attributed to the laboratory treatment these children received. While a connection could exist, such a question cannot be answered in this research. The positive effects of the amount of individual attention these children received during four months of treatment must be considered, especially as these efforts related directly to their learning problem. The possibility of state dependency must also be considered as the subjects were trained to respond in a certain manner under specific conditions. Generalization to the classroom might have been enhanced if biofeedback treatment had been paired with academic training.

Conclusions and Implications

An overview of the neuropsychological and psychoeducational data suggests that gains in abilities for the treatment group over the training period reached statistical significance in two areas, including reading comprehension and visual-perception or perceptual-motor skills. While the writer is aware that these are two measures among many, they are considered important to academic development. It is interesting to note that these two capabilities are considered representative of the two hemispheres. This perhaps speaks to having trained both hemispheres, and could support efficacy of doing so for future studies. As limited positive gains were made, perhaps a longer treatment period would have produced more significantly improved post evaluation results.

The initial electrophysiological measures for all LD children compared to normals produced information which might be helpful for future studies. The increased slow wave activity in both frontal lobes might be related to attentional problems, difficulty with reasoning and impulse control with LDs. This could be a target for research.

Greater power in the 12-16 Hz band in the left temporal and frontal areas during baseline, and increased percentage power in higher frequencies for the left central and occipital areas while drawing are interesting to consider concurrently. This is especially true in light of the fact that most of the weaknesses which typically lead to identification of learning disabilities are thought to be left hemisphere functions. Additionally, one would question the extent to which compensation across hemispheres is occurring, due to hemispheric differences of LD children.

Comparing pre and post electrophysiological measures, significant gains in the targeted frequency bands were not found. However, the results of the biofeedback data produced by individual sessions were more promising. An overview of these data suggests that success occurred during the treatment sessions while no generalization of effect was found. Refinement of this important aspect of treatment could be explored, perhaps with such techniques as are offered by the Neurolinguistic Programming (NLP) body of knowledge. NLP provides methods which could be beneficial in generalizing training and avoiding state dependency limitations.

It is encouraging that different types of improvement were reported for all subjects following treatment. Also important to consider is the statistically significant reduction of errors on the Bender Gestalt drawings of the treatment group, compared to the controls. Certain types of errors on this test are frequently viewed as "signs" of neurological deficits. Hence, any significant improvement is noteworthy.

In reviewing the findings of this investigation, future related research is encouraged. Greater attention might be given to specific factors which would heighten the efficacy of EEG biofeedback treatment for LD children as productive research or a therapy form. Improved methods for motivating subjects would be helpful, considering the fact that treatment forms can be appropriate for some, while not for others. This principle should be applied to those who would (or would not) be capable of attending to the treatment plan. Pairing academics with treatment should be considered.

From the onset, this research was viewed as exploratory in nature. The data generated reflect a trend of desired effects having been obtained, while concrete answers were not forthcoming. However, information has been made available which can enhance and contribute to future research. It is hoped that the children who participated in this research have been rewarded by improvement in academic functioning.

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VITA

Corinne Reed Bell was born on July 6, 1943, in Holly Springs, Mississippi, to a cotton farmer who held a Liberal Arts degree from the University of Mississippi, and a mother who was his assistant and a very determined woman. Corinne moved to East Tennessee in 1971 and began her higher educational studies the following year, receiving an A.A. degree from Roane State Community College in 1974. A Bachelor of Arts degree in psychology was subsequently awarded in 1976 from The University of Tennessee, Knoxville. Corinne graduated Phi Beta Kappa with Highest Honors. In 1978 she obtained a Master of Arts degree in School Psychology from the same institution and continued with her doctoral studies.

Corinne has two children, Jeffrey Kenneth (age 22), of Hollywood, California, and Jennifer Michelle (age 15), who lives in Knoxville with her mother. She is currently an associate in private practice with Leonard M. Miller, Ph.D. and Associates, where she will continue following completion of her doctoral degree.