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AN EXAMINATION OF CEREBRAL LATERALIZATION IN
READING DISABLED CHILDREN.

THE OHIO STATE UNIVERSITY, PH.D., 1979
AN EXAMINATION OF CEREBRAL LATERALIZATION
IN READING DISABLED CHILDREN

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Edward David Farber, B.A., M.A.

***

The Ohio State University
1979

Reading Committee:          Approved By

Dr. Malcolm Helper          Adviser
Dr. Charles Wenar
Dr. Felicisima Serafica
Dr. Marlin Languis

Department of Psychology
ACKNOWLEDGMENTS

For five years Dr. Malcolm Helper has served as my teacher, adviser, supervisor, and mentor. I am ever grateful for his selflessness, devotion and support, without which this project would not have been undertaken.

Dr. Charles Wenar promoted my development within the field of clinical-child psychology. Dr. Marlin Languis' interest in and support of this project was always encouraging and stimulating. Dr. Felicisima Serafica graciously accommodated herself to the needs of this research.

I would like to thank Dr. Walter Kass of New York University Medical Center for the concept initiating this study. Dr. Kass has always demonstrated the highest ideals and standards of a professional psychologist to which I can only hope to aspire.

And most importantly now and always I would like to thank my wife, Pamela Nadell.
VITA

April 9, 1952 ........................................ Born - Jersey City, New Jersey

1971-1972 ........................................ Hebrew University of Jerusalem, Israel, one year study program

1973 ............................................. B.A., Rutgers College, Rutgers The State University of New Jersey, New Brunswick, New Jersey

1974-1976 ........................................ Research Associate, Children's Hospital, Department of Psychology, The Ohio State University, Columbus, Ohio

1975 ............................................. M.A., The Ohio State University, Columbus, Ohio


1977-1978 ........................................ Coordinator, Therapeutic Tutoring Program, Children's Hospital, Columbus, Ohio

1978-1979 ........................................ Second year intern in Clinical Child Psychology, Children's Hospital, Department of Psychology, The Ohio State University, Columbus, Ohio

PUBLICATIONS

with Rie, H.E., Evaluation of a Therapeutic Tutoring program. Manuscript accepted for publication, Professional Psychology.
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I. INTRODUCTION

It has been estimated (Gaddes 1976) that some 7 to 17% of children cannot meet the academic demands of school and are unable to achieve up to expected academic level. Numerous diagnostic categories have been used for these children (Spreen 1976) including learning disability, minimal brain dysfunction, primary reading disorder, reading retardation and others. Yule et al. (1974) have demonstrated that the percentage of children actually experiencing difficulty in mastering reading skills is greater than that expected on purely statistical grounds. This study proposes that the etiology of the academic distress in certain children classified as reading disabled is due to dysfunctional specialization of the cerebral hemispheres.

Orton (1937) conceptualized reading skills as cognitive tasks mediated mainly by the left cerebral hemisphere. In children with difficulty learning to read, he suggested a physiological deficit in specialization of the left hemisphere. This hypothetical construct of incomplete dominance had been based on the observation of left-handedness, crossed hand-eye preference, right-handed clumsiness, and superiority of performance skills over verbal in children with
reading disabilities. More recent knowledge of the functions of the two hemispheres have come from patients who have had their corpus collosums sectioned (Sperry 1974, Gazzaniga 1970) and from studying the effects of lesion or damage to only one of the cerebral hemispheres (Milner 1974, Witelson 1977). With the recent development of the biologically non-intrusive technique of dichotic listening (Broadbent 1954, 1974; Kimura 1961, 1963) it has become possible to study cerebral laterality in normal adults and children. What is proposed herein is that there exists a specific group of reading disabled children whose academic distress is caused by impairment of the left cerebral hemisphere, the hemisphere found to be dominant for verbal-analytic abilities. The impairment may be seen as either a developmental lag in the maturation or specialization of the hemisphere (Satz et al. 1971, Satz 1976) or as a deficit in the cerebral functioning necessary for the acquisition of age appropriate skills (Rourke 1976). What follows is a discussion of two distinct classes of reading disabled children, those whose reading performance is poor relative to grade but not intelligence, and those whose specific underachievement in reading is not explicable in terms of intelligence. It is proposed that the specific underachievement of this second group is due to incomplete lateralization of the left cerebral hemisphere as measured by dichotic listening tasks and that gains in reading achievement over the course
of therapeutic intervention would be related to growth in left hemisphere cerebral lateralization.

**Backward and Retarded Readers**

In a series of studies Yule, Rutter, and their associates examined the prevalence and implications of reading underachievement in over 7000 children aged 9-14 in the Isle of Wight and inner London. They distinguished (Rutter & Yule 1975) between two specific subgroups of learning disordered children, backward and retarded readers. General reading backwardness was defined as poor reading performance relative to the average attainment for that grade, regardless of intelligence. These children may be called low achievers, but not underachievers. Specific reading retardation was defined as poor reading performance relative to the child's general intelligence. Due to the lack of perfect correlation between reading and intelligence, the authors utilized a regression coefficient (Thorndike 1963) that allows for the prediction of reading attainment level accounting for any regression effects. This concept of a discrepancy between potential and achievement is not a novel one and has been used in the past to define learning disability (Myklebust 1968, Burt 1937). But the discrimination between histories and capabilities of those who were low achievers from those who were underachievers appears to
have predictive utility.

Yule et al. (1974) argue that there exist 1 to 3% more children with specific reading retardation than that expected on pure statistical grounds. Geographical location and socio-economic status appear to have an effect on the rate of specific reading retardation. Berger et al. (1975) found the prevalence of retarded reading (scores two standard errors below those predicted) to be nearly 10% in inner London as compared to 4% on the Isle of Wight. General reading backwardness was found among 19% of Londoners, but only 8% of the children on the Isle of Wight.

The authors (Rutter & Yule 1975, Yule & Rutter 1976) find significant differences between backward and retarded readers that appear to justify the distinction of two groups. Some 86 retarded readers were compared to 79 backward readers aged 9-11. As expected on the basis of group selection backward readers had lower intelligence scores. There was an even sex ratio among backward readers, but in the specifically retarded reading group boys outnumbered girls three to one. Whereas 11% of the backward readers had definite organic brain disorder, none was found among retarded readers. The groups did not differ in the number of parents or siblings who had reading difficulties (approximately one-third) or in abnormalities of speech and language development. At 4-5 year follow-up of these children,
Rutter (1976) found that despite their higher intellectual levels, the retarded readers had made significantly less progress in reading than the backward readers. In arithmetic skills, the retarded readers had improved considerably more. These findings led to the conclusions that the distinctions between the two groups were noteworthy and valid and that the disability of the retarded readers appeared to be specifically in the area of reading. There was no attempt to discern possible etiology of the reading retardation or to assess the appropriateness of therapeutic intervention to the disabilities in the two groups.

It is proposed in this dissertation that the specific disability of the retarded reading group is due to delayed or dysfunctional lateralization of the left cerebral hemisphere. Specifically, it is suggested that retarded readers as compared to backward readers will display less left hemispheric lateralization as measured by dichotic listening tasks and that the severity of the reading disability would be related to degree of cerebral laterality. Improvements in reading skills over the course of therapeutic intervention should be related to increasing left hemispheric specialization.
Developmental Lag and Reading Disability

An assumption of many researchers based on early work by Orton (1937) is that the functioning of the left cerebral hemisphere, the hemisphere 'dominant' for verbal-analytic abilities, is somehow impaired in reading disabled children. To Satz and his colleagues, this impairment is seen as a developmental lag in the specialization of the cerebral cortex.

This theory of a specific developmental lag first fully stated by Satz et al. in 1971, claims that skills required for reading proficiency are acquired in a developmentally fixed order so that the child must first learn visual-motor and auditory-visual integration before the later development of language and formal operations. The authors postulate that reading disabilities are the result of a developmental lag in the maturation of the central nervous system which delays the acquisition of age dependent skills.

A developmental lag in a younger child (age 7-8) would theoretically interfere with visual-motor and auditory-visual integration, while in the older child (age 11-12) a lag would affect more specific language skills. To examine the two aspects of this theory, that reading disabled children lag in cerebral maturation and that this lag is specific to ontogenetically developing skills, Satz et al. (1971) examined two age groups of disabled and normal readers on measures of
non-language (earlier developing) and language (later developing) skills.

The authors found some support for their theory. While younger dyslexics made significantly more errors on the Bender Gestalt test than younger normal readers, there was no difference between the older two groups. Using the verbal IQ on the WISC as a measure of language skills, the authors found that older normal readers had a higher verbal IQ than older dyslexics. Contrary to the theory, however, younger controls also had higher verbal IQs than younger dyslexics, giving no indication of a developmental effect. A dichotic listening task where contrasting digits were simultaneously presented to each ear (to be discussed in more detail below) revealed differences in total number of stimuli recalled between dyslexics and controls at either age; a right ear advantage, or left cerebral dominance for speech was found for all groups of subjects. Older controls, however, had a significantly greater degree of right ear advantage than older dyslexics, with no differences found in the younger cohorts.

Although the authors claim these results support a theory of developmental lag in dyslexia, there are a number of methodological problems. The selection of subjects was initially based on teacher assignment; the younger aged group children are not that severely
disabled in reading. It is uncertain that verbal intelligence on the WISC is a pure linguistic function that develops later than performance skills. There was no control for handedness, which, as will be discussed later, affects side of hemispheric dominance.

In an attempt to support the theory of developmental lag, Satz and Friel (1974) present the initial results of a longitudinal study of the precursors of developmental dyslexia. Nearly 500 white middle-class boys were evaluated in kindergarten with a battery including visual-motor, IQ, and dichotic listening tasks. Reading ability was not assessed directly, but was based on teachers' ratings. Poor readers were called high risk subjects for developmental dyslexia (about 15% of the children) and were compared to low risk children. Using a step-wise multiple regression test, the authors found that the measures given in kindergarten that best predicted reading ability at the end of first grade were sensory-perceptual-motor tests, measures the authors postulate are primary in the early years and crucial to early reading skills. Ear asymmetry on the dichotic listening task did not differentiate between the high and low risk groups, although it purportedly was the most direct measure of cerebral maturation utilized.

In a third year follow-up of these children (Satz et al. 1974) the authors report that at the end of the second grade the initially
labelled high risk children were still below the low risk children in reading, but that the dyslexic group caught up with the normal readers on the earlier developing perceptual-motor skills. This would lend some credence to the developmental lag theory that only in the younger dyslexics is there a lag in perceptual integration.

A more recent study of the developmental dyslexic theory (Sobotka et al. 1977) compared 24 dyslexic males at ages 7, 9, 11, and 13 to controls on batteries of perceptual-motor (WISC PIQ and Bender) and verbal (WISC VIQ and dichotic listening tests). The authors found differences between the dyslexics and controls on verbal tests at all ages, but found no differences at younger ages with perceptual motor skills. Thus, although developmental differences are found on the verbal tasks, it is questionable how supportive this study is of the developmental lag theory in that the differences are found at all ages.

To find support for the contention that in older dyslexic children the developmental lag is manifested in language processing skills, Satz turned to the examination of various dichotic listening tasks as more direct measures of cerebral development.
Cerebral Dominance and the Dichotic Listening Task

Dichotic listening tasks (DLT) have been utilized in the past two decades as biologically non-intrusive measures of cerebral lateralization. First introduced by Broadbent in 1954, DLT involve the simultaneous presentation of contrasting stimuli to each ear. Popularized by Kimura (1961, 1963), in DLT digits simultaneous pairs of numbers are broadcast through headphones to each ear at a rapid rate. Generally, a series of two, three or four pairs of numbers is presented in rapid succession. A second form of DLT, introduced by Studdert-Kennedy, and Shankweiler (1970) utilized competing pairs of nonsense syllables composed of consonant-vowel (CV) pairs (ba, da, ga, pa, ka, ta). In this form, DLT CV, only one consonant-vowel pair is presented in a trial. With both DLT, the subject is requested to verbally report all the stimuli following each trial. The number of correct reports for each ear is tabulated.

Kimura (1961, 1963, 1967) first proposed the application of DLT to the theory of primary contralateral connections between sensory modalities and cerebral hemispheres. Using DLT digits, she found patients with known left temporal lobe damage recalled fewer stimuli than patients with right temporal lobe damage. Perhaps more interesting, however, was the finding that for normal subjects, significantly more stimuli were correctly recalled from the right ear than
from the left ear. As the left hemisphere has long been known to subserve language and speech functions (Penfield and Roberts, 1959), this would indicate that stimuli recall for the ear contra-
lateral to the hemisphere dominant for speech was higher than for
the ipsilateral ear. For there to be a right ear advantage (REA)
Kimura found there must be competing stimulation to each hemi-
sphere. When stimuli were not simultaneous, but alternated rapidly,
no significant REA was found. Kimura proposed a greater number of
fibers connecting the left hemisphere to the contralateral ear than to
ipsilateral ear. Further, "when different stimuli are presented to the
two ears, as is the case in the dichotic condition, the impulses
arriving along the ipsilateral pathway would be partially occluded,
and thus the advantage of the contralateral over the ipsilateral
pathway would be enhanced" (1967, p. 171). Kimura proposes that
when normal right-handed subjects recognize the left ear stimuli in
dichotic pairs, they do so from a weakened signal that travels from
the left ear to the right hemisphere, across the corpus callosum to
the left hemisphere.

Kinsbourne (1973, 1976, 1977) has recently proposed an alter-
native to this connectionistic explanation of auditory asymmetry.
Kinsbourne argues that the attention and expectancy of a certain type
of stimulus activates one cerebral hemisphere and suppresses activity
in the other hemisphere. He contends that the subjects' expectation of verbal material would activate the left hemisphere and that the left hemisphere's orientation rightward would lead to the tendency to focus first on the message from the right side of space when simultaneous, conflicting messages are presented. Thus a right ear advantage for digits or other verbal dichotically presented material should be expected as a result of this attentional shift.

Kinsbourne (1974) found that when right-handed subjects were given verbal questioning, they head turned and oriented toward the right. After spatial questioning, the trend in orientation was to the left.

In 1976, Donnenfeld et al. tested Kinsbourne's assumptions that expectancy of either verbal or nonverbal stimuli induces activation of one hemisphere and suppression of the opposite hemisphere. The authors used DLT under conditions of strong and weak expectancy.

In the strong expectancy condition, subjects were told they would hear either verbal (DLT consonant-vowels) or nonverbal (pitch contours) material. In the weak expectancy, subjects were told verbal and nonverbal stimuli would be randomly interspersed. The authors found a right ear advantage for the verbal stimuli, and a left ear advantage for the nonverbal. The group given low expectancy by randomly interspersing verbal and nonverbal material did not differ from the strong expectancy groups in magnitude of ear asymmetries.
questioning Kinsbourne's model.

Morais and Lander (1977) used DLT pairs differing in either the consonant or the vowel. The pairs of syllables were preceded by and followed by either a verbal stimulus (sentence) or nonverbal stimulus (melody). Subjects were instructed to either attend to or ignore the additional information. When relative ear accuracy was assessed, the authors found no effect of context on response to a target stimulus. When response latency was measured, however, an effect of context was found only for consonants. When subjects had to retain verbal material, a right ear advantage was observed; when nonverbal material had to be retained, there was a slight left ear advantage. The authors interpret their findings as arguments against the structural theory of Kimura, noting that laterality is affected by ongoing activity and attentional focus. This contextual effect, however, was not noted in all cases.

While there is no agreement as to whether the structural theory of Kimura or the attentional theory of Kinsbourne is a more accurate explanation of right ear advantage for verbal material, there is general agreement that the contralateral hemisphere, the left hemisphere, is dominant for language functions in normal right-handed subjects. The question of whether this is true for reading disabled children remains at issue.
Scoring the Dichotic Listening Tasks

There are a number of issues relating to the difficulty or scoring of the dichotic listening task that would have an effect on relative cerebral dominance. It must be noted that the terms cerebral dominance or cerebral lateralization are relative ones as measured by dichotic laterality tasks. In normal right-handed adults, both left and right ears process verbal information. Dominance or lateralization would indicate that one ear, the right, is processing consistently more information than the left ear. Searleman (1977) has recently reviewed the linguistic capabilities evident in the right hemisphere of normal subjects, the hemisphere non-dominant for linguistic functions.

Marshall et al. (1975) demonstrated how choice of scoring procedure for the dichotic listening task would affect the interpretation of cerebral dominance. One score often utilized, a between ear difference score where the recall from one ear is merely subtracted from the recall of the other, Marshall et al. find to be significantly negatively correlated with total accuracy. That is, as subjects recall more stimuli, their between ear difference declined. Krashen (1973) indicates that another commonly used score, percent correct which measures correct scores from the right ear divided by total correct scores is also negatively correlated with accuracy.
A percent error score, measuring errors on the left side divided by total errors, is suggested as a more appropriate laterality score. Utilization of different scoring techniques on the same data may yield different results. For example, Krashen and Harshman, as reported by Marshall et al. (1975) indicate that with a between ear difference score children tend to become more lateralized between the ages of 5 and 10. According to a percent error score, there is no increase in lateralization after age 5. Marshall et al. (1975) propose a laterality coefficient which would control for accuracy of total recall. This laterality coefficient divides the between ear differences score by a measure of total accuracy, either total stimuli correctly recalled or total errors.

Blumenstein et al. (1975), however, found no differences on a consonant-vowel dichotic listening task between an absolute ear difference score and a laterality coefficient (right ear correct minus left ear correct divided by total correct). Brikett (1977) examined various scoring methods on a set of data from a tachistoscopic visual half-field study and found that the two scoring methods were highly correlated. Hisock & Kinsbourne (1977) found between ear difference scores and laterality coefficients to be highly correlated ($r = .92$) on a dichotic digits task. Thus there is some disagreement as to whether method of scoring the DLT influences relative cerebral dominance.
Satz (1976) has argued that the difficulty of the dichotic task will influence the laterality score. In developmental studies in particular where the same task is used with children of different ages, ceiling or floor effects must be avoided. Where the task is too difficult (i.e., too many simultaneous digit pairs presented too rapidly to younger children), total recall may only achieve chance level. Where the task is too simple (i.e., too few digit pairs presented slowly to older children) high total recall will obliterate between ear differences.

Reliability of the dichotic listening tasks is relatively high. Using a 60 item DLT of consonant-vowel pairs, Shankweiler and Studdert-Kennedy (1975) found a test-retest reliability of $r = .70$ within a two week period. Blumenstein et al. (1975) used a DLT consonant-vowel task with right-handed subjects and found test-retest reliability over at least a one week period for laterality coefficients to be high, $r = .74$. Some 29% of the subjects, however, reversed their ear preference on repeat testing. Other dichotic tasks, including simultaneous presentations of music or vowels were found to have much lower test-retest reliability.

Fennell, Bowers, and Satz (1977) tested 16 right-handed subjects four times, each one week apart, on a dichotic task where concrete words were used as stimuli. The authors found that recall from
each ear was highly reliable over time, with Pearson correlations ranging from .74 to .90. The percentage of subjects with a right ear advantage ranged from 69% at first trial to 51% on the fourth trial.

Hisock & Kinsbourne (1977) found test-retest reliability over a 2 1/2 week period on a simple digits task to be relatively high (r values in the .60's) for 3 - 5 year olds.

Schulman-Galambos (1977) discusses in detail the reliability of dichotic listening tasks. Using 3 pairs of dichotic words with kindergarten through fifth graders and college students, she found a right ear advantage that did not vary as a function of increasing grade level. Split-half reliability, where subjects were classified as having right, left or no ear advantage for each half of the dichotic listening task, was high with only 10% of the subjects switching ear advantages from first to second half. There was also stability on the total number of correct responses on each half of the DLT. Some 10 subjects were tested twice, ranging from one to five weeks apart. None of these subjects switched ear advantage. The author notes that on the split-half reliabilities, the high score tended to remain high, and the low score remained low, although no statistics are presented.
Hines and Satz (1974) also examined split-half reliability with undergraduate subjects. Using a very difficult dichotic listening task of 12 digits per trial, they found a high split-half reliability of .86 for between ear difference scores.

Bryden (1975) found relatively high split-half reliabilities of .61 for dichotic consonant-vowels and .66 for dichotic digits with a sample of 208 subjects. The correlation between the two dichotic tasks while significant, r = .49, was relatively low, suggesting that perhaps the two tests are not measuring the exact same cerebral functions.

Sobotka (1973 as reported by Berlin & Cullen 1977) found differences on dichotic digits and dichotic consonant-vowels for both normals and disabled readers. Subjects could be right-eared dominant on one task while left-eared dominant on another.
Developmental Changes in Cerebral Specialization in Normal Children

In 1975, Satz et al. hypothesized that speech lateralization as deduced from dichotic listening tasks goes through a transition from bilateral cerebral linguistic representation to unilateral hemispheric specialization. They argue that complete lateralization of linguistic functions in the left hemisphere occurs at about puberty. However, it is questionable whether left hemispheric cerebral dominance is an ontogenetically developing skill or in fact is fixed at a relatively early age. Should dominance in the normal subject be fixed, it would be difficult to claim a developmental lag of dominance theory of dyslexia. Thus to assess whether there is in fact a developmental lag in hemispheric specialization in reading disabled children that may mimic the level of development of the younger normal child, it is important to assess whether there are developmental changes in cortical specialization in normal children.

Kimura in 1963 presented 1, 2, and 3 pairs of dichotic digits to 120 right-handed boys and girls between the ages of 4 and 9. At all age groups, there was a significant right ear advantage of recall (REA). For both sexes the left hemisphere was specialized for speech as early as age 4. Although the total number of digits recalled increased with age, there was no increase in right ear
advantage.

Geffner and Dorman (1976) and Dorman and Geffner (1974) examined the presence of lateralization for speech in 4 and 6 year olds from low and middle socio-economic classes. Among the six year olds the authors found a significant right ear advantage on a dichotic consonant-vowel task that was not affected by race or socio-economic status. A significant right ear advantage was demonstrated by four year old low and middle SES males, but not females. A post-hoc analysis found that whereas two-thirds of the four year old girls did in fact have a right ear advantage for dichotic digits, one-third had a left ear advantage.

Ingram (1975) found that while 3 and 5 year old girls demonstrated a REA on a pointing task for dichotic words, 4 year olds did not. Although it is not clear why 4 year old females differ, it is evident that by age 3 there is a right ear-left hemispheric specialization.

Kinsbourne & Hiscock (1977) found a right ear-left hemisphere advantage on dichotic digits with 150 normal right-handed children ranging from 3 to 12 years old. Degree of ear asymmetry did not increase with age.

Berlin and his colleagues (1973) in the Kresge Hearing Research laboratory presented simultaneous nonsense consonant-vowel pairs
to 150 children ranging in age from 5 to 11. The authors find a significant right ear advantage that is fixed by age 5 and is independent of sex and of the total number of stimuli that are correctly identified. There are no significant changes in degree of right ear advantage over time.

Hynd and Obrzut (1977) recently used the same consonant-vowel DLT with middle-class boys and girls 6 to 12 years old. They found a significant right ear advantage at all ages and no significant effect of sex. There did not appear to be an increase of REA or left hemispheric specialization with age. Piazza (1977) used two different DLT, simultaneous words and environmental sounds with children 3, 4, and 5 years old. She found a significant REA for verbal stimuli and a significant left ear advantage for nonverbal at all ages, with no significant effects of sex or age. The author suggests that hemispheric specialization for speech is set by age 3 and varies little after that.

In arguing that the observed right ear advantage is due to attentional or perceptual factors, Hiscock & Kinsbourne (1977) found marked left hemispheric lateralization for 3 to 5 year olds on a simplified one pair dichotic digits task. There were no significant effects of age or sex on degree of lateralization, again suggesting that specialization is evident at early ages and varies little developmentally.
There is support from areas other than dichotic listening tasks for early onset of left hemispheric specialization for speech. Molfese et al. (1975, 1977) examined auditory evoked responses (AER) to speech and nonspeech stimuli in infants (from one week to ten months old), older children, and adults. They found for all age groups a larger AER from the left temporal region than from the right for verbal stimuli. A larger right hemisphere AER than left hemisphere AER was found for nonverbal stimuli. With auditory evoked response, between hemispheric differences appeared to decrease with age. Molfese et al. (1975) proposed that this developmental decrease in cerebral asymmetry was due to increasing maturation and myelination of the corpus callosum and other connecting commisures, allowing greater interaction of the two hemispheres.

Witelson and Pallie (1973) took anatomical measurements of the language mediating area of the superior surface of the temporal lobe from both the right and left hemispheres of 14 neonate and 16 adult brains. The finding that the left hemisphere was significantly larger in neonates to the same proportion as in adults would suggest that cerebral asymmetry is biologically preprogrammed and that cerebral specialization does not increase with age.

Glanville et al. (1977) assessed cerebral asymmetries in 3 month old infants by measuring cardiac response habituation to verbal
or musical stimuli. The authors found greater response recovery to speech stimuli presented to the right ear than to the left ear, indicating left hemisphere speech processing even in young infants.

Entus (1977) combined dichotic consonant-vowel presentation with a nonnutritive sucking paradigm with infants as young as three weeks. A dichotic stimulus pair was presented contingent to the infant’s sucking. Sucking behavior decreased as the same stimulus was repeatedly presented. The stimulus to one ear was then changed and recovery of sucking behavior was explored. Recovery of sucking was greater in response to a verbal stimulus change in the right ear; with musical stimuli, recovery was greater after a left ear change. These findings indicate a right ear-left hemisphere advantage for verbal stimuli in young infants.

An extensive review by Witelson (1977) of early hemisphere specialization points to evidence in both normal and brain damaged children of greater left cerebral hemispheric involvement for speech and language function in infants and young children. While there is evidence of plasticity of cerebral functioning at early ages (also Moscovitch 1977) so that the right hemisphere could assume speech functions, Witelson (1977) concludes that it is the LH that is lateralized for speech from infancy on.
There is, however, some disagreement with the conclusions of Witelson (1977). Satz (1976) argues that cerebral lateralization is not fixed until puberty and that developmental increases in right ear advantage will be evident on dichotic listening tasks. This argument fits with the theoretical positions of Lennenberg (1967) that the infant is bilaterally dominant and only gradually becomes left hemisphere specialized and of Brown & Jaffee (1975) that cerebral dominance is a continuous process evolving through life.

Satz et al. (1975) studied nearly 200 normal middle-class males and females in Amsterdam at ages 5, 6, 7, 9, and 11 on a dichotic series of four Dutch spoken digit pairs. Using a complex regression statistical model, the authors find that increasingly more information is reported from both right and left ears up until age 9 at which time there are no further age increases. There is a trend for a right ear advantage of recall (left hemispheric specialization) as early as age 5, but this trend does not reach significance until age 9. There were no effects of sex. Thus it can be argued that although there is asymmetry evident at an early age, there is a developmental increase in hemispheric specialization for linguistic functions.

Bryden, in a study reported by Satz et al. (1975) used a dichotic consonant-vowel paradigm and found a developmentally increasing trend in ear asymmetry from age 6 that did not reach significance until age 12.
Although the overwhelming number of studies do not support a theory of developmental changes in cerebral lateralization, Satz claims (1976), that there are artifactual flaws with many of these studies, such as too simple a task so that for older children an upper ceiling is reached. It should be noted that the opposite argument can be made against Satz in that his task may well have been too difficult for younger children, obscuring possible between ear differences.

Porter and Berlin (1975) respond to Satz's criticism of some studies finding no developmental changes in cerebral lateralization by arguing that different dichotic listening tasks tap different cerebral functions. They contend that language processing matures at different rates so that slowly maturing mnemonic or attentional processes are tapped by lengthy digit pair tests, while more early maturing auditory and phonetic processes are tapped by simple pairs of nonsense syllables. The authors argue that many of the studies that do not show developmental increases in REA are not necessarily artifactualy flawed as suggested by Satz (1976), but are tapping simple auditory processing tasks that mature early and do not vary much. Those studies that do demonstrate a developmental effect utilized a difficult digit task involving memory and more difficult acoustic (Dutch four pair number 'words') properties that may mature
more slowly. Thus it remains unclear whether there are general developmental changes in cerebral lateralization in normal children. An examination of the differences in lateralization between normal and disabled readers follows.
Dichotic Listening Tasks with Disabled Readers

In a 1976 review of the literature, Satz finds 15 published and unpublished studies of dichotic listening tasks with reading disabled subjects. The question addressed in many of these studies is whether reading disabled children differ from normal readers on measures of cerebral laterality that would reflect either a deficit or a developmental lag in cerebral specialization in the disabled group.

Sparrow and Satz (1970) administered a 4 pair dichotic digit task to 40 reading disabled and normal boys, aged 9 - 12. Both groups displayed a similar right ear-left hemisphere dominance on this task, although far more disabled readers than normals did display a left ear-right hemisphere advantage. In this test of the developmental lag theory, Satz et al. (1971) examined younger and older disabled and normal readers on a 3 pair dichotic digit task. The authors found a significant right ear-left hemisphere advantage in both the younger and older disabled readers that did not differ from the control groups.

Leong (1976) evaluated 58 dyslexic boys on a dichotic listening task ranging from 2 to 4 digit pairs. Handedness was not controlled. Both dyslexics (mean age 10 years) and controls had significant right ear-left hemisphere dominance, although control subjects had generally higher total recall scores.
Yeni-Komshian et al. (1975) compared 19 good and poor readers in grades 5 to 7 on a dichotic task where the digits were presented at a relatively slow rate. Although in this predominantly black population the controls differed significantly from the disabled readers in intelligence and age, both groups demonstrated a right ear-left hemisphere advantage.

Sobotka et al. (1977) recently administered an extremely difficult dichotic digits task (6 pairs of digits) as well as a consonant-vowel dichotic task to 24 carefully screened dyslexic and control boys, 7 to 13 years old. Both normal and disabled readers had poorer relative recall of the DLT digits than the DLT consonant-vowels. The authors state there were no significant differences between the controls and dyslexics on the dichotic listening tasks, although the results are not presented in such a way as to make laterality scores between groups directly comparable. Among the normal subjects there tended to be developmental increases in total stimuli recalled. Dyslexics did not display such a developmental trend for total recall.

Witelson (1974, 1976a, 1976b) argued that learning to read involved both spatial processing and memory of visual images, right hemispheric functions in the normal individual. Witelson developed the dichotomous tactual stimulation test as a way of demonstrating
right hemispheric dysfunction for spatial processing in dyslexics.

In this test, subjects palpate two different stimuli simultaneously. As with the dichotic listening task, the assumed primary neural connections are contralateral, so that stimuli felt by the left hand are transmitted to the right hemisphere, and those by the right hand to the left hemisphere. Subjects are instructed to touch the two competing objects simultaneously for ten seconds and then to identify stimuli by pointing to pictures. If in fact there is right hemispheric specialization on this task, then items presented to the left hand should have better recall. In a 1974 study of normal 6 to 14 year old boys, Witelson found greater left hand accuracy (right hemisphere specialization) for spatial processing. In 1976, Witelson repeated this task with 49 boys reading 1.5 years below grade level. Although dyslexics and controls did not differ in overall accuracy on this task and accuracy increased with age for both groups, the dyslexic and normal subjects differed in the amount of between hand discrepancy. The normal group had higher left hand than right hand scores. Dyslexics, however, did not have a significant difference between the right and left handed scores. In fact dyslexics had significantly greater right hand scores than normal controls. Witelson suggests (1976) "the lack of behavioral asymmetry observed for the dyslexics may indicate a lack of right hemisphere specialization"
for spatial processing or bilateral spatial representation in dyslexic boys compared to normal boys" (p. 243).

In this same study, Witelson presented two and three pair dichotic digits to the dyslexic and normal boys. Although the normal readers had higher overall accuracy of total stimuli recall, both groups displayed a right ear-left hemisphere advantage that did not vary as a function of age. Approximately 70% of the subjects of each group had a right ear advantage for the dichotic digits task. Thus Witelson postulates that dyslexics may not be deficient in specialization of left hemispheric functioning, but may be deficient in specialization of right hemispheric spatial function. She claims that the bilateral specialization of spatial processing in reading disabled children somehow interferes with the ability of the left hemisphere to process the concomitant linguistic information necessary for reading.

There are a number of difficulties with Witelson’s conceptualization. On dichotic listening tasks, computer programs (Rubino, 1972) control for millisecond differences in stimulus onset that might otherwise obscure ear superiority. There are no such precise controls with the simultaneous tactual stimulation task. Witelson’s dichotic digits task, with a total recall accuracy of 90%, may well have been too easy, obscuring possible between ear differences.
When Witelson dichotomously presented the shapes of letters rather than abstract symbols, she found because of the linguistic nature of the task normal subjects had greater right hand accuracy than left hand. Dyslexic subjects had better left hand recall than right hand. While this can be seen in terms of greater bilateral representation in dyslexics, in fact the dyslexics overall accuracy at all ages was greater than that of the normal readers. The superior performance of poor readers relative to good readers on a task of tactually identifying letters is difficult to explain in terms of a dysfunction. To propose a deficiency in right hemispheric specialization for spatial processing in dyslexics, one should find a left hand deficiency on the abstract symbols test. In examining Witelson’s (1976) data, however, good and poor readers do not differ in left hand performance on this task.

While the studies reviewed above generally indicate that any differences between normal and disabled readers on dichotic listening tasks are found not on between ear differences or degree of cerebral laterality but on total accuracy of stimuli recalled, there are some studies that indicate disabled readers differ from normals in degree of cerebral lateralization.

Satz (1976) found that both good and poor readers had significant right ear-left hemisphere advantage, although the interaction
of ear advantage by age reached significance only in the good
readers. Satz views this as "only tentative support at best for the
theory of delayed hemispheric lateralization of speech in older dys­
lexic children". p. 286. A study by Carby in 1974 reported by Satz
(1976) found that while good readers gradually develop ear asymmetry
to a significant degree, dyslexic children do not demonstrate a sig­
nificant right ear advantage between the ages of 5 1/2 to 12. As
statistics are not presented, it is difficult to evaluate this study.

Thomson (1976) recently compared a clinical population of
older dyslexic boys and girls to a control group of superior readers
on a number of different dichotic tasks including 3 pairs of digits,
words in regular order, words in reversed order and nonsense syl­
lables. Although superior readers had a clear right ear advantage
for most verbal tasks, the dyslexic group had no significant dif­
fERENCE between ears on the dichotic digits and clear left ear ad­
vantages on some of the dichotic word tasks. Unlike the studies
discussed above, in this older clinical population of severely
reading disabled children not only is there no significant left hemi­
spheric specialization for speech, but there are indications of right 

hemispheric specialization.

Bakker and his associates (1973, 1976) postulate that early
reading stages do not require complete lateralization, but that later,
more fluent reading abilities do require complete hemispheric specialization. The authors (1973) examined 40 normal reading second graders on a 3 pair dichotic digit task and found that better readers had the least between ear difference, or the least cerebral lateralization. Older children (8 1/2 - 9 1/2 years) who had the greatest between ear differences were the better readers. Unlike the Satz studies discussed above, only right-handed subjects were evaluated. Bakker et al. conclude that at earlier ages proficient reading is associated with lack of hemispheric dominance, but at later ages proficient reading is related to moderate hemispheric dominance. They argue that, "the progressing learning to read process is associated with a gradually increasing lateralization" p.(309) and that since dyslexics are in the early phases of learning to read they will demonstrate little lateralization, similar to that of younger children.

In the 1976 study, Bakker et al. used a word naming rather than a reading achievement task and again found that in younger children both hemispheres had the capacity to mediate linguistic functions, but that in older children the left hemisphere was specialized for the word naming. The authors characterized these children who were right hemisphere dominant as generally slow, but accurate readers. Left hemisphere dominant children were seen as fast, but careless readers. It was argued that girls pass through these
laterality-reading stages faster than boys and thus more boys than girls may have difficulty in the earlier stages of reading.

Thus there are conflicting data as to whether reading disabled populations differ from normals in their degree of left hemispheric lateralization. If in fact there is a left hemispheric difference in disabled readers, it is unclear whether this is due to a deficit of cerebral functioning as suggested by Rourke (1976) or a developmental lag in cerebral maturation as suggested by Satz and his associates (1971, 1974, 1976).

Kinsbourne & Hiscock (1977) and Shankweiler & Studdert-Kennedy (1975) have argued that between ear differences or relative laterality coefficients may not reflect individual differences in brain organization or in lateralized skills. In finding that only about 80% of normal right-handed adults have right ear advantages on dichotic tasks (also Satz 1976) while it is assumed that 95-99% are actually left hemisphere lateralized (Segalowitz & Gruber 1977), the authors argue that the dichotic tasks cannot be valid indicators of individual differences. Kinsbourne & Hiscock state (1977):

"Unless one can show within one subject that his performance is significantly asymmetrical, that the degree of asymmetry is reliable on retest, and that the asymmetry is not based on attentional factors, one has not elucidated the language lateralization of that subject." (P. 183)
Berlin & Cullen (1977) also question whether the magnitude of the right ear advantage on dichotic tasks is proportional to the dominance of the left cerebral hemisphere and whether a left ear - right hemisphere advantage or no ear advantage is in any way pathological. Moscovitch (1977) in a review finds no proof for the assumption that any deviation from the ideal pattern of hemispheric lateralization is likely to lead to linguistic or reading problems. He states:

"There is no solid evidence that lateralization of function is predictive of superior or normal performance with regard to the function that is lateralized." (p. 203)

What will be examined herein is whether in fact the concept of a continuum of degree of lateralization on dichotic listening tasks reflects individual differences along a continuum of linguistic functions, namely reading skills. Therefore the relationship between degree of cerebral laterality and degree of reading ability will be explored within a population of disabled readers.
Handedness and Sex on Cerebral Laterality and the DLT

In the studies discussed above, there appear to be few differences related to sex. Kimura (1967) had found right ear advantages for both boys and girls, but found younger girls (4 - 6) to have higher total recall scores than boys. Borowy and Goebel (1976) found no significant differences between males and females, 5 - 11, on dichotic listening tasks. They concluded, "It is clear that there is very little difference between males and females in either the age of onset or the development of ear asymmetry" (p. 367). As discussed earlier, Geffner and Dorman (1976) had found more four year old girls to be right hemisphere specialized than boys.

Although Witelson (1976) finds boys and girls do not differ in overall accuracy on the dichaptic stimulation technique, she reports that boys do significantly better with their left hands than with their right hands. For girls, there appear to be no differences between hands, suggesting more bilateral spatial processing.

Lake and Bryden (1976) examined the interaction of sex with familial sinistrality on DLT consonant-vowels. The authors found that adult males were more clearly left hemisphere lateralized than adult females. In females, a history of familial sinistrality increased the likelihood of right hemispheric specialization; in males familial sinistrality decreased the likelihood of RH specialization.
Familial history of handedness with undergraduates was examined as well by Hines and Satz (1974). They found that left-handers tended to be less left hemisphere lateralized than right-handers. Right-handers with familial histories of sinistrality, however, had poorer total recall on a DLT than right-handers with no family history of left-handedness.

Bryden (1975) utilized both DLT digits and consonant-vowels in examining the relationship of cerebral lateralization in parents and children. Having found earlier (Zurif and Bryden, 1969) that DLT performance of non-familial left-handers was like that of right-handers, Bryden examined handedness and familial patterns in seventh and eighth grade boys. Bryden found high correlations between laterality coefficients of mothers and children, no correlations between siblings, and very high correlations between mothers and fathers. Scoring handedness on a continuum, Bryden finds low, but significant correlations between handedness and left hemisphere lateralization.

Briggs and Nebes (1976) found that family history of handedness did not effect errors per ear on a DLT paradigm with college students. This study was flawed by a ceiling effect in that overall there were very few errors. The authors found pure right-handed subjects had large between ear differences. Mixed-handed subjects had some
between ear differences and left-handed subjects failed to demonstrate any between ear differences.

While it appears that the vast majority of right-handed normal subjects are left hemisphere dominant on the dichotic listening tasks, this is less true for left-handed subjects. Using Annett's (1970) graded scale of handedness, Lishman and McMeekan (1977) examined the relationship between handedness and a dichotic word task. They found all strong right-handers to be LH dominant, mixed-handers to be mostly LH dominant, and strong left-handers to be somewhat LH dominant. They postulate that bilateral dominance for language functions may be evident only in strong left-handers with a family history of sinistrality.

The majority of studies discussed above fail to demonstrate more than a slight sex difference in degree of cerebral lateralization. Some studies do seem to indicate that young girls may have higher total recall of stimuli and somewhat greater between ear differences on the DLT than boys. During latency, no sex differences are evident. By adulthood, there may be a slight male superiority of laterality.

While right-handed subjects are overwhelmingly left hemisphere dominant for speech, left-handers are somewhat unpredictable. Family history of sinistrality may increase the likelihood of right
hemispheric speech, although many left-handers with familial sinistrality are still left hemisphere dominant. Handedness varies on a continuum and there is some indication that degree of lateralization is related to that continuum.

Handedness and Crossed Dominance

Prior to the introduction of dichotic listening measures of cerebral laterality, the assumption of dysfunctional lateralization in language or reading disabled children was often based on reports of increased incidence of left handedness or of crossed hand and eye dominance in these children. Crossed dominance indicates that the preferred hand and the preferred eye are not ipsilateral (on the same side), but are contralateral (i.e., right-handed and left-eyed). Orton (1937) noted a high incidence of crossed hand and eye preferences in language disabled children. In 1957, Harris noted that the relationship of handedness to reading disabilities had been a difficult area for years. A recent review (Hardyck et al. 1976) finds this field still far from clear.

Harris (1957) categorized a large population of reading disabled children into right, left, or mixed hand preference. He finds twice as many reading disabled children as normal readers to be mixed handed (40% vs. 20% at age 7) and reports developmental increases in unilateral hand dominance between ages 7 and 11. Of the
9 combinations of handedness and eyedness (each classified as right, left, or mixed), Harris finds 41% of reading disabled subjects right-handed and right-eyed and 20% right-handed and left-eyed. The reading disabled did not differ from the control group in the incidence of crossed dominance.

Belmont & Birch (1965) argue that there are no differences between normal and disabled readers in the incidence of mixed or left-handedness. Examining a school population of disabled readers, the authors found no relationship between lateral preference and reading performance. Belmont & Birch argue that the effects of hand preference on reading may be evident when clinical populations are examined, but not with school populations. Crossed hand-eye dominance was found in 26% of normal and 31% of disabled readers. Among the poor readers, however, crossed dominant subjects tended to have slightly lower mean reading scores than ipsilateral dominant children.

Coleman & Deutch (1964) with a somewhat older (CA 10-12) lower socio-economic status public school population found no significant differences between normal and disabled readers in hand or eye preferences. The groups did not differ in the incidence of crossed dominance and unlike Belmont & Birch (1965), crossed dominance was unrelated to severity of reading disability.
In a recent review of left-handedness and cognitive deficiencies, Hardvyck et al. (1976) examined the total population of elementary school children in a California community. Of over 7000 children studied, they found approximately 10% were left-handed. There were no differences in handedness among grades 1 through 6 and there was no evidence of any shifting in the frequency of handedness through age levels. Of all right-handed subjects, 64% were right-eyed (ipsilateral dominant) and 36% were left-eyed (crossed dominant). The existence of large populations of crossed dominant normal subjects questions any immediate associations of crossed-dominance with reading dysfunction. The authors do, however, acknowledge that handedness is related to cerebral organization in that sinistrals have more variance in cerebral dominance than do dextrals.

Kershner (1975) in a review article finds approximately 90% of the population to be right-hand dominant; approximately three-eighths of these are left-eyed or crossed dominant. Kershner finds that crossed occular-manual laterality was significantly related to superior spatial ability. Using a tachistoscope task, the author finds that ipsilateral lateralized students are superior in the perception of verbal stimuli, perhaps supporting the contention that consistent hand-eye preference may facilitate reading ability.
Despite the limited evidence that crossed dominance is related to dysfunctional cerebral activity, Swiersinski (1977) suggests that crossed dominance, "has been considered a strong clinical sign suggesting congenital or early developmental brain malformation" (p. 134). Studying a large population of WA patients, he found a 30-35% incidence of crossed dominance. There were no significant differences between the crossed and ipsilateral patients on any of the 32 intellectual, educational, or neurological measures employed. Hand-eye preference was unable to predict brain damage or to differentiate other general performance abilities.

From the studies cited above, it appears that crossed dominance is not a sine qua non for reading disability or cerebral functioning.

Yet based on Coleman & Deutch's (1964) study, the question remains whether within a reading disabled population, crossed dominant children differ from ipsilateral dominant in measures of reading and intelligence. In addition, the relationship of hand-eye preference to more direct measures of cerebral laterality, dichotic listening tasks, remains unclear.

Performance - Verbal Intelligence Discrepancies

Discrepancies between verbal and performance abilities have been used in an attempt to differentiate those children with reading disorders from those with normal achievement and to postulate cerebral
strengths and lateralization. In a classic study, Belmont & Birch (1966) reported that 9 and 10 year old boys reading in the lowest 10% of a school population in a Scottish city had lower intelligence scores than average readers. They further discovered that these poor readers generally had poorer verbal than performance scaled scores on intelligence tests. They concluded that inadequacy of linguistic functioning rather than perceptual or manipulative deficiencies was a characterization of the disabled reader.

The predictive utility of this study is questionable. The discrepancy between verbal and performance scores while statistically significant, was slight, only 1.3 points. Some 60% of the disabled readers had greater performance IQ scores; 60% of the normal readers had greater verbal IQs. Disabled readers with full scale IQs below 90 had no significant performance-verbal discrepancies. Those with full scale IQs of 90 and above had significantly lower verbal than performance scores.

Reed (1967, 1968) examined reading skills in children with performance-verbal discrepancies. Subjects were normal public school children in grades 1 and 5. Children were classified into 3 groups with either verbal IQ greater than performance (by 10 points at grade 1 and 15 points at grade 5), performance IQ greater than verbal (by 15 points), or equal IQ scores (within 2 points). For the younger first graders
(CA = 6), performance-verbal discrepancies did not relate to standardized reading achievement scores. Older fifth graders (CA = 10), however, with higher verbal than performance scores read significantly better than other subjects, although they had lower full-scale IQs than the high performance - low verbal group. The high verbal - low performance group of normal readers read exceptionally well; the other children were not reading poorly. No differences were found between children with full scale IQs greater than or less than 100.

In concluding that depressed verbal ability (relative to performance) does not result in poor reading, Reed (1967) disagrees with Belmont & Birch (1966). In comparing good (top one-third) to poor (bottom one-third) readers, Reed (1968) found performance IQ on the WISC more related to younger children's reading achievement while verbal scores were more important for older children.

Rourke and his associates (1971a, 1971b, 1973, 1977) relate discrepancy scores on the WISC verbal and performance scales to differential integrity of the two cerebral hemispheres in children with learning disabilities. Based upon Reitan's demonstration of relationships between lesions of the left cerebral hemisphere and verbal IQ impairment and lesions of the right hemisphere and performance IQ impairment, Rourke hypothesized that children who displayed discrepancies would show evidence of selective impairment in either the
right or left cerebral hemisphere. He found that older children (CA 9 - 14) with learning disabilities and specific performance-verbal discrepancies on the WISC do behave on verbal, perceptual, and psychomotor tasks in a manner similar to that expected if they were experiencing lateralized cerebral dysfunctioning. That is those learning disabled children (definition of learning disabled is not specified in these studies) with high performance and low verbal IQs performed on other tasks (WRAT, Halstead Categories, Trail Making Test, Target Test) differentially from children with high verbal and low performance IQs. For younger learning disabled children (CA 5 - 8), the patterns of abilities and deficits related to lateralized cerebral dysfunctioning were not clear. These studies lend support to Belmont & Birch's (1966) contention that the performance-verbal relationship is for older children a more influential factor of reading disabilities than overall level of intelligence.

A recent study by Dean (1978) examined WISC-R scores of learning disabled and emotionally disabled children and found that while the emotionally disturbed had significant performance-verbal discrepancy scores there was no significant discrepancy within the learning disabled group. It is difficult to evaluate this study, however as no intelligence scores are presented and subject selection for the learning disabled group is not clearly discussed.
Other studies as well have not found discrepancy scores to be of much value. Anderson et al. (1976) note that the learning disabled child does not have large performance-verbal discrepancies when compared to the normal child. Werner & Templer (1976) using more stringent statistical models generally did not find discrepancy scores related to differential motor and psychomotor functioning.

It is thus unclear whether differential performance on the WISC-R as measured by performance-verbal discrepancy scores is in fact a representation of cerebral functioning and an indication of severity of reading disability.
Hypotheses

In the literature discussed above, two distinct groups of reading disabled children were delineated. It is suggested that these groups differ in the degree of cerebral specialization for speech functions as measured by dichotic listening tasks and in the degree of reading improvement over the course of intervention. Specifically it is hypothesized:

$H_1$: Retarded readers will demonstrate less left hemisphere lateralization than backward readers.

$H_2$: Retarded readers will improve less in reading skills than backward readers over the course of therapeutic intervention.

Additional hypotheses relate to measures of cerebral laterality. One of the earlier conceptualizations of cerebral laterality and cerebral dysfunction is explored:

$H_3$: There will be no differences between crossed (manual-occular) and ipsilateral dominant subjects in reading ability or degree of cerebral laterality.

It remains unclear whether degree of cerebral laterality reflects degree of reading abilities or whether reversed hemispheric dominance is reflective of pathology in other functions. It is hypothesized for the entire population:
$H_4$: Degree of lateralization is related to severity of reading disability so that the less left hemispheric dominance observed the more severely disabled the reading.

$H_5$: Increasing left hemispheric specialization over the course of intervention will be associated with greater improvement in reading skills.

It has been suggested that at various age groups there are sex differences in the rate of cerebral lateralization. It is hypothesized that for this age group:

$H_6$: There will be no sex differences in degree of cerebral laterality.

Appropriate computer statistical packages will be utilized to test these hypotheses. For the between groups comparisons (hypotheses 1, 2, 3, 6), SAS program General Linear Models MANOVA procedures will be utilized. Hypotheses 4 and 5 will be examined first with SAS program Pearson product moment correlations and then with CANOVA package program multivariate analyses of variance.
II. DESIGN

Subject Selection and Therapeutic Tutoring

Subjects for this examination of cerebral laterality were selected from the population of the Therapeutic Tutoring Program, a federally supported service project for early intervention and prevention administered through the Psychology Department of Columbus Children's Hospital (NIMH grant #7508A105). Therapeutic tutoring, described in more detail by Rie (1974) and Rie & Farber (manuscript) is an affectively oriented intervention program for children in academic distress. It seeks to identify reading disabled children in the early school years and provide remediation through trained paraprofessional tutors. Therapeutic tutoring focuses on a number of principles. The relationship between the tutor and the child is seen as of paramount importance. The tutor remains a positive, supportive, and accepting figure. Utilization of multiple modes of input to the child is stressed. Tutoring is focused on progressive academic successes and the child is encouraged to actively master his material. Affective states of arousal, which may interfere with academic success, are brought out in the open and discussed between child and tutor.
The therapeutic tutoring program was described early in the school year to the principals of nine inner-city schools within the mental health catchment area of Columbus Children's Hospital. Five of the schools had previously participated in the tutoring program; one of these refused to continue. In a meeting at each of the eight schools, the author explained in detail the nature of the assessment and the tutoring to the principals, guidance counselors, reading specialists, and second and third grade teachers. Teachers were asked to nominate for program consideration up to five children who were reading a minimum of a half-year below grade level. Children of too low intelligence, children with severe emotional disorders, and children involved in many other remedial programs were excluded. In many of the schools, teachers familiar with therapeutic tutoring would describe to new teachers the types of children who in the past had benefitted from the intervention. Following parental permission, screening evaluations were begun by tutoring project staff, graduate students in clinical-child psychology experienced in administering these psychological measures. An attempt was made to screen approximately fifty percent more students than would actually be tutored in a particular school. Subject selection for screening was based on teacher rankings (often with the input of the principal or guidance counselor) and the availability of the subject during the
evaluation period. The WISC-R and Word Identification and Passage Comprehension subtests of the Woodcock Reading Mastery Tests were individually administered. Only children reading at least five months below grade level on the word identification subtest and with full scale IQs greater than 70 were considered for tutoring. Of the approximately 150 subjects initially evaluated, 92 began tutoring in January 1978. Subjects were excluded because of not meeting reading deficits criteria, low IQs, lack of written parental consent, moves, and the school's having more children than tutoring capabilities.

A series of psychological and educational tests including the Wepman Auditory Discrimination Test (1958), Bender Visual Motor Gestalt Tests (1946), sections of the Underlining Test (Doehring, 1968), and a modification of Spivack & Shure's (1974) Alternative Thinking Test was administered individually as part of the therapeutic tutoring program. Classroom teachers compiled the Devereux Elementary Behavior Rating Scales (1967) and sociograms. Two dichotic listening measures of lateralization (digits and consonant-vowels) and the Trail Making Tests (Reitan, 1971) were individually administered by the author. To complete the evaluation each child was seen three to four times between November 1977 and January 1978. Therapeutic Tutoring began in January and continued through June 1978 when all subjects were reevaluated.
Paraprofessionals, often from the same neighborhoods as the children, served as tutors with ongoing consultation from the project staff and director. These eight women tutors were each involved in one school. Many had been referred to the project by school personnel who had known them as teacher's aides, volunteers, or parents. This made them readily acceptable to the school system and also suggested an interest in and a commitment to academic achievement. Tutors were individuals who upon interview were seen as reasonably empathetic. The group included both Caucasian and non-Caucasian women. Four of the tutors had previously been involved in the therapeutic tutoring program.

Tutors were trained in twice weekly sessions for seven weeks in late autumn of 1977 for a total of about 35 training hours. Half of the training time was led by a professional instructor of learning disabilities and focused on methods of teaching early reading skills. The other half of training was led by tutoring project staff and the director and was devoted to therapeutic principles and their implementation. Training procedures included lectures, discussions, observation, and role-playing. Throughout the course of tutoring, the tutors met once every three weeks for discussions, consultations and clarifications. Individual consultations concerning specific children were available and frequently utilized.
Twenty-one children in the therapeutic tutoring program were excluded in this examination of cerebral laterality. Children were excluded if they had full scale WISC-R scores less than 74 \((N = 8)\), were mixed or left-handed \((N = 8)\) or moved prior to post-intervention evaluation \((N = 5)\).

From January through June 1978 each child was individually tutored twice weekly within the schools. Schedules were arranged with teachers to avoid conflicts with critical class periods. Due to absences, the mean number of tutoring sessions was 28.4 (sd = 4.8). Each tutoring session averaged 43.2 minutes (sd = 3.9) and the total mean tutoring time was 1227 minutes (sd = 239) or 20.5 hours per child.

Measures

Each child was individually evaluated at his school during class time. The assessment battery included:

1) Woodcock Reading Mastery Tests (1973). Word identification and passage comprehension subtests were administered in the standard manner except that each subject began with the easiest questions regardless of age or grade level. Grade level and achievement index scores were computed for each subject. Grade level scores on the Woodcock reflect the maximum grade level at which there is a 90% reading proficiency. The achievement index is a measure of reading
performance relative to a normal population that is constant across grades. A child with an achievement index of 0 will have 50% of his class reading above his level and 50% below. Since the achievement index does not vary over grades, children in different grades with the same achievement index scores would be reading at the same relative percentile or level in their classes. An achievement index of -30 or lower is indicative of severely disabled reading ability.

Alternate forms of the Woodcock were used for pre- and post- tutoring evaluations.

2) Wechsler Intelligence Scale for Children - Revised (1974) Digit span was administered in addition to the 10 standard subtests. A discrepancy score reflecting the difference between performance and verbal IQs was computed as well as the traditional three IQs. The WISC-R was not repeated post-tutoring.

3) Bender Visual Motor Gestalt Test (1946). Scoring was by the Koppitz (1963) method. The statistic utilized was the number of errors by which the subject deviated from age norms. Administration was standard.

4) Wepman Auditory Discrimination Test (1958). Subjects making more than 15 errors of auditory discrimination were excluded from the analysis if it was questionable whether they understood the concepts of same and different. The test was administered in the standard
manner following practice trials and alternate forms were used pre-
and post-intervention.

5) Trail Making Test. The children's modification (Reitan, 1971) 
consists of two parts each with practice trials. Trails A has 15 
circles, numbered from 1 to 15 distributed over the page. The task 
is to connect the circles in numerical sequence as quickly as pos­
sible. Errors are pointed out to be corrected immediately, thus con­
tributing to the total time of task completion. Trails B contains 15 
circles labelled 1 to 8 and A to G. The subject is again instructed 
to connect the circles, only now alternating consecutive numbers and 
letters. Thus from 1 a line is drawn to A, to 2, to B, etc. The score 
of each part is the amount of time required to correctly complete the 
task. A ratio score of Trails B divided by Trails A is computed.

6) Handedness. The six primary measures of handedness of 
Annett (1970) were utilized. The subject was asked to demonstrate 
with which hand he wrote, threw a ball, used a racket, struck a 
match, used a hammer, and used a toothbrush. In addition each 
child was asked to write his name. The same questions were asked 
pre- and post-intervention and to be considered right-handed the 
child needed to demonstrate at least 11 of the 12 activities with his 
right hand, including both writing measures. Eight subjects were 
excluded from the study because of mixed or left handedness.
7) Eyedness. A simple task of eye dominance was used. A rolled up paper cone was placed on the center of the subject's desk. The subject was instructed to look through the cone at the examiner's nose or centrally located pen. Eye preference was noted.

8) Dichotic Listening Tasks (DLT). Two different dichotic listening tasks, digits and nonsense syllables consonant-vowels (CV) were presented during the same testing session to each subject. Stimuli were presented via a Pioneer CT 5151 stereo cassette deck through Koss K15 stereo headphones in a quiet school room. Decible levels were adjusted during practice trials until they were reported to be at a comfortable level. A dolby sound system was utilized to eliminate static. Headphones were reversed halfway through each task to control for possible differences and the initial headphone placement was random for each subject.

a) digits - This tape was developed at the New York University Medical Center and is a copy of the original Broadbent tape utilized by Sandra Witelson (1976). Digits from 1 to 10, excluding the two syllable digit 7, were presented simultaneously through the stereo headphones to each ear. Two, three, and four pair digit series were utilized. There were 13 trials to each series and thus a total of 39 trials with 107 digits presented to each ear. No digits were repeated within a particular series. The stimuli were presented at a rate of 2
digits per second in a female voice. Onset of each series was pre­
ceded by a clicking warning stimulus and followed by a pause of
random length. The subject was told that he would hear, "a lot of
numbers, very fast" and was instructed to verbally report all digits he
could remember in any order. The dichotic trials were preceded by
familiarization with the cassette recorder and earphones, monaural
and single pair dichotic practice trials.

Four scores were computed: total digits correct from the right
ear, total digits correct from the left ear, sum of correct responses,
and a laterality coefficient. This laterality coefficient (LC) was right
ear correct minus left ear correct, divided by the total correct multi­
plied by 100. Thus a positive laterality coefficient would indicate
a right ear advantage and a negative LC a left ear advantage while
controlling for actual number of digits correctly recalled. Relative
degree of dominance is indicated by the size of the LC; the greater
the absolute value of the laterality coefficient the greater the degree
of lateralization.

b) consonant vowels nonsense syllables (CV) - This tape was
developed by the Haskins Laboratory in Connecticut and utilized by
Shankweiler & Studdert-Kennedy (1975) and Dorman & Geffner (1974).
The stimuli are the 6CV syllables, "ba, da, ga, pa, ka, ta". Two
different stimuli are presented simultaneously, one to each ear. A
total of 60 pair of consonant-vowels are presented by a male voice. The subjects are instructed to, "listen with both ears and tell me all the funny sounding words you hear". A practice trial consisted of binaural repetitions of the 6 CV syllables and practice trials were continued until the subject was able to correctly identify all 6 stimuli or until 9 trials were failed. Errors were corrected on practice trials. If after three practice trials sounds were not correctly discriminated, the subject was instructed to read the CV syllables from a printed card placed before him. Additional practice trials allowed the subject to point to the sound while pronouncing it. The printed card was removed, however, before the dichotic stimuli were presented. Idiosyncratic pronunciations, such as "bat" for "ba" or "gap" for "ga" were scored as correct if used consistently. The inability to successfully discriminate the practice trials or perseveration of one response throughout the task rendered the score invalid. Four scores, right ear correct, left ear correct, total correct, and laterality coefficient were computed as with the dichotic digits task.
III. RESULTS

Subject Characteristics

A total of 71 right handed second and third graders from eight Columbus, Ohio inner-city schools participated in this study. Mean subject age at initial evaluation was 101 months (8-4 years, sd = 10 months) with a range of 86 - 125 months (7-2 to 10-5 years). Fifty-three (75%) of the subjects were male and 18 (25%) were female including 35 second and 36 third graders (see Table 1). The mean full scale WISC-R IQ was 86.1 (sd = 8.2, range 74 - 109) with mean Verbal IQ of 82.8 (sd = 10.1, range 62 - 112) and mean Performance IQ of 92.0 (sd = 8.8, range 71 - 111). Although no specific measures of socio-economic class were taken, these schools had previously been found (Rie 1974 and Rie & Farber manuscript) to fall within the lowest categories of socioeconomic class, with a predominance of unemployed or laboring class families. Approximately equal numbers of black and white students were represented in these schools. All schools were located in geographical districts designated as highest priority for remedial education programs. School size varied considerably, from only one class at each grade level to three or four.
The population displayed considerable visual-motor dysfunction. On the Bender Visual Motor Gestalt Test scored by the Koppitz method, there was an average of 2.0 (sd = 2.7) more errors than expected for age norms (range -12 to 3). Considerable auditory discrimination difficulty was observed as well, with a mean Wepman Auditory Discrimination Test score of 6.3 (sd = 3.5, range 0 to 15 errors).

Table 2 displays the mean Woodcock reading scores and dichotic listening tasks laterality coefficients for the 71 right-handed subjects. As mean grade placement was 2.72, word identification skills were approximately 1.1 years below grade level and passage comprehension skills approximately 0.8 years below grade level. The range of reading ability was from the 1.0 grade level, the minimum possible score on the Woodcock for even non-readers, to 2.8 grade level. The minimum score of 1.0 on the Woodcock for even non-readers may well inflate the mean reading grade level of the population.

While the effect of therapeutic tutoring intervention on reading improvement was not the focus of this study, it is evident that over the course of 6 months significant improvements were made in 3 of the 4 reading measures (SPSS program pair-wise t-tests, word achievement t = 4.42, p = .001, df = 70; passages achievement t = 1.33, p = .187; words grade t = 9.75, p = .001; passages grade t = 6.75, p = .001).
Sex Differences

It had been hypothesized that in this age group no sex differences would be found in degree of cerebral laterality. The mean reading and laterality scores for the two sexes are presented in Table 3. Analyses of variance revealed no significant differences between male and female reading disabled subjects on measures of IQ, reading achievement, dichotic listening laterality coefficients, and Trail Making Test scores. The sexes did not differ in the amount of reading improvement or cerebral laterality change following intervention. Significant sex differences were noted on teacher rated behavior on the Devereux. The boys were initially seen as more acting-out (z score $\bar{x} = .1246$, sd = 1.08) than the females (z score $\bar{x} = -.7636$, sd = .77) with the difference highly significant ($F = 11.99$, $p = .0009$, df = 70). As there were no significant sex differences in reading or laterality measures males and females were combined in other analyses.

Backward and Retarded Readers

Achievement indices were computed for each subject by the formula, $(\text{full scale IQ}/100) \times (\text{grade placement} - \text{initial word identification grade level score})$. Backward readers were defined as subjects with achievement indices less than or equal to .50 grade level; retarded readers were those with achievement indices
It had been hypothesized that retarded readers, subjects with specific reading disabilities, would improve less in reading over time and would display less left hemispheric dominance than would backward readers. Of the 71 right-handed subjects, 24 (34%) were classified as backward readers and 47 (66%) as retarded readers. In an analysis of variance between backward and retarded readers, the most significant differences was age. The backward readers were significantly younger ($\bar{x} = 95.7$) than retarded readers ($\bar{x} = 103.7$ months), $F = 11.58, p = .001$). As Table 4 indicates, retarded readers tended to have higher Performance IQs than backward readers ($F = 3.31, p = .0732$) and were significantly more disabled on the Woodcock reading achievement scores. To control for the significant age differences and the fact that nearly all third graders were in the retarded reading group, comparisons between backward and retarded readers were recomputed for second graders alone.

Of the 35 second graders, 23 (66%) were backward readers while 12 (34%) were retarded readers. As shown in Table 5, backward second graders tended to be somewhat older ($F = 3.28, p = .0792$) with significantly lower performance ($F = 4.88, p = .0342$) and full scale IQs ($F = 5.63, p = .0236$). Retarded readers are significantly more disabled on all four reading measures (word achievement
F = 11.21, p = .0020; passages achievement F = 8.31, p = .0069; word grade F = 10.22, p = .0031; passages grade F = 6.36, p = .0167) as would be expected on the basis of group selection.

Contrary to prediction, there are no significant differences between groups of second graders on the dichotic laterality coefficients, IQ discrepancies, or Trails. Bender, Wepman, sociograms, and behavior ratings also did not reflect differences between backward and retarded second graders.

Table 6 displays the mean reading and laterality coefficient improvement scores for backward and retarded second graders. There are no significant differences between backward and retarded readers in amount of improvement in reading during the approximately 6 months between pre- and post-testing. Reading group also did not have any effect on the amount of change in laterality coefficients for either of the dichotic listening tasks.

Pearson product moment correlations of the achievement index scores, a continuous measure of severity of reading disability, and measures of laterality, reading, and intelligence were computed, for all subjects. The higher the achievement index the more retarded the reader. The achievement index is significantly correlated with age (r = .339, p = .0038, N = 71); the older the subject the more retarded. Both performance (r = .372, p = .0014) and full scale IQs
(r = .327, p = .0054) are positively related to achievement index. The index is not significantly related to laterality coefficients, IQ discrepancy, or Trails ratio. It is negatively related to Woodcock word achievement (r = - .387, p = .0008) and passages achievement (r = - .398, p = .0006) as expected on the basis of the formulation of the index. Subjects with higher achievement indices made fewer auditory discrimination errors on the Wepman (r = - .342, p = .0040), but this may be accounted for by age: older children make fewer errors on the Wepman and older children had higher achievement indices. There were no significant relationships, however, between the index and amount of improvement in any of the four reading measures or on either of the dichotic listening tasks.

Crossed Dominance

It had been hypothesized that there would be no differences in reading or cerebral laterality between subjects who were crossed or ipsilateral dominant. Forty-five (63%) of the subjects were ipsilateral dominant (right-handed and right-eyed) while 26 (37%) were crossed dominant (right-handed and left-eyed). Analyses of variance revealed no significant differences between the crossed and ipsilateral subjects in age, grade, IQ variables, reading level, Wepman, Bender, sociograms, and behavior rating scores.
Table 7 indicates that the crossed and ipsilateral subjects did not differ on measures of cerebral laterality. Initial laterality coefficient scores, IQ discrepancies, and Trail Making Test scores did not differentiate between groups. There was, however, a significant difference in the amount of change on the consonant-vowel task laterality coefficient ($F = 5.22$, $p = .0289$, $df = 34$) with ipsilaterally dominant subjects becoming less left hemisphere specialized ($\bar{x} = -6.17$, $sd = 20.4$) and crossed dominant subjects becoming more left hemisphere specialized ($\bar{x} = 9.67$, $sd = 19.0$). These differences in changes in cerebral laterality were not predicted.

**Dichotic Listening Tasks-Digits**

All subjects were able to successfully complete DLT digits. The mean laterality coefficient of 10.57 ($sd = 17.9$) indicated left hemisphere dominance for this reading disabled population, but there existed wide variation in the degree of lateralization (range -50 to 66). Fifty-six subjects (79%) were left hemisphere dominant for speech; 15 (21%) were right hemisphere dominant.

There were a total of 234 stimuli presented on DLT digits. The mean total recall of 148.9 ($sd = 20.7$) indicates that 64% of the stimuli were correctly recalled.

It was hypothesized that less left hemisphere lateralized subjects would be poorer readers. Pearson product moment correlations
were computed between digits laterality coefficients (LC) and reading scores. The higher the LC the more left hemisphere specialized the child. It is evident from Table 8 that there are significant negative correlations between digits LC and word identification and passage comprehension grade levels (word achievement approached significance). Thus contrary to predictions, it appears that in this reading disabled group children who were more left hemisphere lateralized for speech on DLT digits were poorer readers at pre-intervention assessment. However, there tends to be a positive relationship between digits LC and improvement on word achievement index and passages achievement index. That is, children who tended to be more left hemisphere (LH) dominant on DLT digits, tended to improve more on reading achievement indices. The relationships were not significant for reading grade levels change.

On the basis of laterality coefficient scores on the DLT digits, subjects were divided into four groups. Group 1 had highly lateralized left hemisphere dominant subjects (digits LC>20, high LH), group 2 had moderate LH specialization (20≥LC>10, mod LH), group 3 had low LH specialization (10≥LC>0, low LH), and group 4 had right hemisphere specialization (LC<0, RH). The mean LC and reading scores of these subjects are presented in Table 9. MANOVA statistics between these subjects of different degrees of hemispheric
specialization on initial reading ability reveals no overall significant differences, although the passages achievement index scores approached significance ($F = 2.57$, $p = .062$, $df = 57$). When the high LH group was compared to all others, it becomes evident that the most strongly lateralized subjects are the poorest readers initially (word index $F = 4.957$, $p = .029$, $df = 67$; passages index $F = 6.818$, $p = .011$; words grade $F = 4.008$, $p = .049$; passages grade $F = 5.771$, $p = .019$). Thus contrary to prediction, strong left hemisphere specialized subjects are the poorest readers.

It was predicted that increased left hemisphere lateralization over time would be related to increased reading ability. Overall there are no significant differences between these 4 groups in amount of reading improvement. The strongly left hemisphere subjects tend to improve significantly more than other subjects in passages achievement change ($F = 3.545$, $p = .064$).

These 4 groups of subjects do not differ in age, grade, Bender, behavior rating, Trail Making Tests, or IQ discrepancy scores. They do, however, tend to differ overall in full scale IQ, but these differences do not fit any recognizable patterns. The strong LH group does not differ from all other subjects in age, grade, behavior, Trails, or any IQ variables.
**Dichotic Listening Tasks—Consonant Vowels (CV)**

Some 21 subjects (30%) were unable to successfully complete the DLT CV despite the training procedures described earlier. The mean CV laterality coefficient for the 50 subjects able to complete the task was 8.50 (sd = 20.4), indicating LH dominance for this reading disabled group as a whole, but with wide variability (range -31 to 60). Thirty-two subjects (64%) were LH dominant, 18 (36%) were RH dominant. The maximum possible total score was 60. The mean total recall of 37.1 indicates that about 62% of the nonsense syllables were correctly recalled.

As with the digits task, it was hypothesized that subjects who were more left hemisphere lateralized would be better readers. Pearson product moment correlations were computed between CV laterality coefficients and reading scores. Contrary to prediction, Table 8 indicates that there are no significant relationships between LC on the CV task and initial reading level or amount of reading improvement over the course of tutoring.

On the basis on CV laterality coefficients, subjects were divided into three groups, left hemisphere lateralized (LC > 0), right hemisphere lateralized (LC ≤ 0), and invalid (unable to successfully complete the task). The mean LC and reading scores for these groups are presented in Table 10. Overall there are no significant
differences between the three groups in initial reading ability or in reading improvement. Nor are there any differences between the LH lateralized and RH lateralized subjects in initial reading levels or in reading improvement. In contrasting the group of subjects who were unable to complete the task to those lateralized either to the left or to the right, subjects unable to complete the DLT tended to be poorer readers on word achievement index \((F = 3.106, p = .082, df = 68)\) and word grade \((F = 3.394, p = .070)\). Over time these 'invalid' subjects grew significantly worse in passages achievement index \((F = 4.132, p = .046)\). Thus degree of laterality or side of specialization had no effect on academic achievement.

There were no significant correlations between CV LC and age, grade, IQ variables, Trails, Wepman, or Bender. LH subjects tended to have higher Verbal \((F = 2.753, p = .102)\) and Full Scale IQs \((F = 3.360, p = .071)\) than RH subjects. Table 11 displays IQ by hemispheric group. Subjects unable to complete the CV DLT did not differ from lateralized subjects in intellectual variables.

Stability and Change

As can be seen on Table 12, test-retest stability is significant over five months for both CV \((r = .335, p = .0397, N = 38)\) and digits \((r = .660, p = .0001, N = 71)\) laterality coefficients. Stability over time is much greater on the digits task than on the CV task.
All subjects were divided into 4 groups on the basis of the amount of change on digits LC from pre- to post-testing. Group 1 had an LC change of 10 or more; group 2's LC change was between 0 and 10; group 3's was from 0 to -10; and group 4's was less than -10. A positive LC change score could indicate either greater LH dominance or a decrease in RH dominance. Similarly, a negative LC change score could indicate either an LH decrease or an RH increase. The means of these 4 groups on intelligence and reading variables are presented in Table 13. It was assumed that intervention would lead to increased lateralization and reading improvement. There were no significant differences in behavior factors, age, IQ variables, Bender, Wepman, sociogram, initial reading or reading improvement scores. There was a significant linear trend so that subjects who became more LH were less so initially (F = 8.204, p = .006). This may well be a regression toward the mean effect.

All subjects were divided into 5 groups on the basis of change on the CV DLT. Group 1 had an LC change greater than or equal to 0 (became more LH or less RH); group 2 had an LC change less than 0 (became less LH or more RH). The remaining three groups had no valid change scores. Group 3 had invalid scores on the pre-test, group 4 had invalid scores on the post-test, and group 5 had invalid scores on both trials. The initial and change scores in reading for
these 5 groups are presented in Table 14. As on the digits DLT, it was assumed that increased laterality would be related to reading improvement.

Although the 5 groups did not differ in initial reading scores, there were significant overall differences on reading improvement measures (word achievement change $F = 3.193$, $p = .019$; passages achievement change $F = 2.898$, $p = .028$; word grade change $F = 4.515$, $p = .003$; passages grade change $F = 2.575$, $p = .071$). In fact when group 1 (became more LH) was compared to group 2 (became more RH) it was evident that as predicted subjects who became more LH dominant over the course of 5 months improved significantly more in reading than subjects who became less LH dominant (word achievement change $F = 10.581$, $p = .002$; passages achievement change $F = 5.392$, $p = .023$; word grade change $F = 14.153$, $p = .001$; passages grade change $F = 6.282$, $p = .015$).

A Dunn's test post-hoc analysis examined the difference between the 22 subjects who became more LH lateralized for speech on the DLT CV to all other subjects (more RH and 3 groups of invalids). While there were no differences between the groups in initial ability, the subjects who became more LH over the course of tutoring improved significantly more in reading (word grade change Dunn's $F = 3.86$, $p < .01$, $df = 66$; passages grade change $F = 2.91$, $p < .05$; words
achievement change \( F = 3.34, p<.01 \); passages achievement change \( F = 2.43, \text{ ns} \).

**Trail Making Test, IQ Discrepancy**

There were 4 measures utilized in this study to assess relative degrees of cerebral lateralization. Table 15 reveals that none of these measures, digits LC, consonant-vowels LC, Trails ratio, and IQ discrepancy are significantly correlated with each other.

It had been postulated that children with greater Performance minus Verbal IQ discrepancy scores would be poorer readers. The mean IQ discrepancy score of 9.4 (sd = 11) indicates that in this reading disabled population the average verbal IQ was 9 1/2 points lower than performance IQ. The range of IQ discrepancies (performance minus verbal) was from -20 to 30. The discrepancy was significantly negatively related to initial word achievement (\( r = -.3374, p = .0040 \)) and word grade (\( r = -.2336, p = .0499 \)). In this reading disabled population then, the greater the P-V IQ discrepancy the more disabled the reading. There were no significant relationships, however, between discrepancy scores and improvement in reading. Discrepancy scores also tended to be negatively related to full scale IQ (\( r = -.2006, p = .0934 \)) and positively related to auditory discrimination difficulties (\( r = .2542, p = .0350 \)). That is, children with greater performance-verbal discrepancies
tended to have lower full scale IQs and have more auditory dis-
crimination problems.

It had been hypothesized that children with higher Trails ratio
scores (time of Trails B divided by time of Trails A) would be less
left hemispheric lateralized and be poorer readers. The mean Trail
Making Test ratio score was 3.43 (sd = 1.8) with a range of about
1 to 10. Ratio scores are unrelated to IQ variables. There tend to
be significant relationships between Trails ratios and initial word
achievement (r = -.2136, p = .0736), word grade (r = -.2486,
p = .0366), and Wepman errors (r = .2127, p = .0794). That is, sub-
jects with higher Trails ratios tend to be poorer readers initially and
have more auditory discrimination difficulty. Trails ratio scores are
unrelated to reading improvement.
IV. DISCUSSION

There were two major issues addressed in this dissertation. It was suggested that there are differences between backward and retarded readers such that the specific reading disability of the retarded readers is related to decreased left hemispheric specialization. Second it was suggested that within a group of reading disabled children severity of reading disability is related to degree of cerebral laterality measured by dichotic listening tasks, IQ discrepancy scores, and Trail Making Test ratios and that increased cerebral lateralization over the time of therapeutic intervention would be related to reading improvement. In addition the notions of crossed hand-eye dominance and sex of subjects affecting reading abilities and cerebral laterality were explored.

Backward and Retarded Readers

The concept of separating disabled readers on the basis of intellectual level as well as severity of reading disability is not a novel one, but was formalized by Yule, Rutter & associates (1973, 1974, 1976). It was hypothesized that the specific reading disability of the retarded readers would be reflected through a lack of LH specialization
for speech. Specifically it was thought that while backward readers might demonstrate less total recall on measures of cerebral laterality, they would show left hemisphere linguistic specialization. The retarded readers, having specific reading disabilities, were thought to be deficient in hemispheric specialization. It was further postulated that backward readers would improve more in reading than retarded readers during this 5 month intervention program. There was no support found for these hypotheses.

No significant effects of sex were found in this study. Backward and retarded males did not differ from backward and retarded females on IQ variables, reading scores, age, grade, eyedness, Trails, or cerebral laterality. There were no significant interactions of sex and backward and retarded readers and thus the sexes were merged in all subsequent comparisons.

Age was important in distinguishing between retarded and backward readers. The retarded readers were older than backward readers (104 months versus 96 months) and while second graders were found in both the retarded and backward groups, nearly all third graders were retarded readers. This strong effect of age on group renders other comparisons dealing with the entire subject population spurious. In an attempt to control for these age and grade effects, only second grade backward and retarded readers were compared. Nearly
two-thirds were backward readers and over one-third were retarded readers. Surprisingly, the backward readers among the second graders were older. As expected on the basis of group placement, retarded readers tended to have higher IQs and to be more disabled in reading.

It was hypothesized that retarded readers would demonstrate less left hemisphere specialization, but there were no differences found between backward and retarded readers in second grade on either the direct measures of laterality—DLT digits LC and CV LC, or the indirect measures—IQ discrepancy and Trails ratio. Thus there were no indications that these groups differ in degree of cerebral lateralization.

Contrary to prediction, there were no significant differences between the 2 groups in reading improvement over the course of the intervention program. Where there were non-significant trends, the retarded readers seemed to improve more.

Group placement then, is most strongly influenced by grade and age. Backward and retarded readers differed only on variables for which they were initially selected, IQ and reading level. The group distinction has no bearing on cerebral laterality or on differences in short-term reading improvement following therapeutic intervention. In this study therefore the distinction between backward
and retarded readers and the use of achievement index appear to be of little relevance. In the Isle of Wight studies, Yule and Rutter (1974, 1975, 1976) found a number of differences between backward and retarded readers. Backward readers had lower IQs and somewhat more evidence of organic brain dysfunction. At 1-year follow-up, retarded readers had made significantly less progress in reading despite their greater intellectual abilities. Backward readers could be seen as children who were generally backward in many skills - intellectual, academic, and neurological. Retarded readers, were as a group disabled specifically only in reading and language development skills.

There are a number of differences between the Isle of Wight study and this design. Whereas Yule and Rutter used 30 months behind grade placement as minimum criteria for reading disability, this study used 5 months. The Isle of Wight study included children between the ages of 9 - 11. The mean age in this study was 8.3 years, with backward readers 1.1 years below grade level on word identification and retarded readers 1.0 years below expected level.

A second difference lies in Yule and Rutter's use of the regression formula advocated by Thorndike (1963). When there is less than a perfect correlation between two measures such as reading and intelligence, predicting one from the other would not account for the regression toward the mean. Rutter & Yule (1975) argue that use of
an achievement index without accounting for the regression effect would overestimate the number of underachievers in children with high IQs, and underestimate the number of underachievers in children with low IQs. As no regression formula was utilized in this study, it is accepted that there may well be an underestimation of low achievers. The possibility that not all reading disabled children in this population of generally low IQ subjects are being identified in no way invalidates the findings of those reading disabled children who are identified.

A third difference lies in the time of follow-up. There is a four to five year follow-up in the Isle of Wight studies without intervention. In this study, there are five months of therapeutic intervention prior to follow-up. The finding of no difference in short-term reading improvement between backward and retarded readers might not be evident if intervention was for a longer period.

Dichotic Listening Tasks and Reading

There are two opposing theories of interest in examining cerebral lateralization in children. One is a developmental theory that suggests increasing left hemispheric lateralization over time; the other proposes that lateralization is fixed at an early age and does not vary in degree over time. The literature is unclear if in fact there is a development of specialization over time. Kimura (1967)
and Porter & Berlin (1975), using dichotic digits and dichotic CV pairs, found a fixed right-ear left hemisphere advantage that did not vary as a function of increasing age. Satz et al. (1975) and Bryden (reported in Satz, 1976) find developmental changes in hemispheric specialization until puberty, fitting into the cerebral development theories of Lennenberg (1967) and Brown & Jaffee (1975).

Only Satz and his associates have evaluated dyslexic subjects over a considerable period of time. The results are not reported in such a way as to make lateralization changes on a DLT interpretable. There have been some short-term reliability studies with the DLT. Shankweiler & Studdert Kennedy (1975) found a test-retest reliability of .70 over two weeks in normal subjects. Blumenstein et al. (1975) had a test-retest $r = .74$ with CV. Fennell et al. (1977) found reliabilities ranging from .74 to .90 with a DLT digit administered one to four weeks apart.

In this study, 71 right-handed reading disabled second and third graders were evaluated with both DLT digits and CV some 5 months apart. Test-retest stability for digits LC was significantly high. The CV task was a more difficult one for these reading disabled children and the laterality coefficients were much less stable. Some 45% of the subjects were unable to complete the CV task on one or both trials, while all subjects were able to discriminate number sounds on DLT digits.
The mean digits LC initially was 10.57. Following therapeutic intervention, the mean LC was 8.29, the difference being insignificant \((t = 1.37, df = 70, \text{ns})\). 79% of the subjects were initially LH dominant, 21% were RH dominant. For the 39 subjects who successfully completed the CV test, there was little change in mean LC (pre = 11.27, post = 13.20, \(t = 0.57, df = 37, \text{ns}\)). Nearly two-thirds of the subjects who completed CV were LH dominant for speech; over one-third were RH dominant. On both trials of the digits task, 54-55% of the stimuli were processed by the LH. On the CV test, the range of REA was remarkably similar, 54-56%. It is quite clear that there was no improvement in degree of cerebral specialization for the group as a whole over 5 months, thus questioning the theory of developmental growth of hemispheric lateralization. It is of course possible that significant improvement would be seen over greater periods of time. The 5 month test-retest period is longer than any other reported in the literature. The between ears difference of approximately 10% is similar to that reported elsewhere (Satz, 1976) for both normal and dyslexic children and adults and thus it may be that subjects were already performing at maximum right ear efficiency on this task.

The lower reliability of the CV DLT reflects its difficulty for these children. Dorman & Geffner (1976) found 48% of lower SES
4 year olds unable to successfully complete the task, while all middle class children were able to do so. In this study, 45% of older low SES children had difficulty discriminating non-competitive nonsense syllables. Although the subjects capable of completing the CV task remained LH dominant, there was a great deal of variability (sd of CV change = 21.1).

Specialization is a relative term. In these tasks, difficulty was established so that 60-65% of all stimuli would be recalled. Approximately 55% of all information recalled was processed in the left hemisphere. While the between ear differences were stable and significant, the fact that about 45% of linguistic information on these tasks is being processed by the RH lends credence to the theory of dominance as a relative, rather than absolute term.

There were initially no significant correlations between CV LC and any of the 4 reading measures. LH dominant children did not differ from RH dominant children in initial reading ability. Children unable to successfully complete the CV task, however, tended to be poorer readers than those who were lateralized to either direction despite equivalent IQs.

There were no significant correlations between CV LC and amount of improvement in reading. LH subjects do not differ from RH in reading improvement. On one of the reading measures, passage
comprehension achievement index, invalid subjects performed significantly poorer over time while lateralized subjects' performances remained stable.

Although the initial prediction was that increased laterality would be related to greater reading ability, the opposite appears to be true with dichotic digits. The more LH lateralized the subject, the poorer the reading within this severely disabled population. The 16 subjects who were most strongly LH lateralized were initially the poorest readers, but improved the most in reading over time. These strongly LH subjects did not differ from others in age, IQ, or other variables.

The 22 subjects who demonstrated an increase in laterality on the CV task (became more LH dominant) improved significantly more over time in all reading measures than the 16 subjects who demonstrated a decrease in LC (became less LH). Although these two groups did not differ in initial reading ability, subjects who became more left hemisphere lateralized improved about 6 months of reading grade skills on word identification and passage comprehension subtests, while those who became less LH lateralized improved only about 2 1/4 months. The groups did not differ in age, IQ, or other variables.
Cerebral Laterality - Conclusions

It has become evident that there are no significant relationships among the various measures of laterality. The two indirect measures of cerebral functioning, IQ discrepancy and Trails ratios are unrelated to each other and to the direct measures of laterality, the dichotic listening tasks. Although the two dichotic measures have been used in a rather random manner in the literature each being assumed to measure hemispheric dominance for speech functions, this study indicates that in a reading disabled population the two measures are not at all related ($r = .1805, N = 50, ns$) and in fact appear to be measuring different aspects of cerebral functioning. Highly LH specialized subjects on digits DLT are the poorest readers. On the CV tasks, LH subjects did not differ from RH in reading, but those unable to complete the task were the poorest readers.

The digits test displayed relatively high test-retest stability over the 5 month period. Degree of laterality remained relatively reliable and changes in LC scores did not reflect any changes in reading ability. The CV test, however, varies far more over time. Only slightly more than half the subjects can successfully complete the task both trials. Although as a group there is no significant increase in lateralization from pre to post test, within the group changes in laterality reflect changes in reading. Children who
become more LH specialized over time improve significantly more in reading than those who become less LH specialized.

The finding that strongly LH subjects on the digits test are the poorest readers invites scrutiny. Porter & Berlin (1975) argue this task, unlike the CV, contains a strong memory component. Up to four pair of stimuli are presented simultaneously. Digit span scaled scores on the WISC-R are unrelated to CV LC. There is, however, a tendency for increased LH specialization on digits DLT to be related to poorer performance on digit span \( r = -.2099, p = .0789 \). More LH subjects have poorer short-term memory facilities. It was found that strongly LH subjects recall the fewest total digits and that overall number of digits recalled tended to be slightly negatively related to LC \( r = -.207, p = .083 \). Total recall of CV stimuli was unrelated to laterality coefficients, despite equivalent IQs.

It is suggested that on the DLT digits there is an informational overload in those subjects with poorer short-term memories. The initial responses are to right ear - left hemisphere stimuli. The overload of memory combined with poorer short-term memory interferes with the secondary, left ear - right hemisphere response. In fact, the strongly LH subjects do not differ from the other subjects in number of digits recalled from the right ear, but do have a lower left ear recall total.
This finding may be related to work done by Bakker et al. (1973) with monaural and dichotic presentation of digits. The authors found that in 7-8 year old children reading was enhanced by a lack of cerebral specialization, but in older children reading was associated with moderate ear dominance. Bakker et al. argue,

"A too advanced lateralization seems to hamper rather than promote efficiency in early reading. This may be due to the fact that in early reading, a great deal of non-lingual as well as lingual information must be processed, which may be facilitated by bilateral hemispheric processes." (p. 309).

Again, in 1976, Bakker et al. find additional support that in the early stages of learning to read both hemispheres have the capacity to mediate; later only the LH becomes specialized for language and verbal mediation. Satz (1976) argues that in younger children reading tasks have strong spatial, or RH components. The theory of developmental lag presented by Satz and his associates in Florida and supported by the Bakker group in Amsterdam argues that dyslexic children are a few years behind normal readers in the development of lateralization and reading skills. Thus older dyslexics, in the 8 to 10 year range studied here, may well be at the developmental stage where low or moderate lateralization would enhance reading skills, whereas strong LH specialization would interfere with spatial and other non-verbal elements necessary in the learning to read stage.
Additional support for the necessity of bilateral representation in the development of reading skills is found in the work of Kraft (1976, 1979) and Kraft et al. (1977). While monitoring brain waves of 18 eight-year-olds, the authors found more right hemispheric functioning during a silent reading task than during verbal responses to questions concerning the reading. Subjects who gave poorer verbal responses to questions (poorer readers) had greater left hemisphere activity during the verbal response period than did children who gave better verbal responses. These better readers tended to have activity in both hemispheres. Kraft (1979) proposes a relationship between bilateral hemispheric functioning and reading comprehension.

The conclusions in this study that strongly left hemisphere lateralized subjects on dichotic digits are the poorest readers and in the Kraft study (1976) that poorer readers have increased left hemisphere EEG activity, suggest that strong left hemisphere lateralization for verbal/analytic processing may well interfere with the complimentary hemispheric functioning necessary in the early stages of learning to read. Witelson's display (1976, 1977) of a lack of right hemispheric spatial specialization in reading disabled boys as compared with normal readers also suggests the need for interfacing of right hemispheric spatial functioning and left hemispheric linguistic functioning for successful reading development. A predominance of one
mode, spatial or linguistic, may well lead to dysfunctional reading.

There are minimal memory components on the CV task and thus no informational overload. LH subjects do not differ from RH in reading ability. Subjects unable to complete the task read less well yet do not differ in intellectual abilities or auditory discrimination capacities. Although neither LH nor RH dominance differentiate reading ability, it is suggested that the combination of intensive training in language skills and developmental growth leads to the conclusion that superior academic growth is associated with increasing left hemisphere specialization.

Degree of laterality, therefore, is associated with reading ability. On DLT digits, greater LH specialization is associated with more severe reading disability. On DLT CV, increasing left hemispheric lateralization during the course of intervention is related to improvement in reading skills. While right hemispheric lateralization on the dichotic tasks does not reflect pathology or severity of reading disability, there is evidence that degree of laterality reflects differential reading skills.

Crossed Dominance

The finding of crossed dominance in 37% of this reading disabled population is remarkably similar to the 36% incidence of crossed-dominance found by Hardyck et al. (1976) in a total
community school population and the 38% estimation within the normal population of Kershner (1975). It can therefore be concluded that crossed dominance does not appear more frequently in reading disabled populations than in normal populations.

As hypothesized, there were no differences found between right-handed right-eyed subjects and right-handed left-eyed subjects on any measures of reading ability or intelligence. Test-retest stability of eye preference over 5 months was high ($r = .8786$, $p = .0001$). There was no correlation between age and eyedness ($r = -.0454$, ns). There was thus no support to Belmont & Birch's (1965) contentions that crossed dominant subjects are poorer readers within reading disabled populations or that eye preference was not stabilized until age 9 or 10.

As hypothesized, the crossed and ipsilateral dominant groups did not differ in measures of cerebral laterality. Both were left hemisphere dominant on the dichotic listening tasks, both had similar IQ discrepancies and Trail Making Test ratios. The finding that crossed dominant reading disabled subjects become more LH specialized on the CV test while ipsilateral subjects become less LH dominant over time suggests a subtle unclear relationship.

It appears that the concept of crossed dominance is of little value. Reading disabled children do not differ from normals in the
incidence of crossed dominance. It is unrelated to intellectual or academic abilities. Its reflection of mixed cerebral functioning, as suggested by Orton (1937), is unsubstantiated by other more direct measures of cerebral functioning.

**IQ Discrepancy**

This population's 9 1/2 point performance IQ superiority over verbal IQ was highly significant ($t = 7.06$, $df = 70$, $p < .001$). Although children with greater P-V IQ discrepancy scores were initially poorer readers on some of the measures, there was no relationship of discrepancy score to degree of reading improvement. Discrepancy scores had little relationship to dichotic listening tasks, direct measures of hemispheric dominance. Laterality coefficients on the CV task are unrelated to either VIQ ($r = .22019$, ns) or PIQ ($r = .16501$, ns). Digits LC has a slight negative relationship to VIQ ($r = -.1981$, $p = .0978$), but no relationship to PIQ ($r = .0966$, ns).

Discrepancies between performance and verbal IQs are often evident in reading disabled populations. Belmont & Birch (1966) found a slight, but statistically significant verbal deficiency of 1.3 points. Rourke et al. (1971, 1973) report that for older learning disabled children (CA 9-14) discrepancy scores were related to reading and other verbal abilities. For younger children, the patterns of dysfunction are not clear. Reed (1966, 1967) found that children whose
PIQ exceeded their VIQ by 15 points were not poor readers, but that children with superior VIQ were superior readers. Wener & Templer (1976) and Anderson et al. (1976) do not find discrepancy scores differentiating learning disabled from controls or related to differential functioning. Dean (1978) recently found significant discrepancy scores in an emotionally disturbed population, but not in a learning disabled one.

Performance subtests on the WISC or WISC-R have been crudely labelled as RH tasks, while verbal subtests have been called LH. Bannatyne (1971) and Rugel (1974 a, b) in their reanalysis of intelligence scores into the three factors of spatial, conceptual, and sequential abilities, find no significant patterns of scores in normal populations. Disabled readers, however, had poorer sequential abilities, skills noted by Ackerman et al. (1976) and others as left hemispheric.

While there are some indications that severity of P-V discrepancy is initially related to severity of reading disability, there are no indications that they can be used as measures of specific cerebral functioning or that Verbal or Performance IQ scores can be termed left or right hemispheric tasks.

**Trail Making Test**

The direct linkage of performance on the Trail Making Test with lateralized cerebral functioning in children was made by Rourke &
Finlayson in 1975. Test-retest stability of the Trails ratio score is not significant in this study ($r = .1291$, ns). Children with higher Trails ratios tend to initially be poorer readers on word identification, but the ratio is unrelated to reading improvement.

Based on work with brain-damaged adults, Reitan & Tarshes (1959) had suggested that performance on Trails A was more associated with RH functioning while performance on Trails B was associated with LH functioning. With a normal population of children Reitan (1971) found no differences between male and female performance with increasing age. Children with known brain damage took significantly more time on both Trails than did normal controls. Davids et al. (1957) found differences between normal, psychiatric, and organic populations in Trails A and B.

Rourke & Finlayson (1975) reported that differential performance on the Trail Making Test was related to a spectrum of neuropsychological abilities in what they termed learning disabled 10-14 year olds. Children with normal performance on Trails A and impaired performance on Trails B performed in a manner similar to that expected if they were to have intact right hemispheres and dysfunctional left hemispheres. They had lower verbal relative to performance WISC-R scores and relatively good psychomotor functioning. Deficits were in verbal and language related skills. Children with
poor scores on both Trails A and B performed as if they were RH dysfunctional. They had higher performance relative to verbal IQs; deficits were in the visual-spatial and visual-motor areas. There was no attempt to compare Trails to reading ability.

The lack of a relationship between Trails scores and the more direct measures of cerebral laterality questions Rourke and Finlayson's (1975) use of the Trail Making Test as a measure of lateralized dysfunction in a reading disabled population. While there is a trend for poorer Trails ratio scores to be related to initial poorer reading, the ratio score had no predictive ability toward reading improvement.

Sex Differences

There is some disagreement in the literature as to whether sex differences are evident in cerebral lateralization. Kimura (1967) and Buffery (1976) report that younger girls, aged 4-6, display laterality at an earlier age than boys. Bowery & Goebel (1976) find no sex differences in DLT ear asymmetry in children. Lake & Bryden (1976) in a normal adult population used a DLT CV task and found adult males more clearly lateralized for speech than females.

In this study there are no sex differences in reading ability or in measures of cerebral laterality. Boys and girls do not differ in the indirect measures of laterality (Trails and IQ discrepancy) or in the direct measures (dichotic listening tasks). Both boys and girls were
predominantly LH specialized for speech.

It remains possible, however, to hypothesize from the research, that while females remain within a stable state of lateralization, there are developmental changes in male laterality. Younger boys may initially be somewhat less LH dominant for speech than girls (Buffery, 1976), be equal to girls during childhood as found in this study, and by adulthood, be more left hemispheric for speech than females (Lake & Bryden, 1976). A longitudinal study would be beneficial in this area.
V. SUMMARY AND IMPLICATIONS

This study focused on cerebral hemispheric lateralization in two groups of reading disabled children, one whose deficiency in reading is relatively appropriate to intellectual level (backward readers), and another whose disability appears specifically in the area of reading and is not a function of intellectual ability (retarded readers). It is suggested that the disability of the retarded readers is related to a deficiency in the left hemispheric lateralization that is often demonstrated in normal reading children and adults. Severity of reading disability was proposed to be related to degree of cerebral specialization, so that children who were not left hemispheric lateralized for speech would be the poorest readers. Reading gain over the course of a therapeutic intervention program was hypothesized to be related to increasing cerebral lateralization.

Subjects were selected from the Therapeutic Tutoring program, a federally funded early intervention project for the identification and remediation of reading disorders. Therapeutic Tutoring is administered through Columbus Children's Hospital in 8 inner-city schools. Paraprofessional tutors meet individually with reading
disabled children twice weekly for about 45 minutes over the course of 20 weeks. Assessment procedures are undertaken prior to and following intervention.

Some 71 right-handed second and third graders served as subjects in this study. Measures administered included two forms of dichotic listening tasks (digits and consonant-vowels), WISC-R, Trail Making Test, Woodcock Reading Mastery Test, Wepman, Bender, sociogram, and Devereux Behavior Rating Scales. The subjects ranged in age from about 7 to 10 1/2 years with a mean of 8 1/3 years. This generally lower class population was three-fourths male and in the lower average overall range of intelligence. Significant visual-motor and auditory discrimination dysfunction were noted. Reading ability was approximately one year below grade level at the time of initial evaluation.

As no differences were found between boys and girls in measures of reading or cerebral laterality, the sexes were merged in all comparisons. The most significant distinctions between backward and retarded readers were in age and grade. As children grew older, the severity of their reading disabilities increased in relation to their intelligence and they were more likely to be classified as retarded rather than backward readers. When only second graders were examined in an attempt to control for these age differences, backward
and retarded readers differed significantly only in the measures for which they were selected, intelligence and initial reading skills. Contrary to prediction, the two groups did not differ in degree of cerebral laterality or in amount of reading improvement over the course of intervention. The utility of distinction between backward and retarded readers as defined in this study must be questioned. If there exist differences between these groups, the etiology of the differences does not appear to be in relative degree of hemispheric specialization.

The finding of crossed manual-occular dominance in over one-third of the subjects is similar to the incidence estimates in normal school populations. Crossed and ipsilateral dominant reading disabled subjects do not differ from one another in reading ability, intelligence, or dichotic listening measures of laterality. There is no substantiation to a relationship between crossed dominance and deficient reading or dysfunctional cerebral functioning.

Four measures were used in this study to assess relative degree of cerebral dominance. There were no significant correlations between these four measures (dichotic digits and consonant vowels, IQ discrepancies and Trail Making Test). The two indirect measures of cerebral laterality, Performance-Verbal IQ discrepancy scores and Trails, tended to be related to severity of initial
reading disability, but were unrelated to improvement in reading over time. A greatly superior mean performance IQ over mean verbal IQ in this study confirms the relative verbal deficit found in other examinations of reading disabled populations.

On dichotic listening tasks this reading disabled group as a whole was left hemisphere dominant for speech. Approximately 55% of all stimuli on both tasks were processed by the left hemisphere, very similar to that percentage found in normal populations. Nearly 80% of reading disabled subjects were left hemisphere dominant on dichotic digits; nearly two-thirds were left hemisphere dominant on dichotic CV.

While laterality coefficients on both dichotic tasks remained significantly stable over time, the lower stability for the CV task may well reflect its relative difficulty for this population. All subjects were able to successfully complete dichotic digits; 45% were unable to successfully complete the CV task at both trials.

Contrary to prediction, strongly lateralized left hemispheric subjects on dichotic digits were the poorest readers. Right hemispheric and moderately left hemispheric children generally did not differ from each other in the severity of reading disability. Increasing or decreasing left hemispheric specialization on dichotic digits over time was unrelated to degree of reading improvement.
Left and right hemisphere dominant children on the dichotic consonant vowel task did not differ in severity of reading disability; degree of laterality had no effect on reading. Subjects initially unable to complete the CV task tended, however, to be the poorer readers, although they did not differ from lateralized subjects in intellectual or perceptual abilities. Increase in left hemispheric specialization on the CV task over time was significantly related to reading improvement. Subjects who over time displayed greater left hemispheric lateralization improved about 6 months in reading grade skills during intervention; children who became less lateralized improved only about 2 1/4 months in reading skills.

With neither of the dichotic tasks is there support for the contention that more left hemisphere dominant children are initially better readers. Increasing lateralization on the CV, but not on digits, is related to reading improvement.

The discrepant findings between these two dichotic tasks leads one to question their growing utilization as direct measures of cerebral dominance. While it is estimated from studies of unihemisphere lesioned patients and from examination of patients with sectioned corpus callosums that 90 to 99% of right-handed subjects are left hemisphere dominant for speech, dichotic studies of normal patients never reveal such high percentages of left lateralization. Even in
studies that attempt to control for such artifacts as handedness, ceiling, or floor effects, rarely does the degree of left dominance even approach 90%.

Performance on the simultaneous digits task is affected by a memory component that is not present in the nonsense syllables. There is a tendency in this study for strongly left hemisphere lateralized children on digits to have the lowest total recall of stimuli and to do poorly on a short-term memory task (WISC-R digit span).

It is suggested that strong lateralization of the left hemisphere for verbal functioning may interfere with successful reading achievement by impeding right hemisphere spatial functioning. Reading skills may well be enhanced by moderate cerebral dominance that allows for utilization of all cerebral functions.

Reading is a complex task that involves spatial recognition and spatial integration as well as verbal analytic functioning. Very little research has explored the involvement and specialization of the right cerebral hemisphere in the early stages of learning to read. The relationship and integration of the functioning of the two cerebral hemispheres in recognition, assimilation, and comprehension as well as the effects of relative specialization of the two cerebral hemispheres on reading abilities and reading styles remain to be explored.
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<tr>
<th>Grade</th>
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<th>Female</th>
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<tr>
<td>Second Grade</td>
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<tr>
<td></td>
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<tr>
<td>Third Grade</td>
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<td>10</td>
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N = 71
Table 2
Reading and Dichotic Laterality Scores for all Subjects: Pre and Post Intervention

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<td>X</td>
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<td>Achievement Index</td>
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<tr>
<td>Achievement Index</td>
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<tr>
<td>Word Identification</td>
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<tr>
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<td>Coefficients</td>
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Table 3
Initial Reading and Laterality Scores for Males and Females

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<th>Males</th>
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<td>Passages Grade</td>
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<td>Dichotic Digits LC</td>
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<td>Dichotic C-V LC</td>
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Table 4

IQ, Age, Initial Reading and LC Scores

for Backward and Retarded Readers:

All Subjects

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<th>Retarded N = 47</th>
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<tr>
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Table 5

IQ, Age, Initial Reading and LC Scores

for Backward and Retarded Readers:

Second Grade Only

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<tr>
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<th>Backward N = 23</th>
<th>Retarded N = 12</th>
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<th>P</th>
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<tbody>
<tr>
<td></td>
<td>X</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>81.70</td>
<td>87.75</td>
<td>2.55</td>
<td>.1198</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>89.57</td>
<td>97.17</td>
<td>4.88</td>
<td>.0342</td>
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<tr>
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<td>84.26</td>
<td>91.75</td>
<td>5.63</td>
<td>.0236</td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
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<td>-27.33</td>
<td>8.31</td>
<td>.0069</td>
</tr>
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<td>1.34</td>
<td>10.22</td>
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</tr>
<tr>
<td>Passages Grade</td>
<td>1.79</td>
<td>1.53</td>
<td>6.36</td>
<td>.0167</td>
</tr>
<tr>
<td>Age (Months)</td>
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<td>91.33</td>
<td>3.28</td>
<td>.0792</td>
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<tr>
<td>Dichotic Digits LC</td>
<td>9.47</td>
<td>17.93</td>
<td>1.71</td>
<td>.2004</td>
</tr>
<tr>
<td>Dichotic CV LC</td>
<td>5.12</td>
<td>16.65</td>
<td>.21</td>
<td>NS (N=11)</td>
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Table 6

Change in Reading and LC Scores for Backward and Retarded Second Graders Only

<table>
<thead>
<tr>
<th></th>
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<tr>
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<td>7.65</td>
<td>11.42</td>
<td>.27</td>
<td>NS</td>
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<td>Passages Achieve.</td>
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<td>Word Id. Grade</td>
<td>.34</td>
<td>.46</td>
<td>.98</td>
<td>NS</td>
</tr>
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<td>Passages Grade</td>
<td>.30</td>
<td>.47</td>
<td>1.12</td>
<td>NS</td>
</tr>
<tr>
<td>Dichotic Digits LC</td>
<td>-1.90</td>
<td>-6.86</td>
<td>1.03</td>
<td>NS</td>
</tr>
<tr>
<td>Dichotic CV LC</td>
<td>2.92</td>
<td>-3.16</td>
<td>.73</td>
<td>NS</td>
</tr>
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Table 7

Initial Laterality Scores for Crossed and
Ipsilateral Dominant Subjects

<table>
<thead>
<tr>
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<th>Ipsilateral</th>
<th>F</th>
<th>P</th>
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<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichotic Digits LC</td>
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<td>8.97</td>
<td>1.04</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>N=26</td>
<td>N=45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dichotic C-V</td>
<td>8.23</td>
<td>8.54</td>
<td>0.27</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>N=17</td>
<td>N=33</td>
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Table 8
Correlations Between Dichotic LC Scores and Initial Reading and Reading Improvement

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<tr>
<th></th>
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<th></th>
<th>CV LC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>r</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>71</td>
<td>-.2151</td>
<td>.0716</td>
<td>50</td>
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<tr>
<td>Passages Achieve.</td>
<td>71</td>
<td>-.1777</td>
<td>.1382</td>
<td>50</td>
</tr>
<tr>
<td>Word Id. Grade</td>
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<td>-.2409</td>
<td>.0430</td>
<td>50</td>
</tr>
<tr>
<td>Passages Grade</td>
<td>71</td>
<td>-.2354</td>
<td>.0481</td>
<td>50</td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>71</td>
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<td>.0551</td>
<td>50</td>
</tr>
<tr>
<td>Passages Achieve.</td>
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<td>.2581</td>
<td>.0298</td>
<td>50</td>
</tr>
<tr>
<td>Word Id. Grade</td>
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<td>.0998</td>
<td>NS</td>
<td>50</td>
</tr>
<tr>
<td>Passages Grade</td>
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<td>.1171</td>
<td>NS</td>
<td>50</td>
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Table 9
Pre and Change Reading Scores for 4 Groups
Based on Initial Digits LC

<table>
<thead>
<tr>
<th></th>
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<th>N=23</th>
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<tr>
<td></td>
<td>HI</td>
<td>LH</td>
<td>MOD</td>
<td>LH</td>
</tr>
<tr>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>-68.5</td>
<td>-56.4</td>
<td>-57.7</td>
<td>-53.5</td>
</tr>
<tr>
<td>Passages Achieve.</td>
<td>-26.6</td>
<td>-16.8</td>
<td>-20.4</td>
<td>-16.9</td>
</tr>
<tr>
<td>Word Id. Grade</td>
<td>1.54</td>
<td>1.71</td>
<td>1.65</td>
<td>1.75</td>
</tr>
<tr>
<td>Passages Grade</td>
<td>1.75</td>
<td>2.04</td>
<td>1.94</td>
<td>2.07</td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>10.75</td>
<td>10.47</td>
<td>7.91</td>
<td>2.40</td>
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<tr>
<td>Passages Achieve.</td>
<td>4.13</td>
<td>-1.82</td>
<td>-0.39</td>
<td>-5.93</td>
</tr>
<tr>
<td>Word Id. Grade</td>
<td>3.88</td>
<td>4.35</td>
<td>4.30</td>
<td>3.20</td>
</tr>
<tr>
<td>Passages Grade</td>
<td>4.25</td>
<td>4.12</td>
<td>3.74</td>
<td>2.27</td>
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Table 10

Pre and Change Reading Scores for 3 Groups

Based on Initial CV LC

<table>
<thead>
<tr>
<th></th>
<th>N = 32</th>
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<th>N = 21</th>
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<tr>
<td></td>
<td>LH</td>
<td>RH</td>
<td>Invalid</td>
</tr>
<tr>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>-56.8</td>
<td>-59.9</td>
<td>-61.4</td>
</tr>
<tr>
<td>Passages Achieve.</td>
<td>-20.8</td>
<td>-21.3</td>
<td>-18.4</td>
</tr>
<tr>
<td>Word Id. Grade</td>
<td>1.72</td>
<td>1.68</td>
<td>1.57</td>
</tr>
<tr>
<td>Passages Grade</td>
<td>2.01</td>
<td>1.93</td>
<td>1.87</td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>8.63</td>
<td>9.83</td>
<td>5.48</td>
</tr>
<tr>
<td>Passages Achieve.</td>
<td>1.06</td>
<td>1.22</td>
<td>-5.67</td>
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<tr>
<td>Word Id. Grade</td>
<td>4.44</td>
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<td>3.14</td>
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<td>4.00</td>
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Table 11
IQ Scores for 3 Groups Based on Initial CV LC

<table>
<thead>
<tr>
<th></th>
<th>LH</th>
<th>RH</th>
<th>Invalid</th>
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</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>84.7</td>
<td>79.7</td>
<td>82.6</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>94.1</td>
<td>90.3</td>
<td>90.3</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>88.1</td>
<td>83.7</td>
<td>85.3</td>
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Table 12

Test-Retest Correlations for Dichotic Digits and CV over 5 Months

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th>Digits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>r</td>
<td>P</td>
<td>N</td>
<td>r</td>
</tr>
<tr>
<td>Total R</td>
<td>38</td>
<td>0.41148</td>
<td>0.0103</td>
<td>71</td>
<td>0.62099</td>
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<tr>
<td>Total L</td>
<td>38</td>
<td>0.34852</td>
<td>0.0320</td>
<td>71</td>
<td>0.65613</td>
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<tr>
<td>Total Correct</td>
<td>38</td>
<td>0.48313</td>
<td>0.0021</td>
<td>71</td>
<td>0.65384</td>
</tr>
<tr>
<td>LC</td>
<td>38</td>
<td>0.33511</td>
<td>0.0397</td>
<td>71</td>
<td>0.66040</td>
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Table 13
IQ and Reading Scores (Pre and Change)
for 4 Groups Based on Change in
Dichotic Digits LC

<table>
<thead>
<tr>
<th>Group</th>
<th>More LH</th>
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<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Hi</td>
<td>Low</td>
<td>Hi</td>
<td>Low</td>
<td></td>
</tr>
<tr>
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<td>85.4</td>
<td>85.0</td>
<td>81.8</td>
<td>81.1</td>
<td></td>
</tr>
<tr>
<td>Performance IQ</td>
<td>90.2</td>
<td>94.2</td>
<td>90.6</td>
<td>93.3</td>
<td></td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>86.5</td>
<td>88.3</td>
<td>84.9</td>
<td>85.9</td>
<td></td>
</tr>
</tbody>
</table>

| Pre            |         |         |         |         |         |
| Word Id. Achieve | -53.4  | -56.1   | -58.9   | -64.0   |         |
| Passages Achieve | -17.3  | -18.3   | -21.2   | -21.8   |         |
| Word Grade     | 1.71    | 1.70    | 1.68    | 1.58    |         |
| Passages Grade | 1.99    | 2.02    | 1.95    | 1.86    |         |

| Change         |         |         |         |         |         |
| Word Id. Achieve | 6.30   | 4.93    | 9.15    | 9.68    |         |
| Passages Achieve | -3.00  | -2.53   | .11     | .11     |         |
| Word Grade     | .44     | .33     | .42     | .41     |         |
| Passages Grade | .34     | .27     | .44     | .34     |         |
Table 14

IQ and Reading Scores (Pre and Change)

for 5 Groups Based on Change in

Dichotic C-V LC

<table>
<thead>
<tr>
<th>Group</th>
<th>More LH</th>
<th>Less LH</th>
<th>3</th>
<th>Invalids</th>
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<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>83.7</td>
<td>85.8</td>
<td>85.5</td>
<td>77.3</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>92.4</td>
<td>93.4</td>
<td>91.6</td>
<td>92.5</td>
</tr>
<tr>
<td>Full Scale IQ</td>
<td>86.8</td>
<td>88.4</td>
<td>87.8</td>
<td>83.4</td>
</tr>
<tr>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Id. Achieve.</td>
<td>-54.68</td>
<td>-57.31</td>
<td>-54.39</td>
<td>-64.50</td>
</tr>
<tr>
<td>Word Grade</td>
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<td>1.69</td>
<td>1.55</td>
<td>1.62</td>
</tr>
<tr>
<td>Passages Grade</td>
<td>2.08</td>
<td>1.93</td>
<td>1.82</td>
<td>1.88</td>
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<tr>
<td>Change</td>
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<td>.23</td>
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<td>.38</td>
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<tr>
<td>Passages Grade</td>
<td>.59</td>
<td>.23</td>
<td>.32</td>
<td>.31</td>
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Table 15
Correlation of Initial Measures of Laterality

<table>
<thead>
<tr>
<th></th>
<th>Digits LC</th>
<th>CV LC</th>
<th>P-V</th>
<th>Trails</th>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV LC</td>
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<td></td>
<td></td>
<td></td>
</tr>
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<td>P-V IQ Discrepancy</td>
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<td></td>
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<td>Trails Ratio</td>
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<td></td>
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<td>-.06425</td>
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<tr>
<td></td>
<td>(p=.1492)</td>
<td></td>
<td></td>
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