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EFFECTS OF HEMISPHERE-SPECIFIC STIMULATION ON ACADEMIC PERFORMANCE AND EVENT-RELATED POTENTIALS IN DYSLEXIC CHILDREN

by

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

There exists a paucity of research addressing the treatment of dyslexia despite its high prevalence and its potential debilitating effects on an individual's cognitive and emotional status. One of the few research programs addressing this issue is headed by Dirk Bakker. Bakker proposes a balance model of dyslexia, specifying L- and P-type dyslexics and an associated treatment technique called hemisphere-specific stimulation (HSS). In general, Bakker's findings suggest that HSS may improve the accuracy and efficiency of reading performance, particularly in L-type dyslexics. In addition, HSS appears to modify the electrophysiological activity of the brain, reflected by a relative change in the left- and right-sided amplitude of the event-related potential (ERP), elicited by flashed words. Although Bakker's findings suggest that HSS may be a potentially successful treatment approach to dyslexia, no studies attempting replication of his results by independent investigators have been published. The present study was designed to replicate the major findings reported by Bakker (Bakker & Vinke, 1985).

In the present study, 26 reading-disabled children were classified into 17 L-type and 9 P-type readers (mean age = 11.0 years) and then randomly assigned to experimental and control groups. Disabled readers in the experimental groups

(L1, N=8; P1, N=5) received 18 sessions (45 minutes twice weekly) of HSS according to Bakker's specifications. HSS involved the stimulation of the right or left cerebral hemisphere through the computerized presentation of words and letters flashed in the left and right visual fields for L- and P-types respectively. Control subjects (L2, N=9; P2, N=4) received no treatment, and remained in their classrooms during training sessions. All subjects were tested with reading and spelling measures prior to training (pre-test), halfway through training (mid-test), and after training (post-test). In addition, ERPs, in response to centrally flashed words, from left and right parietal and temporal locations were collected from all subjects before and after training.

In general, neither the academic nor the electrophysiological results of this study replicated those of Bakker and Vinke (1985). Although all groups tended to show improvements over time on most academic variables, experimental groups did not improve significantly more than controls on most measures of reading and spelling.

In terms of ERP changes, the P300 component of the waveform corresponded most closely to the portion of the ERP on which Bakker and Vinke based their findings. In contrast to Bakker's results, L1 in the present study showed a "leftening" effect (a relative increase in left hemisphere activity) relative to L2. However, consistent with Bakker's findings, P1 showed a leftening effect relative to P2.

Although replication of Bakker's results did not occur, the study was of considerable heuristic value in the critical appraisal of Bakker's model of dyslexia and associated treatment. Critical analysis of the L/P classification system revealed that the most serious difficulty is poor internal validity. It was argued that Bakker's classification system is in need of revision and further testing before external validity, i.e., the efficacy of HSS, can be accurately assessed.

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DEDICATION

This dissertation is dedicated to my husband, Michael.

CHAPTER ONE

Review of the Literature

Reading is a skill that most people take for granted in today's highly literate society. All facets of our society contain written symbols; they appear on signs, newspapers, books, menus, application forms, public transportation, and television. Even if a dyslexic individual attains a grade 5 or 6 reading level, this represents "functional illiteracy" when the individual is faced with job applications, income tax forms, directions on self-assembled merchandise, or even the daily newspaper (van den Honert, 1977). Given the emphasis placed on literacy in today's society, an individual unable to read has an extreme disadvantage academically, socially, emotionally, and vocationally. The purpose of this chapter is to present the current scientific knowledge regarding the major parameters of the disorder of severe difficulty in learning to read, known to most as dyslexia.

Historical Background and Current Status of Dyslexia

Over the years, a variety of terms have been used to denote disorders of learning to read, which have been described as the most common form of learning disability (Doehring, 1978; Helveston, 1987; Hynd & Semrud-Clikeman, 1989; Stanovich, 1988). The earliest description of dyslexia was written in

1896 by Morgan, an English physician (Spreen, 1989a). In 1917, Hinshelwood, an ophthalmologist, published a monograph on the disorder (Applebee, 1971; Spreen, 1989a). Both of these medical practitioners referred to the disorder as "congenital word blindness" to distinguish it from acquired alexia. Since these original descriptions, the disturbance has been referred to as "primary reading retardation", "specific dyslexia", "strephosymbolia" (literally meaning twisted symbols), "analfabetia partialis", and "congenital symbolambolia". One author (Drew, cited in Applebee, 1971) has compiled as many as 14 terms, all of which refer to reading disorder.

The terms that appear to be used most frequently today include "developmental dyslexia", "specific reading disability", and "dyslexia". It has been suggested (Thomson, 1984) that the term "dyslexia" is the most succinct and useful term due to its brevity and accurate translation, "difficulty with words" ("dys" meaning difficulty with or bad, and "lexis" meaning words). In agreement with this view, the term dyslexia will be used throughout the present volume unless the work of certain investigators, who use alternate terms, is under review.

During the last several decades, research into dyslexia has become widespread. Voluminous amounts of published material have been produced by investigators from various disciplines, most notably psychology, education, and medicine.

However, despite the thousands of articles written on the subject of dyslexia, most of the research has yielded conflicting results and incompatible theoretical perspectives. One prominent researcher in the field of learning disabilities has described the research into dyslexia as "inconclusive, trivial, or sadly incomplete" (Rourke, 1975, p. 917), and another has likened the behavioral research on dyslexia to a "tangled web" (Doehring, 1978). Unfortunately, despite the prolific quantities of research, the ultimate goals have remained unattainable, i.e., little has been learned that can benefit the individual child with dyslexia directly (Applebee, 1971). Today, the goal of research in dyslexia is essentially identical to the goal some 87 years ago when Hinshelwood (cited in Eisenberg, 1978) put forth:

> It is a matter of the highest importance to recognize the cause and the true nature of this difficulty in learning to read which is experienced by these children, otherwise they may be harshly treated as imbeciles or incorrigibles, and even neglected or punished for a defect for which they are in no wise responsible. (p. 34)

Definitions of Dyslexia

One of the major problems in the field of dyslexia, perhaps accounting partly for the dearth of progress, has been the lack of consensus regarding a definition of dyslexia

(Applebee, 1971; Doehring, 1978; White & Miller, 1983) or learning disabilities in general (Hammill, Leigh, McNutt, & Larsen, 1987; Kavale & Forness, 1987; McKinney, 1984). That there has been a lack of a consistent definition of dyslexia is hardly surprising given the number of different disciplines involved in the research.

Fruitful systematic examination of an area such as dyslexia necessitates a consistent and clear operational definition that can be used consensually by all investigators (Applebee, 1971). A definition that is unclear or ambiguous will result in ambiguity in processes that are contingent upon that definition e.g., assessment, diagnosis, prevention, remediation, and research. Thus, a precise definition of the phenomenon under question is a basic prerequisite for all procedures that follow from it (Berk, 1983). An investigation into the genetic, neurological, cognitive, and epidemiological factors of dyslexia clearly cannot proceed without a clear notion of what dyslexia is (Benton, 1978).

Part of the definitional problem concerns the wide variety of mechanisms that can adversely affect a child's ability to read (Benton, 1975). These include mental retardation, emotional disturbance, sensory deprivation, cultural deprivation, poor motivation, poor socioeconomic status, inadequate instruction, obvious brain damage, and sensory impairments. Although children with such handicaps may indeed manifest problems in learning to read, such children are not considered to be under the rubric of dyslexia as traditionally defined.

The term specific dyslexia or developmental dyslexia is usually reserved for those individuals whose skills in reading are severely disturbed despite adequate educational and cultural advantages and no obvious anomalies in other realms of functioning including intelligence, sensory functioning, or brain functioning (Applebee, 1971). Dyslexia refers to the unexpectedly poor performance in reading when taking into account the child's age and level of intelligence. Applebee (1971) described dyslexia as that part of reading retardation which we have not yet been able to explain. "Non-specific" reading disorders, on the other hand, often have a variety of causes including physical, mental, emotional, cultural, and educational, as mentioned earlier. The particular interest in dyslexia involves the assumption that the reading difficulties subsumed by the dyslexic child arise from a different source than those difficulties of the non-specific reading-disabled child or the "garden-variety poor reader" (Stanovich, 1988).

Most investigators presume that some kind of dysfunction at the level of the cerebral cortex is responsible for the disorder (Johnson & Myklebust, 1967; Rourke, 1975). The evidence for the neurological basis of dyslexia, however, remains scant and circumstantial in this early stage of investigation, and the neurological basis continues to be only a presumption (Benton, 1975; Dorman, 1985). Furthermore, although there is a general consensus (among neuropsychologists) that dyslexia is due to brain anomalies, there has been no agreement regarding the specific nature of the dysfunction. Therefore, it is unclear whether dyslexia is due to an isolated cerebral insult (caused by an early encephalopathic event such as anoxia, trauma, stroke, or encephalitis), a developmental lag or permanent deficit, or a genetic/constitutional defect (Dorman, 1985). Etiological explanations proposed for dyslexia will be discussed further in a later section.

In the context of the preceding discussion, one of the most common and widely-accepted (Taylor, Satz, & Friel, 1979) definitions of dyslexia quoted frequently is that accepted in 1968 by the Research Group on Developmental Dyslexia of the World Federation of Neurology (Critchley, 1970, p. 11). They describe developmental dyslexia as "a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and socio-cultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin." Another frequently quoted definition that is representative of most operational definitions of dyslexia has been presented by Eisenberg (1967, cited in Eisenberg, 1978, p. 34), "Operationally, specific reading disability may be defined as the failure to learn to read with normal proficiency despite conventional instruction, or culturally adequate home, proper motivation, intact senses, normal intelligence, and freedom from gross neurological defect". Therefore, these definitions present dyslexia as a "residual disorder" diagnosable by exclusion.

Criticisms and Support of Exclusionary Definitions

Despite the popularity and wide use of exclusionary or negative definitions, criticisms of these definitions abound in the literature. Most criticisms are based on the exclusionary clauses such as "despite conventional instruction, or culturally adequate home". Such clauses tend to encourage a misconception that learning disabilities cannot occur concomitantly in a child who is not "adequately" intelligent, "conventionally" instructed, or deprived of "cultural opportunity" (Hammill et al., 1987; Rutter, 1978). Diagnosis by exclusion is therefore problematic because it excludes the possibility that dyslexia may co-exist with, and be exacerbated by other disorders (Boder, 1973). There is social danger in the use of the traditional exclusionary definitions for public educati[illegible] policy. Such a practice can and has adversely affected the lives of many poor readers who do not fall into the specific pigeon-holes of the exclusionary definition

(Eisenberg, 1978). Although most investigators would agree that while other disorders can be secondary to a learning disability or occur concomitantly, a learning disability cannot be the direct result of such problems.

The ambiguity of the definitions constitutes another criticism. Rutter (1978) argues that phrases such as "conventional instruction" and "adequate intelligence" are vague and merely promote confusion.

Several authors have criticized the criterion of "adequate intelligence", i.e., that a discrepancy must exist between intelligence and reading achievement. There are three arguments against the use of discrepancy-based definitions. The first issue concerns the psychometric problem inherent in most tests, standard error of measurement (Thomson, 1984). Thus, the possibility of measurement error in testing of both intelligence and reading may limit the accuracy of a diagnosis of dyslexia. The second issue is statistical in nature and involves the problem of regression to the mean which occurs when two imperfectly correlated test scores are compared (Fletcher, Epsy, Francis, Davidson, Rourke, & Shaywitz, 1989; Thomson, 1984; Yule & Rutter, 1976). Regression refers to the "tendency for scores on one test to move closer to an average score in the presence of an extreme score on the other test" (Fletcher et al., 1989, p. 334-335). The use of a regression equation has been suggested as an alternate approach to discrepancy-based definitions since this procedure corrects for regression artifacts (Fletcher et al., 1989; Rutter, 1978).

The third issue involves the use of IQ tests to measure potential (Fletcher et al., 1989; Thomson, 1984). Many dyslexic children possess certain cognitive problems which may reduce their scores on IQ tests, particularly on the verbal scale. For example, there are four subtests in particular on the Wechsler Intelligence Scale for Children - Revised (WISC-R) that are especially difficult for dyslexic children (e.g., arithmetic, coding, information, and digit span). Most of these tests require the child to work with symbols, an area in which a child with dyslexia is deficient. In addition, a child who cannot read well has been restricted in receiving input in the form of written script which may result in below-average vocabulary and informational knowledge (Orton, 1928). Furthermore, the standards or norms of IQ tests are determined through the assessment of normal children, presumably only a small proportion of which had dyslexia. Therefore, these standards may be unjust for dyslexic children (Orton, 1928). Thus, for these reasons, the low IQ attained by a dyslexic child may be secondary to his dyslexia.

Related to the previous issue is the use of a fixed criterion to demarcate dyslexic performance (Benton, 1975; Thomson, 1984). Many investigators use an arbitrary value of two years behind chronological age in reading level as their cut-off criterion. This practice is inappropriate not only due to the problems of standard error of measurement and regression to the mean, but a two-year discrepancy does not reflect the same deficit at different age or grade levels. For example, a child in grade 2 with a two-year discrepancy is clearly different from such a child in grade 7. The alternate use of a ratio score (e.g., reading level divided by age) has been offered as a solution (Benton, 1975). However, the statistical problems already mentioned apply equally to a ratio score. Again, use of a regression equation appears to be the most viable alternative (Rutter, 1978).

Fletcher et al. (1989) emphasized the need for research into the reliability and validity of commonly used definitions of dyslexia. In their study, two approaches to the definition of dyslexic children were compared (cut-off scores for IQ and reading versus a regression-based definition). They found differences in the number of children identified as dyslexic depending on the method used. One difference was that more lower-IQ children were diagnosed with the regression approach while more higher-IQ children with higher although discrepant reading scores were not identified. This study illustrates that samples of dyslexic children may vary depending on the criteria employed in defining them.

Another criticism of exclusionary definitions arises from the comparison between children defined as dyslexic (using the

World Federation of Neurology definition) and children with non-specific reading disorders who do not meet the criteria of the definition. From a sample of 80 reading-disabled children, Taylor et al. (1979) found that 50% met the definition of dyslexia. However, a comparison between the dyslexic and non-dyslexic groups found no differences on a variety of variables including initial severity and progression of reading disturbance, frequency of reversal errors, familial reading and spelling ability, math skills, neuro-behavioral performance, or personality functioning. The authors suggested that the findings raise "serious doubts" as to the clinical significance and utility of the World Federation of Neurology definition of dyslexia.

Studies such as that of Taylor et al. (1979) have caused researchers to question the value of carefully defining and studying the "dyslexic" if their problems are not qualitatively different from "non-dyslexic" poor readers (Stanovich, 1988). In response to these problems with exclusionary definitions, some authors (e.g., Benton, 1978; Rutter, 1978) have suggested that the concept of dyslexia be broadened to include children who do not meet these strict, and apparently "invalid" criteria of dyslexia.

Yule and Rutter (1976) have adopted a perspective of dyslexia which may help to clear confusion and allow for future progress. They see specific reading retardation (a term they prefer to dyslexia) as determined by an interaction of multiple factors such as dysfunction of the cerebral cortex, neurological damage, lack of adequate environmental stimulation, or a combination of all three. They suggested that it is difficult and probably pointless to try to tease out the socially transmitted disadvantages from the genetically or neurologically transmitted ones. All factors are inextricably bound and interact closely with each other. Yule and Rutter advocate the use of only one restrictive criterion, that reading level be well below that predicted on the basis of age and intelligence. The authors point out that dyslexia as traditionally defined cannot be differentiated from this broader group which they called "specific reading retardation" and therefore the exclusionary definitions along with the term dyslexia serve no useful purpose.

Another explanation of the confusion in the literature involves the selection of reading-disabled children for studies. Yule and Rutter (1976) argued that conclusions based on studies of highly selected groups of children (e.g., reading-disabled children referred to a neurologist) are biased and not representative of the dyslexic population in general. They suggest that such biases can be avoided through the alternative use of epidemiological studies of total child populations.

Results from various epidemiological studies carried out by Rutter and colleagues have revealed useful information (Yule & Rutter, 1976). First, underachievers in reading show an unexpectedly large distribution in the general population. Rather than the expected 2.28% of students who are two standard units below the mean reading level, they found percentages of 3.5 and 6 in two separate distributions in the Isle of Wight (an island off the English Coast) and London, respectively. The authors suggested that the "hump" at the far left of the distribution represents a "pathological excess" due to unspecified neurological factors. Therefore, it does not appear that the distribution of underachievement is entirely normal. Rather, an excess of severe underachievers in reading exists.

Second, a comparison of children with "specific reading retardation" (reading level below that expected on the basis of age and IQ) and those with "general reading backwardness" (reading level below that expected on the basis of age only) revealed marked differences between the groups on sex ratio (e.g., 54.4% of backward readers were male; 76.7% of retarded readers were male). In addition, a higher degree of neurological disorders and motor and praxic abnormalities in backward readers was found.

Third, the two groups of readers discussed above were shown to progress differently in reading achievement. The retarded readers, despite their higher intelligence, progressed significantly slower during a 4 to 5 year follow-up period. At follow-up, retarded readers were over 6 months behind backward readers in reading accuracy and 8 months behind in spelling. However, the retarded readers progressed further in arithmetic than did the backward readers.

Despite the heavy criticisms of exclusionary definitions, some arguments for their value have also been put forth. For example, Stanovich (1988) has pointed to a body of literature that supports the existence of qualitative differences between dyslexics and non-dyslexic poor readers. Critchley (1970) states his own viewpoint rather adamantly:

> When neurologists demarcated "congenital word blindness" as an entity, they did not for a moment intend to embrace the whole community of illiterates, semi-illiterates, poor readers, slow readers, retarded readers, bad spellers, or reluctant writers. That was a problem which lay outside their sphere of influence, and furthermore only remotely concerned the distinctive cases of constitutional disability in which they as neurologists were interested. (p. xi)

Although the exclusionary definitions may be simplified and limited, and do not accurately reflect the nature of dyslexia as it exists in its complex, "real world" forms, they may nonetheless be considered useful as operational definitions at this early stage in dyslexia research (Eisenberg, 1978). Logically, it is easiest to investigate a disorder in its purest form possible e.g, dyslexia without the added complications of cultural deprivation, poor instruction, poor vision, etc. Use of an exclusionary operational definition will result in clearer research results since it will act to reduce false positives (poor readers who are not dyslexic). Benton (1978) agreed that dyslexia must first be established as a disorder in negative terms to reduce confusion between it and other varieties of reading disturbance.

Diagnostically, it may be important to differentiate the dyslexic from the non-specific reading-disabled child because a diagnosis of specific dyslexia suggests specialized remedial reading techniques that may not be necessary in the treatment of reading disturbances due to non-specific causes. A child whose poor reading is due to a non-specific cause such as attention deficit disorder may have normal reading potential, calling for completely different intervention procedures.

Such use of an operational definition in research activities does not preclude the recognition that dyslexia can occur concomitantly with other disturbances or restrict the opportunities of children with poor vision, environmental deprivation, etc. for remedial attention. It simply allows for greater ease in understanding and treating dyslexia with the "error variance" partialled out. Only after dyslexia in its purest form is understood fully would it be appropriate to examine the disorder in conjunction with other disturbances and the potential interaction effects created.

It is of great importance, however, that a clear distinction be made between a clinical or theoretical definition that should not be exclusionary, and a research or operational definition in which exclusion is desirable. The social danger of using exclusionary definitions for public policy has been pointed out earlier (Eisenberg, 1978).

The previous discussion illustrates the state of confusion and contention that exists in the field of dyslexia. The current debate regarding the definition of dyslexia is demonstrated by the results of a recent survey. Adelman and Taylor (1985) sent a survey regarding the future of the learning disabilities field to prominent professionals. Among the questions asked was, "What are the most significant and fundamental concerns facing professionals in the learning disabilities field?" One of the most overriding concerns listed by 59% of the 85 respondents involved the definition of the disorder. Solutions to the problem were conflicting, however, with some professionals advocating a broadening of the definition, and others suggesting it be narrowed.

It is indeed surprising that so much work has been carried out on a disorder whose existence and nature is only now being debated, and remains equivocal. Stanovich (1988, p. 591) stated, "the field of learning disabilities expanded and grew in virtual absence of the critical data needed to test its foundational assumptions."

Concerning the definition of dyslexia, Spreen (1976, p. 449) pointed out cogently: "What we call it does not matter so much, but the exact definition of the group under investigation is crucial". Spreen suggests that a practical alternative to an unlikely consensus of a common definition in the near future is to at least state clearly the details of subject selection to allow for replication and cross-validation. He suggests five factors in particular that be made clearly explicit in the description of studies of learning disabilities: (a) Are cases with mental retardation excluded? (b) Do cases show a lag in emotional or social maturation as well as an academic lag? (c) Is the disability specific to one area (e.g., reading) or does the disability encompass a wider range of skills? (d) Are children with lack of motivation or environmental stimulation excluded? (e) Has the presence of neurological damage been screened for and excluded?

A definition can be described as a theoretical statement which states the "delimiting characteristics" of a learning disability. The definition must be encompassing enough to describe all known varieties of the disorder in question, but specific as well to differentiate the disorder from other similar problems (Hammill et al., 1987). Clear and valid definitions of a human disorder arise only after extensive quality research has been carried out to elucidate clearly the characteristics, etiologies, and other dimensions of the disorder (Rourke, 1983). As knowledge is gained through research, the old "premature" definitions must change, accommodating the new perspectives. Such is the case with the definition of learning disabilities, and more specifically, dyslexia. For example, it may be that as more knowledge is gained about the underlying neurological and genetic mechanisms of dyslexia, the defining features used today may be discarded in favour of ones based on etiology (Benton, 1978).

Due to many of the reasons cited above, many investigators and professionals in the field of learning disabilities have felt a need for a new definition. In 1981, the National Joint Committee for Learning Disabilities (NJCLD) agreed upon a new definition of learning disorders. The committee includes representatives from the American Speech-Language-Hearing Association, the Association for Children and Adults with Learning Disabilities, the Council for Learning Disabilities, the Division for Children with Communication Disorders, the International Reading Association, and the Orton Dyslexic Society. The definition is as follows (Hammill et al. 1987):

> Learning disabilities is a generic term that refers to a heterogenous group of disorders manifested by significant difficulties in the acquisition and use of listening,

> speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual and presumed to be due to central nervous system dysfunction. Even though a learning disability may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, social and emotional disturbance) or environmental influences (e.g., cultural differences, insufficient/inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences. (p. 109)

Etiology of Dyslexia

Etiology is another aspect of dyslexia which has not met with consensus among the different disciplines concerned with the disorder. Consequently, a variety of etiological factors concerned with widely varying perspectives have been proposed.

Quadfasel and Goodglass (1968) proposed a classification system for the broad domain of reading disability based on etiology. Three categories were proposed: (a) symptomatic reading disability - due to early cerebral damage including pre-, peri-, or post-natal trauma; (b) specific reading disability (dyslexia) - not due to brain damage, rather a congenital form without neurological signs based on a genetic mechanism and thought to be due to a deficient functional organization of the brain; and (c) secondary reading retardation - due to environmental, cultural, emotional, and other exogenous factors.

In line with the second category above, one of the major etiological explanations for dyslexia is congenital organic dysfunction, usually implying abnormal function of the brain not necessarily accompanied by structural pathology. The explanations concerning what abilities or functions specifically are dysfunctional, however, vary widely. In general, most investigators have adopted a multidimensional view of the etiology of dyslexia (Spreen, 1978). That a single focal lesion is the source of all dyslexia is not logical considering the multidimensionality of skills necessary for reading as well as the existence of several subtypes of dyslexia.

Neurological Theories of Dyslexia

Benton (1975) categorized the neurological theories into two types. The first formulation suggests a focal dysfunction of the brain. For example, the first descriptions of dyslexia by Morgan and Hinshelwood were explained as defective development of the left angular gyrus in the parietal lobe of the brain. Other authors (e.g., Geschwind, cited in Benton, 1975) postulated a bilateral parietal maldevelopment, specifically in the inferior parietal lobule (the junction of the visual, auditory, and somatosensory association areas of the brain). This "parietal theory" of dyslexia (Benton, 1975) assumes that early trauma or a congenital condition leads to parietal dysfunction, resulting in deficits in auditory-visual-motor integration and temporal sequencing, important components necessary for reading. Another explanation which fits in the focal deficit category implicates the dysfunction of the limbic and/or reticular system as a cause of dyslexia (Spreen, 1978). This theory suggests that the problem lies in poor arousal or attentional ability.

The second category of neurological theory postulates that a defect in the organization of the cerebrum is responsible for dyslexia. One of the most well-known and well-studied theories in this category is that of Samuel Orton, who believed that dyslexia resulted from incomplete cerebral dominance. Orton (1928) characterized dyslexia by directional or reversal errors (e.g., confusion between p, q, b, and d; confusion of palindromic words such as "was" and "saw"), improper scanning (e.g., right-to-left), considerable ability to read from a mirror, and greater frequency in mirror-writing (e.g., writing from right to left with complete reversal of all letters). Orton believed that there was a strong relationship between dyslexia and deviant hand and eye preference (e.g., left-handedness, ambidexterity, nonconcordance of hand and eye preference).

Orton (1928) explained these cardinal features of dyslexia or "strephosymbolia" through a defect in cerebral organization at the highest level of visual processing. He hypothesized that at the third and highest level of visual cerebral functioning, where an association occurs between the printed word and its meaning, mediated by the parieto-occipital area, efficient reading could occur only if one hemisphere became dominant and functioned with concurrent suppression of the other hemisphere. If one hemisphere failed to dominate in the perception of graphic symbols, or if the suppression of the nondominant hemisphere did not occur, the result would be competing mirror-image representations of letters and words in both hemispheres simultaneously. The dyslexic child, consequently, would find it difficult to interpret graphic symbols, and consequently produce many reversal and mirror-image errors.

Although neither of the two major formulations mentioned above has overwhelming support, neither has been disproved (Benton, 1975). In terms of Orton's theory, however, there is a growing body of strong evidence suggesting that dyslexics do not lack hemisphere specialization for language. Rather, like normal readers, dyslexics also show left-hemisphere specialization for language (Witelson, 1976). In addition, most investigators have failed to demonstrate associations between lateral preference, such as left-handedness, and reading ability (see Bakker, 1979a; 1982b).

The neurological theories stated thus far to explain dyslexia arise from a "disease" or "deficit" model. That is, the cause of poor reading is attributed to some permanent defect or dysfunction in the central nervous system. Another theory, proposed by Satz and his associates (Satz, Rardin, & Ross, 1971; Satz & Sparrow, 1970), asserts that the basis of dyslexia is not a deficit, but rather a developmental delay. Satz's model of dyslexia has been heralded as the "most elaborated neuropsychological model of dyslexia" (Bakker, 1983, p. 498). Proponents of the "developmental lag theory" postulate that a lag in brain maturation, primarily in the left cerebral cortex, leads to a delayed rate of acquisition of the necessary skills to learn to read. Specifically, Satz attributes dyslexia to a functional delay of left hemispheric specialization. He hypothesizes that in normal readers, left hemisphere specialization occurs first for fine motor skills around age 5, followed by perceptual (age 8) and linguistic (age 11) functions. Dyslexia is due to a functional delay in this progressive lateralization of function. Since this view implies no deficit, there is an implication that delayed readers will eventually "catch up" to attain a normal reading level. Satz's model predicts that young dyslexics will be troubled by visual-motor deficits in comparison to normal readers. At older ages, however, the difficulties should be resolved, and problems in complex linguistic processes will prevail.

There is evidence to support both the deficit and developmental lag models. Rourke (1976) reports that the developmental lag position is supported if one considers relatively simple, developmentally early abilities such as finger localization, visual-spatial, visual-motor, and verbal expression. The deficit model, on the other hand, has support if more complex, higher-order abilities are considered, such as abstract thinking, problem-solving, vocabulary, and arithmetic. In terms of the lag versus deficit debate, Spreen (1976) points out that a maturational lag does not occur in a neurological vacuum. Dysfunction must exist at some level, even if at a subtle biochemical level. The debate is reminiscent of the nature-nurture controversy (Spreen, Tupper, Risser, Tuokko, & Edgell, 1984). In both cases, the debate is in many ways a moot issue because both factors have been shown to play vital roles.

Evidence for the Neurological Basis of Dyslexia

Although many researchers attest to the neurological basis of dyslexia, there is little direct evidence to support this view unequivocally (Hynd & Semrud-Clikeman, 1989). Hynd and Semrud-Clikeman (1989) reviewed the current supportive evidence for the neurological hypothesis of dyslexia yielded by the indirect and inferential behavioral psychometric approach, brain measurement techniques, electrophysiological studies, and post-mortem studies.

Results from neuropsychological studies on the nature, pattern, and extent of some deficits exhibited by learning disabled children (including dyslexic children) appear to support the notion that central nervous system (CNS) dysfunction is an important etiologic factor in learning disabilities (Rourke, 1975). Using this "behavioral-psychometric" approach, dyslexics have been shown to do poorly on a wide variety of cognitive and neuropsychological tests. The patterns of deficits that arise are similar to those of patients with brain damage, and are therefore inferred to represent a deficient level of integrity of the underlying neurological substrates (Hynd & Semrud-Clikeman, 1989). Therefore, many researchers using a neuropsychological perspective agree that the basis of learning disabilities is neurological dysfunction and limit the classification of learning disability to those children whose academic difficulties are explainable primarily on the basis of cerebral dysfunction (Rourke, 1975). This definition therefore excludes the influence of other possible etiologic factors. Although much research has been conducted using the behavioral-psychometric approach, evidence from this method is indirect and circumstantial (Benton, 1975), and does not provide unequivocal support for the neurological basis of dyslexia.

Brain measurement techniques constitute a more direct approach, and include techniques of neuro-imaging such as computerized tomographic (CT) scans and magnetic resonance imaging (MRI). Studies which have examined CT scans of dyslexic individuals have found normal patterns of asymmetry (larger left temporal-posterior cortex) in approximately two-thirds of right-handed dyslexics. There is evidence of a greater degree of symmetry in left-handed dyslexics. Also, some support exists for the more frequent presence of reversed anatomical asymmetry in dyslexics with severe language deficits (see Galaburda, 1983). It is of interest that CT scans show no evidence of brain damage in dyslexics. However, the resolution and technology of CT scans are limited.

Electrophysiological techniques such as electroencephalography (EEG) and event-related potential (ERP) studies have provided another method of examining the neurological correlates of dyslexia. Keeping in mind that the recording and evaluation of EEG is fraught with complications (Hughes, 1978), studies have found a higher incidence of significant EEG abnormalities in children with severe reading problems compared to normal readers (Hynd & Semrud-Clikeman, 1989; Hughes, 1978; Rourke, 1978a).

A more refined electrophysiological technique, the ERP, has provided additional evidence for the electrophysiological differences between normal and dyslexic readers. Several studies using ERPs have found differences between dyslexics and normal readers. Evidence also exists for significant electrophysiological differences between subtypes of dyslexia (Hynd & Semrud-Clikeman, 1989). This topic will be reviewed further in a later section.

Another promising technique for studying brain electrical activity was developed by Duffy and colleagues. Their brain electrical activity mapping (BEAM) involves a computer program that constructs a topographic map of images of differences in electrical brain activity (Duffy, 1981). Using this technique, Duffy, Denckla, Bartels and Sandini (1980) demonstrated that dyslexics compared to normal readers showed electrophysiological differences (more diffuse and poorly organized activity) in certain brain areas known to subserve language and reading (e.g., Broca's area, Wernicke's area, supplementary motor area, parietal cortex, and primary visual and association cortices). The authors speculated that dyslexia may therefore involve dysfunction over a widely distributed system believed to be important for reading rather than a discrete brain region.

The most direct evidence to support a neurological structural abnormality underlying dyslexia requires an examination of the brain itself. Relatively few autopsy studies of dyslexics, however, have been reported. The first study, described by Drake (1968), reported significant neuropathy in a 12-year old dyslexic boy who died of a massive cerebellar haemorrhage. Autopsy revealed abnormal convolutional patterns bilaterally in the parietal lobes, a thin corpus callosum, and ectopic neurons deep within the white matter. Similar neurodevelopmental anomalies were found by Galaburda and associates in the brains of four male dyslexic individuals (see Galaburda, 1983, 1985). The developmental cortical alterations included dysplasias (disordered neuronal architecture) and ectopias (displaced neuronal elements; Galaburda, 1985). Focal cytoarchitectonic abnormalities were found primarily in the left frontal and left perisylvian region and lack of normal asymmetry was noted in the left planum temporale, an area important for auditory perception and association. The cytoarchitectonic anomalies and lack of asymmetry are not reflective of brain damage at birth due to complications such as trauma or hypoxia. Rather, such disturbances are highly suggestive of disruptions in neuronal migration which occurs sometime between the 16th and 24th week of gestation (Galaburda, 1983, 1985).

Galaburda (1985) has hypothesized that developmental anomalies in the left hemisphere of dyslexics could lead to a subsequent increased survival rate of, and increased connectivity of neurons in the right hemisphere. Such a mechanism would explain the lack of typical anatomical asymmetries in dyslexics, and the greater incidence of a larger planum temporale in the right hemisphere. In addition, this anatomical pattern is consistent with the deficient linguistic skills of dyslexics combined with better or exceptional nonlinguistic skills (e.g., in music, visuo-spatial abilities, etc.) as well as the higher incidence in dyslexics of left-handedness and ambidexterity found by many investigators (Galaburda, 1985).

Along the same lines, Geschwind and colleagues recently found a relation between left-handedness, immune-related disorders, and learning disabilities (see Galaburda, 1985; Geschwind & Galaburda, 1985). Their research findings indicated that left-handed individuals and their first and second degree relatives have much higher frequencies of immune diseases (e.g., migraine, allergies, thyroid disorders) and developmental learning disabilities. Conversely, individuals with immune disorders resulting in problems such as Crohn's disease, celiac disease, and thyroid disorders were found to show a higher incidence of left-handedness.

Geschwind has postulated that the explanation for this three-fold link may be an elevated level of, or increased sensitivity to testosterone during fetal development. Evidence in the form of .t studies is cited that shows testosterone to delay left hemispheric development as well as development of the thymus gland, an important structure of the immune system. The hormonal effects can also explain the higher frequency of dyslexia, left-handedness, and pre-pubescent allergic disorders in males. Although much of Geschwind's hypotheses are speculative at this stage, the proposals are fascinating, and have opened the door to a new and potentially fruitful area of biological research in dyslexia. With the recent research into the biological and anatomical markers of dyslexia, Galaburda (1985) expressed the hope that dyslexia will be defined more clearly and the search be facilitated for new forms of prevention and treatment.

Despite these exciting discoveries, Hynd and Semrud-Clikeman (1989) point out that the post-mortem studies are not without flaws, and together represent only a few cases. The data, therefore, do not support unequivocal conclusions about the neurological basis of dyslexia.

Hynd and Semrud-Clikeman (1989) suggest that the inconsistencies present in the literature may be due to the limitations of the measurement techniques currently available. For example, it is not surprising that CT scans, which operate on principles of tissue density, would not pick up focal cellular abnormalities which are not necessarily associated with abnormal densities. The authors conclude that there is a small body of literature that supports the notion of a neurological basis for dyslexia. Furthermore, it appears that the etiology of dyslexia is of a neurodevelopmental nature, although it is unclear whether this is influenced genetically or through teratogenic or other effects on the developing fetus.

The relation between neurological "soft" and "hard" signs and dyslexia has also been investigated. In this case, the rationale is that neurological signs in dyslexic individuals are indicative of a neurological abnormality underlying the disorder. Although most of the signs suggest subcortical dysfunction, it is probable that the prenatal or perinatal etiology which produced these subcortical anomalies resulted also in other subtle anomalies at the cortical level (Spreen, 1989a) In a review of the topic, Spreen (1989a) discussed the as yet unsorted complexities in relating neurological signs to learning disabilities. He cautions that such signs be taken only as possible indications of CNS abnormality which may or may not be linked to learning disabilities rather than direct indications of dyslexia or "minimal brain dysfunction".

Genetic Basis of Dyslexia

There are several studies which provide impressive evidence for a genetic role in dyslexia (Owen, 1978). Benton (1975, 1978) reported that there is no question that dyslexia can be inherited, and although genetic transmission of dyslexia may explain only a subgroup of dyslexic children, it is likely a significant proportion. However, various studies done over the years (see Benton, 1975) have reported estimates that vary widely (e.g., 90%, 37%, 49%, and 85% familial incidence) and the form of genetic transmission has not been agreed upon. As Benton (1978) pointed out, a high familial incidence supports a genetic basis for dyslexia, but does not prove it, since competing possibilities exist such as "familial cultural transmission" of the disability. However, the few studies of dyslexia using monozygotic and dizygotic twins provide impressive evidence for a hereditary role.

A genetic involvement in dyslexia has been suggested since the days of Hinshelwood (Owen, 1978). The work of Hermann and Hallgren is usually mentioned in a discussion of the genetic aspects of dyslexia. Hermann conducted the first twin studies in 1959. He found a concordance rate of 100% in all 11 sets of monozygotic twins tested and only 33% concordance in 27 sets of dizygotic twins. In the late 1940s, Hallgren carried out a Mendelian genetic analysis on 112 families with a dyslexic child after carefully testing and interviewing the children and families. Hallgren concluded, after conducting a genetic statistical analysis, that an autosomal dominant mode of inheritance could account for the results.

More recent investigations have resulted in the proposals of variable dominance in males and a recessive mode in females, no single mode of genetic transmission but rather a multifactorial inheritance, and multifactorial genetic predisposition which may or may not instigate development of dyslexia, depending on later environmental experiences (Owen, 1978).

Although evidence is far from conclusive, current research points to a mode of multifactorial inheritance for certain types of dyslexia (Owen, 1978). This may involve numerous genes with varying amounts of contribution to the trait. The phenotypic expression of dyslexia would depend on the strength of the genetic predisposition, environmental factors, and the effectiveness of intervention methods.

In the quest for a neurological or "nature" explanation of dyslexia, it has been common to de-emphasize or ignore totally the role of "nurture" in the disorder (Spreen 1989a). The study of etiology should not ignore the contributions of factors such as family background, school and home environment, and intervention attempts. In addition, other intrinsic variables of the child must be considered such as personality and emotional disorders. As Spreen (1989b) points out, there likely exists a complex interaction between learning disabilities, environmental experiences, emotional disorders, genetic/constitutional factors, and brain dysfunction/damage.

Prevalence of Dyslexia

It is a very difficult task to measure the prevalence of a disorder which has not yet been acceptably defined or understood in terms of etiology (Benton 1975, 1978; Rutter, 1978; Taylor et al., 1979). Therefore, it is not surprising that the reported prevalence of dyslexia is highly variable depending on several factors such as sample characteristics, age range, and operational definition utilized. Many studies also fail to differentiate between reading disturbances due to extrinsic and intrinsic factors (Applebee, 1971), making it unclear if the figures include dyslexics in the "pure" sense (Thomson, 1984). Given these caveats, the prevalence rates reported in the literature range from 1 to 30% of the school-age population with the majority of studies citing the figure of 10% (Applebee, 1971). Another frequently cited value is 15% (Satz, Taylor, Friel, & Fletcher, 1978).

Similar estimates have been reported for Canada, the United States, Great Britain, France, and Denmark. However, dyslexia appears to be more prevalent in northern Europe and North America than in Italy and Spain (Benton, 1975). Benton reports that one interpretation of this is that English script is considerably ambiguous and inconsistent in its grapheme-phoneme correspondence. The following rhyme by Horace Mann, which includes seven different pronunciations of the grapheme "ough", illustrates well the unruly orthography of the English language (Quadfasel & Goodglass, 1968):

Though the tough cough and hiccough
plough me through
O'er life's dark lough, I still my way
pursue. (p. 594)

Such a complex orthography could theoretically result in greater difficulty in learning to read in children who have inherent problems in sound-symbol relationships. In contrast, Italian and Spanish languages have a much higher degree of grapheme-phoneme correspondence.

Despite the range in rates, even the conservative estimates of prevalence are dramatic and underscore the gravity of the disorder. If a rate of only 5% is accurate, the problem is substantial, considering that 2 dyslexics would exist per 40 children.

There is substantial evidence that dyslexia is much more common in males than in females (Thomson, 1984). Benton (1975) described this sex ratio as "established beyond doubt". However, as with prevalence rates, the exact ratio varies depending on the criteria employed, e.g., 4 to 1 (Critchley, 1970); 2 to 1 (Money, 1966 cited in Thomson, 1984); 5 to 1 (Myklebust & Johnson, 1962); 6 to 1 (Rourke, 1978a); and 3.5 to 1 (Berger, Yule, & Rutter, 1975 cited in Rutter, 1978). There is some evidence that the ratio between sexes grows larger with increasing age, suggesting the problem may be more transient in girls or more enduring in boys (Benton, 1975).

Difficulties Associated with Dyslexia

Many investigators define dyslexia as a specific disorder with the implicit assumption that the deficit is confined to reading ability. Several authors have suggested that the interpretation of dyslexia as a specific deficit in reading may be misleading or erroneous (Rourke, 1975; Rourke & Orr, 1977; Witelson, 1977).

Rourke and Orr (1977) described reading disability as a "multifaceted problem" involving many deficits including verbal, visual- and auditory-perceptual, visual-motor, and cognitive. Witelson (1977) has suggested that the syndrome of dyslexia be relabelled as a "specific cognitive deficit" rather than a specific reading deficit, since it is clear that many other deficits exist besides those in reading. For example, Benton (1975) pointed out that most dyslexics exhibit some degree of deficiency in oral language development (e.g., poor vocabulary, fluency, or grammar).

Thus, dyslexia is rarely an isolated disorder and dyslexic children frequently manifest a wide range of other deficits (Johnson & Myklebust, 1967; Myklebust & Johnson, 1962; Rourke, 1975). The most common disabilities associated with dyslexia are: (a) deficits in memory ability (e.g., auditory or visual memory, immediate or delayed recall, often modality specific); (b) dyschronometria or disturbances in learning the significance of sequence and time (e.g., difficulty in remembering letter sequences, months of the year in the correct order, etc.); (c) disturbances of orientation and direction sense, and poor left-right orientation with regard to self, others, and objects; (d) impaired orientation to time (e.g., difficulty telling time or acquiring a sense of time); (e) disturbances in body image; (f) difficulties in writing and spelling which are dependent upon intact reading ability; (g) topographic disorders (e.g., inability to read maps, graphs, globes, floor plans, etc.); (h) dyscalculia i.e., difficulty learning the symbolic significance of numbers and arithmetical signs; (i) inability to auditorize or visualize e.g., poor memory for phonemes or graphemes; (j) neurological disturbances; and (k) minor deficits in motor ability and manipulative skills (e.g., poor motor coordination, balance, or manual dexterity; trouble tying shoelaces or buttoning clothes).

Benton (1975) listed several correlates of dyslexia which he considered most prominent: (a) visuoperceptual defects reflected by deficient form discrimination, figure-ground differentiation, visuomotor ability, and visual memory; (b) poor directional sense (e.g., poor right-left discrimination); (c) defects in audioperceptual ability (e.g., poor discrimination of speech sounds); (d) impaired intersensory integration, particularly in the matching of visual and auditory symbols; (e) impaired oral language development (e.g., articulation, verbal memory, oral vocabulary); (f) poor conceptual and symbolic thinking skills; (g) anomalies of hand and eye preference (suggesting abnormal cerebral lateralization); (h) abnormal responses elicited from electroencephalogram and evoked potential tests; and (i) dysfunction of the central nervous system (e.g., reflected by motor awkwardness, dyspraxia, hyperkinesis, etc.). Benton notes that all of these factors as well as numerous others have been hypothesized to play a causative role in dyslexia.

Finally, Rutter (1978) noted a few additional cognitive disturbances not included in the previous lists: (a) problems in spatial perception; (b) color anomia or difficulty in naming colours; (c) difficulty in recognizing the meaning of pictures; (d) severe and bizarre spelling errors, and (e) a family history of reading problems.

The lists of features described have been observed more frequently in dyslexic children, but they are only correlates. Not all dyslexics exhibit all signs, and children with normal reading ability may manifest some of these signs (Thomson, 1984).

Dyslexia, which is a serious and stressful disorder in today's highly literate society is also associated with secondary behavioral and emotional disturbances (Kline, 1986; Thomson, 1984; Witelson, 1977). Kline (1986) emphasized the close relation between dyslexia and emotional problems by referring to the "dyslexia-emotional dyad." He described dyslexia as a leading cause of emotional disturbance in children and adolescents in North America and Britain. How a child perceives his performance at school and his evaluation by teachers, parents, and peers influences strongly his self-concept and self-confidence. Children with difficulties in reading face the consequences of repeated academic failure, and commonly experience on a daily basis feelings of frustration, embarrassment, and devaluation.

Given this continuous experience of failure, it is hardly surprising that dyslexic children develop secondary behavioral reactions, which are generally of two types (Thomson, 1984). Depending on personality factors, the child may experience an "under" reaction which may involve withdrawal, extreme anxiety, depression, low self-esteem, and behavioral regressions (e.g. bed-wetting, thumb-sucking, etc). On the other hand, a child may also manifest an "over" reaction in which he or she tries to compensate by being successful in other realms of school life. For example, the child may become the class "joker" or disrupter. Other more extreme forms of acting out may also occur such as aggression, stealing, truancy, and general delinquency. Kline (1986) reported that approximately 80 percent of juveniles charged with delinquency are severely retarded in reading.

Although numerous investigators have stressed the serious emotional impact of dyslexia, others have presented a more sceptical view of this notion. Rourke (1989, p. 43) discussed the notion that learning disabilities lead inevitably to emotional disturbance: "This proposition has a very compelling, tacit appeal for most clinicians; it concretizes a view that is widely held and has become almost a cornerstone of clinical lore in this area". In contrast to this widely-held view, Rourke suggested that most learning disabled children show no signs of significant socioemotional disturbance. His position is based on the results of multivariate Q-factor analysis studies using the Personality Inventory for Children (PIC). In general, findings revealed three subtypes of socioemotional difficulties. The first and largest group (about 50% of those classified) showed no significant emotional disturbance on any scales of the PIC. The second group (about 25% of those classified) were characterized by an "internalized" profile with elevated scores on scales of depression, withdrawal, and anxiety. The third group (about 15%) manifested an "externalized" profile typical of children with hyperkinetic disorders.

It is important to note that the relation between dyslexia and the numerous disturbances often seen concomitantly with dyslexia is not necessarily a causal one. For example, in the case of emotional disturbances, it is possible that difficulties in reading are caused by emotional disturbances or that emotional disturbances are caused by dyslexia. It is also possible that there is no direct link between the two factors; rather both factors may be associated with a third causal factor such as brain dysfunction (Rourke, 1989; Spreen, 1989b).

Long-term Effects of Dyslexia

The long-term effects of dyslexia and other learning disabilities have been investigated (see Spreen 1988b for review). Although several investigators have reported follow-up studies with optimistic prognostic conclusions, these studies have included students with high IQ from high SES backgrounds, and have excluded subjects with neurological impairment. The conclusions are not as bright when subjects are drawn from a wider range of IQ and SES, and possess neurological soft or hard signs (Spreen, 1989a).

In a 15-year follow-up longitudinal study, Spreen (1988a) examined the long-range outcome of 203 learning disabled and 52 normal children (see also Peter & Spreen, 1979; Spreen, 1988b; Spreen, 1989a, 1989b). Children were first examinined at age 10, and followed up at ages 18 and 25. The learning disabled children were divided into three groups at the beginning of the study depending on the degree of observed neurological impairment: neurological hard signs, neurological soft signs, and no neurological signs. Results indicated that 62% of learning disabled children (including dyslexics) dropped out of high school, 12% enrolled in college, and 46% were unemployed (Spreen, 1988b, 1989a). Learning disabled individuals with obvious neurological impairment (i.e., with hard signs) were found to suffer an even bleaker long-term outcome.

In addition, all three groups when compared to normal learners showed significantly deviant behavior and greater personal maladjustment as adolescents and young adults (Peter & Spreen, 1979). There was a significant relation between greater behavioural deviance and degree of neurological impairment at follow-up, indicating that deviant behaviours associated with cerebral dysfunction in childhood persist into young adulthood.

Spreen (1988b) briefly reviewed other follow-up studies in the area of learning disabilities and dyslexia. He concluded that although the results of recent studies are not entirely consistent, all studies have found that learning disabilities tend to persist as a child grows up. The degree of academic, socio-emotional, and occupational difficulty in adulthood is dependent on several factors such as SES background, IQ, and presence of neurological soft and hard signs. In addition, Spreen (1976) reported that when children were identified as learning disabled at an early age, the prognosis appeared somewhat more hopeful. However, when the diagnosis occurred at a later age in childhood, the outlook was fairly grim with a high probability of serious socio-emotional maladjustment. One explanation for poorer prognosis for dyslexic children diagnosed later concerns the longer amount of time older children have spent struggling and failing in school. A vicious circle may contribute to hostile feelings toward school, poor motivation, and a poor future outlook. Children do not like tasks at which they are unsuccessful. Their inner language may be along these lines (Spreen, 1976, p. 461), "If I am not doing well on the task, I dislike it, and if I dislike it, I am not doing well on it."

Trites and Fiedorowicz (1976) examined the rate of academic progress over a 3 year period in 27 dyslexic boys who were on the average 11.6 years old at the time of the first testing. The authors found that discrepancy between grade placement and actual level of achievement in reading, spelling, and arithmetic grew larger over time despite remedial help. This study emphasizes the persistence and exacerbation over time of academic deficits relative to age and grade placement.

Thus, despite a few optimistic results, the general conclusion to be drawn from this research is that dyslexic children have an unfavourable prognosis for both academic achievement and social adjustment (Rourke, 1983; Yule & Rutter, 1976). The effects of dyslexia on an individual are serious and far-reaching. The problem goes beyond the realm of the educational system to the social, economic, and legal systems of society (Satz et al., 1978).

Neuropsychology of Normal Reading

It is clear that knowledge and understanding of the normal reading process and its development are necessary to understand the deviant reading of dyslexic children. There are various definitions of reading, each with its own emphasis (Weiner & Cromer, 1967). Definitions vary according to the emphasis placed on the relative importance of acquisition versus accomplished reading or on identification versus comprehension. The following is one description of reading (Gibson, cited in Wiener & Cromer, 1967):

> There are several ways of characterizing the behavior we call reading. It is receiving communication; it is making discriminative responses to graphic symbols; it is decoding graphic symbols to speech; and it is getting meaning from the printed page. A child in the early stages of acquiring reading skills may not be doing all these things; however, some aspects of reading must be mastered before others and have an essential function in a sequence of development of the final skill. The average child, when he begins learning to read, has already mastered to a marvellous extent the art of

> communication. He can speak and understand his own language in a fairly complex way, employing units of language organized in a hierarchy and with a grammatical structure ... (pp. 625-626)

In dealing with dyslexia, which is a difficulty in acquiring the ability to read, the concern is mainly with the processes involved in acquisition of reading. Many authors have discussed the consistent sequence of abilities that must be acquired to become a proficient reader. Wiener and Cromer (1967) discussed three major sequential processes that occur during the learning-to-read process. The first process is discrimination which involves the "ability to make proper focal adjustments, to distinguish figure-ground, brightness, lines, curves, and angles; and to respond to differences in the amount of white space surrounding the forms" (p. 635).

The second step is identification or word recognition, the transformation of a visual stimulus into its auditory counterpart. The identification process can occur via two major routes. One is the "look-say" method whereby the reader must hold many specific graphic configurations in his or her memory along with the specific sound that goes with each. Words are distinguished on the basis of angles and curves, word length, different letter sequences, and spatial orientation of the visual stimulus. The second method of identification, the phonetic approach, involves the use of explicit rules for the transformation of words into specific sounds (e.g., when there is only one vowel at the beginning or middle of a word, it is a "short" vowel sound).

After words are identified, the third step in the reading process is comprehension, the association of meaning with the identified words. It should be noted, however, that under certain circumstances, identification does not lead automatically to comprehension (e.g., when the reader has no previous experience with the word in his auditory language reservoir), and comprehension may at times facilitate identification (e.g., if the reader has highly advanced language skills in terms of vocabulary and structure).

Another perspective on the reading process has been reported by Myklebust and Johnson (1962). They described reading as a symbol system which is the fourth step in the five steps of sequential development of language. These five steps are: (a) acquisition of meaning or "inner language" (e.g., the association of the spoken word "dog" in the presence of a dog); (b) comprehension of the spoken word or receptive language (e.g., the auditory symbol "dog" triggers the memory of a dog); (c) expression of the spoken word (i.e., speech); (d) comprehension of the printed word (i.e., reading); and (e) expression of the printed word (i.e., writing). As this developmental hierarchy implies, oral language development (speech) is a necessary prerequisite for the acquisition of reading.

The normal process of learning how to read requires the learning of associations between the printed symbol, the auditory symbol, and meaning (Johnson & Myklebust, 1967). Myklebust and Johnson (1962) have described reading as a visual symbol system superimposed upon auditory language. It is a symbol system that is twice removed from the reality that the symbol represents. Developmentally, a child must first comprehend and integrate a nonverbal experience (e.g., the experience of seeing, feeling, and hearing a cat). Second, the child learns the auditory symbol associated with the previously nonverbal experience (e.g., the spoken word, cat). Finally, the visual verbal system is acquired (e.g., the written word - cat) which represents both the auditory symbol and the experience (Johnson & Myklebust, 1967).

Reading is regarded by cognitive psychologists as one of the most complex and interactive informational processing skills (Lovett, 1984). Normal acquisition of reading ability requires the integrity of numerous abilities. These include: integration of nonverbal experience; attachment of symbols to nonverbal experience; auditory discrimination of symbols; visual perception and symbol discrimination; and auditory and visual memory (Johnson & Myklebust, 1967).

Rutter (1978) states that the abilities necessary for reading are threefold: perceptual discrimination, sequencing ability, and cross-modal association and transfer. Perceptual discrimination involves closure (e.g., o versus c), line to curve discriminations (e.g., u versus v), and rotational discriminations (e.g., b versus d versus p versus q; m versus w). Sequencing skill is necessary both for single word identification (e.g., dog versus god) and for the extraction of correct meaning from phrases and sentences (e.g., man bit dog versus dog bit man). Finally, cross-modal association involves translating visual input (graphemes) into auditory symbols (phonemes).

In addition to the abilities already noted, Boder (1973) reported that directional orientation, cross-modal integration, and auditory and visual sequential memory are also necessary. Boder stated that reading requires intact integration of mainly the visual and auditory channels, both peripherally and centrally. She describes two main processes, the gestalt and analytic, which interact to produce normal reading ability. The gestalt process involves mainly the visual mode whereas the analytic process of phonetic analysis utilizes the auditory mode. In a dyslexic individual, the normal reading process which contains an interplay of the gestalt (recognition of visual gestalts of whole words) and analytic (phonetic analysis and synthesis) components is dissociated or disrupted (Boder, 1973).

Development of normal reading clearly requires the complex integration of numerous skills and abilities involving input, output, and mediating forces. A deficit in any one of these processes would logically impair the acquisition of normal reading. Such reasoning logically suggests that there are different subgroups of dyslexic children, who exhibit different patterns of abilities and deficits (Johnson & Myklebust, 1967; Kinsbourne & Warrington, 1963; Mattis, 1978; Mattis, French, & Rapin, 1975; Rutter, 1978). This notion of heterogeneity in the dyslexic population will be discussed in the next section.

Subtypes of Dyslexia

The historical development of the neuropsychological study of brain-injured adults and of the investigation of learning disabled children is quite similar (Fisk & Rourke, 1983; Rourke, 1989). Prior to the late 1970's, most researchers viewed reading disabilities and learning-disabilities in general as a unitary concept. For example, all reading-disabled children were thought to constitute a homogeneous group with similar characteristics (Rourke, 1989). This notion paralleled the similar, much earlier idea in the early 1900s that brain-damage in adults was of a unidimensional nature.

The single-syndrome paradigm implies that dyslexia, a single effect, is due to a single cause (Doehring, 1978). However, the search for the sole cause of dyslexia or for the one profile of the dyslexic child has proved to be fruitless. The unidimensional perspective of reading disabilities has not endured the test of time and research as countless studies comparing a sample of "dyslexic" readers with that of normal readers have met with conflicting and inconsistent results (Boder, 1973; Mattis et al., 1975). Studies which have treated dyslexia as a homogeneous entity have found dyslexics to exhibit "almost every disorder of higher cortical functioning recognized in children" to a greater frequency than in normal readers (Applebee, 1971; Mattis et al., 1975, p. 150). This conclusion is in direct conflict with the fact that a given dyslexic child does not manifest all deficiencies, and no specific deficiency has been observed in all dyslexic children (Mattis et al., 1975).

Researchers were eventually able to account for the contradictions and inconsistencies by suggesting that the learning and reading disabled population is a heterogenous rather than a homogeneous group. That dyslexia is a heterogenous disorder should not be surprising given the many subprocesses that comprise the skill of reading mentioned earlier (White & Miller, 1983) and the varying types of acquired dyslexia (alexia) found in brain-injured adults (see

Spreen et al., 1984). Today, the "nomothetic approach" (Rourke, 1989, p. 3) to reading disabilities has become, for the most part, obsolete as observers of learning disabled children have found distinct differences in their patterns of abilities and deficits across multivariate data sets. The results have been too contradictory and inconsistent to continue to support a unidimensional view or single-syndrome theory of dyslexia (Benton, 1975; McKinney, 1984) There is now considerable support for the notion that reading disabilities comprises a heterogenous population (Benton, 1975; Rourke, 1978a). It is now acknowledged that dyslexia is a "class of specific learning disorders, presumably heterogeneous with respect to etiology, presentation, and sequelae" (Lovett, 1984, p. 68).

With this realization, some advances in the field of reading disabilities have occurred. It is now becoming clear that the neuropsychological dimensions of reading disability are highly complex (Petrauskas & Rourke, 1979), and the search for a taxonomy of learning disabilities that is valid and consensual is the most outstanding and pressing issue in the field (Rourke, 1983). It is now obvious that a single-syndrome approach with solely a "level of performance" methodology is no longer useful for either research or clinical purposes. A much more complex multiple-syndrome, theoretical model of dyslexia must be advanced to account for the complex nature of dyslexia

(Doehring, 1978; Rourke, 1978a). However, classification in the field of learning disabilities is complex, and goes beyond simple categorization. Classification must be concerned with many variables and is invariably based on a theoretical position (Kavale & Forness, 1987).

Working on the assumption that dyslexia constitutes a group of disorders rather than a single syndrome, several groups of investigators have attempted to identify homogeneous subtypes of dyslexic children. There is the implication or assumption that different subtypes arise from different etiologies (Rourke & Strang, 1983) or are due to a variety of differing brain-related explanations (Fisk & Rourke, 1979). Therefore, subtype classifications are often part of a conceptual model of dyslexia which may suggest the specific type of cerebral dysfunction involved. Although such a neurological-etiological relationship has not yet been supported empirically, some investigators (e.g., Mattis, 1978) believe that future research, using technologically advanced brain-imaging equipment, will demonstrate unique anatomic and physiological anomalies for each "syndrome" of dyslexia.

There are several reasons why the elucidation of reliable and valid subtypes is important. As with any classification system, there is an enhancement in order, coherence, communication, and specificity. Such improvements act to encourage better sample selection procedures in research which should in turn lead to a more accurate body of knowledge in the field (McKinney, 1984). Specification of homogeneous groups may also result in an enhancement of the diagnostic process such that early identification is facilitated as well as differentiation from reading problems due to non-specific causes (McKinney, 1984).

The identification of subtypes has prognostic and therapeutic implications as well on the basis of the "subtype by treatment interaction hypothesis" (Rourke, 1989). This hypothesis involves the idea that different subtypes should respond differently to different forms of intervention strategies. Treatment can therefore be tailored to accommodate the specific deficits and abilities that a given subtype exhibits. Furthermore, the knowledge gained through research into subtype classification may function as a catalyst to facilitate the realization of some of the most important goals of research in dyslexia i.e., reliable prediction of young children who will become dyslexic, delineation of specific etiologies to individual cases, and development of effective remedial techniques for all cases of dyslexia (Applebee, 1971). Therefore, subtype identification can set the stage for potentially successful intervention strategies, and provide prognostic and etiologic information (Rourke, 1978b).

There have been essentially two major methodological approaches to the elucidation of learning disabled subtypes.

These are the clinical inferential or a priori approach and the statistical or a posteriori approach (McKinney, 1984; Rourke, 1983). The clinical and statistical methods are equivalent to what Adams (1985) has called phyletic and phenetic classification systems respectively. Phyletic systems of taxonomy focus on the qualitative aspects of the population under study, involving the use of theoretical or developmental knowledge to classify. The phenetic system, in contrast, focuses on quantitative aspects, and makes use of empirical approaches to classification such as mathematical models. Although these two systems are clearly different, Adams espouses that the goals of the systems are complementary and the use of both systems can lead to important research contributions. Well-known subtype classifications have been derived from both approaches, and are discussed below.

The clinical inferential approach, an a priori method, involves grouping children on the basis of a priori rules, usually based on theoretical grounds and visual inspection of multivariate data sets (Kavale & Forness, 1987; McKinney, 1984). Children are first divided into groups on the basis of a particular sign or pattern of performance (Rourke, 1983). The preselected groups are then shown to exhibit validity by comparing them on various measures that indicate central nervous system dysfunction or dysfunction on various skills of reading (Rourke, 1983).

One of the first groups to recognize the heterogeneity of the dyslexic population used the clinical approach to describe two subtypes of dyslexic readers, visual and auditory (Johnson & Myklebust, 1967). The first type, visual dyslexia, was attributed to a difficulty in learning through the visual modality despite intact visual processes. This type of reader was said to be characterized by: (a) visual discrimination difficulties resulting in confused reading of similar letters or words (e.g., pin and pen); (b) slow rate of perception (e.g., words are read slowly and determination of difference or similarity in words is slow); (c) tendencies to reverse letters or words in reading and writing (e.g., dig for big; was for saw); (d) tendencies to invert and misread letters (e.g., u for n; m for w); (e) difficulties with visual sequences (e.g., memory intact for letters in a particular word, but correct sequence of letters is wrong); (f) exhibit visual memory problems (e.g., great difficulty in revisualizing past experiences and in particular, the written word); (g) poor drawing ability (e.g., important details are omitted frequently); (h) problems in visual analysis and synthesis (e.g., difficulties with jigsaw puzzles; understanding of part to whole relationships is poor); (i) preference for auditory activities is shown (e.g., child may have excellent auditory memory); and (j) difficulties may be evident with visually demanding games or sports (e.g., baseball, model-building, etc.).

The second subtype described by Johnson and Myklebust is the auditory dyslexic. In contrast to the visual subtype this type manifests reading problems due to a difficulty with the auditory demands of reading. While a visual dyslexic is unable to learn whole words, the auditory dyslexic relies on this strategy. Problems are evident with sound blending and the phonetic approach to reading is met with great resistance. The auditory subtype may have many of the following features: (a) disorders of auditory discrimination and perception resulting in poor phonetic analysis ability (e.g., words such as rust or bent may be perceived as rut or bet; rhyming is difficult); (b) difficulty with auditory analysis and synthesis (e.g., inability to break a word into syllables or sounds; inability to combine parts of a word to form a whole, i.e., sound blending); (c) problems with reauditorization or auditory memory, resulting in the poor translation of a visual symbol to an auditory one. The meaning of a word is often recalled, however, and results in the substitution of words with similar meanings (e.g., dad for father; food for dinner); (d) disturbances in auditory sequencing, resulting in a transposition of letters in a word (e.g., emeny for enemy); and (e) preference for visual activities is shown (e.g., woodworking, athletics, etc.).

A similar dichotomy was described by Ingram, Mason, and Blackburn (1970) who distinguished between "audiophonic" and "visuospatial" types of dyslexia. Audiophonic difficulties involve poor sound blending skills (e.g., b-u-n pronounced but), confusion of vowel sounds (e.g., bed read as bad), poor phonetic knowledge (e.g., poor memory for sounds of diphthongs), and general deficiency in phonetic analysis. Visuospatial problems include confusions of letters with the same shape but different orientation (e.g., b, d, p, q), slow word recognition of even simple words, poor visual discrimination of visually-similar words (e.g., road read as read), and directional errors (e.g., saw read as was).

Also among the first to suggest heterogeneity in the dyslexic population were Kinsbourne and Warrington (1963). Using the clinical approach, they selected two groups of disabled readers according to their large Verbal-Performance IQ discrepancies on the WISC. The authors then demonstrated that the two groups could be classified on the basis of a test of finger differentiation. Group I (language retardation) showed a significantly higher performance score, and were comparable to adult aphasics. Group II (Gerstmann group) showed higher verbal IQs, were significantly deficient on tests of finger differentiation, and likened to adults with Gerstmann syndrome.

Another investigator to use the clinical approach to subtype identification has been Boder (1970; 1973). She described three subtypes of dyslexic readers based on their distinct profiles of reading and spelling errors on a diagnostic screening test battery for dyslexia. Boder claims that one of the three patterns can be found in all severely reading-disabled children. The subtypes were identified on the basis of an examination into <u>how</u> a child reads and spells (e.g., types and patterns of errors). This approach considers the child's functional assets as well as the deficits. Boder suggests that dyslexic children can manifest different problems in reading depending upon whether their deficits involve the analytic component, the gestalt component or both component processes of reading. Group I, the largest group labelled as dysphonetic dyslexia (67% of sample), showed deficits in symbol-sound (grapheme-phoneme) integration and consequently had poor phonetic word analysis and synthesis skills. Group II, dyseidetic dyslexia (10% of sample), exhibited their primary deficit in the perception of letters and whole words as visual gestalts. Group III, mixed dysphonetic-dyseidetic dyslexia (23% of sample), was characterized by deficits in both phonetic word analysis-synthesis skills and perception of letters and whole-word configurations.

Mattis et al. (1975) also isolated three subtypes. Although their method involved a posteriori inspection of data and the use of multivariate statistics, their clustering technique was of a clinical nature. Groups were chosen from a sample of 82 dyslexic readers on the basis of their unique clusters of deficiencies determined from a battery of neuropsychological tests. The clusters were thought to represent deficits in abilities necessary for learning to read. The three subtypes comprised 90% of the dyslexic sample. Type I, language disordered (39% of sample), manifested a disorder of language development with anomia, poor comprehension, poor repetition, and a disorder of speech-sound discrimination. Type II, articulatory and graphomotor dysco-ordination (37% of sample), showed motor-speech problems in articulation and also manifested dyscoordination in gross and fine grapho-motor ability. Type III, visuospatial perceptual disorder (16% of sample), was characterized by poor visuospatial perception. In a cross-validation study (see Mattis, 1978), the three syndromes were again identified, but the percentages of children manifesting each type differed. In addition, unlike in the original study, some children (9% of sample) exhibited features of more than one syndrome. Finally, 10% exhibited a "sequencing" disorder, similar to that discovered by Denckla, discussed below.

Denckla (1977) examined a group of 52 dyslexics between the ages of 7 and 14 years, and clinically identified several syndromes from this sample. Three of these were highly similar to the groups of Mattis et al. (1975). These were language disorder with anomia (N=32, 62% of sample), articulatory-graphomotor dyscoordination syndrome (N=6, 12% of sample), and the visual-perceptual disorder (N=2, 4% of sample). Within the language group, a subgroup (N=7, 13% of sample) was identified with a dysphonemic sequencing difficulty (poor repetition with phonemic substitutions and faulty sequencing in the context of normal naming, comprehension, and articulation). Another group (N=5, 10% of sample) manifested a "verbal memorization disorder characterized by deficient sentence repetition and poor verbal paired-associate learning with other language skills intact. The final group (N=3, 6% of sample) had a right hemisyndrome with mixed language disorder.

Lovett (1984) described two subtypes of specific reading disability derived on the basis of a cognitive theory of reading skill acquisition. The reading model of LaBerge and Samuels (1974) implicates two main criteria in the development of reading ability, namely accuracy and automaticity. Lovett's groups were identified on the basis of their performance on a battery of oral reading tests. Group 1 was selected on the basis of a disturbance in decoding accuracy (accuracy disabled). Group 2, with adequate accuracy skills, was chosen to represent a deficit in rate of reading (rate-disabled). Lovett proposed that the two groups should respond favourably to specifically tailored treatment approaches. Lovett's dichotomy is superficially similar in some respects to Bakker's P- and L-type dichotomy to be discussed in a later section.

The majority of early subtyping studies have used the inferential classification method. However, such studies have been criticized on the basis of several limitations (Fletcher & Satz, 1985; Satz & Morris, 1981). Subtypes derived from a clinical approach are seen by some scientifically-rigorous investigators as questionable in regards to reliability and validity (Rourke, 1985). For example, Fletcher and Satz (1985) discussed the difficulty of demonstrating the properties of reliability and validity of the typologies discovered by this approach. In addition, they pointed out that a priori bias inherent in this method can influence the outcome of visual inspection of the data. More recently, with the goal of "establishing a reliable taxonomy of learning disabilities that would be amenable to empirical validations and heuristic extensions" (Rourke, 1985, p. 5), subtyping research has turned to the use of multivariate statistical techniques (McKinney, 1984).

The statistical approach, or a posteriori method, involves the elucidation of subtypes through statistical techniques. Reliable subtypes are isolated by employing techniques such as cluster analysis and Q-type factor analysis of childrens' scores on a wide variety of tests sensitive to brain functioning. Q-factor techniques differ from the usual practice of factor analysis by analyzing the correlations between subjects, resulting in the description of different groups of children (versus the analysis of correlations between tests resulting in factors representing groups of tests, McKinney, 1984). Cluster analysis works by matching subjects successively on the basis of their responses across many variables. Its goal is to find subgroups with maximal homogeneity and minimum group overlap (Kavale & Forness, 1987).

One of the first groups of investigators to use multivariate statistical classification procedures to identify subtypes of dyslexic children was Doehring and Hoshko (1977). Using the Q-technique of factor analysis with 34 children given 31 tests of rapid reading skills, they discovered three subtypes. Subtype one (linguistic deficit, 35% of sample) demonstrated poor oral word and syllable reading skills, and exhibited higher performance than verbal intelligence quotients. Subtype two (phonological deficit, 32% of sample) exhibited a deficit in auditory-visual letter association. Subtype three (deficit in intersensory integration, 24% of sample) was characterized by a deficit in the auditory-visual association of syllables and words (as opposed to letters).

Also using the statistical approach, Petrauskas and Rourke (1979) described three subtypes of reading disability in young children using Q-type factor analysis. Whereas Doehring and Hoshko utilized tests of reading-related skills, subtypes in this study were identified by their unique patterns of performance on a neuropsychological battery of 44 tests.

Unlike many of the other subtype studies, these authors limited the age range to children between 7 and 9 years. This was done in light of the importance of developmental factors in reading disabilities. Three reliable subgroups were elucidated from 50% of the subject sample. Type 1, the largest subgroup (25% of sample), was similar to that of Doehring and Hoschko (1977) and Mattis et al., (1975). This group was described as having a language disorder with disturbance in auditory-verbal memory and auditory-perceptual skills. Well-developed visual-spatial and eye-hand coordination abilities were present in this group and a higher performance IQ than verbal IQ on the WISC was found. The authors noted that these deficiencies have been observed in adults with lesions of the left temporal lobe. Type 2 (16% of sample) was characterized by a combination of difficulties in language, sequencing, and finger localization. Such deficiencies were found to be similar to those due to lesions of the left posterior cerebral regions of the brain. Type 3 (8% of sample) showed deficits primarily in conceptual flexibility, verbal expression and retention, and some psychomotor skills. Some similarities in performance were noted between the type 3 profile and individuals suffering injuries in the left frontal lobe of the brain.

Although the multivariate statistical approach may be considered a more empirical method to subtyping than the clinical approach, conceptual and methodological problems exist with the statistical approach (McKinney, 1984). The use of such procedures requires numerous decisions and judgement calls from the investigator. In addition, the numerical taxonomic approaches suffer from the popular criticism "garbage in, clusters out", i.e., clusters may turn out to be spurious or meaningless, and can be generated from random data. Furthermore, different clustering methods can result in surprisingly diverse classifications using the same data (Adams, 1985; Kavale & Forness, 1987).

In addition to the subtypes mentioned, there have been several other proposals of subtypes (e.g., Denckla, 1972; Fisk & Rourke, 1979; Rourke & Finlayson, 1978). Spreen (1989b) noted that there are at least 16 learning disabilities typologies that have been reported. However, many of these deal with subdivisions of children generally diagnosed as learning disabled as opposed to specifically dyslexic (see Spreen & Haaf, 1986 for a review). Since this dissertation is concerned specifically with children who have difficulties primarily with reading, the discussion has been limited to those subtypes classified from a dyslexic population.

Treatment of Dyslexia

One of the outstanding issues in research on learning disabilities is treatment (Rourke, 1983). This is not surprising given the high prevalence of dyslexia and the potential debilitating effects it can have on an individual's cognitive and emotional status. The importance of remediation is further underscored by the fact that approximately 10% of children in the educational system are given remedial aid for reading difficulties (Hewison, 1982).

Historically, the treatment of reading disabilities has been closely paralleled by the views of learning disabilities in terms of the homogeneous-heterogenous dimension. Influenced by the univocal perspectives of learning disabilities of the time by people such as Strauss and Orton, remediation for learning disabled children in the 1950's and 1960's was for the most part, univocal. Therefore, all learning disabled children were placed in similar remedial programs aimed at providing a certain type of remediation based on the current theory of the time (Rourke, 1985).

Review of Traditional Treatment Approaches

Johnson (1978) reviewed the major methods of remediation that have been used for dyslexics: the Orton-Gillingham approach, the Fernald Approach, the colour phonics method, and the Initial Teaching Alphabet method.

One of the earliest and most popular methods was the Orton-Gillingham approach, designed for children whose reading difficulty was with the sight method, characterized by confusions with orientation and/or order of letters. These children were often left-handed or ambidextrous and exhibited speech and language deficiencies as well.

Orton's approach to remediation included two fundamental principles. The first was the importance of the simultaneous association of visual, auditory, and kinesthetic written stimuli. Thus a child would be required to trace over a letter or word while sounding it out and scrutinizing it visually. The second principle stressed the fusion of small units (e.g., letters, words) into more complex wholes (e.g., words, sentences). Orton's multisensory approach begins with individual letters and phonemes, with gradual build-up to simple words. Much of the support for the Orton-Gillingham method is anecdotal or of a single-case variety. Of the group studies completed, most did not use adequate control groups. Guthrie (1978) stated that this approach is also known as the alphabetic method, and is essentially the same approach used to teach normal readers.

The Fernald approach concentrates on kinesthetic procedures and emphasizes a "reconditioning method" designed to de-emphasize experiences that are unpleasant for the child. The goal is to provide the child with successful experiences in reading. In contrast to the highly controlled Orton approach, the child is given control by selecting the words to be learned. Words, written in large letters, are traced and spoken until they can be written from memory. Words are learned as whole entities and meaning is stressed; phonetic strategies are not used. The procedure is designed so that motor imagery will reinforce audio-visual associations. Eventually, the child is expected to generalize from known words to unfamiliar ones.

The rationale of the colour phonics method is to use colour coding to enhance learning of written material. For example, one approach developed by a dyslexic individual, Edith Norrie, uses colours to emphasize a phonetic approach to reading (e.g., vowels are printed in red and consonants are colour-coded according to various lip sounds). Use of a mirror helps the child become aware of the position of the tongue, lips, and jaws when producing phonemes. After individual letters and syllables are mastered, phonetically regular words are introduced. This approach has been found useful for children with auditory sequencing difficulties because the colour cues help to stabilize the audiovisual sequence of the letters in a word.

The Initial Teaching Alphabet (ITA) method is based on the theory that dyslexic children encounter difficulty due to the irregular spelling patterns of the English language. The ITA consists of 44 characters or graphemes each of which represent a particular phoneme. This modified alphabet is purported to make reading easier than with the traditional alphabet. After the ITA is thoroughly mastered, a transfer is made to the traditional system.

<u>The Heterogeneity of Dyslexia and Treatment</u>

One of the first principles discovered early in the history of remediation was that no single method can be successful for all dyslexics (Johnson, 1978). The ultimate goal in remediation is to "match the child's overall pattern of strengths and weaknesses with a particular method, to select a method by choice rather than by chance" (Johnson, 1978, p. 400). Accordingly, other approaches to remediation have stressed the heterogeneity of dyslexia and the need for a treatment by subtype paradigm.

For example, well before their time, Johnson and Myklebust (1967) proposed highly specific and differing treatment strategies believed to be helpful for each of their subtypes (see Johnson, 1978). Remediation is based on the philosophy that treatment is most effective when it begins with the enhancement of the child's strengths and subsequently involves additional training to improve the weaknesses. Thus, for visual dyslexics, the major technique recommended is a synthetic phonic one, beginning with phonetically regular words. While major emphasis is given to phonetic analysis, synthesis, and blending, which presumably capitalizes on the child's strengths, some degree of emphasis is placed on improving the deficits. Therefore, exercises for visual perception and memory are also provided. In all cases, work is done with the printed word as opposed to nonverbal material. Auditory dyslexics, on the other hand, are taught by a whole-word approach, emphasizing the association of whole words to objects or pictures. Words not easily visualized such as prepositions, are taught in context. In addition to the major emphasis on whole-word learning, the auditory dyslexic is instructed in auditory analysis and synthesis.

Boder (1973) also suggested very specific remedial approaches for each of her three subtypes. Similar to Johnson and Myklebust, she insisted that initial remediation should cater to the abilities of the child rather than to the deficits. For example, dysphonetic readers, whose primary deficit concerns the auditory modality, should be treated initially with a whole-word technique. Phonic approaches should follow only after an adequate sight vocabulary has been developed. In contrast, dyseidetic readers, manifesting problems in the visual channel, are taught remedial phonics initially, and subsequently are introduced to the tactile-kinesthetic channel. Boder's mixed subtype, who have the most severe problems, are offered a tactile-kinesthetic approach.

During the past two decades, a proliferation of numerous and diverse remediation programs for dyslexic readers have been developed (Gittleman, 1983; Hewison, 1982). Currently, remedial programs can be categorized into two main conceptual frameworks based on different theories of dyslexia (Gittleman, 1983).

The majority of remedial methods used today have arisen from the first approach which has been variously called "differential diagnosis-prescriptive teaching" (Hewison, 1982), the "basic factors" viewpoint (Gittleman, 1983; Guthrie & Seifert, 1978), and the "process training" approach (Zigmond, 1978). This traditional educational approach, based on theoretical grounds, involves the assessment of reading-related abilities such as psycholinguistic and perceptual-motor skills. Following assessment, the child's pattern of abilities and deficits is formulated, and an individualized remedial plan is implemented. Remediation is largely aimed at the strengthening of weaknesses which are thought to impede a child's ability to read. (e.g., deficits in visual perception, auditory perception, psycholinguistic ability, kinesthetic or motor ability). The basic feature of this model is emphasis on the improvement of perceptual-motor deficits thought to underlie reading problems rather than on the reading skills themselves (Gittelman, 1983). Advocates of this technique argue that poor reading is due to a lack of the necessary prerequisite skills such as visuoperceptual and visuomotor skills that underlie reading (Gittelman, 1983; Zigmond, 1978). For example, a remedial program concentrating on the improvement of visual perception may include activities such as finding shapes in pictures, reproducing designs on pegboards or with beads on a string, completing puzzles, and identification of tachistoscopically presented pictures (Guthrie & Seifert, 1978).

In a critical review of the approaches to remediation, Zigmond (1978) reported that there is no convincing evidence to justify the basic factors approach. Guthrie and Seifert (1978) also reported lack of empirical evidence as a major criticism. Such programs, particularly those attempting to remediate visual perceptual disability, have not demonstrated any effect on reading.

Kavale and Mattson (1983) carried out a meta-analysis involving a review of 180 empirical studies investigating the effectiveness of perceptual-motor training, one of the most popular intervention techniques of the basic factors approach. Results identified only an average effect size described as negligible not only for the overall analysis but also for more specific analyses of programs, subject groups, grades, and design variables. The authors concluded that perceptual-motor training is not an effective form of intervention for improving either academic, cognitive, or even perceptual-motor functioning in learning disabled children.

The second category of remediation has been referred to as "skill-oriented" teaching (Hewison, 1982). This approach focuses directly on reading and spelling skills rather than underlying psychological skills related to reading (Guthrie & Seifert, 1978). Advocates of this method believe the most effective way to improve reading is to teach reading. The main focus of this approach is on decoding ability, word-attack and word-analysis skills, phonetic analysis, and sound-symbol association.

The treatment of dyslexia should not be considered limited to educational remediation alone. As mentioned earlier, many authors have emphasized the importance of secondary emotional problems in dyslexic children. Kline (1986) emphasized the need to deal with the child's emotional disturbances in addition to the academic ones. The belief that reading remediation will automatically resolve secondary emotional problems is described as a fallacy.

Controversial Approaches to the Treatment of Dyslexia

In addition to the major traditional approaches to remediation mentioned above, there are numerous techniques not based on confirmed research or replicated research findings (Hewison, 1982; Silver, 1987). Hewison (1982, p. 185) listed several of the more controversial techniques that have been used in attempts to improve reading: "training of eye movements, megavitamin therapy, eurhythmics, the provision of "alpha biofeedback", the learning of Chinese ideographs, the learning of Braille, music therapy, training in creative thinking, attribution training, physical education, and the administration of motion sickness drugs."

Under the rubric of controversial therapies for learning disabilities, Silver (1987) listed two categories, neurophysiological retraining and orthomolecular medicine.

Neurophysiological retraining is a broad category of approaches based on the rationale that specific sensory stimulation or exercise of specific motor groups will result in the retraining or recircuiting of the CNS, leading to improvement. One popular and widely used technique in this category is optometric visual training. This method is advocated by optometrists who believe that dyslexia is caused by visual defects. A variety of educational and sensory-motor-perceptual training techniques are used. However, there is little or no evidence to support this approach (Helveston, 1987; Silver, 1987) and numerous professional organizations (e.g., American Academy of Pediatrics) have expressed formally concerns about this type of intervention.

Orthomolecular medicine was introduced originally by Linus Pauling, and involves the treatment of a disorder through the correction of the body's biochemical imbalances (Silver, 1987). This approach seeks to supplement the body with whatever it is lacking (e.g., through the provision of megavitamins or trace elements), and to remove aversive substances from the diet (e.g., food additives, refined sugar, fats, etc.). Some investigators (e.g., Baker, 1985) have discussed the promising effects of biochemical investigation and treatment for certain dyslexic children. In general, however, little research has been done to investigate the efficacy of these approaches. On the basis of research available, there appears to be a very small subgroup of learning disabled children who may respond favourably to methods such as diet control (Silver, 1987).

Another line of treatment for dyslexia involves the use of certain drugs. The administration of anti-motion sickness medication is one example. This approach is based on a hypothesized causal relation between dyslexia and vestibular-cerebellar dysfunction (Levinson, cited in Silver, 1987). However, no research has provided conclusive evidence for the validity of this hypothesis or for its related treatment (Silver, 1987).

The nootropic drug, piracetam, has received recent attention as a possible treatment for dyslexia. Some evidence exists that piracetam has beneficial effects on reading, and on verbal learning and retention in normal and dyslexic readers (Conners, Reader, Reiss, Caldwell, Caldwell, Adesman, Mayer, Berg, Clymer, & Erwin, 1987). In addition, piracetam has been shown to influence brain activity specifically in the left hemisphere as reflected by enhanced amplitudes of ERPs elicited by visual verbal stimuli (Conners et al., 1987).

<u>Critical Analysis of Remedial Techniques for Dyslexia</u>

Despite the multitude of methods available, it has not yet been established whether or not dyslexia is amenable to treatment (Lovett, Warren, Ransby & Borden, 1987). Reviews of the literature conclude that despite the growing size of this remedial enterprise, there has been very little research done on this important issue, and there are very few published reports that provide convincing evidence that dyslexia can be successfully treated (Gittelman, 1983; Hewison, 1982). In addition, there has been little empirical research done on the relative effectiveness of different remedial methods (Hewison, 1982; Johnson, 1978). Gittleman (1983, p. 536) stated that given the existence of numerous techniques for studying and treating a disorder that has been known for almost a century, it is "dismaying to confront the extraordinary limited research done on this important issue, especially when one contemplates the enormous public resources allocated to remedial programs by school systems that, in their decision-making roles, essentially institutionalize ignorance." For example, although a battle of over 150 years has raged between proponents of the phonetic approach versus those of the whole-word or look-say method, there have been no studies comparing the two techniques (Gittleman, 1983).

Although it is not possible to accurately evaluate the effectiveness of the different approaches given the dearth of empirical data, it remains apparent that there is no particular intervention technique that has surpassed others in terms of reliable, long-term impact on dyslexic childrens' reading ability (Hewison, 1982; Silberberg, Iversen, & Goins, 1973). Many researchers, on the basis of objective evaluation, have come to the conclusion that although the present forms of intervention may result in some short-term gains for reading disabled children, long-term improvements (over months and years) are rare, rendering the effects of such intervention virtually negligible (Hewison, 1982; Tobin & Pumfrey, 1976; Silberberg et al., 1973).

There are many plausible explanations why there have been few convincing research reports on the treatment of dyslexia. First, remediation of cognitive disorders is a relatively new area of research, therefore a paucity of work exists, especially carefully planned longitudinal studies. Instead, most of the "evidence" for various techniques comes from clinical progress reports, uncontrolled case studies, and anecdotes. Second, poorly executed studies are abundant in this field of research. Studies are plagued with flaws in sampling, design, or statistical analysis. Third, stringent control groups are rarely employed, resulting in findings that are possibly confounded by "Hawthorn effects" or expectancy effects (Johnson, 1978). Fourth, problems of generalization often exist. Many methods may result in an improvement on tests of the particular skill trained (e.g., auditory discrimination), but have no real impact on reading ability per se (Hewison, 1982). Fifth, the lack of consensus regarding the definition and specific diagnostic criteria of the disorder has resulted in an unacceptable amount of variation in samples between studies (Gittleman, 1983; Johnson, 1978). For example, studies using the criterion of a 6-month decrement for the definition of reading disability are hardly comparable to studies using a 2-year decrement. Sixth, confusion has been generated by the poor and ambiguous description of treatment techniques and the varying durations and frequencies of treatment sessions that are employed (Gittleman, 1983).

Seventh, past efforts at remediation may have been unsuccessful because heterogenous dyslexic children were treated as members of a homogeneous group (Rourke, 1978b; Rourke, 1983). As mentioned earlier, given the heterogeneity of the dyslexic population, it is clear that there can be no single best method of remediation (Johnson, 1978; Rourke, 1983). The failure of most outcome studies to demonstrate the success of a particular remedial approach may be due to the tendency of researchers to "fit" children to the procedures instead of tailoring the procedures to fit the child (Petrauskas & Rourke, 1979). Therefore, although some children of a given type may benefit from a particular intervention program, others, of a differing type may not improve. Certain children may even be harmed by some intervention methods, and others who are helped may experience possible "social, emotional, or other side effects" of the intervention (Rourke, 1983).

Although the heterogeneity of dyslexia is acknowledged and several typologies of dyslexia have been proposed, most of the current research does not appear to incorporate these notions (Applebee, 1971; White & Miller, 1983). For example, of 45 studies reviewed by White and Miller (1983) in the Journal of Learning Disabilities from 1971 to 1980, only one was found to specify the type of dyslexia under investigation or classify readers into subtypes. The authors concluded that the relatively recent proposed schemes for classifying dyslexic readers have been largely ignored. Applebee (1971, p. 98) summed up succinctly the manner in which researchers have utilized the concept of heterogeneity, "Everyone admits to obtain (it), but few deal with (it)." Although several subtype-specific treatment programs have been proposed and purported to be effective (e.g., Boder, 1973), very few efficacy studies have been carried out (Gittleman, 1983).

The issue of timing is another aspect of remediation that has been largely ignored. There is some evidence that treatment is more effective at earlier ages (prior to grade 3), presumably when the central nervous system is more plastic and malleable and the child has not yet experienced repeated failure (Johnson, 1978; Satz et al., 1978). Strag (cited in Satz et al., 1978) found that almost 82% of identified dyslexics in grades 1 or 2 improved to a normal level after treatment. However, this figure dropped to 46% of dyslexics first diagnosed in the third grade, and to only 10-15% in grades 5 to 7. Given such information, it is disappointing that most dyslexic children are not referred until the ages of 9 to 11 when they are past the optimal point of plasticity and already accustomed to years of academic failure (Satz et al., 1978).

To ameliorate the apparently dismal state of knowledge about the remediation of dyslexia, it is resoundingly clear that controlled, empirical studies be done. Well-controlled single-subject studies employing a multiple-baseline design such as those advocated for the evaluation of cognitive rehabilitation in brain-injured adults (Sohlberg & Mateer, 1987; Wilson, 1987) could also be fruitful (Johnson, 1978). In addition, future research must use a heterogenous model of dyslexia and take the next step to evaluate remediation strategies in an empirical, systematic, and scientifically rigorous fashion.

Using a heterogenous model of dyslexia, Dirk Bakker, a prominent neuropsychologist at the Free University Paedological Institute in Amsterdam, has developed a neuropsychological treatment technique that employs the subtype by treatment approach. In addition, he has taken precedence in attempting to test his treatment program in an empirical fashion. An examination of Bakker's theories and methods will be discussed in the following section.

The Research of Dirk Bakker

Review of Bakker's Research

Another subtype classification system based on the clinical approach has been formulated by Bakker (1982a; 1983), and is known as the balance model of dyslexia. In this model, Bakker accounts for two subtypes of dyslexia on the basis of evidence pointing to developmental changes in hemisphere-specific reading strategies that occur in normal readers. Because Bakker's work is the foundation of the present project, the development of his balance model of dyslexia will be chronicled by a description of his past work and hypotheses relevant to his model.

Bakker's first work can be traced to 1967 when he began investigating ear-asymmetry in children presented with auditory verbal and nonverbal stimuli. Bakker (1967, 1968, 1969, 1970) and others (e.g. Bryden, 1963; Kimura, 1961, 1967) found that when dichotically or monaurally presented auditory verbal stimuli such as digits are presented to adults or children, the stimuli are better retained when presented to the right ear (right-ear advantage: REA) than to the left ear in the majority of subjects. The asymmetry is thought to reflect cerebral dominance for language in the left hemisphere of the brain. In a similar vein, a left-ear advantage (LEA) or higher left ear score is indicative of cerebral dominance in the right hemisphere, although this organization is much less frequent (Kimura, 1961, 1967). The contralateral pattern (i.e., right ear-left hemisphere; left ear-right hemisphere) is mediated by the organization of the auditory pathways from the cochlea to the temporal lobe of the brain. Although both ipsilateral and contralateral pathways exist, the contralateral projections are stronger or more effective than the ipsilateral ones (Bakker, Smink, & Reitsma, 1973; Kimura, 1967).

After the concept of REA with verbal stimuli was established firmly, Bakker subsequently became interested in the relation between reading ability (a form of language presumably subserved by the left hemisphere) and ear-asymmetry. He found (Bakker, 1969; Bakker, Smink, & Reitsma, 1973) along with other investigators (e.g., Satz, Rardin, & Ross, 1971) that a positive relation existed between right ear dominance and reading ability in older children, i.e., better reading is associated with a higher degree of right-ear dominance. This relation, however, was reported to be valid for older children only (i.e., ages 11-12; Satz, Rardin, & Ross, 1971). For younger children (i.e., ages 7-8), the dichotic listening test did not discriminate between dyslexic and control children, who both showed a similar degree of REA.

This issue was explored further by Bakker, Smink, and Reitsma (1973) who reported the results of three experiments with normal right-handed readers. The first experiment (20 girls, 20 boys) showed that in children aged 7 to 7.5 years, a lack of ear advantage was associated with a significantly higher score in reading. In contrast, experiment two found that in older readers aged 8.5 to 9.5 years (19 girls, 19 boys), a positive relation between ear dominance and reading ability was evident (i.e., either strong LEA or REA was associated with higher reading scores). An absolute value of right minus left ear scores was used, therefore it was unclear whether efficient reading in older children was associated with left, right, or both types of ear advantage. Experiment three confirmed the results of the first two studies. Fifty girls and fifty boys, aged 7 to 11, were divided into two age groups, 7 to 8 and 9 to 11. In the younger age group, subjects with little or no dominance read significantly better than those with definite ear dominance. In the older group, findings were reversed; children with definite dominance read better than those without. It should be noted that good reading was associated with moderate, but not maximum ear advantage.

Satz, Bakker, Teunissen, Goebel, and Van der Vlugt (1975) showed that in a sample of 5 to 11 year old normal children, magnitude of REA increased with age, becoming significant at 9 years. In addition, Bakker, Teunissen, and Bosch (1976) reviewed additional studies all of which indicated that poor older readers tend to show less REA than do normal readers. Taken together, these studies support the conclusion that efficient reading is associated with lack of ear advantage in very young children. At older ages, however, reading ability appears to correlate positively with the absolute values of between-ear difference scores, whether they are positive or negative.

On the basis of this age-dependent relation between ear-dominance and reading ability, Bakker proposed a developmental theory of reading, incorporating the change in hemisphere specialization with age (Bakker, 1973; Bakker, Smink, & Reitsma, 1973). He noted that because children begin reading around age six, well before lateralization is complete, early reading skills therefore must not require fully lateralized language abilities. Rather, he hypothesized that novice reading required a high degree of perceptual discrimination and analysis to deduce meaning from the subtle form and sequence differences of letters and words. Such demands could be easily carried out with bilateral hemispheric control. In fact, a young child who has become over-lateralized at too early an age should be compromised in reading ability. Thus, Bakker speculated that a bilateral hemispheric system may be better suited to the large processing demands of non-lingual material in combination with the normal lingual demands (e.g., syntactic and semantic) required for early reading. Fluent reading, at later ages, however, requires a greater proportion of analytic, lingual activities such as syntax and meaning, best subserved by the left hemisphere. Therefore, another source of difficulty in reading could be failure to lateralize at a later age.

In a subsequent study on the laterality reading patterns at different ages, contradictory results were obtained (Bakker, Teunissen, & Bosch, 1976). The authors found that efficient reading was associated with either right or left ear dominance in young boys (aged 8 to 9), while poor reading proficiency was related to lack of ear advantage at this age. More consistent with the previous study, a REA was linked to higher reading ability in older children. In addition to these findings, a marked difference in the laterality-reading ability patterns was found between normal boys and girls. Third grade girls showed a linear pattern with better reading performance associated with left hemispheric language (REA). Boys, however, showed a U-shaped nonlinear trend, indicating that reading proficiency was associated with either left (REA) or right (LEA) language subservience (see also Bakker, 1981a). Better performance and higher degrees of REA at earlier ages for girls suggested that girls progress more quickly through the stages of the learning to read process. Thus, while reading proficiency was associated with REA in girls at the third grade level, this pattern was not evident in boys until the fifth or sixth grade. At the second grade level for girls and third grade level for boys, reading proficiency was related to moderate LEA or REA.

From these results, Bakker and his associates concluded that the relation between ear asymmetry and reading ability is dependent on sex and age. In light of the contradictory findings for early reading, Bakker revised his theory to state that in early phases of learning to read, either hemisphere appears capable of mediating written language whereas in later phases, mediation is restricted to the left hemisphere only. The authors stated further that there was growing evidence that right hemisphere dominance is particularly appropriate for early reading.

Bakker (1979a, 1979b, 1981a, 1982b, 1983), suggesting that the right hemisphere plays a prominent role in the processing of written material, cited several studies supporting the participation of the right hemisphere in certain aspects of reading, viz. the spatial-perceptual components. For example, one study required adults with brain lesions to perform a letter matching task (Faglioni, Scotti, & Spinnler, 1969). A letter printed in a conventional way (normal print) or a perceptually complex way (masked by curlicues) was to be matched with one of 10 choices below the letter. Results indicated that left brain-damaged patients performed more poorly with the conventional letters while right brain-damaged patients did worse in matching the non-conventional letters. On the basis of these findings, the authors suggested that the matching of perceptually complex letters was dependent upon intact right hemispheric functioning.

Visual half-field studies have also demonstrated the importance of the right hemisphere in the perceptual aspects of processing written material. Gibson, Dimond, and Gazzaniga (1972) found a left-field superiority for making quick judgements about the matching of normally printed words to each other. Concrete words as opposed to abstract words have been shown to undergo more efficient processing in the right hemisphere (Ellis & Sheperd, 1974). Bryden and Allard (1976), using a visual half-field paradigm, demonstrated a reliable left visual-field (right hemisphere) preference for letters printed in non-conventional, perceptually complex typefaces. Letters printed in easily identifiable typefaces resulted in a right visual-field superiority. Given such evidence, Bakker has concluded that the right hemisphere in adults is the primary processor of non-conventional and perceptually-complex written material.

Bakker (1979a, 1979b, 1981a, 1981b, 1982a, 1982b, 1983) went further to suggest the importance of right-hemisphere subservience for reading holds true also for children who are learning to read. Right-hemispheric involvement in the initial stages of reading appears logical since all written material is new and perceptually complex at this stage. Studies supporting this position are cited (Bakker, 1979b; 1983), illustrating left visual-field superiority for word and letter recognition in younger children (grade 1 or 2), switching to right visual-field advantage in older children (beyond Grade 4). A longitudinal study which tested ear advantage in kindergarten, and at the beginning and end of Grade one, illustrated a significantly greater proportion of children with LEA in kindergarten, and a higher proportion of children with REA at the end of Grade 2 (see Bakker, 1979b). However, another longitudinal study found ear preference to be stable over a 5 year period, with REA being predominant (Bakker, Hoefkens, & Van der Vlugt, 1979).

With his revised theory and new evidence for the role of the right hemisphere in reading, Bakker (1979b, 1981a, 1981b, 1983) speculated that hemispheric strategy may change with the successive stages in the process of learning to read. Since early reading is novel and perceptually demanding, it requires a high degree of "spatio-perceptual" analysis. Therefore, a novice reader would appear to benefit most from a right-hemispheric or bilateral strategy (i.e., have right or bilateral control of speech). As reading becomes more advanced, perceptual analysis becomes more automatic, and the processing of syntax and meaning takes on a larger role. "The preprocessing capacities of the right hemisphere are no longer relevant; the graphemes become lingual entities having direct access to the language hemisphere" (Bakker, 1981a, p. 67). Fluent reading requires both speed and accuracy, needs not appropriately met by the right hemisphere. However, a "syntactic-semantic" strategy can be provided by a left hemisphere subservience of language.

In support of this notion that proficient reading is associated with right- and left-hemisphere speech control at early and later ages respectively, Bakker (1979b, 1983) described the results of a longitudinal study. Children who exhibited LEA at kindergarten were better readers at grade 5 than those with REA. However, children with LEA at the end of grade one tended to become poorer readers at grade 5 than those children with REA in grade 1. Therefore, a LEA appeared most advantageous when first beginning to learn to read, but a transition to REA before the end of grade 1 seemed necessary for a good prognosis in later reading proficiency.

Van Duyne & Bakker (cited in Bakker, 1979c) reported similar results from a cross-sectional study of first, second, and third graders of a normal primary school. Words and digits were presented monaurally and reading tests were administered. Regression analyses showed LEA to be most strongly related to proficient reading in grade 2. In grade 3, REA was associated with better reading. The shift was most marked in girls, supporting the notion that girls are faster than boys in passing through the successive laterality-reading stages.

Bakker (1979b, 1979c) reviewed several visual half-field studies which revealed an age by visual-field superiority interaction for normal readers presented with verbal stimuli through the visual half-fields. The results were consistent with those employing the dichotic listening paradigm. In general, a left-field advantage was demonstrated in younger children (age 6 and 7) and a right-field advantage was evident in older children.

The work of other investigators also suggests the differential importance of perceptual and verbal-semantic abilities in novice and advanced reading respectively. One example is the extensive longitudinal studies conducted by Satz and colleagues. Satz et al. (1978) found that sensori-perceptual skills differentiated good and poor readers at early school ages while verbal-conceptual skills were associated with reading ability at older school ages.

Bakker's suggestion of a developmental shift in hemispheric subservience in the normal reading process is consistent with and provides support for the well-known theory of Goldberg and Costa (1981). These authors postulated that the right hemisphere is better at intermodal integration and processing of novel stimuli whereas the left hemisphere is a better processor of familiar, well-learned stimuli. Thus, in very young children, who are learning to read, the right hemisphere may play the critical role in the first stages of reading acquisition. As the child progresses to a higher level of competence, a right-to-left shift in hemispheric superiority would be expected to occur. ᐧ ᐧ dberg and Costa suggested that this functional dichotomy is du to differential neuroanatomical characteristics of the left and right cerebral hemispheres.

In line with his findings, Bakker postulated the existence of two different, although equally proficient reading strategies for normal children in the initial stages of reading, dependent upon hemispheric dominance for speech (Bakker, 1979b, 1981a, Bakker, Teunissen, & Bosch, 1976). He hypothesized that children with right hemisphere speech dominance (reflected by LEA) would be more sensitive to the perceptual features of written material, resulting is a slow reading style but with few errors. On the other hand, left-hemisphe dominant children (reflected by REA) would be expected pay less attention to perceptual features, read quickly, and consequently make numerous errors. In support of this theory, Bakker, Teunissen, and Bosch (1976) demonstrated that right- and left-ear dominant young readers at grades 2, 4 and 6 differed in their strategy used, but not in reading level. Speed was measured as the number of items attempted within a time limit; accuracy was reflected by the number of errors made. As predicted, children with REA were shown to be fast but careless; LEA was associated with a slow but accurate strategy. The effects were less marked as grade level increased.

Children with the two reading strategies were shown to differ also in the types of reading errors they made, namely substantive and time-consuming errors (Bakker, 1979b, 1981a). Substantive errors include the omissions of words or letters, substitutions or additions of words, inversions of words or letters, and similar uncorrected word-mutilating errors. Time-consuming errors are substantive errors that are self-corrected, stuttering that is corrected, repetition of words, and self-corrected errors in emphasis or pronunciation. In general, a time-consuming error results ultimately in a correct response while a substantive error remains a clear, uncorrected mistake.

Normal readers from grades 2 and 5 were administered a dichotic listening test and a sample of text to read. Results revealed that children with consistent LEA manifested less substantive and more time-consuming errors than did children with consistent REA. These differences were significant within and across grades 2 and 5. This finding was taken to support the theory that left-ear dominance is associated with a right-hemispheric reading strategy which allows for careful analysis of the perceptual features of text. These readers are slow, but accurate, tending to correct any "substantive" errors that are made. Conversely, right-ear dominance may reflect a left-hemispheric reading strategy which concentrates on fast abstraction of meaning, but results in less attention payed to perceptual characteristics. Thus, these readers tend to be fast, but inaccurate (Bakker, 1979b). Therefore, although the right and left hemisphere are both capable of controlling initial reading behavior, the two types of hemisphere-specific reading strategies differ qualitatively in regards to speed, accuracy, and types of errors committed.

The information presented above represents the foundation upon which Bakker's current model of dyslexia is grounded. On the basis of evidence suggesting that differential strategies of reading (dependent on hemispheric dominance for speech) are associated with differential prognosis in later reading proficiency, Bakker (1979b; 1982b; 1983) expanded his perspective to explain two subtypes of dyslexic readers. One type, called L-type (due to their linguistic-semantic approach to text, Bakker, 1982a) is characterized by the omission of the spatio-perceptual stage subserved by the right hemisphere. Such children would instead use left-hemispheric syntactic-semantic strategies from the outset of the learning to read process. Children with the other type of dyslexia, called P-type (due to their sensitivity to the perceptual features of the script, Bakker, 1982a) have problems due to their disproportionate over-reliance on spatio-perceptual strategies and a failure to shift from right- to left-hemispheric strategies necessary for advanced reading.

Bakker noted that these types of dyslexia are equivalent to the two types of characteristic profiles outlined earlier for normal readers. L-type dyslexics exhibit a REA on dichotic listening tests (reflective of primarily left cerebral control of speech), read relatively quickly but inaccurately, and make many substantive errors. These characteristics are consistent with a view of the left hemisphere as a relatively fast, but inaccurate scanner of printed material. In contrast, P-types show either a LEA or absence of ear advantage on dichotic listening tests (reflective of primarily right cerebral control of speech), demonstrate relatively slow but accurate reading, and make primarily time-consuming errors. Thus, P-type children appear to have reading skills subserved by the right hemisphere, which can be described as a slow, but accurate scanner of printed material. The difference between L- and P-type normal and dyslexic readers is that normal readers will adapt in time to the appropriate strategy while dyslexic readers will not. Bakker (1983) described the distinction between L- and P-types as follows:

> P-type dyslexics, while stuck to the generation of right-hemispheric reading strategies, will show non-left-hemispheric speech control, definite right-hemispheric control of form perception, correlated form and letter perception, and time-consuming errors... L-type dyslexics, while relying on left-hemispheric reading strategies, will show left-hemispheric speech control, ambivalent hemispheric control of form perception, noncorrelated form and letter perception, and substantive reading errors. (p. 505)

In a study designed to further validate these features of L- and P-type dyslexics, 38 learning disabled children (primarily reading and spelling problems; ages 8 to 12) were classified according to ear advantage and given word and text reading tests (see Bakker, 1979b). The results of an error analysis showed that children with REA made substantially more substantive errors. LEA, in contrast, was associated with a higher incidence of time-consuming errors. In addition, readers with LEA tended to show a higher degree of functional asymmetry concerning visual-perception. This was reflected by faster reaction times in the left visual field than the right visual field to a nonverbal matching task. Children with REA did not show such an asymmetry.

Bakker (1979b; 1982b; 1983) speculated about the underlying mechanisms of the two dyslexias. He hypothesized that the difficulties of L-types may be mediated by a relatively underdeveloped spatio-perceptual system, perhaps due to a lessened degree of cerebral lateralization (Bakker, 1979b). Alternatively, the problem could be a functional overdevelopment of left-hemisphere linguistic functioning reflected by the strong REA (Bakker, 1982b). Bakker (1983) suggested that overdevelopment of the left hemisphere may impede the development of right-hemispheric visuospatial functioning. In a similar vein, P-type dyslexics may possess an overdevelopment of right hemisphere spatio-perceptual functioning with subsequent depression of left-hemispheric linguistic functioning (Bakker, 1983). The preponderance of a right hemispheric strategy may be encouraged through the subservience of speech in their right hemisphere as reflected by their LEA on dichotic listening (Bakker, 1982b).

Further evidence for the validity of the L/P classification has been reported recently by Van Strien, Bakker, Bouma, and Koops (1988). L- and P-type dyslexic boys and their biological parents were administered a number of neuropsychological tests including measures of perceptual asymmetry. L-type dyslexics performed better on verbal tests and worse on spatial tasks than did the P-types. In addition, some of the parents reflected the specific deficits of their children, e.g., parents of P-types performed better than parents of L-types on certain spatial tasks; fathers of L-types demonstrated better verbal memory ability than fathers of P-types. Correct classification of parents with either a P- or L-type child occurred with 76% of the fathers and 69% of the mothers.

Bakker has labelled his theory the balance model of dyslexia. He explained (1982a, p. 40), "Reading requires both perceptual and lingual analysis, subserved by right and left hemispheric strategies respectively. The balance shall bend to one or the other side depending on the stage of the learning to read process. However, dipping of the scale causes differential problems".

Bakker has taken pains to communicate his theory and findings in non-technical terms to interested persons who may not readily understand the technical style and jargon of a scientific journal. He has recently completed a book designed for such a reader (translated from a Dutch version) which summarizes the theory, methodology, and results of his research (Bakker, 1990).

To enhance the communication of his research, in both technical and non-technical publications, Bakker often uses vivid metaphors. For example, he has often used a metaphor of horse-back riding to further describe the developmental process of reading for normal and dyslexic readers (Bakker, 1982b, 1990): A child learning to ride a horse would benefit most from a quiet, slow, and stable horse, labelled an R-horse

(R=right hemisphere). This horse is careful, perceptive of upcoming obstacles, and rarely stumbles, and therefore highly suitable for a novice rider. As the child becomes more confident and skilled in riding, however, speed and a challenging ride may become more desirable. The R-horse is clearly no longer suitable. The child now requires a faster, more skilful animal, labelled an L-horse (L=left hemisphere). Given this dichotomy of horses, two types of disabled riders can be envisioned. One subtype may prefer to begin riding with the L-horse. This type of child, who lacks experience, will likely take many falls on this horse. The ride may be swift, but it will also be sloppy. The other type of disabled rider may prefer to begin to ride with the R-horse but then fail to switch over to the more skilful L-horse at the appropriate time. Thus, although this type of child will ride well, the ride is slow and there is little opportunity for advancement into more complex riding skills.

In terms of the prevalence of L- and P-types in the dyslexic population, Bakker (1990) noted that the classification system is not exhaustive, classifying no more than 60% of dyslexics from a given sample. Bakker offered two possible explanations for this: (a) There are other types of dyslexia besides L- and P-types; and (b) Measuring instruments to classify L- and P-types are not yet completely accurate.

This implies that all dyslexics could be classified given accurate measures.

Electrophysiological Evidence for Bakker's Model

With behavioral evidence pointing to a qualitative difference in reading strategy between normal and dyslexic readers with REA and LEA, Bakker's next step was to demonstrate electrophysiological cerebral correlates of the behavioral pattern. Because the theoretical basis of the L/P classification concerns the differential activity of the left and right hemispheres, electrophysiological studies demonstrating this differential pattern would add substantially to the external validity of the classification system and theory.

Bakker and colleagues chose to use event-related potentials (ERPs) as their method of investigating brain neurophysiology. Before describing the results of this work, a brief description of the ERP method and the relevant work with it in regards to dyslexia is in order.

The ERP is similar to electroencephalographical (EEG) activity in that it represents the summed electrical activity of thousands of neuronal membranes, largely dendritic activity, acting in synchrony (Hillyard & Woods, 1979). The ERP differs from the passive EEG recording, however, in that the ERP is elicited from an active challenge in the form of a visual, auditory, or somesthetic stimulus presented to the brain (Conners, 1978). For example, in the case of reading, a word or letter can be presented with subsequent effects expected to be fairly localized, particularly in the region of the left angular gyrus (Conners, 1978).

ERPs are, as the name implies, "time-locked" or temporally linked to a particular event such as a stimulus output, a response output, or an intermediate stage of sensory or cognitive processing (Hillyard & Woods, 1979). ERPs are known to have distinctive characteristics of waveform and latency, reflecting the type of stimulus, the state of the subject, and the site of the recording. The sensitivity of this method is also one of its drawbacks, however, since it can be influenced by many variables difficult to control e.g., body, facial, and eye movements, changes in respiration, etc. (Kolb & Wishaw, 1985).

Typically, a series of ERPs are computer-averaged to arrive at a reliable estimate of the elicited cerebral activity. The averaging procedure acts to cancel out the "noise" of EEG fluctuations which unlike the ERP, are not time-locked to the reference event. Since the waveform of the ERP remains constant over trials, but the EEG does not, the EEG will average out to zero over a large number of trials (Hillyard & Woods, 1979).

Despite its undeniable technical problems, the ERP is considered by many investigators to be a useful and valid indicator of the brain's activity during information processing. The technique has been heralded by Begleiter as "the interface between cellular neurobiology and the behavioral or cognitive sciences" (cited in Hynd & Semrud-Clikeman, 1989, p. 206). This non-invasive method allows one to study in the intact functioning brain the association between particular behavioral events and related brain activity (Hillyard & Woods, 1979).

Hillyard and Woods (1979) describe three categories of ERPs: the exogenous, endogenous, and intermediate. Exogenous ERPs are responses due to the sole influence of an external event, such as a light flash or an auditory stimulus. These ERPs are stable and consistent between normal persons, unaffected by the psychological state of the subject. The morphology and latency of these waveforms are, however, quite sensitive to the integrity of the sensory receptors and pathways mediating the response. Exogenous ERPs are used as a valuable tool for the diagnosis of problems in sensory acuity and neurological functioning.

In contrast to the exogenous type, the endogenous ERP is highly influenced by internal perceptual, cognitive, and motor processes in the brain. This type of ERP is, as a result, highly variable within and between people.

The third type is intermediate between the exogenous and endogenous forms. The morphology of this type of waveform is often characteristic, but amplitude and/or latency can vary depending on psychological variables such as attention, motivation, and alertness. The exogenous, intermediate, and endogenous types of ERPs correspond roughly to the early (0 to 10 ms), middle (50 to 250 ms), and late (300 ms and longer) components respectively of a representative waveform. It is the intermediate and endogenous types that are generally employed in the study of the neurophysiological correlates of complex cognitive-behavioral activities such as reading.

Measurement of ERPs is a particularly useful technique for the study of differential hemispheric functioning (Van de Vijver, Kok, Bakker, & Bouma, 1984). Through the use of ERPs in this regard, electrophysiological differences have been shown to exist between normal and dyslexic readers. Conners (1971) demonstrated an attenuation of amplitude in a late negative component of the visual ERP elicited by flashed lights. This effect was evident in the left parietal area (electrode placement P3 according to the international 10-20 system) for most members of a family of poor readers. Similar findings were obtained by Conner from a comparison of poor and better readers from a learning disabilities school. Good readers showed significantly more negativity of a late component wave in the left parietal location (P3) than did poor readers. In another experiment, learning disabled subjects exhibited moderately high correlations (in the order of .63) between left parietal (P3) amplitude and reading ability. Thus, all experiments reported in Conner's paper indicated a consistent significant trend toward attenuated negativity of a particular portion of the waveform (about 200 ms after stimulus onset in the left (P3) parietal location) among poor readers.

Similar findings to those of Conners have been reported by Preston, Guthrie, and Childs (1974). They found that compared to normal readers, reading disabled children exhibited a significantly attenuated amplitude in the negative wave, 180 msec after stimulus onset, measured with a left parietal (P3) electrode location. This effect was found not only in response to light flashes, but also to a flashed word, "cat". The reduced amplitude, characteristic of reading disabled children, was explained as reflecting inadequate neural processing in an area critical to reading. Despite these results, however, it should be noted that these findings have not been replicated by at least two laboratories (see Stelmack, Saxe, Noldy-Cullum, Campbell, and Armitage, 1988).

More recently, Stelmack et al. (1988) found that reading-disabled children demonstrated enhanced P200 amplitude and reduced N440 amplitude relative to normal readers. This occurred during both the acquisition and recognition stages of a recognition memory task for words.

Some research has demonstrated hemispheric differences in ERPs between different subtypes of dyslexia. Fried, Tanguay, Boder, Doubleday, and Greensite (1981) compared normal, dysphonetic, and dyseidetic readers on ERP responses to auditorily presented words and musical chords. Amplitude difference scores between ERPs elicited by word and chord stimuli were found to be greater in the left than the right hemisphere in normal and dyseidetic readers. Dysphonetic dyslexics, however, showed no such hemispheric asymmetry. This finding suggested that dysphonetic dyslexics have left hemisphere dysfunction, not allowing them to develop normal left hemisphere dominance for linguistic processing.

Conners (1971), in a comparison between dyslexics with high verbal-low performance IQ and those with low verbal-high performance IQ, found significant differences between the groups on latency measures of the late ERP components in both right and left occipital regions. Latencies were significantly longer in the high verbal-low performance IQ group.

Bakker, Licht, Kok, and Bouma (1980) measured ERPs from temporal and parietal locations in response to monosyllabic words flashed centrally on a computer screen. Subjects (8-12 years) were normal and disabled readers divided into REA and LEA groups. ERPs were analyzed in terms of reading level (normal vs disabled), ear dominance (LEA vs REA), and electrode location (left vs right temporal and parietal). Results revealed that normal readers and disabled readers differed in their electrophysiological responses to word stimuli. Normal readers showed ear by side interactions, i.e., for both temporal and parietal locations, readers with REA showed higher amplitudes of the N440 component in the left hemisphere than the right hemisphere, and readers with LEA showed higher amplitudes in the right hemisphere than the left hemisphere. The disabled readers, however, did not show such a pattern; children with REA and LEA tended to show similar patterns with respect to side of electrode. LEA and REA disabled readers showed differences, however, in amplitude averaged over side. Dyslexics with LEA showed less positive temporal activity in the P310 component and less negative parietal activity in the N440 component than those with REA. Disabled readers also differed from normal readers in longer latencies in the parietal areas for certain components of the waveform. The authors interpreted these findings as suggestive that the brains of dyslexic children lack a division of labour between hemispheres and instead appear to function in a bilateral fashion. This abnormal equality may result in slower and less efficient processing, reflected in the longer latencies that were observed.

More recently, Bakker and associates have provided electrophysiological support for other theories and hypotheses proposed by Bakker. Further support has been shown for the notion that proficient reading acquisition in novice readers is associated with right rather than left hemispheric processes (Licht, Kok, Bakker, & Bouma, 1986). ERPs were recorded in kindergarten children during a word-naming task. Prior to recording, children were taught to identify four words and their reading acquisition speed (RAS) was noted. Findings indicated that fast RAS was associated with smaller N380 amplitudes and larger positivity of the slow wave. Furthermore, the relation between RAS and ERP components was stronger at the right temporal location. The authors suggested that fast RAS children were more proficient in the visuospatial (right hemispheric) aspects of word processing.

Licht, Bakker, Kok, and Bouma (1988) reported results from a longitudinal study which provided additional electrophysiological evidence for Bakker's developmental theory of hemispheric subservience for reading. Beginning at kindergarten and continuing for four consecutive years, ERPs to a word naming task were recorded from right and left temporal and parietal locations in 51 normal readers. Findings indicated a stronger relation between reading performance and ERP amplitudes over the right parietal location in young children (Kindergarten and Grade 1) than over the left hemisphere location. This relation was reversed at the temporal location in Grade 3 children. Bakker (1990) reported that the transition appears to occur at the end of the first grade/beginning of the second grade (about 7 to 8 years).

More evidence for the validity of the L/P classification was reported in Bakker's recent book (1990; also see Bakker, 1986). In the first study cited, ERPs to flashed words were recorded in L- and P-type dyslexics using the typical paradigm previously described. The amplitudes of negative ERP components from the temporal electrodes were found to be larger in the left hemisphere for the L-types, and larger in the right hemisphere for the P-types. The second study involved the recording of ERPs twice with an inter-test interval of 9 months. L-dyslexics showed an increase in left hemispheric activity over the interval. P-types showed the opposite pattern, i.e., a relative increase of right hemispheric activity. Thus, without intervention, it appears that L- and P-types exhibit an even greater reliance on their characteristic reading style subserved by the increasingly active hemisphere.

Bakker's Rationale for Neuropsychological Treatment of Dyslexia

Growing evidence for environmental influence on the brain has inspired Bakker to suggest a unique treatment approach to P- and L-type dyslexia. The theoretical assumptions underlying his approach involve viewing the brain as a "dependent variable" (Bakker, 1984). That is, traditionally, over the last 500 years, the brain has been seen primarily as having an impact on behavior (i.e., acting as an independent variable). This viewpoint included the notion that the brain was generally immutable to environmental influences. Within the last 25 years, however, research has shown that behavior, environmental manipulation, and sensory experience can have a durable impact on the brain.

A considerable body of literature exists regarding the effects of the environment on laboratory animals (Stein, Finger, & Hart, 1983). Research has investigated the effects of enriched versus impoverished environments, sensory restriction, and maze-learning on the anatomical, physiological, and chemical parameters of the brain (Bakker, 1984). For example, the well-known studies of Rosenzweig and associates, comparing the effects of standard, impoverished, and enriched environments on anatomical and biochemical responses in the rat brain, are particularly illustrative. Findings from numerous studies showed that rats living in enriched environments (12 rats together in a large cage with playthings changed on a daily basis) compared with rats living in impoverished conditions (1 rat alone in an empty cage) had heavier and thicker cerebral cortices, increased levels of the cortical enzymes acetylcholinesterase and cholinesterase, more glial cells, larger neurons in terms of cell bodies and nuclei, increased ratios of RNA to DNA (indicative of higher metabolic activity), larger ratios of cortex to subcortex, more dendritic spines, and increased synaptic contacts (Rosenzweig, Bennett, & Diamond, 1972). In addition to the animal studies, some evidence suggests psychological stimulation or lack of such can have enduring effects on human brains (see Bakker, 1984).

There is now no doubt that brain anatomy and chemistry can be altered by experience (Rosenzweig et al., 1972) and the evidence is overwhelming that the brain is a dynamic rather than immutable organ (Bakker, 1984).

Bakker conceptualizes this relatively recent notion in terms of a causal triad: environment - brain - behavior. The sensory environment is seen as having an effect on the structural response of the brain (e.g., mediated through anatomical, physiological, or chemical changes) which in turn results in a subsequent behavioral response (e.g., a change in cognition, emotion, motivation, or motoric activity). Using this perspective, Bakker asks the question: "Would it ... be possible to create stimulation in such a way that human brain structures would change to the advantage of the behaviors which are primarily mediated by these structures?" (Bakker, 1984, p. 7). Bakker's attempt to answer this question has involved the use of his P- and L-type classification of dyslexia as well as a view of the brain as a dependent variable. Bakker's strategy has been to study all three components of the causal triad. Specifically he planned to demonstrate that specific environmental stimulation of the brain can cause behavioral improvements, and to show that these behavioral changes are correlated with electrophysiological changes in the brain.

Hemisphere-Specific Stimulation

Bakker's treatment technique for dyslexic children, known as hemisphere-specific stimulation (HSS), involves stimulation of the right hemisphere in L-type dyslexics and the left hemisphere in P-type dyslexics through the visual half-field presentation of verbal stimuli. Words and letters are briefly presented on a computer monitor in the right visual field for P-types and in the left visual field for L-types. Before and after the training, school-achievement and neuropsychological tests are given and ERPs to centrally flashed words are recorded from left and right temporal and parietal electrode locations.

Bakker hypothesized that HSS would improve the reading and related academic abilities of a dyslexic child by altering the poorly balanced hemispheric involvement in reading ability. That is, stimulation in L-types and P-types will significantly activate the right and left hemispheres respectively such that over time, the increase in activity will lead to significant changes in reading strategy. He postulated that the improved reading ability would be accompanied by a concomitant electrophysiological change at the level of the brain, as measured by ERPs. Specifically, Bakker has hypothesized that HSS in L-type dyslexics should produce a significant relative increase in hemispheric activity from the left hemisphere to the right. P-types, on the other hand, should reveal a relative increase in left hemispheric activity.

Empirical Studies of the Efficacy of HSS

Bakker has published the results of two major studies investigating the efficacy of his remediation approach to dyslexia.

In the first of these, described as a pilot study, Bakker, Moerland, and Goekoop-Hoetkens (1981) studied 19 boys who were described by their teachers as suffering from a moderate to severe reading problem. These children were classified as P- or L-types according to three criteria: ear advantage, type of predominant reading error, and reading speed. L-types were those children showing right-ear advantage and either above-average reading speed or more substantive than time-consuming errors, or both. P-types were required to show left-ear advantage and below-average reading speed or more time-consuming than substantive errors, or both.

Three groups, one experimental and two control, were formed within the L- and P-type dyslexics, matched for age and number of reading errors. The experimental group (4 L-types, 3 P-types) received HSS as previously discussed for 16 sessions of 40 minutes, two sessions per week. L-types received letters and 2- to 4-letter words with concrete meanings printed in perceptually-demanding typefaces. Half of the trials required naming the letters or words. The other half required the discrimination of two words as the same or different after they were flashed together, one on top of the other. P-types received letters or words with abstract meanings in a conventional typeface and were asked to name each stimulus. In addition, P-types were asked to spell the words forwards and backwards or to indicate the sequential position of certain letters in each word.

Fixation was controlled by flashing a digit in the center of the monitor simultaneously with the peripherally presented verbal stimuli. Subjects were instructed to fixate on the center and identify the digit prior to the word or letter.

Control group one (3 L-types, 3 P-types) received varying remedial training for 16 sessions as deemed appropriate for each child by remedial teachers. Control group two (3 L-types, 3 P-types) received no training and stayed in classrooms during the experimental and control group one sessions.

All subjects were given 10 reading measures at pre- and post-test times (e.g., number of words read, substantive errors, time-consuming errors, reading speed). Bakker et al. (1981) used a nonparametric analysis (chi square) denoting any degree of improvement as a plus (+), worsening as a minus (-), and no change as zero (0). ERPs to centrally flashed words were also collected in temporal (T3, T4) and parietal (P3, P4) electrode locations (according to the 10-20 international system).

In terms of the academic measures, more than expected improvement was found for the experimental group, with L-types improving significantly more than P-types. Control group one did not show any significant changes. Control group two exhibited less than expected improvement.

Between-hemispheric difference (BHD) changes (the change in right minus left hemisphere parameters from the pre- to post-test ERP) were analyzed for amplitudes and latencies. A significant effect was revealed for BHD changes in temporal P310 amplitudes (no significant effects were found for latencies). L-types receiving HSS showed raised activity in the right-hemisphere at post-testing while L-types receiving alternate treatment showed an increase in left hemispheric activity. P-type experimental subjects showed a lowering of right hemisphere activity at post-testing, while alternately treated P-types of control group one showed a right hemisphere increase. The magnitude of BHD changes was correlated with reading improvement in the order of $\underline{r} = .60$.

Although the authors assumed a cautious attitude in interpreting the results due to their limited scope, they suggested that HSS is more effective than certain traditional remedial approaches. Furthermore, the efficacy of HSS is supported by electrophysiological correlates of changing hemispheric activity.

A more extensive study than the pilot in terms of levels of training, controls, and analysis was conducted by Bakker and Vinke (1985). Subjects were from six schools for learning-disabled children, whose predominant difficulty was with reading according to their teachers. Classification of L- and P-type dyslexics was on the basis of ear-advantage and type of reading error (reading speed was not used as a criterion in this study). L-types were those children showing right-ear advantage, and more than the average number (across all subjects) of substantive errors and/or less than the average number (across all subjects) of time-consuming errors. P-types were subjects showing left-ear advantage or absence of ear advantage and more than the average number of time-consuming errors and/or less than the average number of substantive errors. Subjects with low intelligence (IQ < 70), irregular school attendance, or poor cooperation of parents were not included in the study. The mean age of all subjects was 125.5 months (approximately 10.5 years). The mean reading age across all subjects was 89.1 months (approximately 7.5 years), approximately 3 years behind the mean chronological age.

P-type dyslexics (N=35) and L-type dyslexics (N=35) were divided into 5 groups of 7 subjects each (L-types: L1, L2, L3, L4, L5; P-types: P1, P2, P3, P4, P5) using stratified random sampling for years of reading experience (see Figure 1). Within each subtype, one group (L1 and P1) received HSS as previously described. Groups L2 and P2 served as controls for L1 and P1, receiving all words (half L-type and half P-type words) in the central visual field instead of lateral presentation.

Groups L3 and P3 served as alternate experimental groups, receiving experimental text training which was designed to stimulate primarily the left or right hemisphere without the use of the lateralized presentation as in the HSS technique. This type of training has been referred to as hemisphere-alluding stimulation (Bakker, 1990). Thus, L-types were given perceptually difficult texts that were illustrated and involved a mixture of capital and lower-case letters within words, in order to stimulate the right hemisphere. L-types were also provided with verbal exercises high in perceptual complexity. P-types received texts without pictures or special typefaces in order to de-emphasize perceptual processing requirements. Phonetic and semantic tasks, such as rhyming and temporal ordering designed to stimulate the left hemisphere were given to P-types. Groups L4 and P4 served as controls for L3 and P3. They were given texts with an equal mixture of the L3 and P3 treatment.

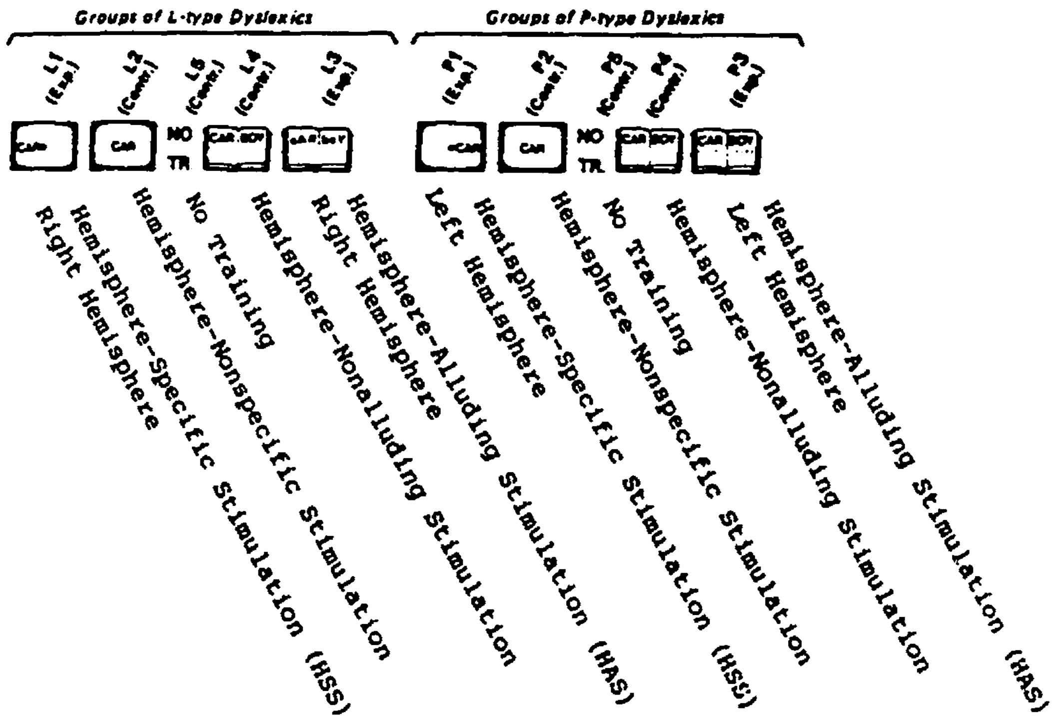

Figure 1. Groups of L- and P-type dyslexics used in Bakker & Vinke (1985) (from Bakker, 1990)

Groups L5 and P5 were overall controls, receiving no special training. They remained in their classrooms during all training sessions. All groups except L5 and P5 received training for 22 sessions of 45 minutes, one session per week.

The procedure for HSS was similar to that described for the pilot study, and will be described in detail in the method section of this dissertation.

Subjects were administered pre- and post-tests involving reading and spelling. Measures included reading speed, word reading, sentence reading, writing to dictation (spelling), and analysis of substantive and time-consuming errors. ERPs were collected at pre- and post-times to 60 centrally flashed four-letter words. Electrode locations were identical to those used in the pilot study (T3, T4, P3, P4). The number of errors in identification of the words were recorded as another measure of reading ability (flashed word test: FWT).

In terms of academic achievement, changes were most prominent in L-type subjects. L1 showed a significant decrease in reading speed and substantive errors, and a significant increase in correct words in writing to dictation. No other L groups showed significant effects. In P-types, the only significant effect was a decrease in words attempted in P1. Between group contrasts only approached significance ($p < .08$) for L1 vs L2 on substantive errors (L1 showing less errors), P1 vs P5 on words attempted (P1 showing less words attempted) and flashed word test (P1 showing less errors), and P3 vs P4 in words attempted (P4 showing more words attempted).

Bakker and Vinke also created measures of verbal accuracy and reading efficiency through composite scores and ratios of measures respectively. A comparison of the groups on verbal accuracy (composite score of the standard scores of substantive errors, writing to dictation test, and the flashed word reading test) clearly showed the superior performance of L1, the only group showing significant improvements. Reading efficiency (accuracy of reading relative to reading speed) was significantly improved in Groups L1, L3, P3, P4, and P5.

Principal components analysis (PCA) was used to identify the major components of the grand mean of the ERP waveform. BHD changes were described as indicative of either a relative increase in left hemispheric activity (leftening) or a relative increase in right hemispheric activity (rightening) on the post-test compared to the pre-test. It was hypothesized that groups L1 and L3 would demonstrate rightening while groups P1 and P3 would demonstrate a leftening effect.

Training-induced BHD changes were found only in the parietal P250 amplitudes. Within group analyses found P1 to show significant leftening of hemispheric activity while P3 showed no significant BHD changes. Neither L1 nor L3 showed the predicted significant rightening effects. Unexpectedly, L2 revealed a significant leftening effect, and in L5, the leftening effect approached significance.

Between-group comparisons of parietal BHD changes indicated significant differences between L1 and L2, L1 and L2 + L5, L1 and L4, and L3 and L5. No significant contrasts were found for P-types.

Bakker and Vinke interpreted these results as indicating that direct or indirect right-hemispheric stimulation in L-types (L1, L3) attenuates a leftening process which occurs in L-types not receiving such stimulation (e.g., L2, L5). Direct left-hemispheric stimulation in P-types (P1), on the other hand, promotes a leftening effect which other treatments and controls did not exhibit.

As a means of investigating the development of hemispheric reading subservience in groups who received no intervention, BHD changes were standardized across groups L5 and P5. With this analysis, P5 showed significant rightening of parietal activity while L5 showed leftening although this result was not statistically significant. The authors took these results to indicate that without treatment, L-and P-types develop opposite patterns of hemispheric subservience for reading. The authors speculated that these patterns may reflect the sustained bias of L-types and P-types in the absence of effective intervention to rely primarily on left and right hemispheric reading strategies respectively.

Significant correlations between parietal BHD changes and changes in substantive errors across subjects were found (*r* = .27, $p < .02$). This correlation indicates that substantive errors increased as leftening increased, a relation which is consistent with the findings discussed above. Temporal BHD changes were significantly correlated with changes in the number of words attempted (*r* = .38, $p < .01$), indicating increased speed with increased leftening. On the basis of these findings, Bakker and Vinke speculated that parietal functioning may mediate reading accuracy while temporal functioning mediates reading speed.

The authors concluded that HSS in L-types results in reading and spelling improvement, improved reading efficiency, and moderation of reading speed. In the case of P-types, groups P3 and P4 which received indirect loading of the left hemisphere appeared to show more improvement on the measure of reading efficiency than did P1, which received HSS. P1 showed significant improvement on the FWT and unexpectedly a reduction in reading speed.

In summary, the results of this study provide some evidence that HSS modifies parietal P250 activity asymmetrically in P- and L-type dyslexics, as reflected by BHD changes in ERPs. Academically, L-type subjects receiving HSS appear to improve to the greatest degree in both accuracy and efficiency of reading performance. P-types receiving HSS, however, do not appear to benefit from the treatment, and show an unexpected reduction in reading speed. Significant correlations were apparent between hemispheric electrophysiological changes and changes in certain aspects of reading performance. The authors concluded that the results may warrant the use of HSS in L-type dyslexics to improve reading and spelling performance. P-types may benefit more from an indirect approach using phonetically-loaded texts.

Other Support for the Efficacy of HSS

There are at least two other recent reports that support the use of HSS. In the first investigation, Bakker, Bouma, and Gardien (in press) found that 20 sessions of HSS through the tactile modality (i.e., presenting raised letters, words, and sentences to the left and right hands of L- and P-types respectively) improved to a greater degree the reading performance of both subtypes compared to a control group receiving standard remedial techniques. The improvements found in P-types tended to be more robust than those found in L-types.

In the second study, Spijer, De Jong, and Bakker (1987) investigated the interaction effect of HSS and doses of piracetam on the reading performance of an L-type and a P-type dyslexic. Piracetam is a nootropic drug reported to enhance reading performance and most notably, reading speed. The P-type child showed significant improvements of reading speed and accuracy (in passage reading but not in single-word reading) with piracetam alone, and substantially better performance when tactile HSS was added. In contrast, the L-type dyslexic showed a decrease in reading performance and increased reading speed with piracetam alone. Addition of HSS did not improve the child's performance.

Bakker (1990) has discussed the results of several other studies which contribute to the positive role of HSS in the treatment of dyslexia. However, these studies are unpublished reports, described as limited in their scope, subject number, control measures, and statistical analyses. Given their limitations, these studies will not be discussed here.

Preliminary (Pilot) Replication Study

As a first step to the present research project, a pilot study was conducted to determine the feasibility of conducting a larger-scale study. The study used six reading disabled children who attended the public summer school program in Victoria (Grades 4 or 5). Three children (one L-type and two P-type readers) were given HSS (as specified by Bakker & Vinke, 1985) for 12 sessions (3 times per week for 4 weeks). Three of the children served as controls, and did not receive HSS. Once the study began, one of the controls was removed by his parents from the summer school reading program, but he was allowed to remain in the study. Training sessions involved stimuli consisting of either single words or letters flashed into either the right or left half-field of a computer monitor. The one L-type child received stimuli in the left visual field (in order to stimulate the weaker right hemisphere) while the two P-type children were stimulated in the right visual field (to activate the weaker left hemisphere). All six children underwent pre- and post-testing involving measures of intelligence, oral reading, spelling, arithmetic, and dichotic listening. ERPs from left and right parietal and temporal locations were collected at the Royal Jubilee Hospital (Electrodiagnostic Services) before and after the training period in response to centrally flashed words on a computer screen.

The results from this preliminary study were encouraging. As might be expected, the two controls who attended the summer school reading classes showed improvement in their oral reading skills. The one control who did not attend summer school, however, failed to show any improvements on any of the measures administered. The trained children also showed improvements, but these were of considerably greater magnitude than those of the controls. Furthermore, the improvement in the trained group was particularly evident in areas that were specifically trained (e.g., P-type children made fewer time-consuming errors). In terms of the ERPs in this study, changes in the between-hemispheric differences (from pre- to post-test) in the amplitudes of the parietal P320 component were consistent with Bakker's findings. Specifically, the two trained P-types showed a "leftening" of parietal P320 activity (a relative increase of activity in the left hemisphere as would be expected by the treatment). The one trained L-type also showed "leftening" of activity, but not to as great an extent (about half as much) as one untrained L-type. This finding is also consistent with Bakker's findings that suggest that HSS results in a "leftening" of brain activity in P-types and a preclusion of "leftening" in L-types. The other two control children showed no major changes in their brain hemispheric differences.

Description of Current Research

The Issue of Replication

One important and fundamental, although neglected, component in the process of scientific research is replication (Spreen, Tupper, Risser, Tuokko, & Edgell, 1984). It is essential that all scientific findings, in particularly those pertaining to human health and welfare, be subjected to replication studies (see Rourke & Costa, 1979). It is incumbent upon researchers to replicate their colleagues' work.

Spreen (1978) notes that in the field of learning disabilities, with its large share of contradictory findings, replication and cross-validation are necessary strategies.

Spreen et al. (1984, p. 89) state: "replication is a powerful tester for determining the relevance of an investigation and for weeding out findings that may show significance by pure chance or may have become obsolete". Furthermore, spurious findings, particularly in hemispheric-asymmetry studies, which are not subject to replication attempts, pose barriers to scientific progress (Soper, Cicchetti, Satz, Light, & Orsini, 1988). It is unfortunate, however, that replication studies are not common, perhaps due to the reluctance of reviewers to publish these studies, and similar or even greater reluctance to publish studies attempting replication which find null results (Soper et al., 1988).

The attempt to replicate Bakker's findings is especially necessary in light of (a) the potential clinical significance of the training technique for dyslexic children if indeed the effect is robust, and (b) the inconsistencies in the results of the two studies reported by Bakker. Within the two studies reported by Bakker (1981, 1985), there are differing methodologies and results. For example, his criteria for his classification system is changeable; he used reading speed for the pilot study but not for the main study. In his most recent study employing tactile HSS, criteria for classification of L- and P-types were different again. In this study, type of error (substantive or time-consuming) was the only criterion employed. In terms of changes in schclastic performance for the visual HSS studies, HSS was successful for both L- and P-types in the pilot study, but only for L-types in the main study. In terms of ERP findings, there are also differences between the two studies. In the pilot study, significant BHD changes were found in the temporal electrode location; in the Bakker and Vinke study, significant changes occurred at the parietal electrodes. Correlations of BHD changes with scholastic improvements were significant but weak. Furthermore, in the major study, although it was the trained L-types who improved to the greatest extent, the trained P-types, who did not improve, showed the most substantial electrophysiological changes. Thus, although Bakker's findings suggest a potentially successful remediation approach to dyslexia, the positive training effects he reported are limited and the conclusions based on these results can only be tentative. Given these inconsistencies, a replication of Bakker's findings is highly desirable.

Study Design

Although Bakker's findings are promising, and represent a potentially successful treatment approach to dyslexia, no replication studies of his work have been published. Given the significant practical potential of these findings and their equivocal nature at this time, it is necessary and important for them to be replicated by other independent investigators.

The goal of the present study is to demonstrate the validity of Bakker's treatment model by attempting to replicate some of the findings of Bakker and Vinke (1985). If such independent corroboration results, the findings can be built upon in various ways in future research. If results of this study are consistent with Bakker's findings, further research can be justified that will act to refine and extend this potentially successful treatment approach to dyslexia (e.g., examine the role of treatment variables such as length or number of training sessions on reading improvement). A successful replication may also serve to stimulate research about the remediation of other specific learning disabilities and cognitive disorders.

Encouraged by the pilot results discussed earlier, as well as the potential benefits that such a remediation strategy could provide for dyslexic children, the present study was planned as a more extensive and sophisticated study. A longer HSS training period (18 sessions over a 9-week period) was employed and a greater number of children was used (17 L-types, 9 P-types).

Several of the materials and procedures used in Bakker's research are of Dutch content, and unavailable in Canada. Therefore, certain materials (e.g., tests, computer programs) and procedures (e.g., specific tasks used in training) used by Bakker were modified, added, or omitted in the present study.

However, when possible, every attempt was made to keep tasks as close as possible to the originals. The alterations made are therefore minimal and innocuous to the design; they are intended to improve the study without changing its conceptual intentions. Many of these changes have been discussed personally with and approved by Dr. Bakker.

<u>Hypotheses</u>

The following hypotheses were examined:

1. (a) L-type and P-type disabled readers receiving HSS will show significantly greater improvements on measures of reading and spelling than subjects who do not receive training.

(b) Improvements in reading will be particularly evident in areas that are specifically trained (e.g., L-type readers will show the greatest improvements in substantive errors, and P-type readers will show the greatest improvements in time-consuming errors).

2. L-type and P-type readers who are trained will show a significant change in their between-hemispheric differences in ERP amplitude (from pre- to posttest times). Trained P-types will show a significant "leftening" of brain activity; untrained P-types will show significant "rightening" over time. Trained L-types will show a preclusion of "leftening" activity (i.e., less leftening than would be seen without HSS);

untrained L-types will demonstrate a significant "leftening" process.

3. Significant correlations will be found between BHD changes and reading/spelling improvements.

In addition to the main hypotheses, the present study sought to explore some additional aspects of HSS:

4. On the basis of Bakker's previous results, it was predicted that relative activity between the right and left hemisphere as reflected by ERPs would differ for L- and P-types at the pre-test time. Specifically, L-types should demonstrate a relatively higher degree of activity in the left hemisphere in response to word stimuli. This pattern should favour the right hemisphere in P-type dyslexics.

5. In addition to pre- and post-tests, the present study included an intermediate testing session, half-way through the study. There is some evidence (see Bakker, 1990; Bakker, Bouma, & Gardien, 1989) to suggest that in L- and P-type dyslexics, reading improvement reaches maximal values after only 10 treatment sessions followed by a levelling off. The design of three testing sessions thus allowed for the examination of reading improvement in relation to session number.

6. Another interesting issue concerns the reliability or stability of Bakker's classification system of L- and P-type dyslexia. Therefore, another aim of this study was to

determine whether or not classification of subjects remained stable at the end of the study for the control group not receiving treatment.

7. Little is known about the child's subjective feelings about being subjected to HSS. The practical value of the technique may be based partly on a favourable reaction from dyslexic children. Therefore, at post-test time, all subjects were asked to rate the treatment on a five-point scale ranging from high like to strong dislike. The subjects' comments about the treatment were recorded as well.

CHAPTER TWO

Methodology

Subjects

The present study involved reading-disabled children attending grades 2 to 7 at two primary schools in Victoria, British Columbia (Oaklands School, Gorden Head School; School District no. 61). Subjects were initially selected for screening on the basis of their teachers' report that the students' primary difficulty was with reading. Letters explaining the purpose of the study, the methods involved, and its voluntary and confidential nature were given to the selected children to take home to their parents. In this letter, parents were informed that if their child met the criteria for the project, he or she would have a 50 percent chance for inclusion into the training group. Parents interested in allowing their child to participate in the study signed a consent form attached to the informing letter. A total of 35 consent forms were returned, resulting in 36 potential subjects (two children were identical twins). A copy of the letter and consent form is provided in Appendix A. At the end of the study, parents of all subjects received a neuropsychological report describing results of their child's performance on the pre- and post-testing sessions. Appendix B contains a sample feedback report.

Subject Screening and Pre-testing

All 36 subjects were administered a number of psychometric measures to (a) provide screening criteria to ensure that subjects met the definition of dyslexia; (b) provide a means for classification into L- and P-types; and (c) provide baseline measures on which to later evaluate treatment effects. All tests were administered in the schools by one examiner over a two-week period. Administration time for each child was approximately 90 minutes.

The tests administered were:

1) Wechsler Intelligence Scale for Children - Revised (WISC-R; Wechsler, 1974). The WISC-R was administered in the standardized fashion to ascertain the psychometric intellectual status of each subject.

2) Wide Range Achievement Test - Revised (WRAT-R; Jastak & Wilkinson, 1984); Reading and Spelling Subtests. The WRAT-R reading subtest requires the recognition (oral reading) of progressively more difficult words. The spelling subtest requires writing to dictation of progressively more difficult words.

3) Gilmore Oral Reading Test (GORT; Gilmore & Gilmore, 1968). This test required subjects to read aloud several paragraphs of increasing difficulty. Subjects were asked to read each paragraph as carefully as possible. They were not

informed that their responses were being timed so that they were free to exhibit their natural preferred style and speed of reading. The number of paragraphs read by each subject depended on their reading proficiency. The basal (easiest) paragraph was one in which two or fewer errors were made. The ceiling (most difficult) paragraph was one in which ten or more errors were made. After each paragraph, questions regarding the content of the paragraph were asked to assess comprehension. Responses were audio-taped to allow for later measurement of reading speed and for careful analysis of substantive and time-consuming errors.

Because the number of paragraphs read by each subject varied according to reading level, substantive and time-consuming errors were tallied across all paragraphs (basal to ceiling) and expressed as a percentage of total words read. At post-testing, the same paragraphs were used for scoring of reading errors for ease of comparison with pre-testing time even though a subject may have progressed to a more difficult ceiling paragraph at post-testing time.

4) Dichotic Listening Test (DLT; Spellacy, Graves, & Allison, 1985; 22 trials; 3 word pairs/trial; one pair/sec; intensity 70 dB; free recall). This test consists of 22 trials, each consisting of three pairs of words, each pair presented simultaneously to the right and left ears via headphones. Each trial was followed by an intertrial interval

of 12 seconds to allow for free recall of the words. Subjects were asked to listen carefully and repeat as many words as they could remember from both ears. Prior to the test, a screening test consisting of 10 words was presented to the right ear alone and then to the left ear alone to ensure adequate word discrimination and auditory acuity. The tape was presented by means of a Toshiba AM FM Stereo radio cassette recorder (model RT-SX1) and Koss Professional KO-727B stereophones. Sound was calibrated by a sound level meter through calibration tones on the tape to a volume of 70 dB and balanced for each headphone channel. As an extra precaution against possible intensity differences between channels, the position of the headphones were reversed half way through the test. Channel separation on the tape-deck was measured to be 32 dB.

Determination of ear advantage on the DLT is a controversial issue due to the confounding contribution of attentional factors inherent in the task. Clark (1981) discussed various methods of calculating ear advantage, including methods which are thought to measure ear advantage independent of accuracy and attention. In line with Clark's discussion, the present study used the following procedure to reduce the contamination of attentional factors in the determination of ear advantage.

Ear advantage (i.e., ear with the most efficient perception of words) was calculated by labelling each of the 22 trials as either right-ear trials (i.e., more right-ear words were recalled than left-ear words) or as left- or neither-ear trials (i.e., more left-ear words were recalled than right-ear words, or the number of words recalled was equal for right and left ears). If the number of right-ear trials exceeded the number of left- plus neither-ear trials, a subject was considered to have right-ear advantage. Alternatively, if the number of left- plus neither-ear trials exceeded the number of right-ear trials, the subject was considered to have left-ear or lack of ear advantage.

<u>Subject Selection</u>

Prior to classification into L- or P-type readers, subjects were required to meet the following criteria for dyslexia. These criteria are consistent with those specified by Bakker and Vinke (1985).

1) Overall psychometric intelligence was within the average range (e.g., Full-scale IQ on the WISC-R was between 80 and 120. Although the average IQ in other Victoria normative data is higher (X = 105, SD = 15), the cut-off of 80 was used for comparability to Bakker's studies.

2) Reading level was at least one grade level below current grade level as measured by either or both WRAT-R Reading and GORT Reading.

3) Children with a significant defect in audition or vision, with behavioural or emotional disorders, or with hyperactivity were not included in the study. Parents and/or teachers were questioned about the existence of these factors prior to the treatment phase.

4) Although not specifically examined for, it was deemed unlikely that the reading difficulty of any subject was due to environmental factors such as cultural deprivation or poor school instruction.

Twenty-six subjects met these screening criteria. Ten subjects were excluded for the following reasons: full-scale IQ less than 80 (N=5), reading scores too high (N=3), family moved out of town (N=1), and visual and auditory difficulties (N=1). Qualifying subjects were classified into L- and P-type categories on the basis of Bakker's specific subtype criteria based upon his balance model of dyslexia outlined in Bakker et al., (1981). Classification was based on three factors: ear advantage, type of reading errors, and speed of reading.

1) Ear Advantage on DLT Subjects were classified as L-type if a right-ear advantage on the DLT was demonstrated. P-types demonstrated either a left-ear or lack of ear advantage.

2) Type of Reading Errors Substantive errors are considered to be any type of word-mutilating error. These errors include omissions, additions, reversals, and substitutions. Time-consuming errors are initial errors which

are immediately self-corrected, resulting in an ultimately correct response. These include fragmentations, stutterings, corrections, and repetitions. The mean percentage of substantive and time-consuming errors relative to total errors for all dyslexic readers in the study was computed (substantive errors - 61%; time-consuming errors - 39%). L-type readers were expected to make more than the mean percentage of substantive errors and less than the mean percentage of time-consuming errors. Conversely, P-type readers were expected to make more than the mean percentage of time-consuming errors and less than the mean percentage of substantive errors.

3) Speed of Reading Reading speed (words/minute) was calculated from all paragraphs on the GORT except the ceiling paragraph. Each subject received a rating of slow, average, or fast based upon grade-related norms. L-type subjects were expected to show a reading speed of average or above-average. P-types were expected to demonstrate a below-average reading speed.

The specific classification procedure integrating these three criteria was as follows: Subjects were classified as L-type if they exhibited REA and demonstrated average or fast reading speed and/or a greater percentage of substantive errors than the grand mean across all subjects. P-types were classified as such if they exhibited LEA or lack of ear advantage and demonstrated below-average reading speed and/or a greater percentage of time-consuming errors than the grand mean.

Using this three-factor classification system, 22 of the 26 operationally-defined dyslexic children were easily classified as either L- or P-type. In light of the rather small number of subjects, the remaining 4 subjects were classified on the basis of 2 out of 3 criteria best fitting an L-type or P-type profile. The procedure resulted in 17 subjects classified as L-types and nine subjects classified as P-types.

In order to minimize between group differences in reading level, age, and sex, a matched-groups design was employed. Within each subtype and each school, subjects were matched hierarchically according to reading level, chronological age, and sex. Following matching, subjects were randomly assigned to experimental or control groups. This resulted in the following four groups: L-type experimental (L1, N=8); L-type control (L2, N=9); P-type experimental (P1, N=5); P-type control (P2, N=4).

<u>Event-Related Potentials (ERPs)</u>

Parents of all subjects were requested to bring their children to the Royal Jubilee Hospital (Electrodiagnostic Services) for ERP recording. The ERP procedure was carried out twice for all subjects, once prior to and once following the treatment phase of the study. One P-type (P2) subject did not show for post-test ERP recording and therefore was not included in the statistical analysis of the ERP data.

ERPs were elicited in response to 60 four-letter words flashed for 500 ms each at the center of a computer screen connected to an Apple II Plus microcomputer. The words were chosen from a list of words described by Paivio, Yuille, and Madigan (1968) and varied in concreteness rating from concrete to abstract according to Paivio et al. with concreteness values between 1.18 and 7.00 represented. Word frequency was higher than 32 in one million words with the majority being A (50 in one million words) or AA (100 in one million words) words according to Thorndike and Lorge (1944). Words were also varied according to initial letter such that most letters were equally represented. Appendix C presents the word list used with corresponding frequencies and concreteness values for each word.

The ERPs were recorded in a quiet room designed for that purpose. Lighting conditions were kept constant for all subjects within and between sessions. During the ERP recordings, subjects were seated in a comfortable semi-reclining chair and were asked to relax as much as possible as they read aloud each flashed word. The number of identification errors were recorded and used as an additional measure of word-reading ability (Flashed Word Test, FWT).

The subjects' distance from the monitor was approximately 90 cm (from eyes to monitor) and the height of the words was approximately 1.3 cm. This resulted in an eye-level presentation at an angle of 1.9 to 2.7 degrees horizontally and 0.76 to 0.95 degrees vertically as calculated by a trigonometric formula (Rice & Dorsett, 1969).

Scalp electrodes (Grass gold discs) were positioned at right and left temporal (T5 and T6) and parietal locations (P3 and P4) according to the international 10-20 system of electrode placement (Silverman, 1973; see Figure 2). ERP waveforms reflect voltage differences between the recording electrodes (T5, T6, P3, P4) and the reference electrode. In the present study, the active leads were referenced to linked mastoids (a neutral reference point) and a ground connection was positioned at the vertex (CZ). Impedance was checked prior to recording and was maintained below 5 Kohm in all except 3 cases with impedance less than 10 Kohm. The author was fully trained and supervised in the application of electrodes and ERP procedures by the EEG technician at the Royal Jubilee Hospital.

Each ERP waveform was recorded during a 2000 ms epoch. ERP recording commenced 500 ms prior to word presentation (baseline) and continued for 1500 ms after word presentation. Subjects were asked to fixate upon a small white square (1000 ms duration) presented in the center of the monitor along with a tone (1000 Hz, 70 dB, 100 ms). Each word was flashed for 500

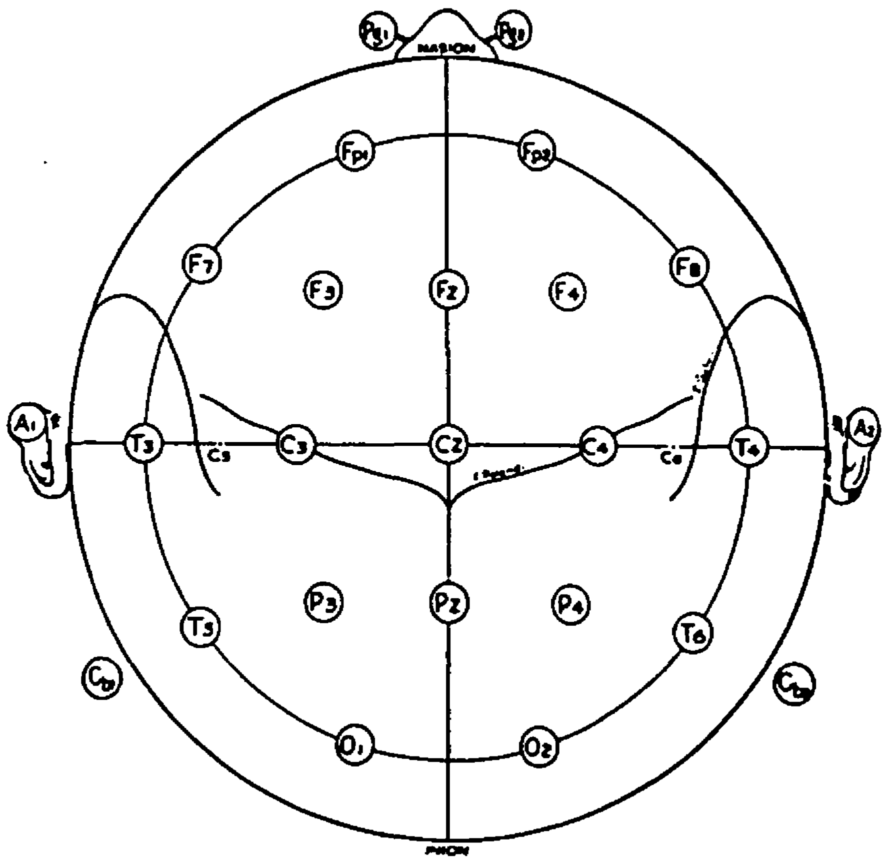

Figure 2. Electrode placement in the International 10-20 System (from Silverman, 1973)

ms. The words were presented white on a dark background. Figure 3 illustrates the sequence of recording events described above.

In order to enhance the reliability of the final ERP, the 60 words were presented twice with a short rest in between presentations. The 120 individual waveforms were amplified and averaged on-line by a Cadwell 7400 evoked potential instrument. The computer rejected single trials in which large amplitude potentials occurred such as would be generated by eye blinks or other movement artifacts. After averaging, ERPs were smoothed by a digital filter and stored on disk for later analysis. Figure 4 presents a sample pre- and post-test ERP.

ERP Analysis

The analysis epoch was the first 750 ms following stimulus onset. Amplitude of the waveform was measured by the computer at 30 intervals of 25 ms beginning at stimulus onset and ending at 750 ms after stimulus onset. Amplitude was measured relative to the average EEG of each ERP during the 500 ms pre-stimulus baseline.

Hemisphere-Specific Stimulation (HSS)

L-type and P-type subjects in the training groups received 18 sessions of HSS twice weekly over a 9-week period. Sessions took place in a quiet room within each school for approximately

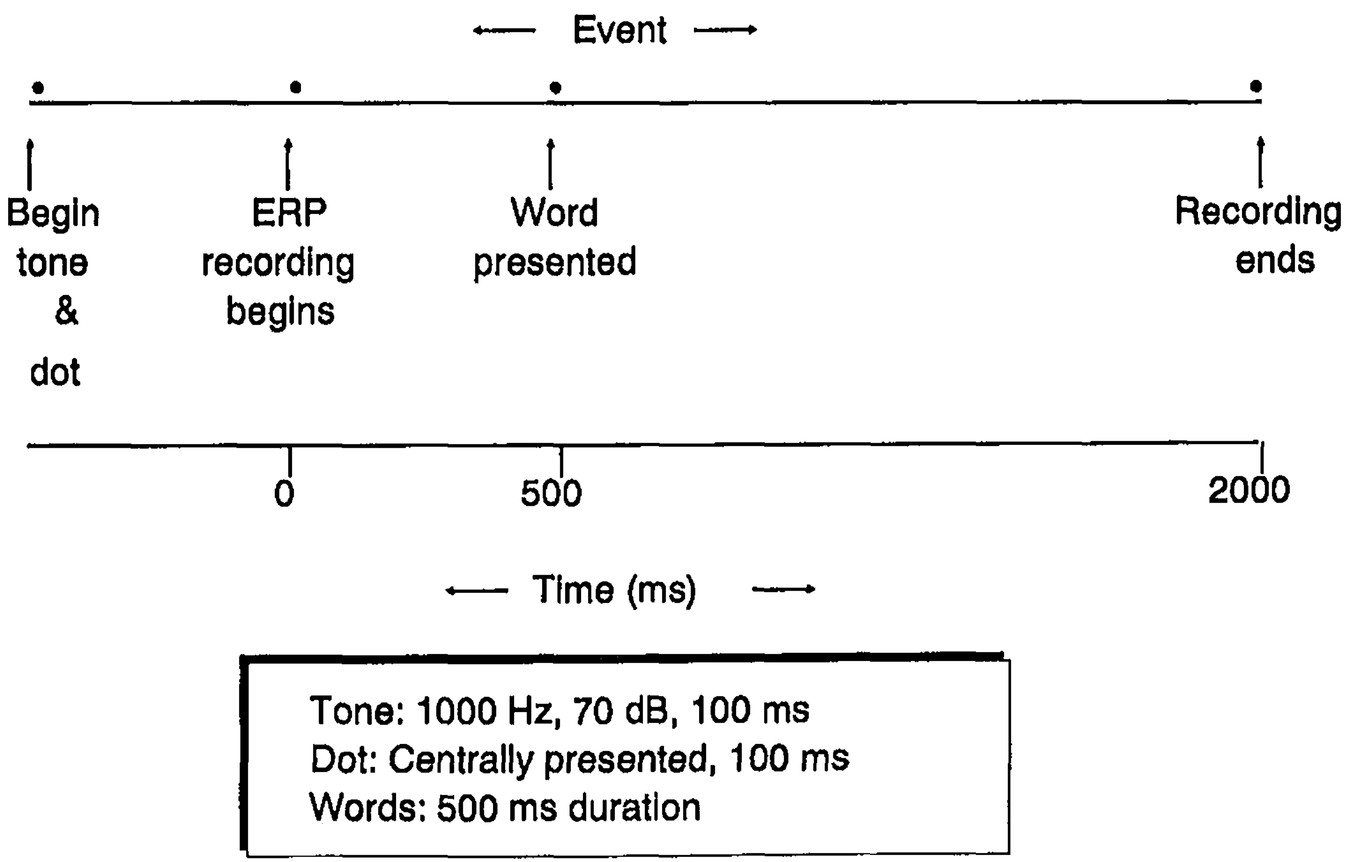

Figure 3. Schematic representation of an ERP word trial

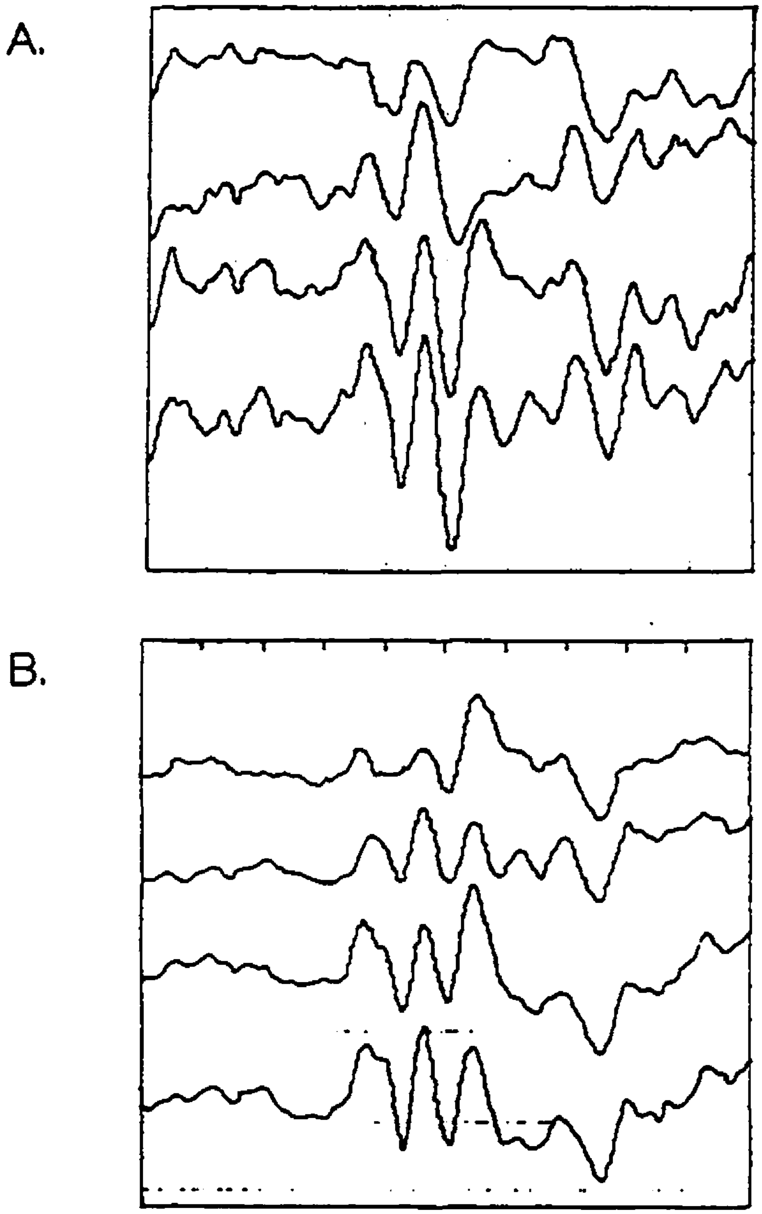

Figure 4. Sample ERPs averaged over 60 trials
in a P2 subject

A. Pre-test session
B. Post-test session

45 minutes each. For approximately 5 minutes at the end of each session, subjects were allowed to play a video game. Subjects were scheduled at times convenient for the teachers. If a subject was unable to attend a training session due to illness or other circumstances, a make-up session was scheduled. Of the 13 children who received HSS, 12 completed all 18 sessions. One subject received 17 sessions. L- and P-type control subjects remained in their classrooms during the HSS sessions. In addition to HSS received by the experimental groups, all subjects received specific attention for their reading disability in the schools.

The rationale of HSS is based upon the unique organization of the visual system in the brain. Within this system, the fibers from the nasal half of the retina decussate at the optic chiasma and join the temporal fibers from the other eye at this point. Both sets of fibers then project to the primary visual area in the striate cortex of the hemisphere contralateral to the eye of the nasal fibers. This organization results in a selective presentation to either the right or left hemisphere when stimuli are selectively presented to the left or right visual hemifield respectively (see Bakker, 1979). Figure 5 depicts schematically this organization.

HSS involved the flashing of either single letters or words presented onto either the right or left half-field of a computer monitor connected to an Apple II Plus computer.

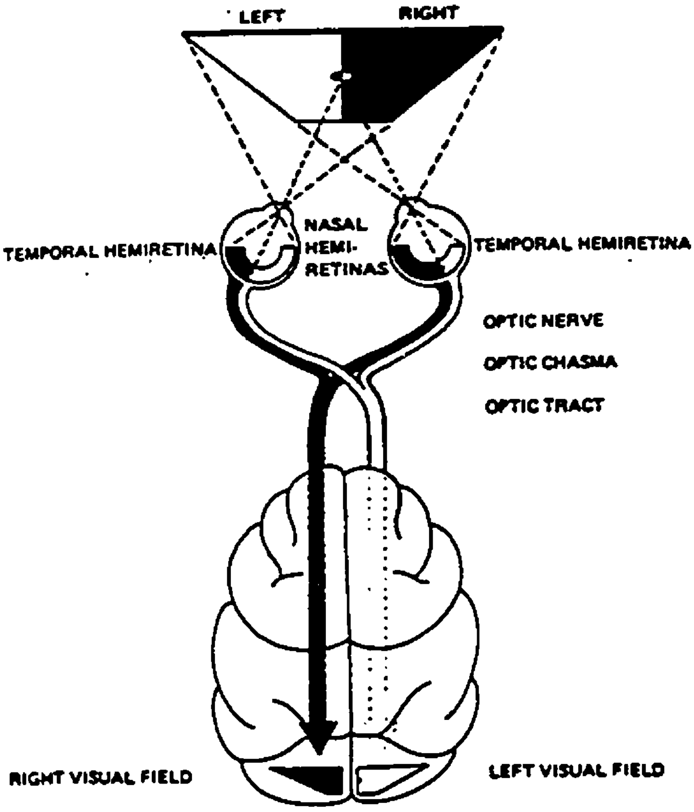

Figure 5. Organization of the visual system illustrating the crossed relation between visual fields and cerebral hemispheres (from Gazzaniga & LeDoux, 1978)

Concrete and abstract words were chosen to maximize appeal for right and left hemispheric processing of L- and P-types respectively (Bakker, 1990; Ellis & Sheperd, 1974). Sessions were organized into blocks of 20 single- or dual-word presentations. Words varied in length (one to five letters) and in degree of difficulty according to the frequency of the word in the English language (20 to greater than 100 occurences per million words; Thorndike & Lorge, 1944). Word length and frequency remained constant within blocks. The subject's progress determined the number of blocks presented during one session (minimum of three, maximum of five).

Task complexity was further varied by adjusting the duration of word presentation, which varied from 20 to 300 ms depending on the subject's progress. Initial word presentations commenced at 300 ms. If less than two mistakes were made in the block of 20 words, the latency time was shortened to the next interval for the next block. Lengthening occured when 10 or more errors were made during the presentation of a single block. Intervals were fixed at: 20, 30, 40, 50, 75, 100, 150, 200, 250, and 300 ms. In the case of a incorrect response, the word was re-flashed until it could be identified. At no time did the presentation time exceed the eye movement latency, which has been measured as approximately 300 ms (Bakker, Moerland, & Goekoop-Hoetkens, 1981). Subjects were seated approximately 90 cm away from the computer monitor, such that laterally presented words were perceived at an angle of 2.5 to 5.5 degrees horizontally and 0.76 to 0.95 degrees vertically.

Fixation was controlled by two methods. With each lateral presentation, subjects were asked to first identify a central digit (P-types) or figure (L-types) flashed simultaneously with the words or letters. L-types subjects were asked to point to the central figure on a cardboard response board in front of them. There were five figures to choose from, each of which was difficult to verbalize (see Figure 6). P-types' central stimulus consisted of the random presentation of the numbers 1 to 5, of which each subject was asked to verbalize. The second control for fixation involved the random presentation of a plus sign ("+") in the "empty" visual field (e.g., right visual field in L-types; left visual field in P-types). Thus with each presentation, subjects were trained to report (a) the central digit or figure; (b) the presence or absence of a lateralized "+"; and (c) the lateralized word(s) or letter. Trials were repeated if subjects did not accurately report the fixation stimuli.

L-type subjects received letters and concrete words in the left visual field (to stimulate the right hemisphere) presented either singly or in pairs (one word above the other). In the case of single-word trials, subjects were required to read words aloud. In dual-word presentations, subjects were asked

& % # * (

Figure 6. Symbols used in central fixation control technique for L-type dyslexics

to indicate whether or not the words were identical. Six different typefaces (e.g., Block, Western, Stencil, Compute, Outline, and Squareball; see Figure 7 for an illustration of similar fonts) were utilized as a means of varying the perceptual complexity of the task. The type of task (i.e., reading or discrimination) and typeface were constant within blocks.

P-type subjects received letters and abstract words in the right visual field (to stimulate the left hemisphere). Typeface was perceptually simple (i.e., uppercase roman lettering) and remained constant throughout training. Subjects were required to read aloud each stimulus as well as perform additional tasks specifically designed to improve phonetic analysis: a) forward or backward spelling; b) identification of the sequential position of a letter in a word; c) indication of whether or not a particular letter was in a word; d) generation of words that rhyme with the stimulus word; and e) generation of words that start with, end with, or contain the stimulus letter or word.

A computer program designed to perform the above functions was utilized. A word base of 400 words (20 blocks) suitable for P-type readers and 480 words (15 single word blocks, 9 dual-word blocks) for L-types was available. These words were derived from the word lists of Thorndike and Lorge (1944). The word lists used in training are presented in their order of

HIGHER TEXT-L

BLOCK-L

old english-kl

SHADED-L

THREE-D-L

Figure 7. Typefaces similar to the ones used in the present study for HSS of L-type dyslexics (from Bakker, 1990)

presentation in Appendix D. Tables 1 and 2 illustrate the content of a typical schedule of training sessions for L-types (Table 1) and P-types (Table 2).

Two trainers were necessary for the training of 13 subjects twice weekly at the two schools. Each trainer remained at one school and carried out all 18 sessions on their designated subjects.

Intermediate and Post-testing

After 9 sessions (half-way through training), all subjects received the GORT and WRAT-R Reading and Spelling tests to assess any early effects of treatment. All tests administered for pre-testing (with the exception of the WISC-R) were re-administered after the HSS training period. Similarily, electrophysiological brain changes were assessed with another ERP recording session at the Royal Jubilee Hospital.

Subjects' Rating of HSS

If the remedial method of HSS is to be used on a regular basis with reading-disabled children, it is important that the children find the method agreeable and interesting. In an attempt to investigate this issue, all trained subjects (N=13) were asked to rate the training method at the end of the study and to provide comments about the method. They were presented with a Likert-type scale (1 to 5; 1 representing boredom and

Table 1

Typical 18-Session Training Schedule for
an L-type Dsylexic *

Session	Set	# of Letters	Word Frequency	Font	Task
1	1S	1	-	0	N
1	2S	2	AA	0	N
1	3S	3	AA	0	N
2	2S	2	AA	0	N
2	3S	3	AA	0	N
2	4S	3	A	0	N
2	5S	3	20-49	0	N
3	2S	2	AA	2	N
3	3S	3	AA	2	N
3	4S	3	A	2	N
3	5S	3	20-49	2	N
4	1D	2	A-AA	0	D
4	2D	3	A-AA	0	D
4	3D	3	A-AA	0	D
5	4S	3	A	1	N
5	5S	3	20-49	1	N
5	6S	4	AA	1	N
5	7S	4	A-AA	1	N
6	2D	3	A-AA	2	D
6	3D	3	A-AA	2	D
6	4D	3	A-AA	2	D
6	5D	3	A-AA	2	D
7	6S	4	AA	5	N
7	7S	4	A-AA	5	N
7	8S	4	A	5	N
7	9S	4	20-49	5	N
8	2D	3	A-AA	1	D
8	3D	3	A-AA	1	D
8	4D	3	A-AA	1	D
8	5D	3	A-AA	1	D

Table 1 (Continued)

Session	Set	# of Letters	Word Frequency	Font	Task
9	7S	4	A-AA	3	N
9	8S	4	A	3	N
9	9S	4	20-49	3	N
9	10S	4	20-49	3	N
10	6D	4	A-AA	0	D
10	7D	4	A-AA	0	D
10	8D	4	A-AA	0	D
10	9D	4	A-AA	0	D
11	9S	4	20-49	4	N
11	10S	4	20-49	4	N
11	11S	4	< 50	4	N
11	12S	4	< 50	4	N
12	6D	4	A-AA	5	D
12	7D	4	A-AA	5	D
12	8D	4	A-AA	5	D
12	9D	4	A-AA	5	D
13	8S	4	A	2	N
13	9S	4	20-49	2	N
13	10S	4	20-49	2	N
13	11S	4	< 50	2	N
14	4D	3	A-AA	4	D
14	5D	3	A-AA	4	D
14	6D	4	A-AA	4	D
14	7D	4	A-AA	4	D
15	10S	4	20-49	1	N
15	11S	4	< 50	1	N
15	12S	4	< 50	1	N
15	13S	4	< 50	1	N
16	12S	4	< 50	5	N
16	13S	4	< 50	5	N
16	14S	5	A-AA	5	N
16	15S	5	A-AA	5	N

Table 1 (Continued)

Session	Set	# of Letters	Word Frequency	Font	Task
17	4D	3	A-AA	2	D
17	5D	3	A-AA	2	D
17	6D	4	A-AA	2	D
17	7D	4	A-AA	2	D
18	12S	4	< 50	3	N
18	13S	4	< 50	3	N
18	14S	5	A-AA	3	N
18	15S	5	A-AA	3	N

* All words used for L-types were chosen to have concrete meanings.

Set

S = Single word set
D = Double word set

Task

N = Naming
D = Discrimination (same or different)

Word Frequency
(as per Thorndike & Lorge, 1944)

AA = over 100 occurences per million words
A = over 50 occurences per million words
20-49 = 20-49 occurences per million words
< 50 = < 50 occurences per million words

Font

0 = Block
1 = Stencil
2 = Western
3 = Compute
4 = Outline
5 = Squareball

Table 2

Typical 18-Session Training Schedule for
a P-type Dsylexic *

Session	Set	# of Letters	Word Frequency	Task
1	1	1	-	WF
1	2	2	AA	FS, BS
1	3	3	AA	FS, BS
2	2	2	AA	FS, BS
2	3	3	AA	FS, BS
2	4	3	AA	FS, BS
2	5	3	AA	FS, BS
3	2	2	AA	WR
3	3	3	AA	WR
3	4	3	AA	WR
3	5	3	AA	WR
4	5	3	AA	FS, BS
4	6	3	35-A	FS, BS
4	7	3	35-AA	FS, BS
4	8	3	A	FS, BS
5	5	3	AA	SP, WR
5	6	3	35-A	SP, WR
5	7	3	35-AA	SP, WR
5	8	3	A	SP, WR
6	7	3	35-AA	FS, BS
6	8	3	A	FS, BS
6	9	4	AA	FS, BS
6	10	4	AA	FS, BS
7	3	3	AA	WF
7	5	3	AA	WF
7	6	3	35-A	WR
7	8	3	A	WR
8	9	4	AA	SP, WR
8	10	4	AA	SP, WR
8	11	4	AA	FS, BS
8	12	4	AA	FS, BS

Table 2 (Continued)

Session	Set	# of Letters	Word Frequency	Task
9	11	4	AA	SP, WR
9	12	4	AA	SP, WR
9	13	4	AA	FS, BS
9	14	4	AA	FS, BS
10	13	4	AA	SP, WR
10	14	4	AA	SP, WR
10	15	4	A-AA	FS, BS
10	16	4	25-AA	FS, BS
11	9	4	AA	BS, WR
11	10	4	AA	BS, WR
11	11	4	AA	BS, WR
11	12	4	AA	BS, WR
12	5	3	AA	WF
12	6	3	35-A	WF
12	7	3	35-AA	WF
12	8	3	A	WF
13	14	4	AA	SP, WR
13	15	4	A-AA	SP, WR
13	16	4	25-AA	SP, WR
13	17	4	A	FS, BS
14	15	4	A-AA	FS, BS
14	16	4	25-AA	FS, BS
14	17	4	A	SP, WR
14	18	5	AA	FS, BS
15	16	4	25-AA	SP, WR
15	17	4	A	FS, BS
15	18	5	AA	SP, WR
15	19	5	A	FS, BS
16	17	4	A	SP, WR
16	18	5	AA	FS, BS
16	19	5	A	SP, WR
16	20	5	20-A	FS, BS

Table 2 (Continued)

Session	Set	# of Letters	Word Frequency	Task
17	10	4	AA	WR
17	12	4	AA	WR
17	14	4	AA	WR
17	16	4	25-AA	WR
18	17	4	A	FS, BS
18	18	5	AA	SP, WR
18	19	5	A	FS, BS
18	20	5	20-A	SP, WR

* All P-types received abstract words always presented in a regular font (e.g., block).

Word Frequency
(as per Thorndike & Lorge, 1944)

AA = over 100 occurences per million words
A = over 50 occurences per million words
35 = 35 occurences per million words

Task

FS = Forward Spelling
BS = Backward Spelling
SP = Sequential position of letter in word
WF = Word finding, ie., subject asked to produce a word that begins, contains, or ends with the stimulus letter or word
WR = Subject produces a rhyming word in response to stimulus

dislike, and 5 representing high interest and extreme like) and asked to provide a comment about HSS (e.g., Each subject was asked, "What did you think of this method to help you learn to read?").

Design and Statistical Analysis

L- and P-type readers were subjected to separate analyses in this study due to the difference between the groups in nature of reading disturbance and type of treatment.

Due to the high degree of variability between subjects and the small numbers of subjects combined with the relatively large number of dependent variables (8), multivariate analysis of variance (MANOVA) was not considered appropriate for the analysis of differences between groups. Therefore, the univariate tests were considered directly. Despite the use of multiple t-tests, the alpha level was controlled to the extent that planned a priori comparisons were made (Pagano, 1986). In order to easily compare changes over time with different variables and to control for covariance, all original scores (both academic and ERP) were transformed into standardized z-scores. The original academic scores were composed of standard scores (corrected for age; WRAT-R Reading, Spelling), raw scores (all Gort scores, FWT), and percentage scores (SE, TCE). Prior to z-score transformation, trend analysis was carried out on the raw scores to assess general effects over time.

For the academic data, z-score transformation was performed over groups (experimental and control) and within subtypes (L and P) and testing session (pre, mid, and post). Within-group analyses involving paired t-tests (one-tailed) were done to determine significant changes over time (from pre- to mid-test or from pre-to post-test) within each group (L1, L2, P1, P2). Two sets of academic difference scores were then calculated using the z-scores: (a) pre-test scores were subtracted from mid-test scores; and (b) pre-test scores were subtracted from post-test scores. Planned a priori between-group comparisons (t-tests, one-tailed) between experimental (L1, P1) and control (L2, P2) groups were carried out on the two sets of difference z-scores.

Analysis of the ERPs began with principle components analysis (PCA; SPSS-Inc., 1988) to mathematically identify the reliably different components of the overall ERP waveform. ERPS were recorded from 25 subjects twice (pre and post) at four electrode locations (P3, P4, T5, T6). This resulted in 200 individual ERPS which were each sampled at 30 time intervals of 25 ms each beginning at stimulus onset. Thus, the PCA involved a 6000 (30 x 200) data matrix.

After components were generated, component scores, representing individual subject scores on each component, were used in subsequent analyses. As with the academic data, the ERP component scores were transformed into standard z-scores.

This was done over groups (experimental and control) and within types (L and P), sessions (pre and post), hemispheres (right and left), and locations (parietal and temporal). In order to investigate hemispheric changes in amplitude within subjects, sessions, and locations, between hemispheric differences (BHD) in amplitude were calculted by subtracting each subject's left hemisphere score from the right hemisphere score. Changes in BHDs over time (pre to post) were then analyzed within electrode locations by subtracting pre-test from post-test BHDs (see Figure 8).

For each identified component, a priori within-group comparisons (paired t-tests, one-tailed) were done on the BHD scores to determine significant changes over time (pre to post) for each group (L1, L2, P1, P2). To investigate between-group differences (experimental vs control), planned a priori comparisons (t-tests, one-tailed) between BHD changes in experimental and control groups were carried out for each identified component.

All statistics were calculated through the use of the SPSS-X statistical analysis system (SPSS-Inc, 1988).

Differences in Method from Bakker & Vinke (1985)

In general, the methodology of the present study was highly comparable with that of Bakker and Vinke (1985). The following issues represent some minor differences between the

PRE-TEST

LH	RH	
5 uV	10 uV	BHD (pre) = RH - LH
		= 10 - 5
		= 5

POST-TEST

LH	RH	
6 uV	15 uV	BHD (post) = RH - LH
		= 15 - 6
		= 9

BHD change = Post BHD - Pre BHD
= 9 - 5
= +4 (RIGHTENING)

Figure 8. Sample calculation of BHDs and BHD changes in electrophysiological activity

present study and those described by Bakker and colleagues (e.g., Bakker, Moerland, & Goekoop-Hoetkens, 1981; Bakker & Vinke, 1985).

1) Dichotic stimulation used in Bakker's studies consisted of digits, presented in 4 pairs per trial. The use of words in the present study should not have produced a difference in the identification of ear advantage since both words and digits are verbal in nature.

2) The fixation procedure used was the same as Bakker et al. (1981) except for an additional control (i.e., random flashing of a plus sign in the "empty" visual field). The fixation control of Bakker & Vinke (1985) was more complex. Subjects were asked to respond manually as quickly as possible to a dot flashed centrally at the point of fixation. The response triggered the flashing of a word in the suitable visual field. In addition, the random asterisks procedure was employed.

3) In addition to the supplemental training tasks described for P-types in Bakker's articles (e.g., forward and backward spelling), P-types were also given rhyming tasks in the present study.

4) Maximum word length was with five-letters as opposed to four-letter words in Bakker's work. Longer words were included because pilot work revealed that four-letter words were not challenging enough for the older subjects.

5) Bakker's studies involved the use of earphones during HSS. For P-types, the voice of the subject and trainer was fed into the right ear, and classical music played into the left ear. This was reversed for L-type subjects. This procedure was considered difficult to employ in the present study. Bakker (personal communication) agreed that this procedure is not vital to HSS.

6) Bakker and Vinke required L-types to respond manually to indicate similarity or difference in the dual-word presentations. The present study differed in the use of a verbal response.

7) Bakker and Vinke monitored eye movements during ERP recording through the use of electro-oculogram (EOG). Trials with eye blinks or large eye movements were eliminated in this way. While the current study did not use EOG, a control for movement artifact was programmed into the ERP instrument such that unusual waveforms were eliminated from the averaging procedure.

8) The present study used the average of two 60-word trials to attain a more reliable waveform. Bakker apparently used only one trial of 60 words.

9) This study used T5 and T6 electrode locations rather than T3 and T4 locations used by Bakker. This was done primarily because Bakker & Vinke did not find significant differences with temporal electrodes. In addition, there is

evidence that the ERP recorded from T3 and T4 is relatively weak due to an artifactual cancelling out effect. Finally, T3 and T4 are thought to measure activity from the Sylvian Fissure and Hechl's gyrus whereas T5 and T6 appear to measure activity from the angular gyrus, the area of the brain thought to subserve some of the higher cognitive aspects of reading abilities.

10) The current study analyzed 30 time points of 25 ms on the averaged ERP covering a 750 ms epoch of time. This is in contrast to Bakker's analysis of 50 time points of 20 ms over a 1000 ms epoch of time.

CHAPTER THREE

Results

Pre-test Group Differences

Table 3 lists the group (L1, L2, P1, P2) means, grand means, and standard deviations of several pre-test subject variables. The mean age across subjects was 131.9 months (*SD*: 13.3, Range: 99-155). Mean full-scale IQ was 102.1 (*SD*: 9.3, Range: 81-118). Due to the ordinal nature of grade scores, descriptive statistics on the grade-level variables of grade placement, reading accuracy (GORT), paragraph comprehension (GORT), word recognition (WRAT-R) and spelling (WRAT-R) were not calculated. However, Appendix E lists the grade scores for each subject on these variables. Most subjects (N=22) were at least 2 years below current grade placement on either Wrat-R Reading or Gort Accuracy. The remaining subjects (N=4) were at least one year below current grade placement.

Student's t-tests (for interval data in Table 3) were carried out to determine any significant differences in the pre-test variables between experimental and control groups within L- and P-types. No significant differences (p > .05) were found for any variable.

In terms of ERPs, Bakker (1986, 1990) reported that L-type and P-type readers demonstrate relatively more electrical

Table 3

Pre-test Group Characteristics
[Means ($\bar{X}$) and Standard Deviations (SD)]

Variable Mean		Group L1	L2	P1	P2	Overall
Gender/N		6M/2F	6M/3F	3M/2F	2M/2F	17M/9F
Chronological	$\bar{X}$	136.4	131.2	126.2	131.5	131.9
Age (Months)	SD	6.0	14.0	18.8	17.2	13.3
Full-Scale	$\bar{X}$	100.9	104.2	103.0	98.5	102.1
IQ	SD	7.8	12.5	6.4	8.3	9.3
Verbal IQ	$\bar{X}$	95.3	98.2	101.2	93.8	97.2
	SD	6.4	10.2	9.5	9.7	8.8
Performance	$\bar{X}$	108.1	109.9	105.6	104.0	107.6
IQ	SD	12.3	16.7	15.1	5.4	13.3
WRAT reading	$\bar{X}$	75.1	80.1	76.2	73.8	76.8
(Stand. Score)	SD	6.6	9.0	9.4	9.1	8.3
WRAT Spelling	$\bar{X}$	77.0	80.1	75.4	73.0	77.2
(Stand. Score)	SD	5.2	8.4	6.8	5.5	6.9
GORT Reading	$\bar{X}$	25.9	24.0	20.4	19.8	23.2
Accuracy (Raw Score)	SD	4.8	8.6	10.6	9.0	8.0
GORT Paragraph	$\bar{X}$	22.4	23.2	23.6	22.3	22.9
Comprehension (Raw Score)	SD	4.3	5.1	10.3	2.1	5.6
GORT Paragraph	$\bar{X}$	98.3	97.3	88.8	82.5	93.7
Reading Speed (Words/min.)	SD	19.0	33.6	17.7	22.7	24.7

Table 3 (Continued)

Variable Mean		Group L1	L2	P1	P2	Overall
Dichotic Listening++	$\bar{X}$	15/4/3	14/4/4	8/8/6	12/4/6	
% Substantive Errors* (Total words)	$\bar{X}$	8.9	8.6	8.6	6.3	8.3
	SD	2.4	4.6	3.2	3.2	3.5
% Substantive Errors** (Total Errors)	$\bar{X}$	70.8	62.7	59.4	39.0	61.0
	SD	15.2	22.2	7.5	14.0	19.1
% Time-Consum. Errors*** (Total Words)	$\bar{X}$	3.8	4.9	6.3	9.5	5.5
	SD	2.1	2.8	4.0	3.9	3.4
% Time-Consum. Errors**** (Total Errors)	$\bar{X}$	29.3	37.3	40.4	61.0	39.0
	SD	15.2	22.2	7.4	14.0	19.6
Flashed Word Test	$\bar{X}$	99.1	100.8	88.8	86.3+	96.1
	SD	15.0	20.3	28.5	22.1	20.3

+ N = 3

++ R/L/N, R = trials favoring right ear
L = trials favoring left ear
N = trials favoring neither ear

* % Substantive errors (Words) =
(Number of Substant. Errors/ Total words read) X 100

** % Substantive errors (Errors) =
(Number of Substant. Errors/ Total errors) X 100

*** % Time-Consuming errors (Words) =
(Number of TC Errors/ Total words read) X 100

**** % Time-Consuming errors (Errors) =
(Number of TC Errors/ Total errors) X 100

activity in the left and right hemisphere respectively in response to flashed word stimuli. In an attempt to replicate this finding, paired t-tests were carried out on the pre-test ERP factor scores to determine if significant differences existed in amplitude between hemispheres (right vs left). Analyses were done separately for L- and P-types. Table 4 lists the pre-test means and standard deviations for cases in which significant differences occurred. On the P300 component, which corresponds most closely to the portion of the ERP on which Bakker & Vinke based their findings, L-types showed a significant difference in hemisphere with a right hemispheric advantage for both parietal [$\underline{t}(16) = 2.76$, $\underline{p} < .01$] and temporal locations [$\underline{t}(16) = 3.69$, $\underline{p} < .001$]. However, on other components of the waveform (P75, N550, and N225), the expected left hemispheric advantage was evident. No significant differences were found for P-types on the P300 component.

<u>Changes in Academic Performance</u>

Figures 9 through 16 illustrate the group changes over time (pre-, mid-, and post-tests) on the following variables respectively: WRAT-R Reading, WRAT-R Spelling, GORT Reading, GORT Comprehension, GORT Reading Speed, percent Substantive Errors (%SE), percent Time-Consuming Errors (%TCE), and Flashed Word Test (FWT). In general, all groups tended to show improvement on most variables over time. An exploratory

Table 4

Significant (p < .05) Amplitude Differences between Right and Left Hemispheres for L- and P-types at Pre-test Time

A. L-types

Component	Location		Mean	SD	Interpretation
P300	Parietal	R	0.37	.98	RH amp > LH amp
		L	-0.23	.79	
P300	Temporal	R	0.47	1.13	RH amp > LH amp
		L	-0.38	.79	
P75	Parietal	R	0.19	1.01	LH amp > RH amp
		L	0.94	1.30	
N550	Parietal	R	-0.22	1.17	LH amp > RH amp
		L	-0.82	1.14	
N550	Temporal	R	0.73	1.01	LH amp > RH amp
		L	-0.05	.88	
N225	Parietal	R	-0.14	1.04	LH amp > RH amp
		L	-0.48	1.26	

Table 4 (Continued)

B. P-types

Component	Location		Mean	SD	Interpretation
N550	Parietal	R	0.44	.85	LH amp > RH amp
		L	-0.01	.65	
N550	Temporal	R	1.03	.45	LH amp > RH amp
		L	.25	.68	
P700	Parietal	R	0.54	1.12	RH amp > LH amp
		L	-0.01	1.00	

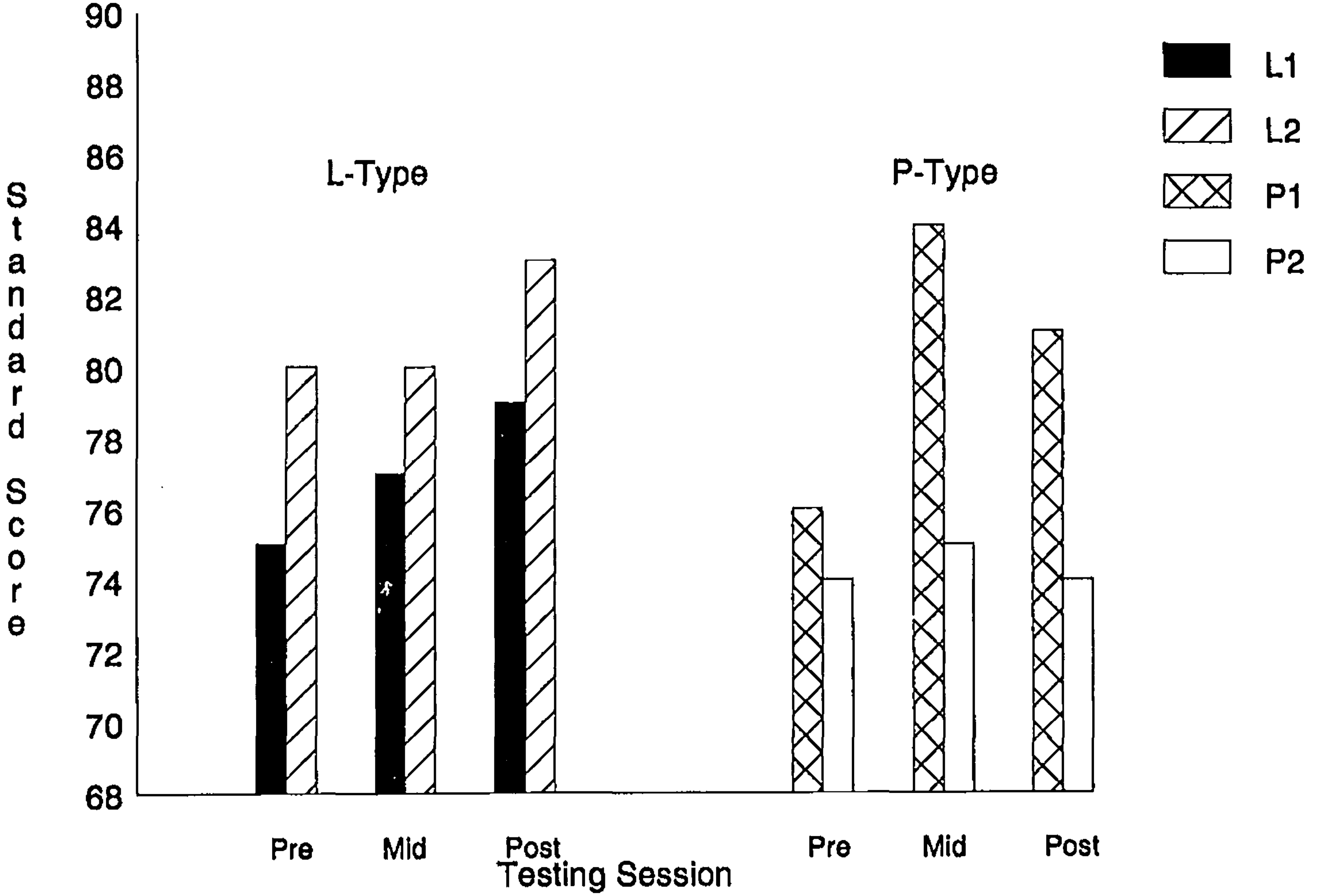

Figure 9. Changes in WRAT-R reading

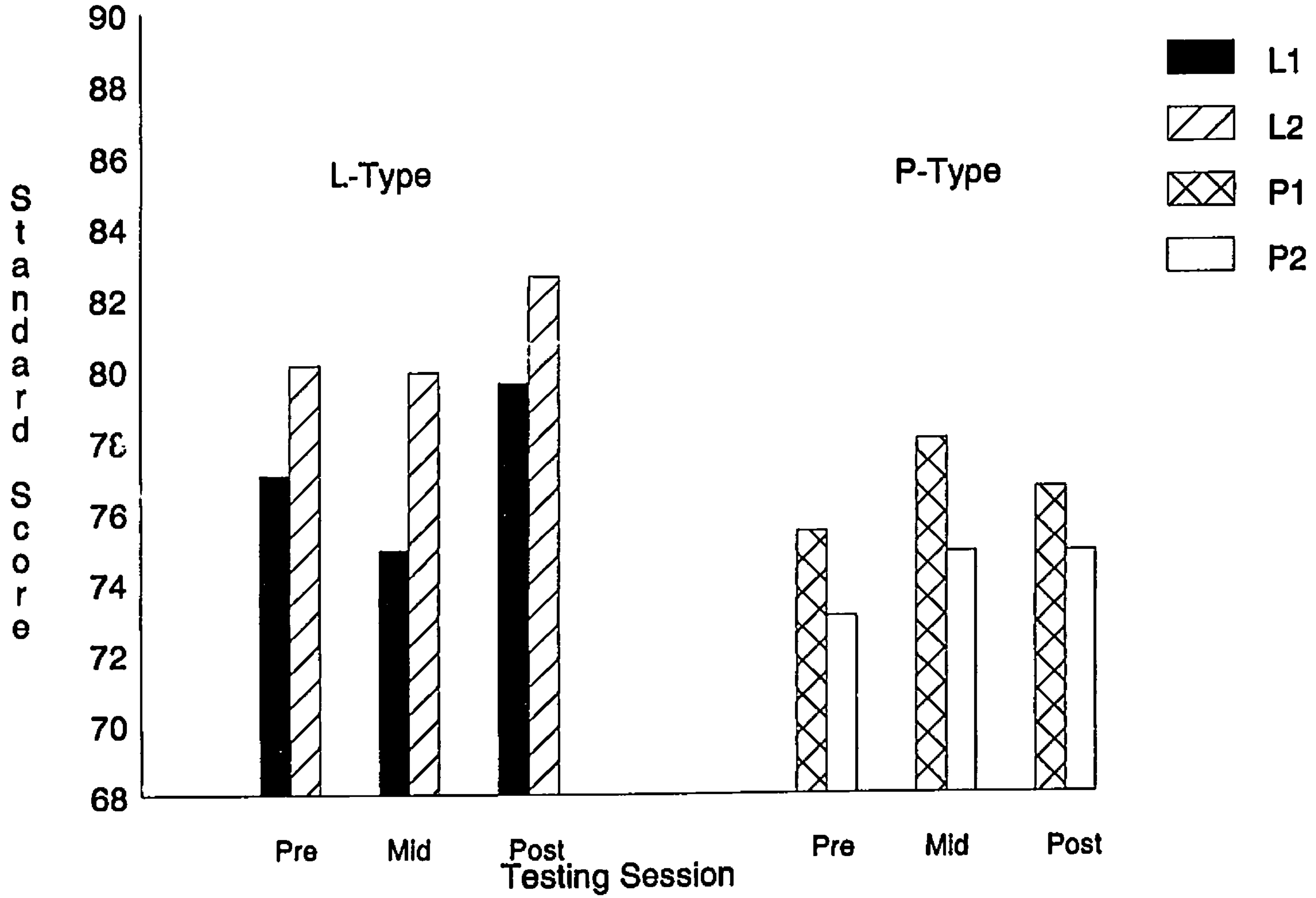

Figure 10. Changes in WRAT-R spelling

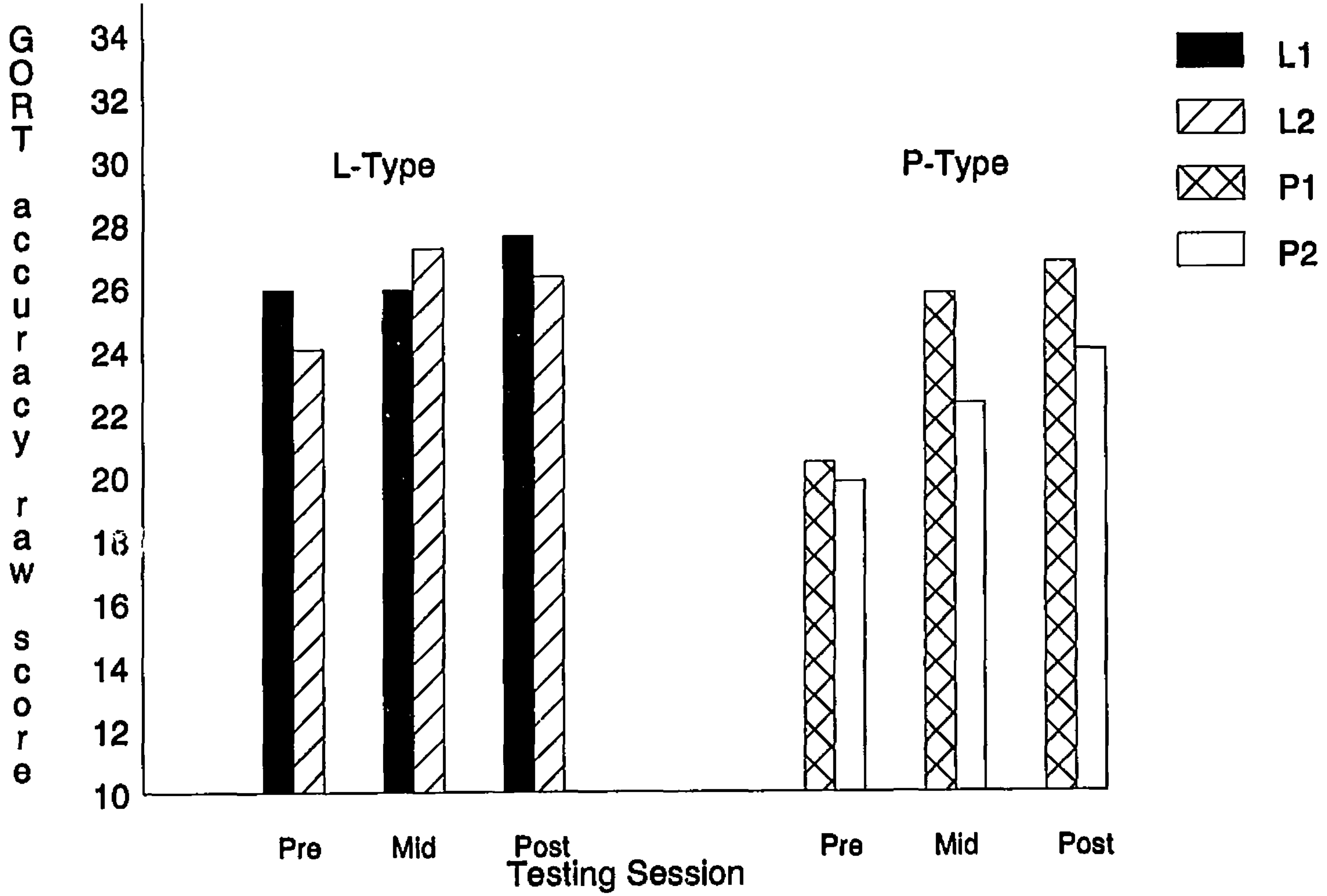

Figure 11. Changes in GORT reading

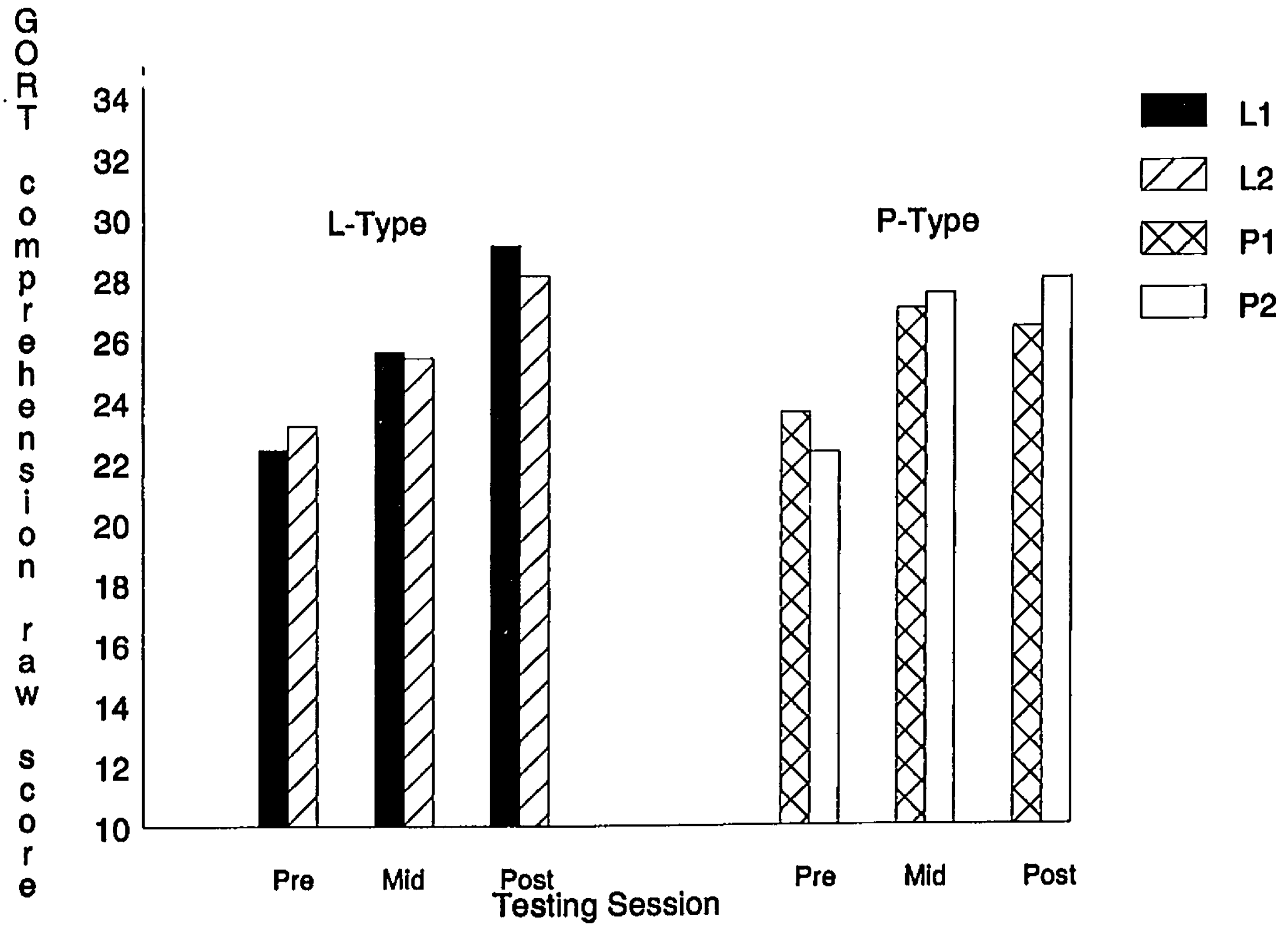

Figure 12. Changes in GORT comprehension

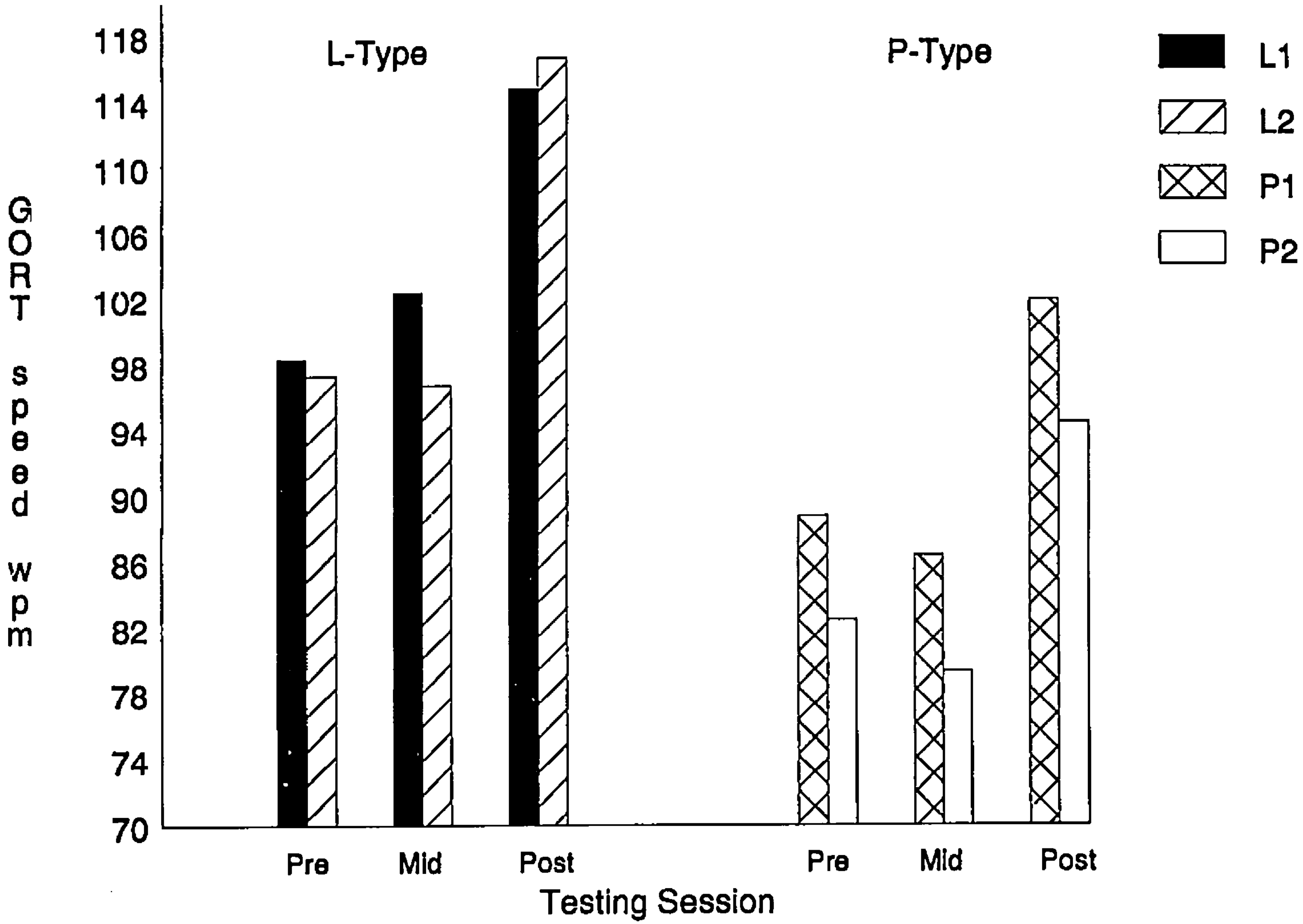

Figure 13. Changes in GORT reading speed (wpm)

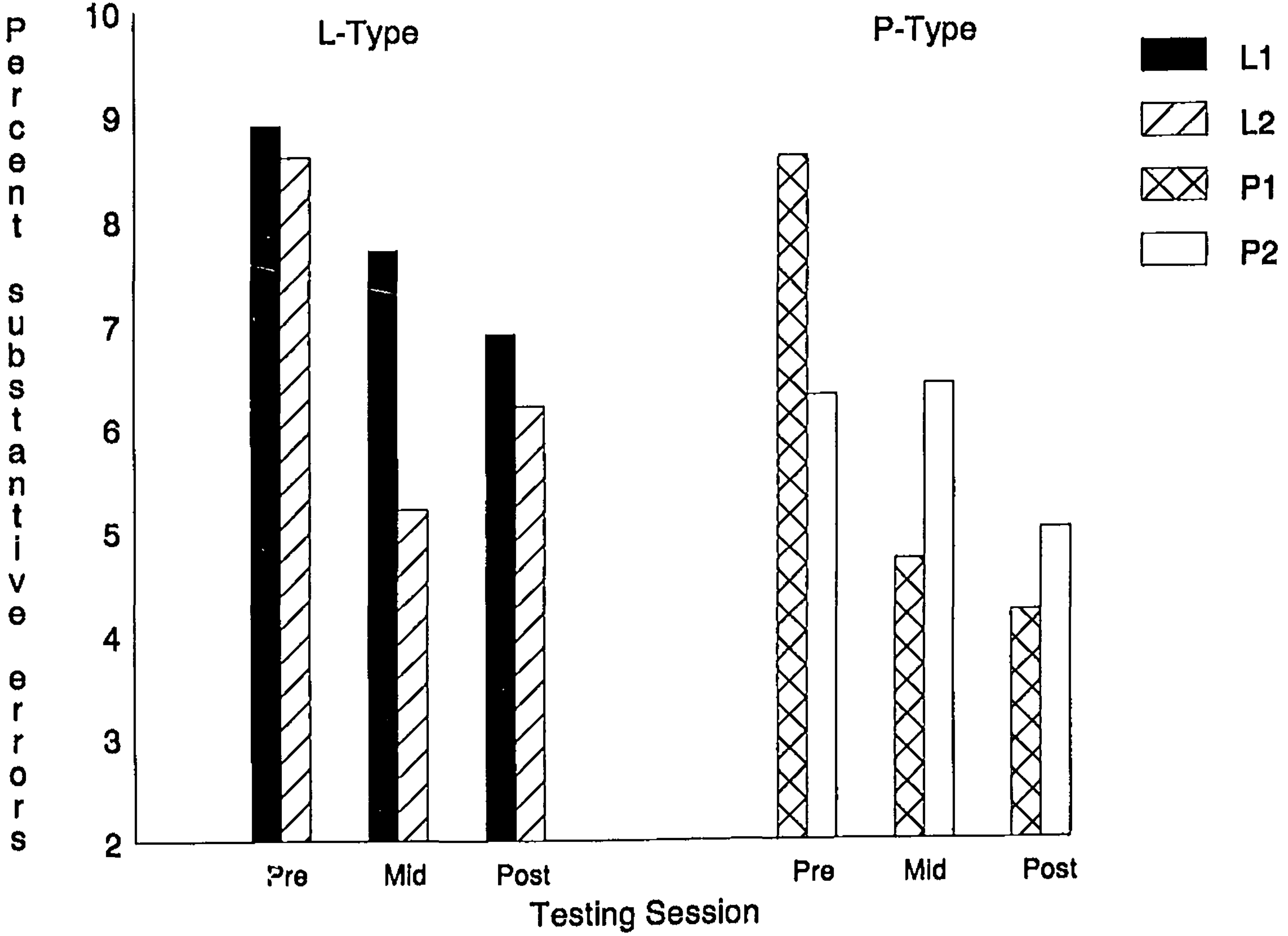

Figure 14. Changes in percent substantive errors

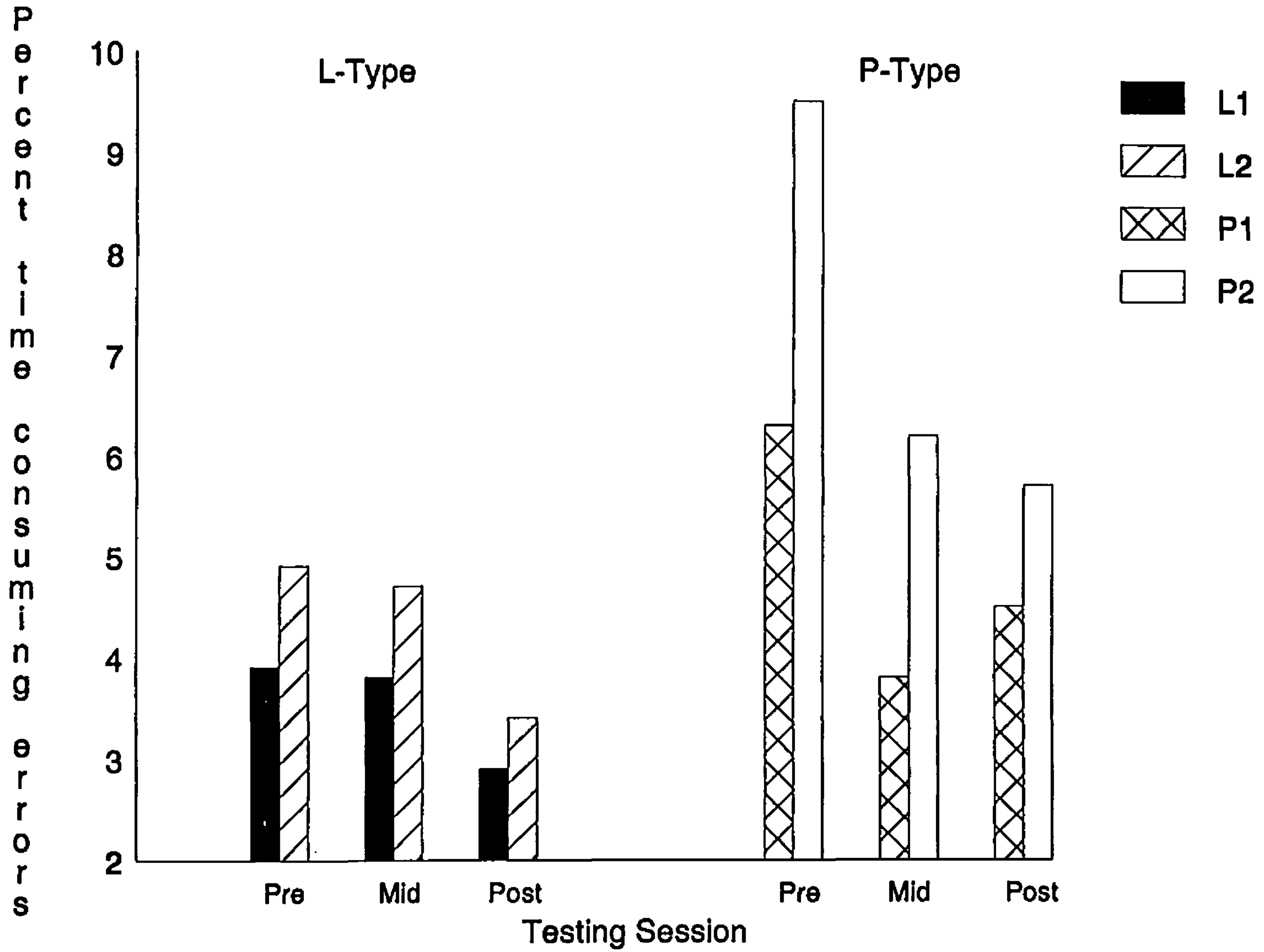

Figure 15. Changes in percent time-consuming errors

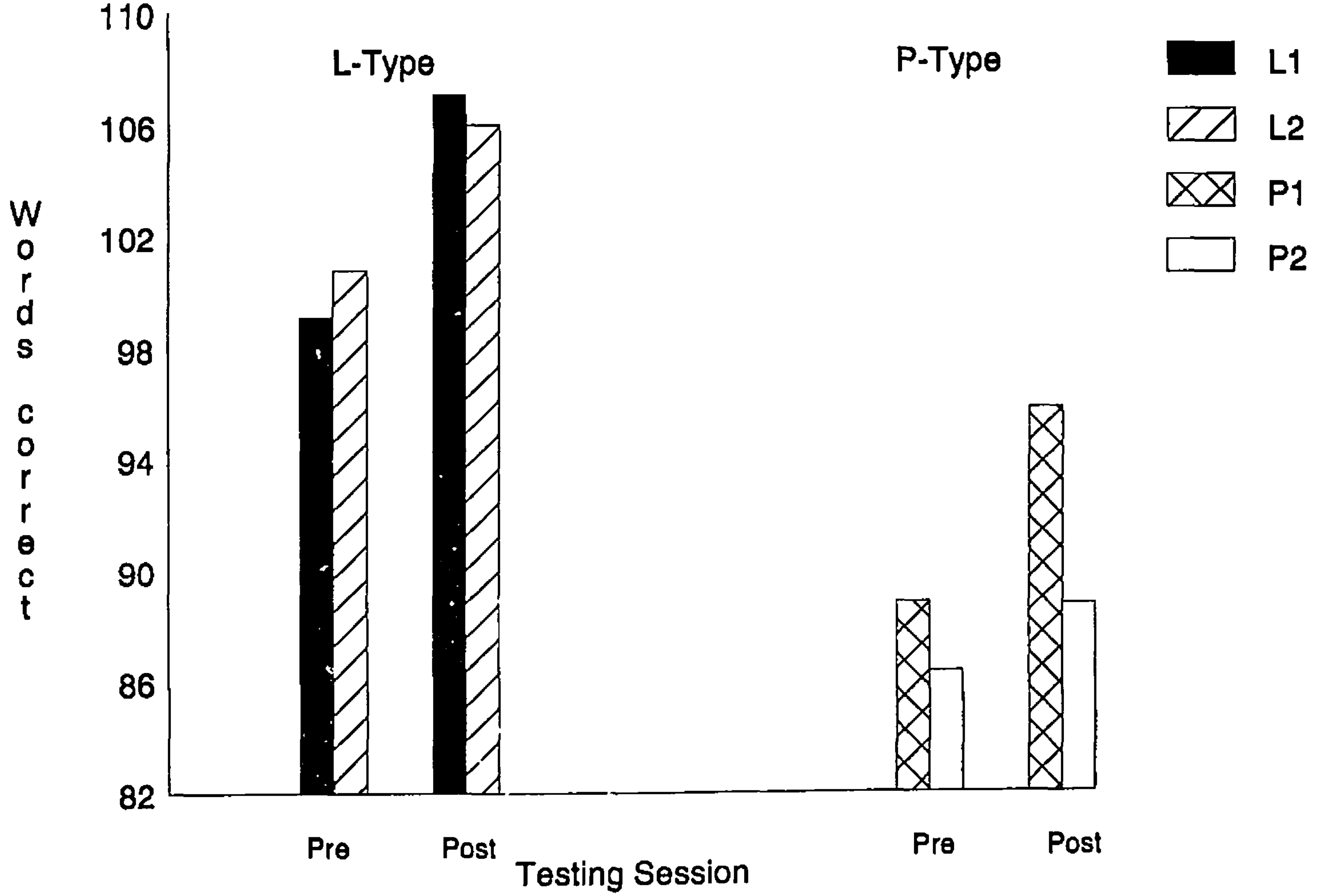

Figure 16. Changes in Flashed Word Test

post-hoc trend analysis revealed significant ($p < .05$) or near-significant ($p < .10$) linear trends in many cases indicating an improvement over time. Several significant or near-significant quadratic trends were noted as well. However, in all cases of quadratic trends, the post-test means indicated improvement over the pre-test means. Table 5 lists the linear and quadratic trends that were found.

Within-Group Comparisons

Figures 17 through 24 illustrate the relative changes (in z-scores) between experimental and control groups from pre- to mid-test and pre- to post-test on the following variables respectively: WRAT-R Reading, WRAT-R Spelling, GORT Reading, GORT Comprehension, GORT Reading Speed, %SE, %TCE, and FWT. Because the data are expressed in z-scores (computed over experimental and control groups), all differences are to be considered relative. For example, although both L1 and L2 improved in WRAT-R reading from pre-to post-testing (see Figure 9), L1 showed a larger improvement relative to L2. Thus, when these scores are transformed into z-scores (over L1 and L2), L1 demonstrates a relative increase and L2 demonstrates a relative decrease in performance. Within-group changes therefore reflect changes over time for each group within the z-score distribution.

Table 5

Linear and Quadratic Trends for Academic Performance Over Time (Pre, Mid, and Post-Tests)

Variable	Group	Trend	Probability
WRAT-R Reading	L1	Linear	$p < .02$
	P1	Quadratic	$p < .10$
WRAT-R Spelling	L1	Quadratic	$p < .05$
	L2	Linear	$p < .10$
	P1	Quadratic	$p < .10$
GORT Reading	L2	Quadratic	$p < .01$
	P1	Quadratic	$p < .10$
GORT Comprehension	L1	Linear	$p < .001$
	L2	Quadratic	$p < .05$
	P2	Quadratic	$p < .10$
Gort Reading Speed	L2	Linear	$p < .002$
	P1	Linear	$p < .10$
	P2	Linear	$p < .10$
Substantive Errors	L1	Linear	$p < .05$
	L2	Quadratic	$p < .005$
Time-Consuming Errors	L2	Linear	$p < .05$

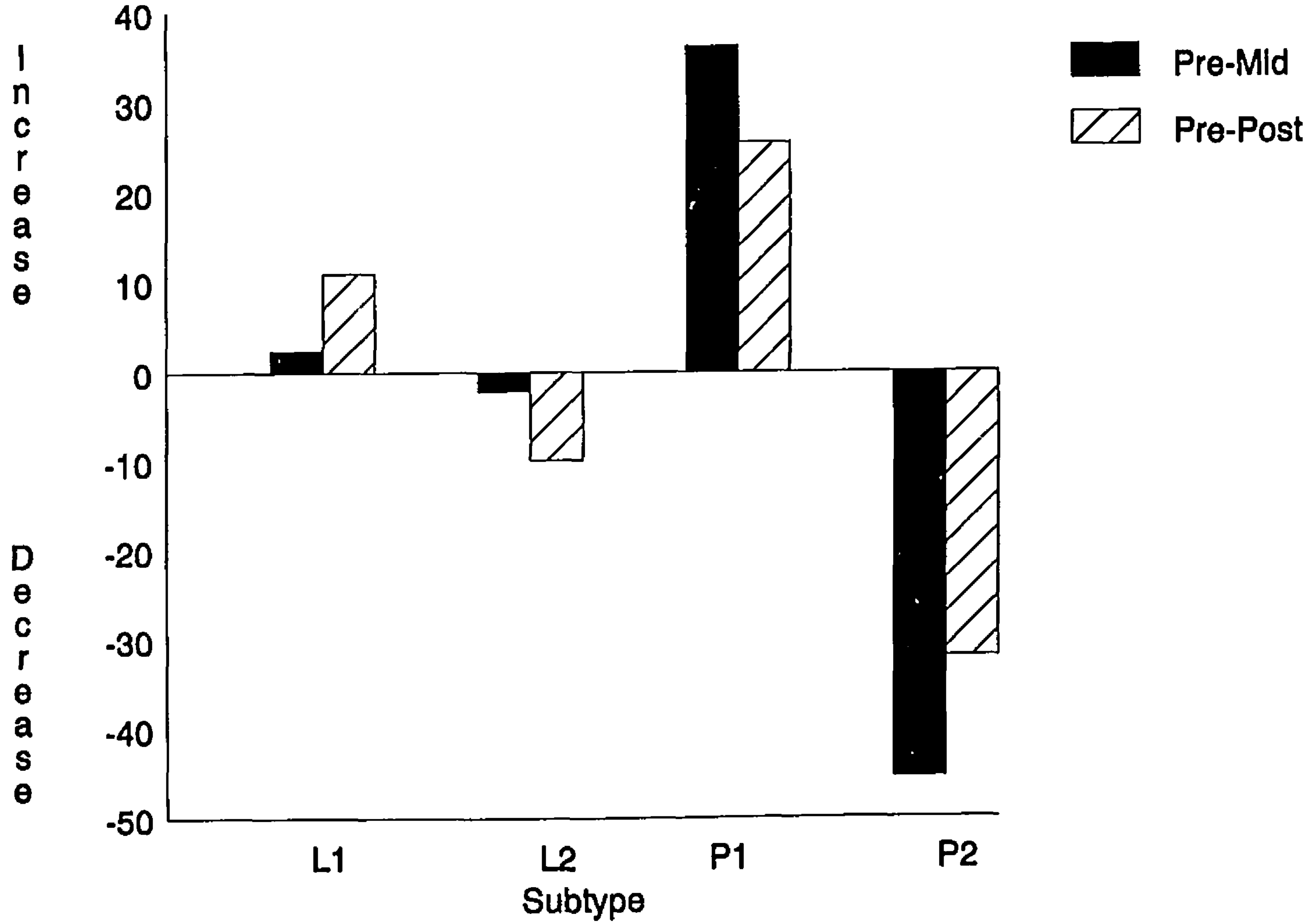

Figure 17. Relative changes in WRAT-R reading (z-scores)

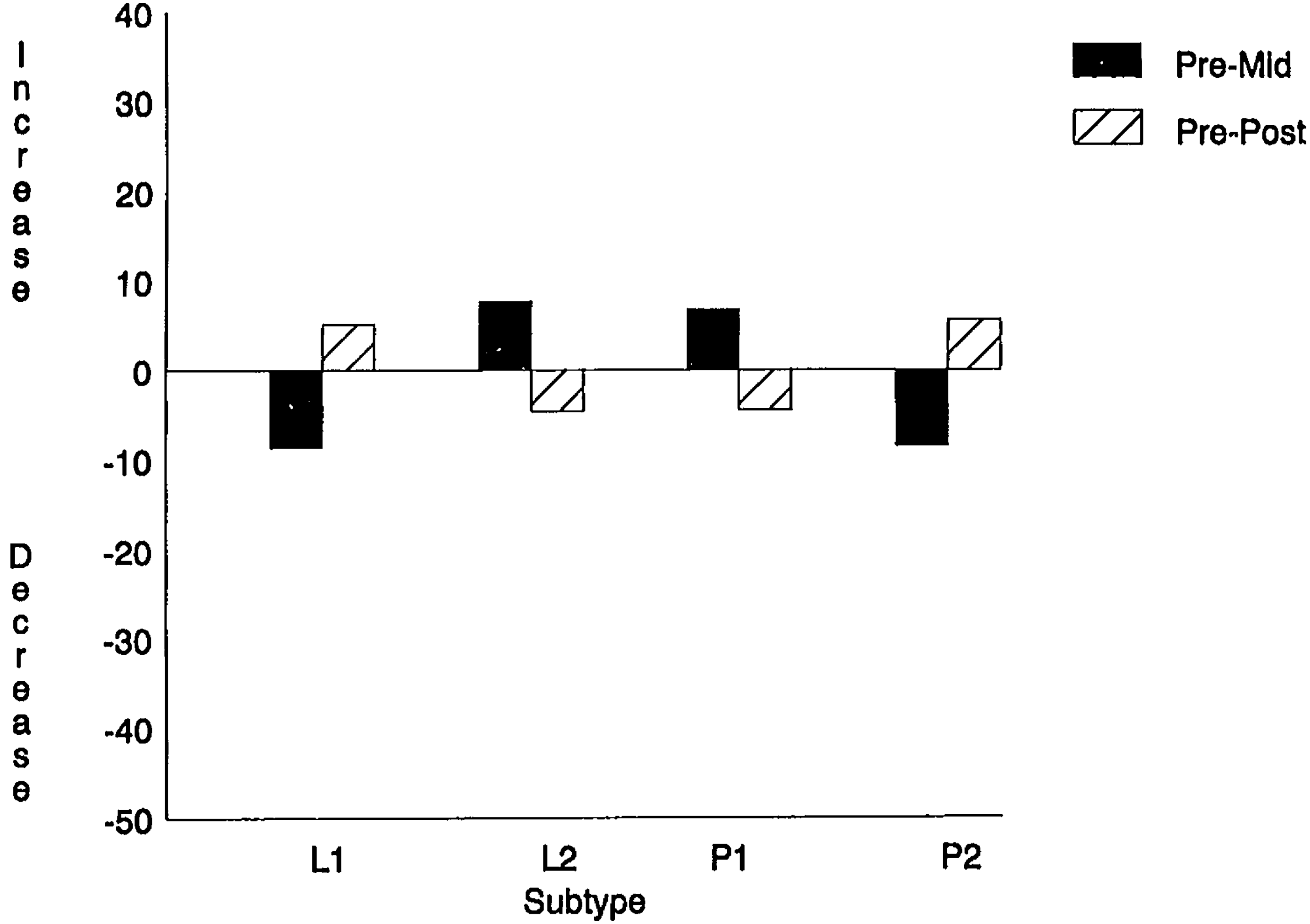

Figure 18. Relative changes in WRAT-R spelling (z-scores)

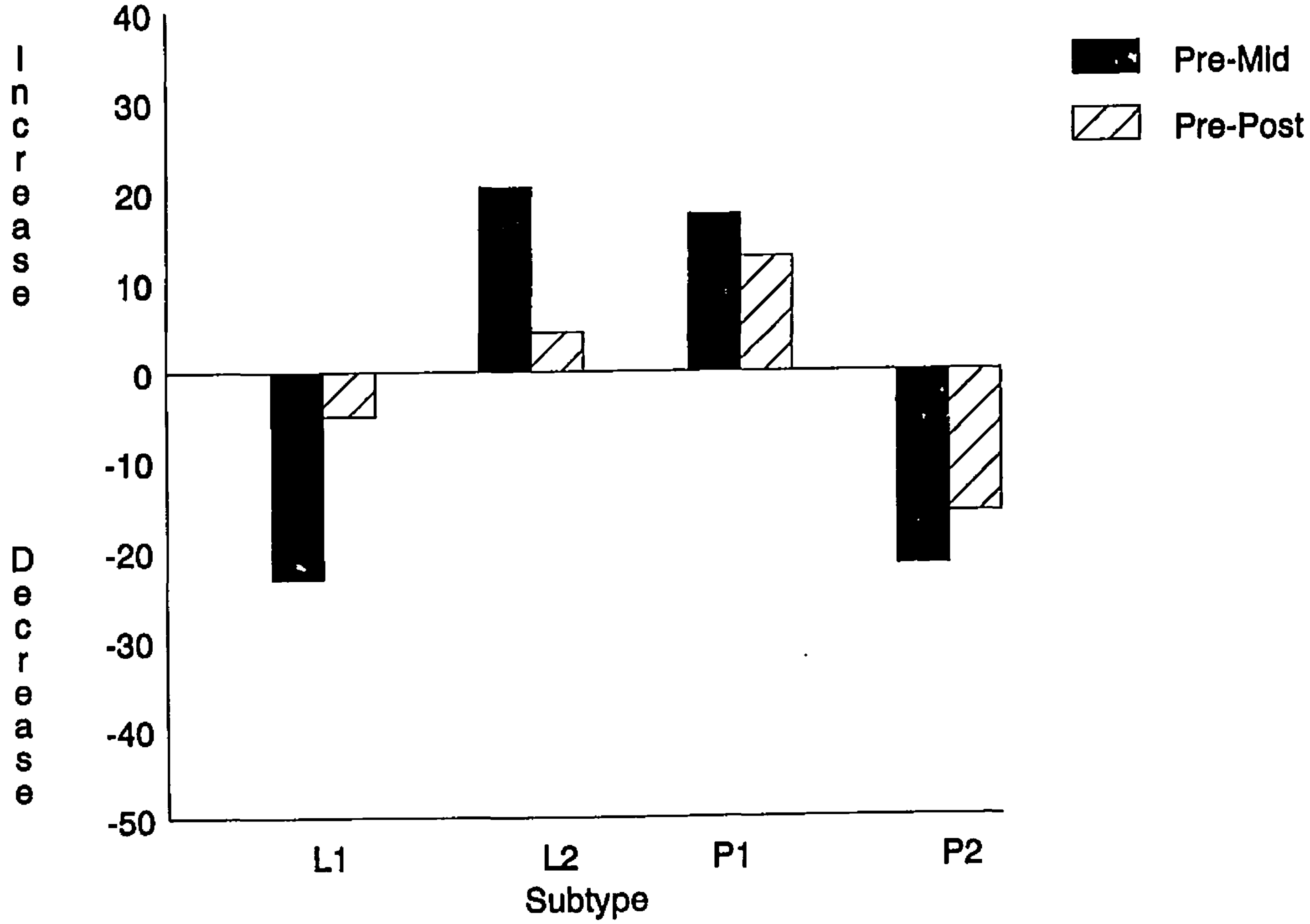

Figure 19. Relative changes in GORT reading (z-scores)

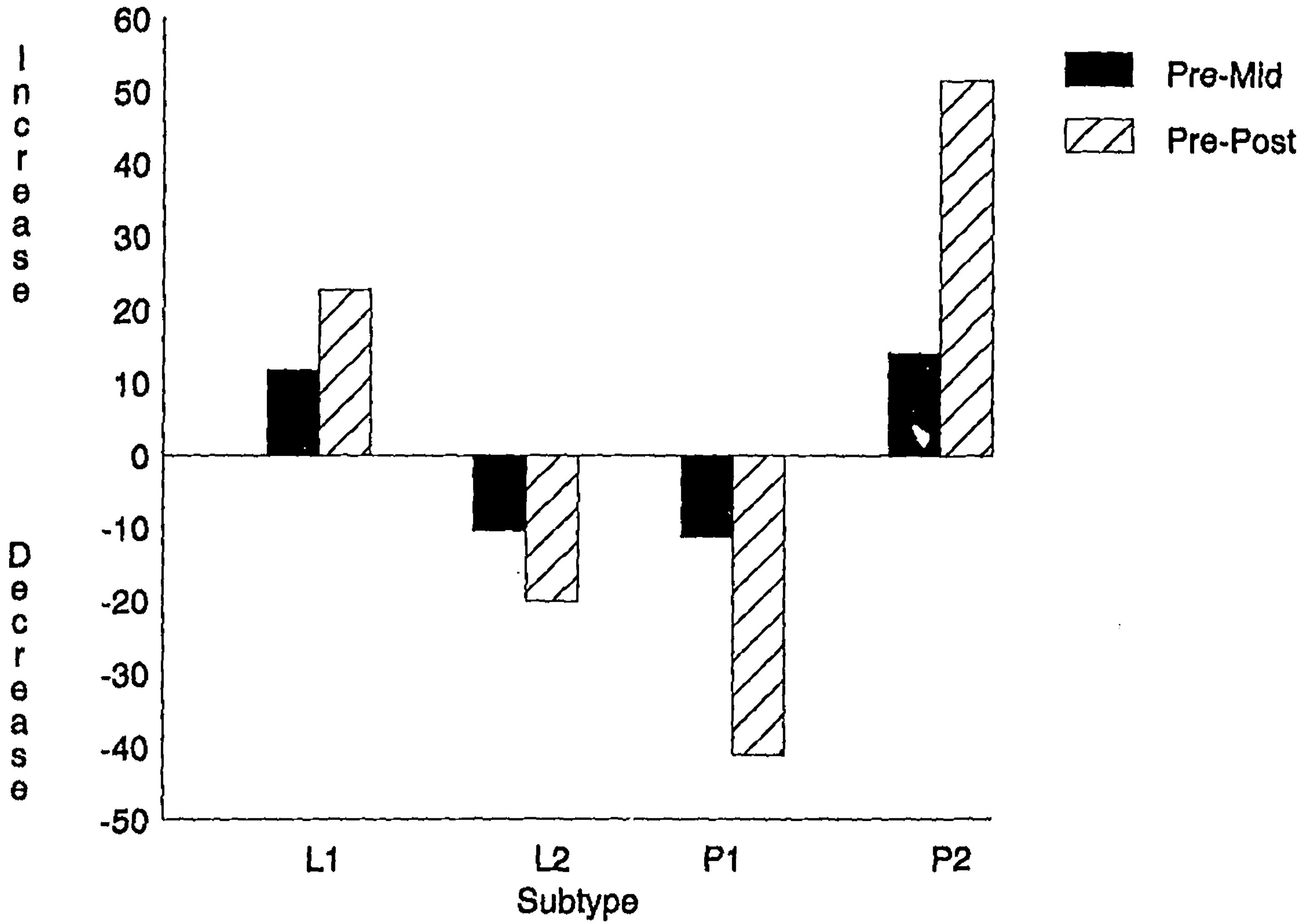

Figure 20. Relative changes in GORT comprehension (z-scores)

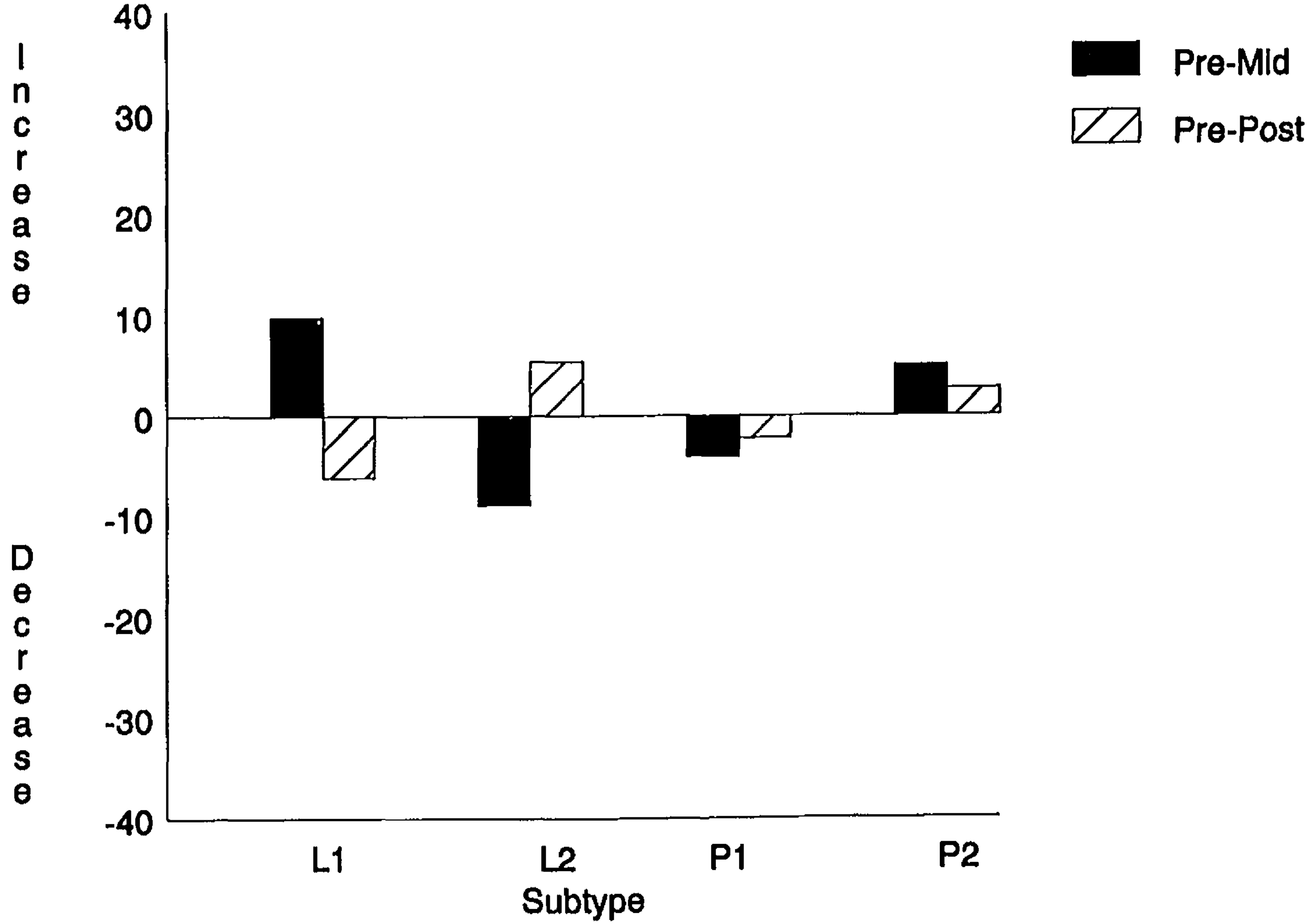

Figure 21. Relative changes in GORT reading speed (z-scores)

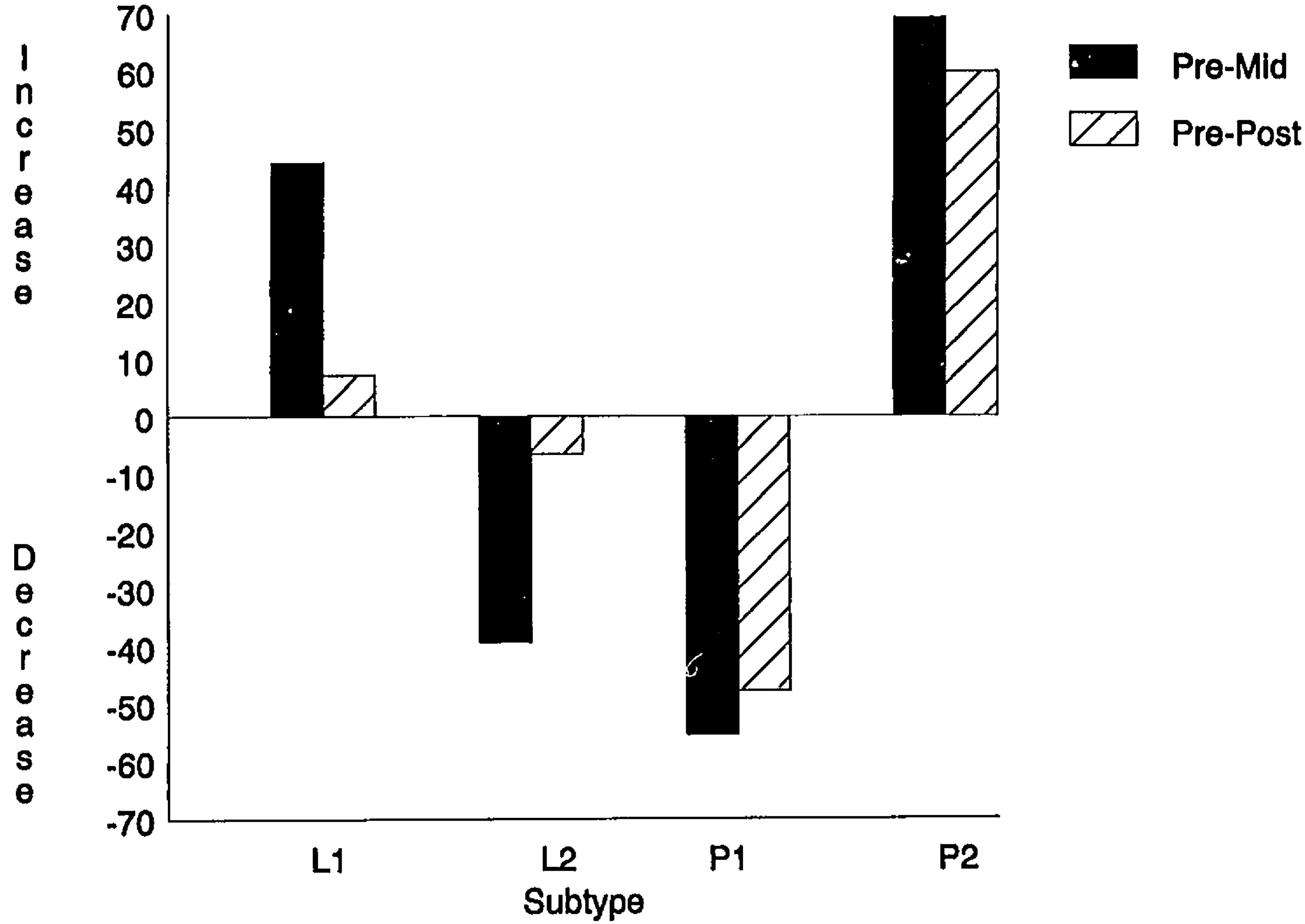

Figure 22. Relative changes in percent substantive errors

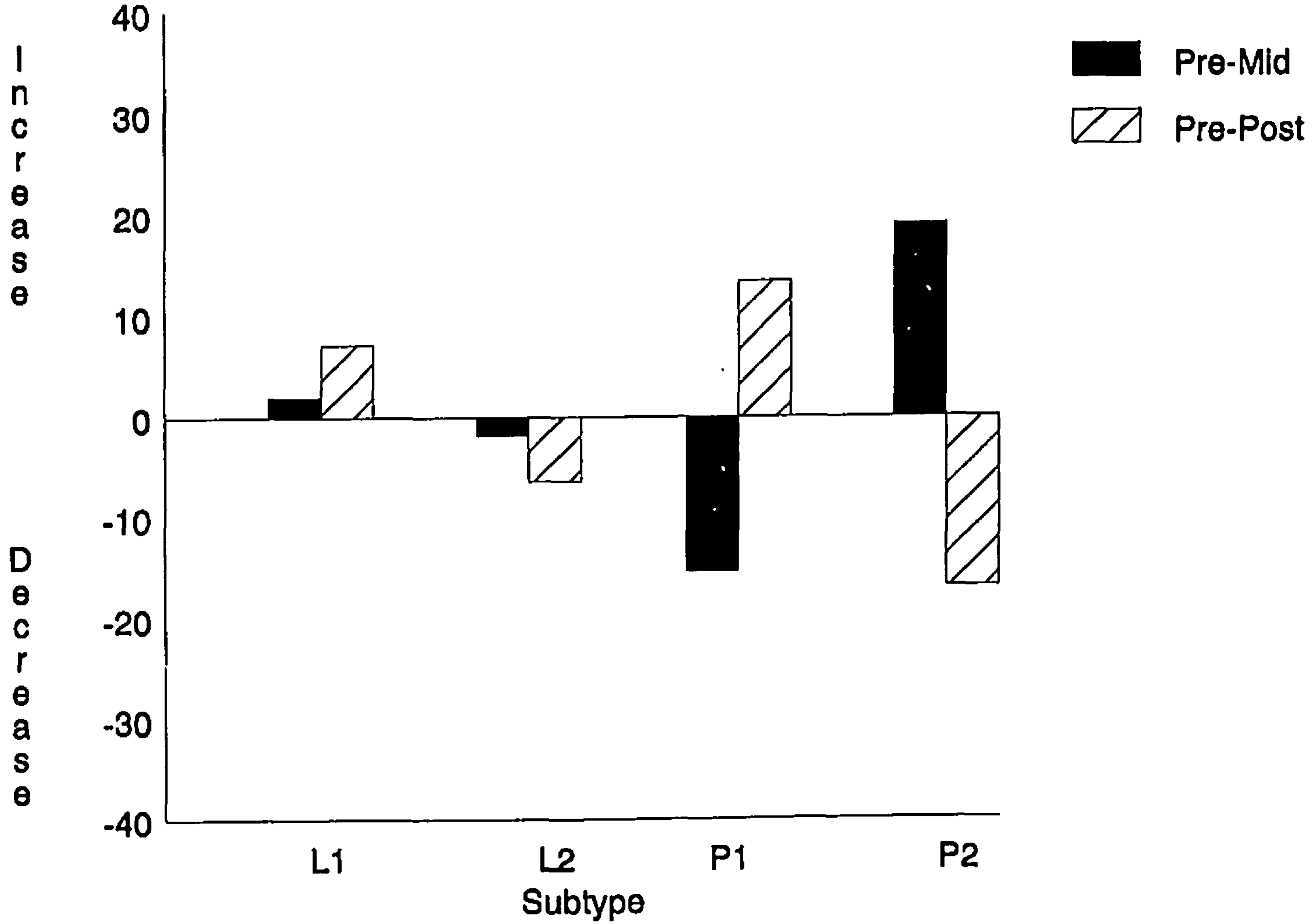

Figure 23. Relative changes in percent time-consuming errors

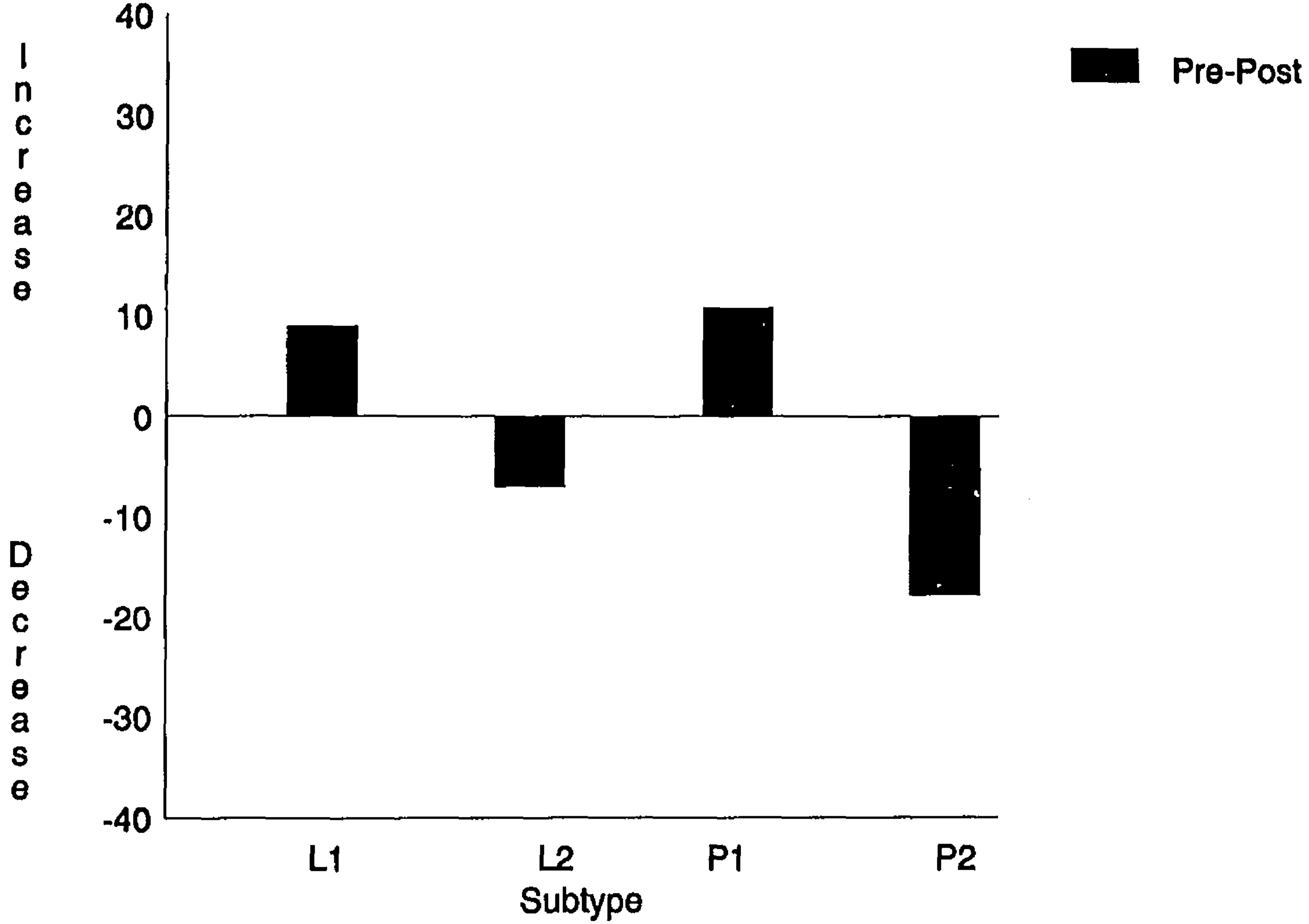

Figure 24. Relative changes in Flashed Word Test

Within-group comparisons (paired t-tests, one-tailed) yielded only three significant changes over time, all in relation to substantive errors. First, Group L1 showed a significantly smaller decrease (an increase in errors relative to L2) in %SE from the pre- to mid-test [$\underline{t}(7) = 1.90$, $\underline{p} < .05$]. Second, Group P2 showed a similar significantly smaller decrease in substantive errors (an increase relative to P1) from the pre- to mid-test [$\underline{t}(3) = 3.11$, $\underline{p} < .05$]. Third, Group L2 demonstrated a significant improvement (i.e., a decrease in %SE) from pre- to mid-test times (see Figure 22).

Between-Group Comparisons

Results revealed only two significant between-group differences. First, L1 demonstrated less improvement relative to L2 (a decrease in performance relative to L2) in %SE from the pre- to mid-test [$\underline{t}(15) = 3.09$, $\underline{p} < .005$, see Figure 22]. Second, P1's performance on the post-test FWT compared to the pre-test FWT was significantly better than that of P2 [$\underline{t}(6) = 1.98$, $\underline{p} < .05$, see Figure 24]. In addition, several tendencies in the data were noted although they did not reach significance ($\underline{p} < .10$): P1 improved more than P2 on Wrat-R Reading from pre- to mid-test [$\underline{t}(7) = 1.66$, $\underline{p} < .10$, see Figure 17]; L1 performed more poorly than L2 on Gort Reading from pre- to mid-test [$\underline{t}(15) = -1.62$, $\underline{p} < .10$, see Figure 19]; P1 showed fewer substantive errors from pre- to mid-test than did P2 [$\underline{t}(7) = -$

1.49, $p < .10$, see Figure 22]; and L1 performed better than did L2 on the FWT from pre- to post-test [$t(15) = 1.35$, $p < .10$, see Figure 24].

Changes in ERPs

Orthogonal (quartimax) rotation of the principle components solution converged after 12 iterations, resulting in 6 major components accounting for 84.1% of the waveform variance (component 1 - 35.3%, component 2 - 18.1%, component 3 - 11.5%, component 4 - 8.5%, component 5 - 6.2%, component 6 - 4.5%). Loadings for each component were highest around 75, 550, 400, 700, 225 and 300 ms after the onset of the flashed word (components 1 to 6 respectively). Visual inspection of the grand mean waveform (see Figure 25) confirmed that the major peaks of the waveform corresponded to the statistically generated components. Components 1, 4, and 6 reflect major positive peaks (P75, P700, and P300); components 2, 3, and 5 represent major negative peaks (N550, N400, and N225). Table 6 displays the factor solution found by PCA for the ERP data.

Within-Group Comparisons

Figures 26 through 31 illustrate the relative changes in BHDs of all groups on components P75, N225, P300, N400, N550, and P700 respectively. As mentioned earlier, Bakker has labelled a relative increase over time in ERP amplitude in the

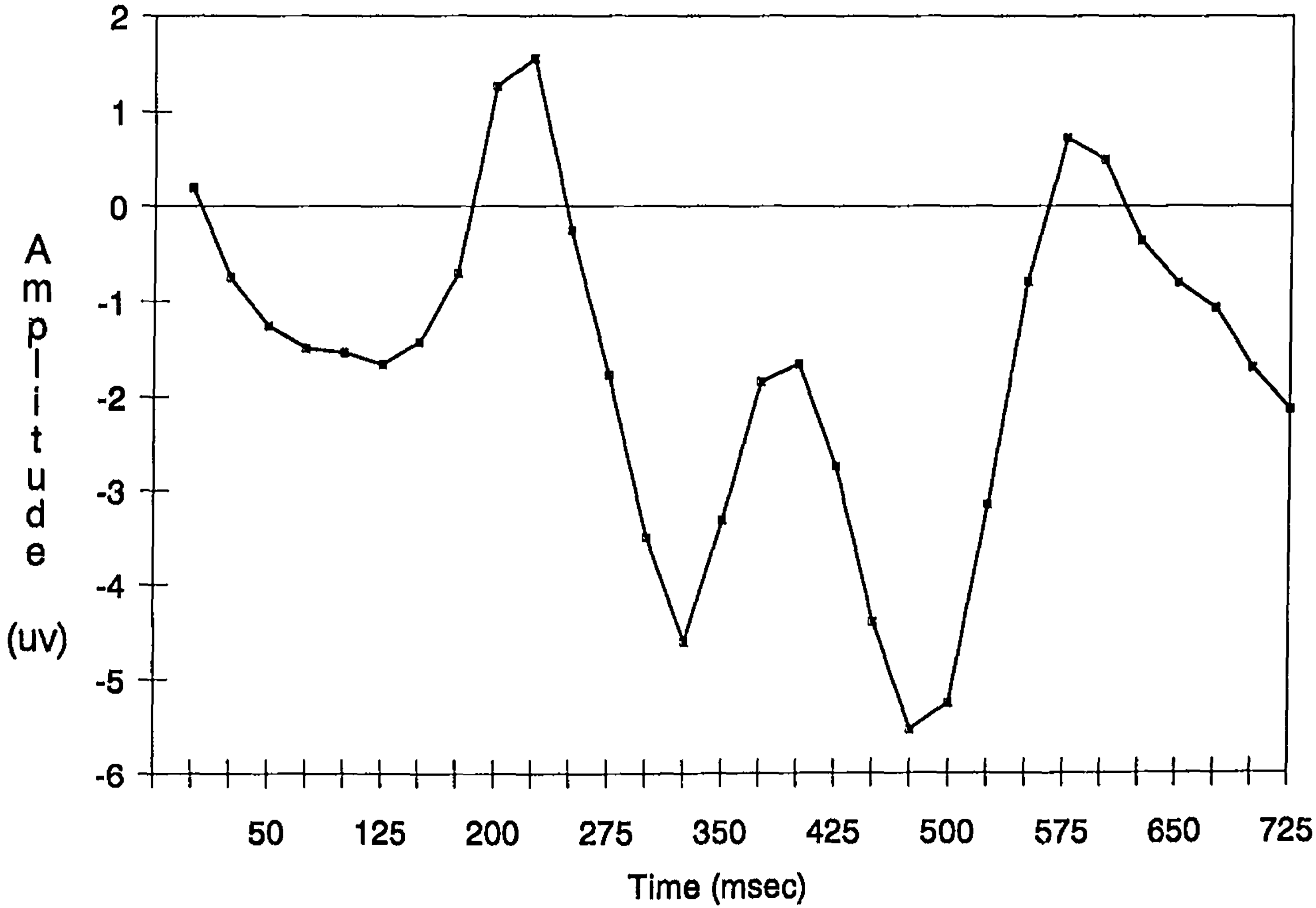

Figure 25. Grand mean of the ERPs

Table 6

Factor Solution for Principle Components Analysis

Factors	Proportion of Variance	Cummulative Variance	Highest Loadings
1	35.3	35.3	P75
2	18.1	53.4	N550
3	11.5	64.9	N400
4	8.5	73.4	P700
5	6.2	79.6	N225
6	4.5	84.1	P300

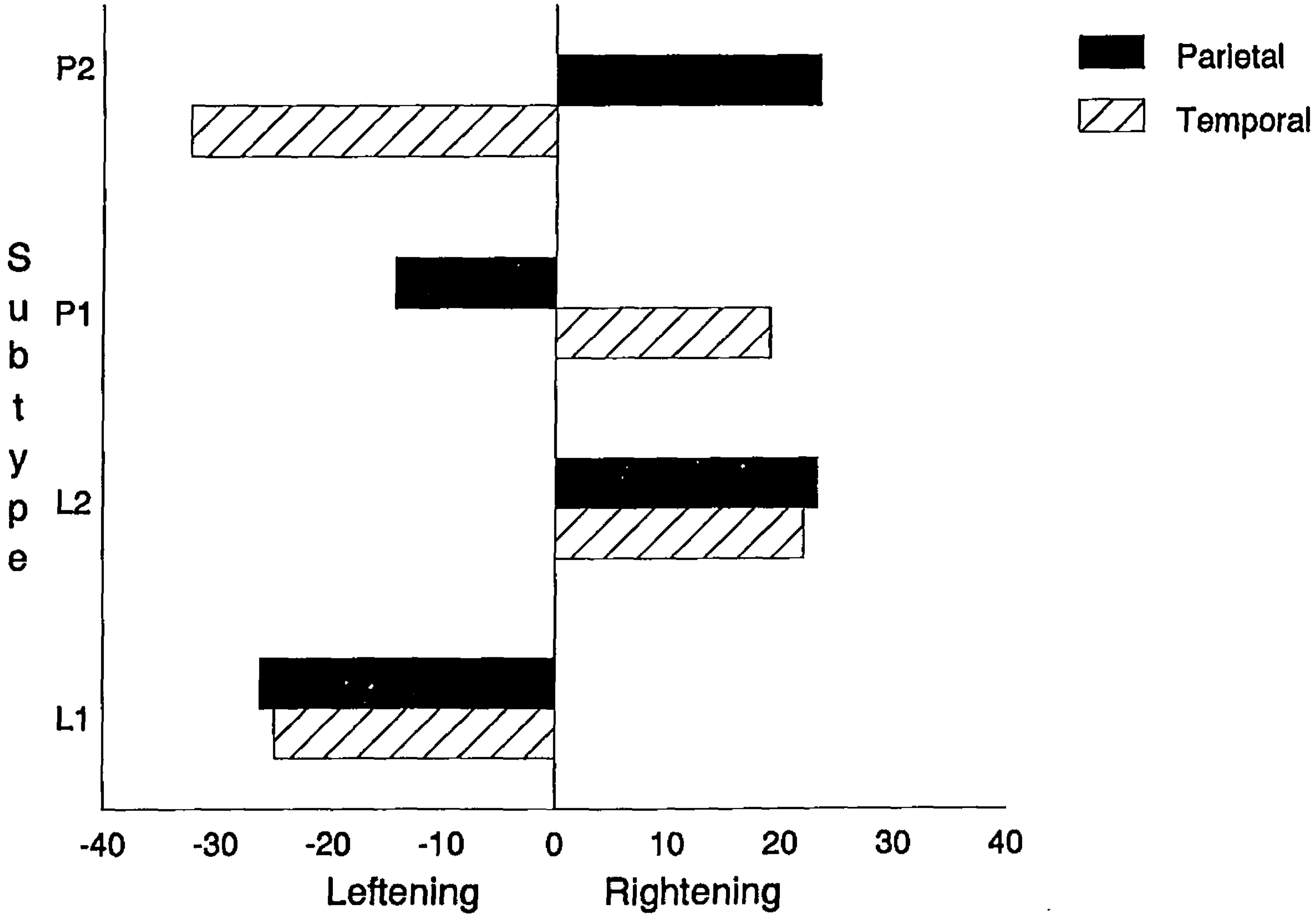

Figure 26. Relative changes in ERP ampiitude - P75

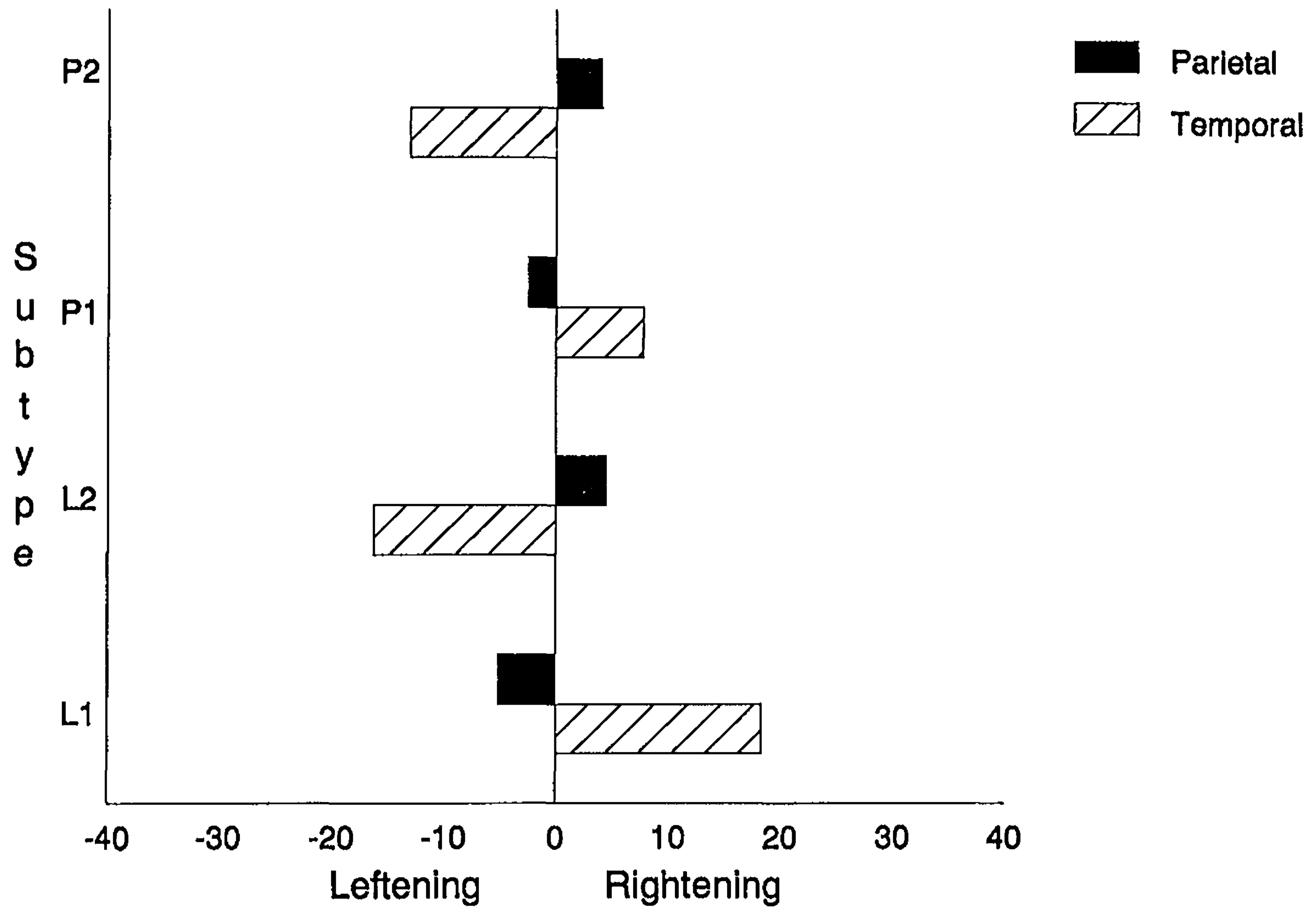

Figure 27. Relative changes in ERP amplitude - N225

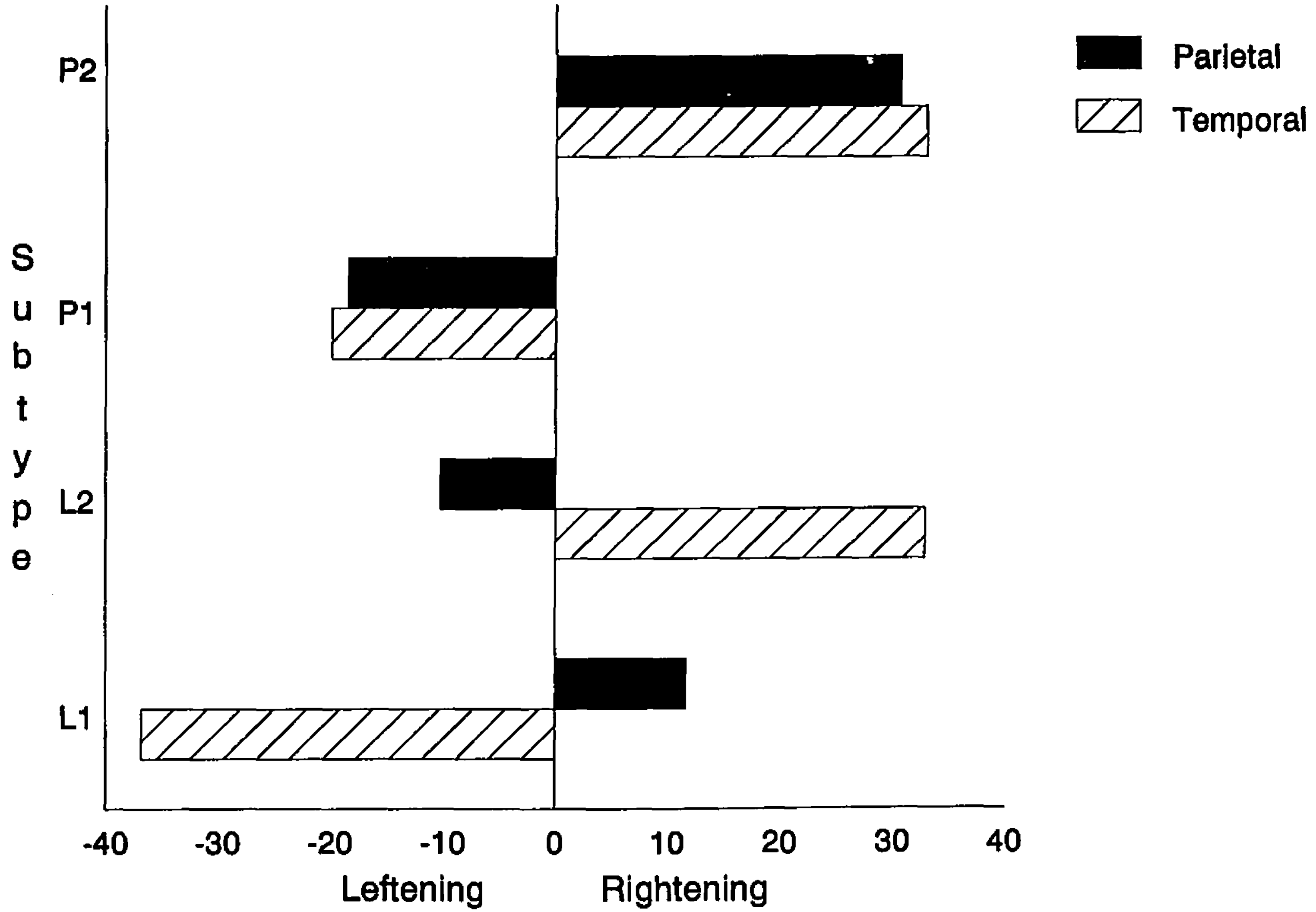

Figure 28. Relative changes in ERP amplitude - P300

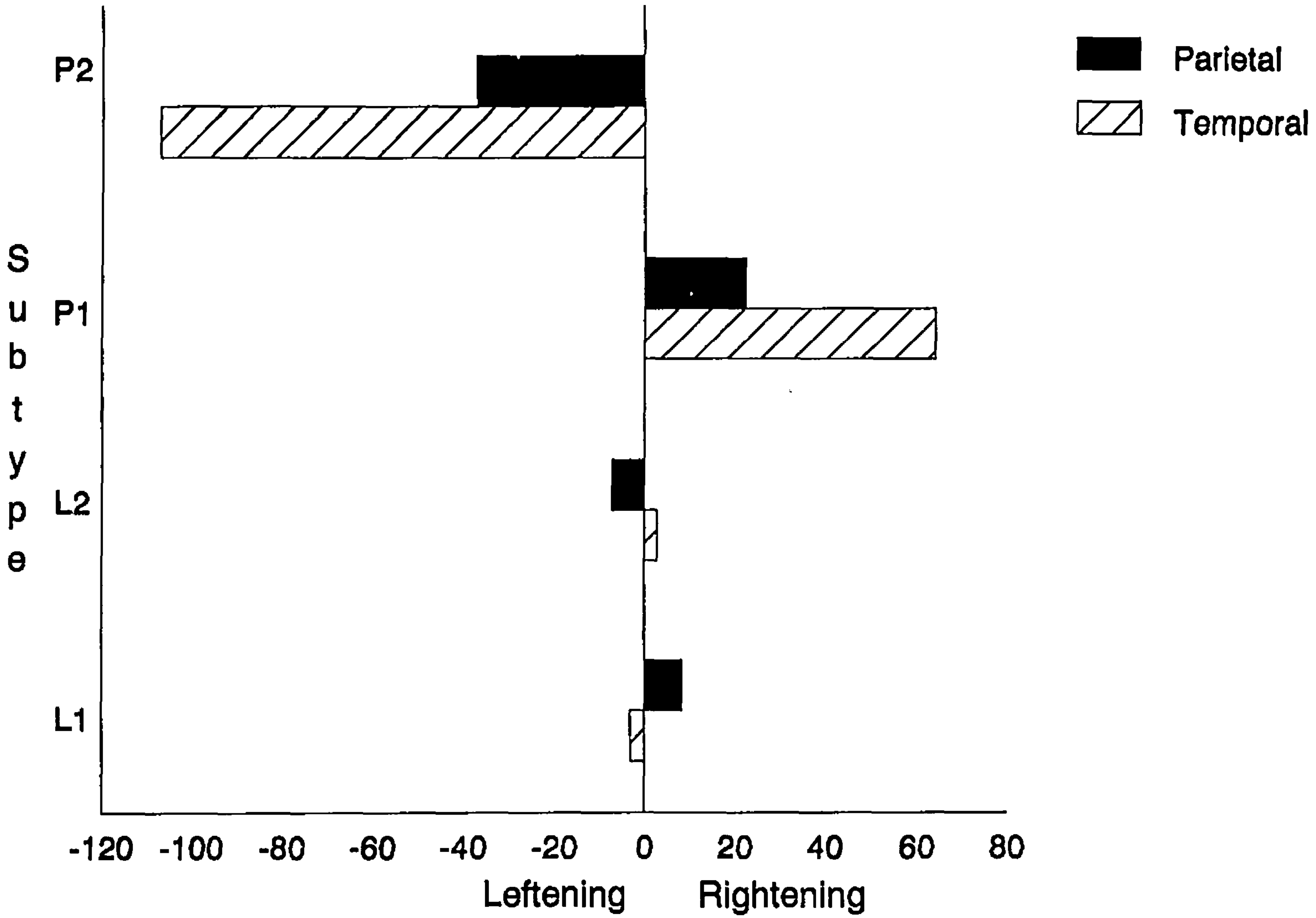

Figure 29. Relative changes in ERP amplitude - N400

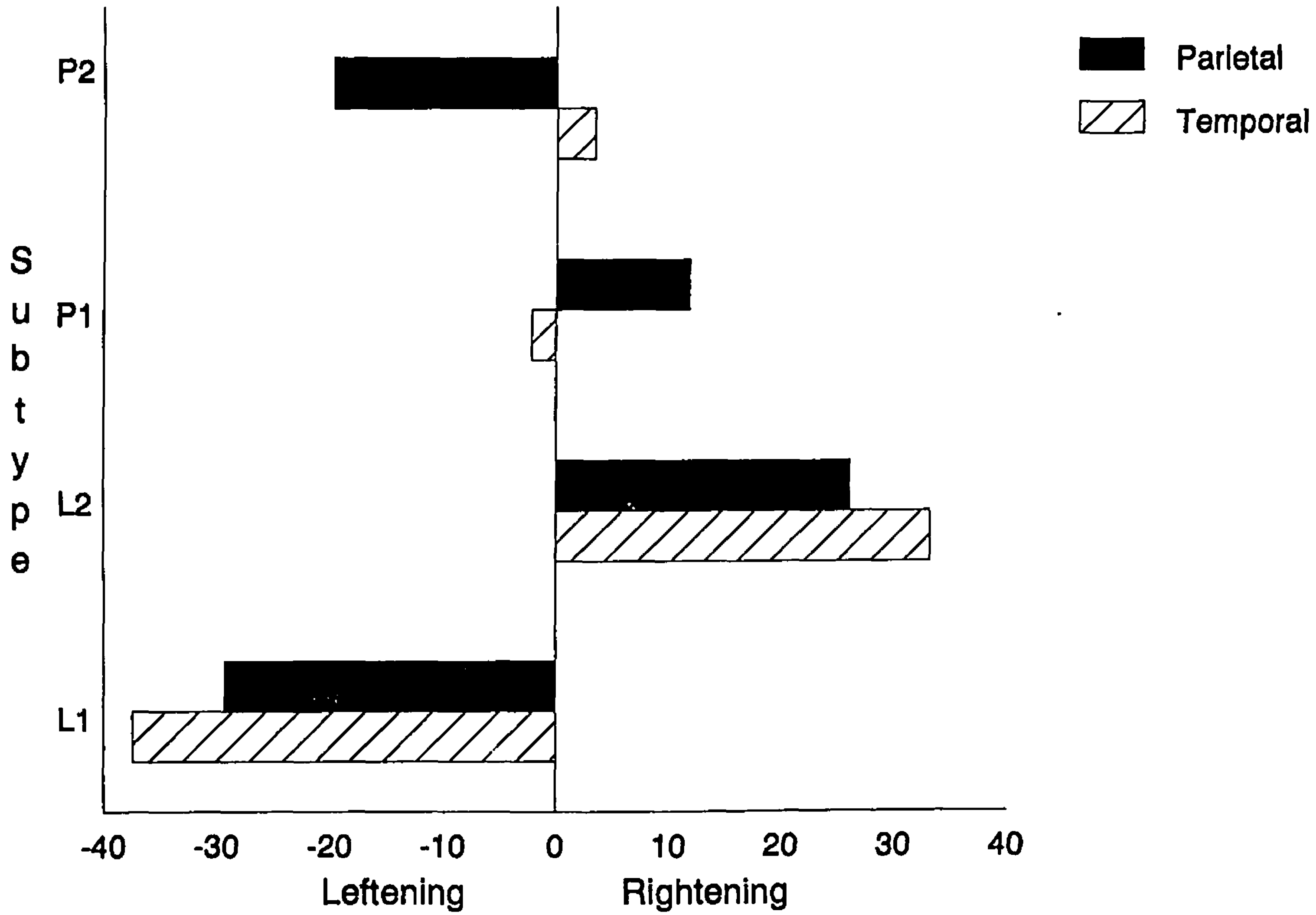

Figure 30. Relative changes in ERP amplitude - N550

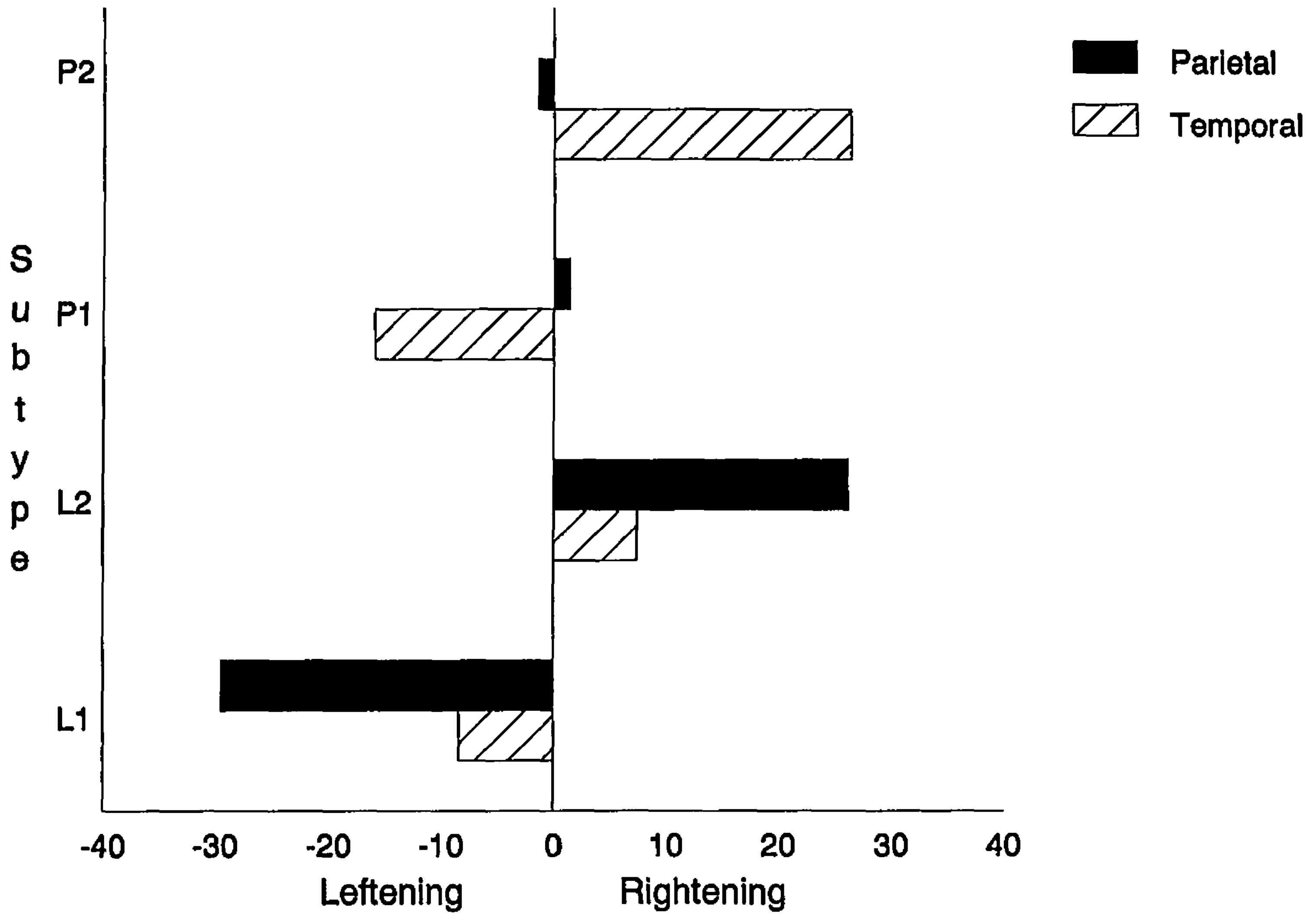

Figure 31. Relative changes in ERP amplitude - P700

left hemisphere as "leftening". Similarly, a relative increase in the right hemisphere over time has been referred to as "rightening".

For component P300 (see Figure 28), temporal BHD changes showed a leftening tendency for Group P1 [$t(4) = 1.69$, $p < .10$] and parietal BHD changes showed a rightening effect for Group P2 [$t(2) = -2.13$, $p < .10$]. For the N400 component (see Figure 29), parietal BHD changes indicated significant leftening for Group P2 [$t(2) = -4.05$, $p < .05$] and temporal BHD changes showed significant rightening for Group P1 [$t(4) = 2.46$, $p < .05$] and leftening for Group P2 [$t(2) = -10.06$, $p < .005$]. For component N550 (see Figure 30), temporal BHD changes indicated a leftening tendency for Group L1 [$t(7) = -1.63$, $p < .10$]. For the P700 component (see Figure 31), parietal BHD changes revealed significant rightening in Group L2 [$t(8) = -2.40$, $p < .05$].

Between-Group Comparisons

Significant differences or near-significant tendencies between groups were apparent for four of the components (P300, N400, N550, and P700). For P300, differences were apparent in BHD changes between L1 and L2 at the temporal location, indicating a relative leftening effect for L1 and a relative rightening effect for L2 [$t(15) = -1.56$, $p < .10$]. A difference was found also between P1 and P2 at the temporal location, with P1 demonstrating a relative leftening effect and P2 showing a relative rightening effect [$t(6) = -1.77$, $p < .10$]. Table 7 presents the significant differences and non-significant tendencies found for the four components.

Correlations Between BHD Changes and Changes in Academic Performance

Correlations between pre-post academic changes and BHD changes were calculated for components P300, N400, N550, and P700 at parietal and temporal locations. Correlations were not computed for components P75 and N225 because these components did not yield significant BHD changes between or within groups.

Significant correlations calculated within L- and P-types were in accordance with the results reported above. For L-types, improvements in Gort accuracy were associated with rightening in N550 parietal activity [$r(17) = -.44$, $p < .05$] and in P700 parietal activity [$r(17) = .61$, $p < .005$]. This finding is in accordance with the fact that L2, which showed rightening in components N550 and P700, also showed more improvement than L1 in Gort accuracy. Improvement on the FWT was associated with leftening of parietal N550 activity [$r(17) = .54$, $p < .02$]. Accordingly, L1, which showed leftening, demonstrated more improvement than L2.

For P-types, improvement in Wrat-R Reading was highly related to rightening in parietal N400 activity [$r(8) = -.86$, p

Table 7

Significant Differences (*p* < .05) and Near-significant Trends (*p* < .10) between Groups (L1 vs L2; P1 vs P2) in BHD Changes

A. L-types

Component	Location	*t* value, Probability	Interpretation
P300	Temporal	$t(15) = -1.56$, $p < .10$	L1 - Leftening L2 - Rightening
N550	Temporal	$t(15) = 1.91$, $p < .05$	L1 - Leftening L2 - Rightening
	Parietal	$t(15) = 1.43$, $p < .10$	L1 - Leftening L2 - Rightening
P700	Parietal	$t(15) = -2.00$, $p < .05$	L1 - Leftening L2 - Rightening

B. P-types

Component	Location	*t* value, Probability	Interpretation
P300	Temporal	$t(6) = -1.77$, $p < .10$	P1 - Leftening P2 - Rightening
N400	Parietal	$t(6) = -1.82$, $p < .10$	P1 - Rightening P2 - Leftening
	Temporal	$t(6) = -4.79$, $p < .002$	P1 - Rightening P2 - Leftening

< .005]. P1 demonstrated rightening and a higher degree of improvement. Improvement on the FWT was related to leftening in temporal P300 activity [$\underline{r}(8) = -.77$, $\underline{p} < .02$]. This finding agrees with the significantly greater improvement in P1, which demonstrated a significant leftening effect.

Numerous other significant correlations were discovered as well. However, these were found despite the lack of significant differences between groups on the academic changes or BHD changes. For example, a high correlation for P-types was found between Gort Reading speed and leftening of temporal N550 activity [$\underline{r}(8) = .85$, $\underline{p} < .005$]. However, there were no differences between groups P1 and P2 on either Gort Reading Speed improvement or in BHDs. A list of all significant correlations is presented in Table 8.

Reliability of Bakker's Subtype Classification System

Table 9 demonstrates the stability of Bakker's classification system in control subjects who did not receive HSS. Almost half of the subjects (6 of 13) required re-classification after the 9-week period. Thus, only 53 percent of subjects were found to fit their original type at post-test time. Four of these six subjects were re-classified because ear advantage changed from pre- to post-test.

Given that ear advantage may not be a reliable measure of the L/P classification, it is perhaps not the best primary

Table 8

Significant Correlations Between Academic Changes and BHD Changes in L- and P-type Dyslexics*

A. L-types

Variables Correlated	*r* value	Probability	Interpretation
GORT Reading with N550 Parietal	-.44	$p < .05$	Rightening goes with Improvement
GORT Reading with P700 Parietal	+.61	$p < .005$	Rightening goes with Improvement
GORT Comprehension with P300 Temporal	+.43	$p < .05$	Rightening goes with Improvement
GORT Comprehension with P700 Parietal	-.59	$p < .01$	Leftening goes with Improvement
GORT Speed with N400 Temporal	-.66	$p < .002$	Rightening goes with Improvement
TCE with P300 Parietal	-.58	$p < .01$	Rightening goes with Improvement
TCE with P700 Parietal	-.44	$p < .05$	Rightening goes with Improvement
FWT with N550 Parietal	+.54	$p < .02$	Leftening goes with Improvement

Table 8 (Continued)

B. P-types

Variables Correlated	r value	Probability	Interpretation
WRAT-R Reading with N400 Parietal	-.86	$p < .005$	Rightening goes with Improvement
GORT Reading with P300 Parietal	+.62	$p < .05$	Rightening goes with Improvement
GORT Speed with N550 Parietal	+.71	$p < .05$	Leftening goes with Improvement
GORT Speed with N550 Temporal	+.85	$p < .005$	Leftening goes with Improvement
GORT Speed with P700 Temporal	+.63	$p < .05$	Rightening goes with Improvement
TCE with P300 Parietal	-.83	$p < .005$	Rightening goes with Improvement
TCE with N400 Parietal	-.74	$p < .02$	Leftening goes with Improvement
FWT with P300 Temporal	-.77	$p < .02$	Leftening goes with Improvement

* All changes are from pre- to post-test times

Table 9

Stability of Subtype Classification in Control Subjects with Two L/P Subtype Classification Systems

	Bakker System *			Errors Only System **	
Subject	Pre	Post		Pre	Post	
1	L	L		P	L ++
3	L	L		L	L
12	L	L		P	P
16	L	L		L	L
18	L	P	++	P	P
22	L	P	++	L	P ++
23	unclass	L	++	L	L
24	L	L		L	L
36	L	L		L	L
7	unclass	L	++	P	P
26	P	unclass	++	P	P
29	unclass	L	++	P	P
33	unclass	unclass		P	P

* Bakker System: e.g., L-type = REA and Average or Fast reading speed and/or a greater % of SE than grand mean across all subjects.

** Errors Only System: e.g., L-type = A greater % of SE than grand mean across all subjects (ear advantage and reading speed not considered).

++ indicates cases in which classification of subject changed.

Note: Subjects listed as "unclass" were technically unclassifiable under the Bakker system. These subjects were therefore classified as L- or P-types on the basis of 2/3 criteria best fitting a L-type or P-type profile.

criterion to use. An alternative classification system might involve categorizing subjects on the basis of type of reading error alone. Such a system is consistent with Bakker's theory of dyslexia and is the basic foundation of HSS. In order to test out the stability of this alternate system, all control subjects were re-classified on the basis of errors only. An illustration of the reliability of this "Errors Only" system is presented in Table 9. As can be seen, the reliability of this new system is considerably higher than that of Bakker's system. Only 2 of 13 subjects were classified differently between pre- and post-test times using the Errors Only system (85 percent of subjects were found to fit their original subtype at post-test time).

Re-Analysis of Data with Errors Only Classification System

Given that the Errors Only system for classification of L- and P-types appears more stable than that of Bakker, it was of interest to re-classify all subjects (N=26) according to this system, and then to re-analyze the pre-test ERP scores. It was hypothesized that the revised system would be more successful in reflecting the differential BHDs for L- and P-types (prior to treatment) that Bakker has shown (1986, 1990).

Table 10 lists the pre-test means and standard deviations for cases in which significant differences occurred. The ERP findings did not substantially change with the new

Table 10

Significant (p < .05) Amplitude Differences between Right and Left Hemispheres for L- and P-types at Pre-test Time after Re-classification with Errors Only System

A. L-types

Component	Location		Mean	SD	Interpretation
P300	Parietal	R	0.40	1.14	RH amp > LH amp
		L	-0.35	.80	
P300	Temporal	R	0.69	1.28	RH amp > LH amp
		L	-0.38	.87	
P75	Parietal	R	0.17	1.11	LH amp > RH amp
		L	0.84	1.48	
N550	Parietal	R	-0.01	1.32	LH amp > RH amp
		L	-0.56	1.29	
N550	Temporal	R	0.83	1.13	LH amp > RH amp
		L	0.12	.96	
N225	Parietal	R	-0.15	1.21	LH amp > RH amp
		L	-0.64	1.25	

B. P-types

Component	Location		Mean	SD	Interpretation
P75	Parietal	R	-0.07	.83	LH amp > RH amp
		L	0.35	1.11	
N400	Parietal	R	0.89	1.09	LH amp > RH amp
		L	0.47	1.00	
N550	Parietal	R	-0.01	.83	LH amp > RH amp
		L	-0.57	.76	
N550	Temporal	R	0.83	.42	LH amp > RH amp
		L	-0.04	.64	

classification system. L-types continued to demonstrate a right hemispheric advantage on the P300 component (both parietal and temporal locations). Also as before, no significant differences were found for the P-types on the P300 component.

With re-classification of all trained subjects (N=13) by the Errors Only system, 4 of 13 subjects reversed in subtype. Therefore, if the Errors Only system is a more valid system, 4 subjects were misclassified and administered the incorrect treatment in this study. Given such a possibility, it was of interest to do a post-hoc analysis comparing those trained subjects whose classification was reversed under the Errors Only system (Impure L-types, N=2; Impure P-types, N=2) with those subjects who did not become re-classified and who furthermore satisfied all three of Bakker's criteria (Pure L-types, N=2; Pure P-types, N=3). Thus, the only difference between Pure and Impure types was that Impure types did not manifest the type of reading error expected on the basis of their classification. Both Pure and Impure types showed the expected ear advantage and reading speed. Due to the small numbers of these subjects, no formal statistics were carried out to assess group differences. However, descriptive statistics were used to illustrate the tendencies associated with this data (see Figures 32 to 39).

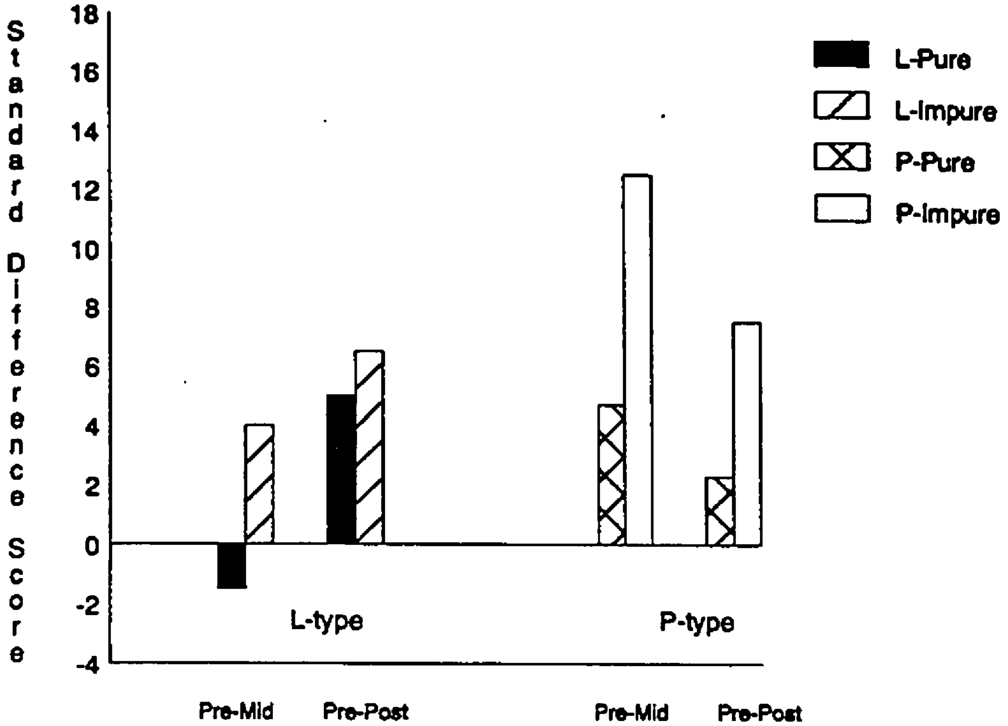

Figure 32. Changes in WRAT-R Reading: Pure vs impure types

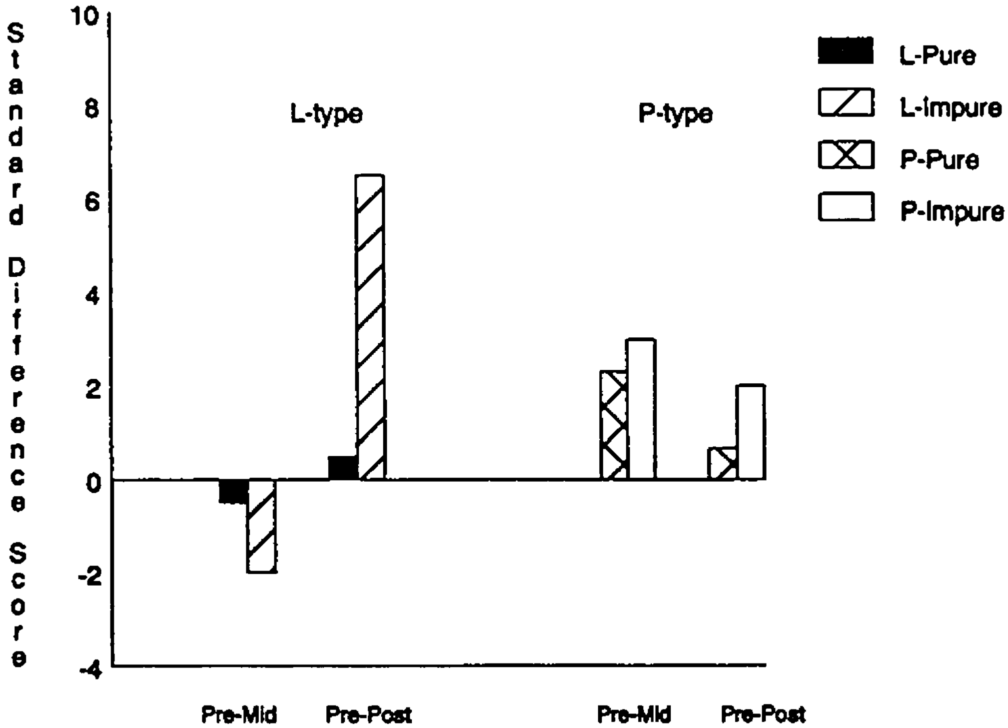

Figure 33. Changes in WRAT-R Spelling: Pure vs impure types

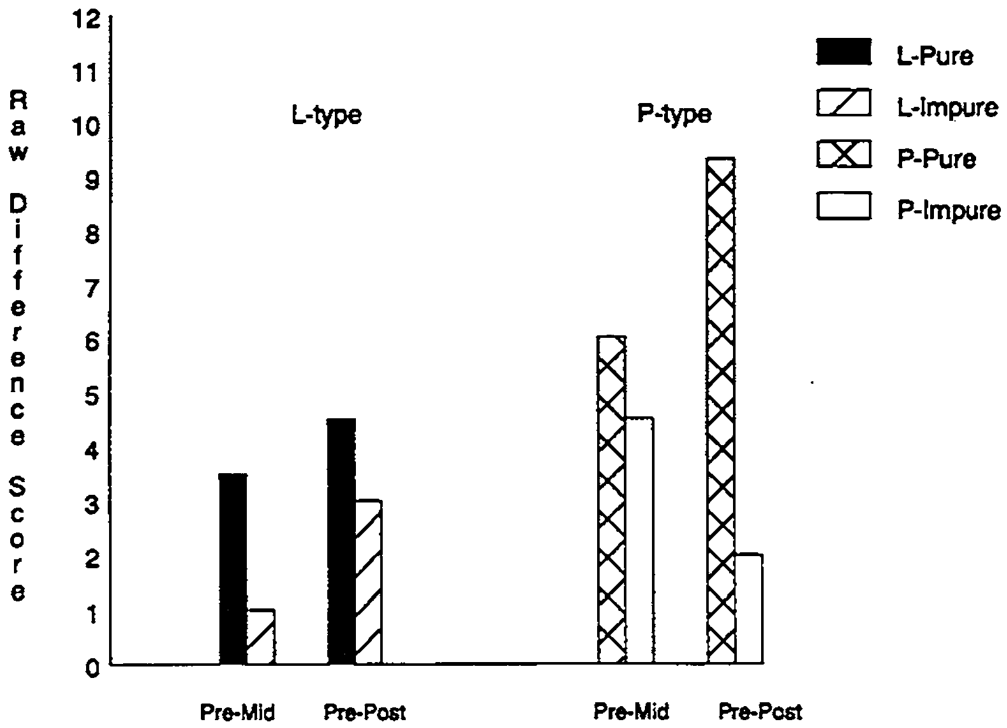

Figure 34. Changes in GORT Reading: Pure vs impure types

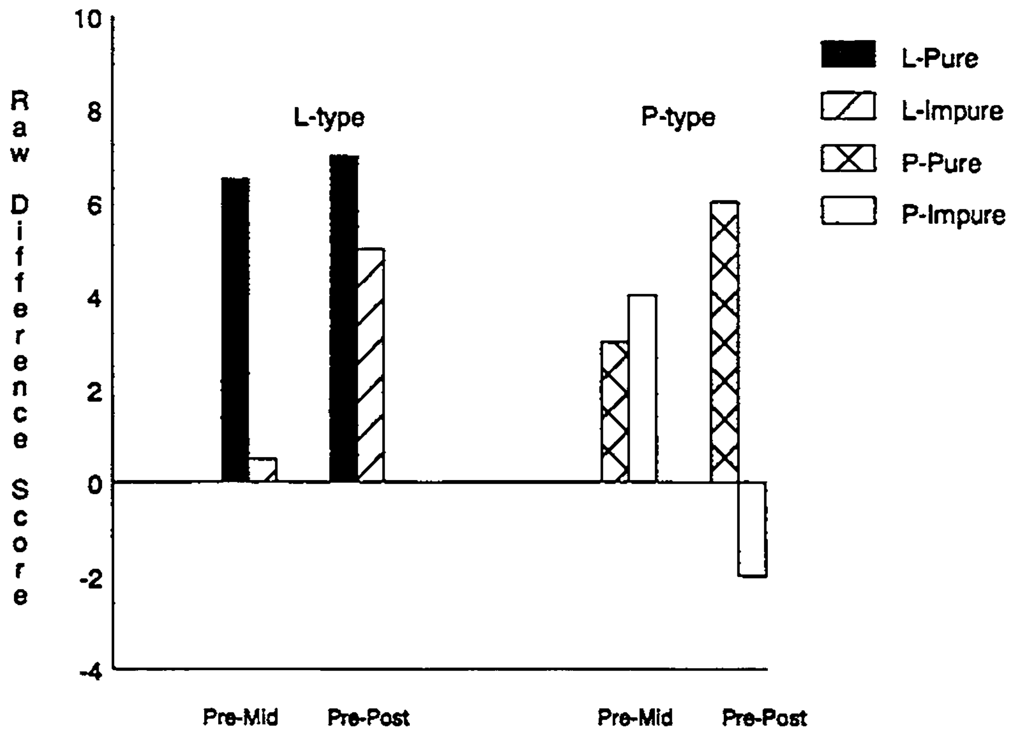

Figure 35. Changes in GORT Comp.: Pure vs impure types

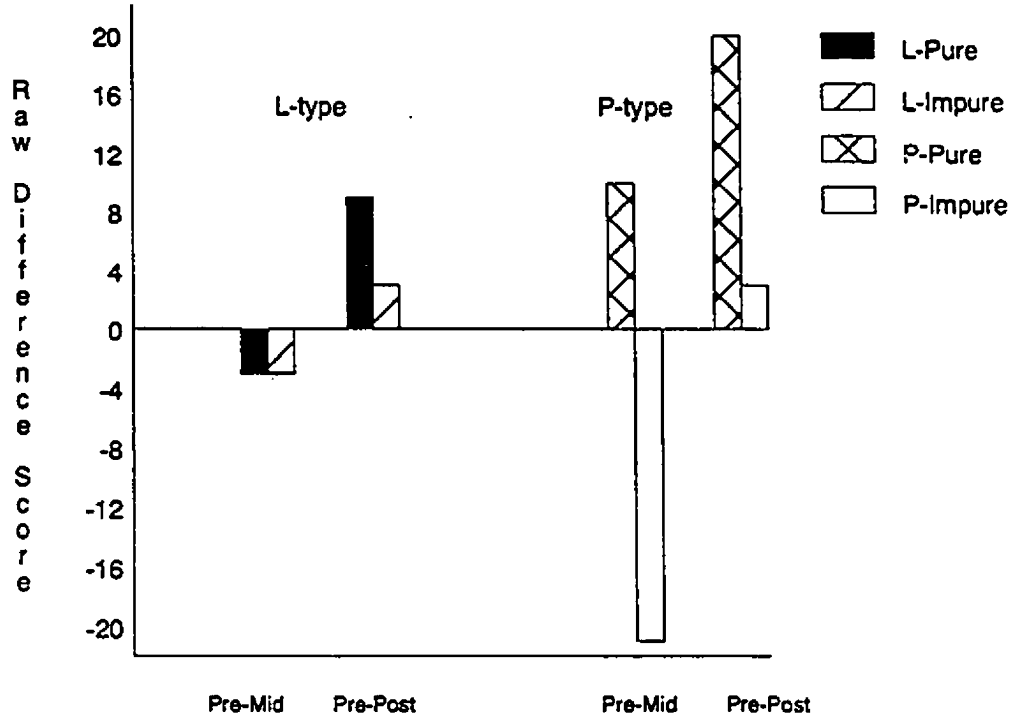

Figure 36. Changes in GORT Speed: Pure vs impure types

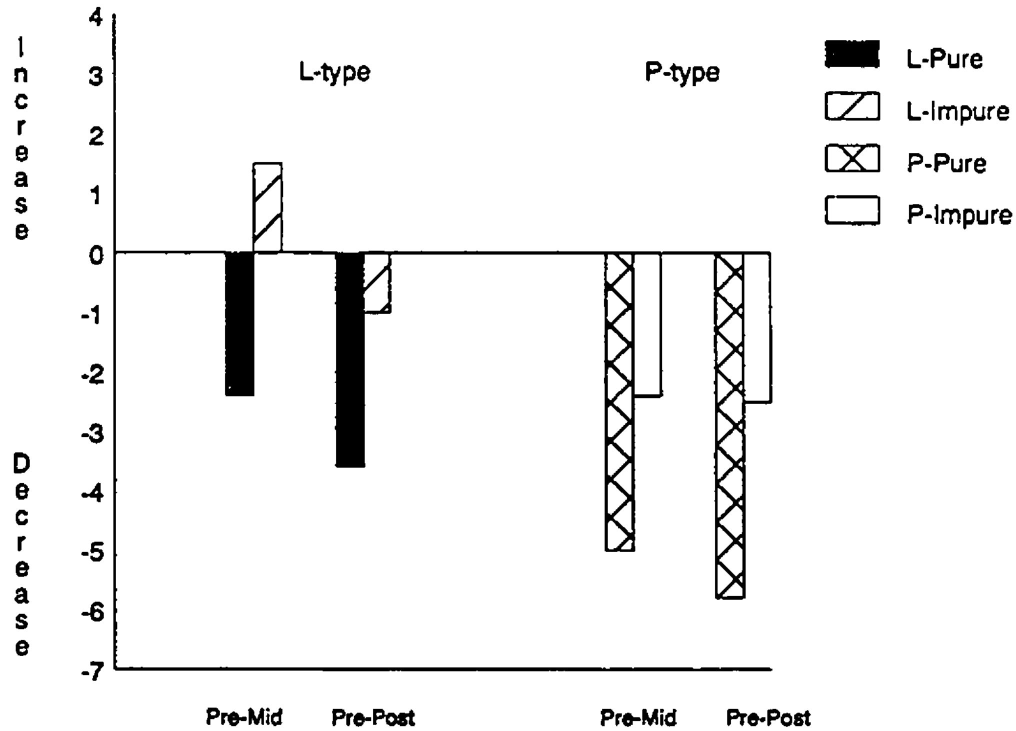

Figure 37. Changes in percent SE: Pure vs impure types

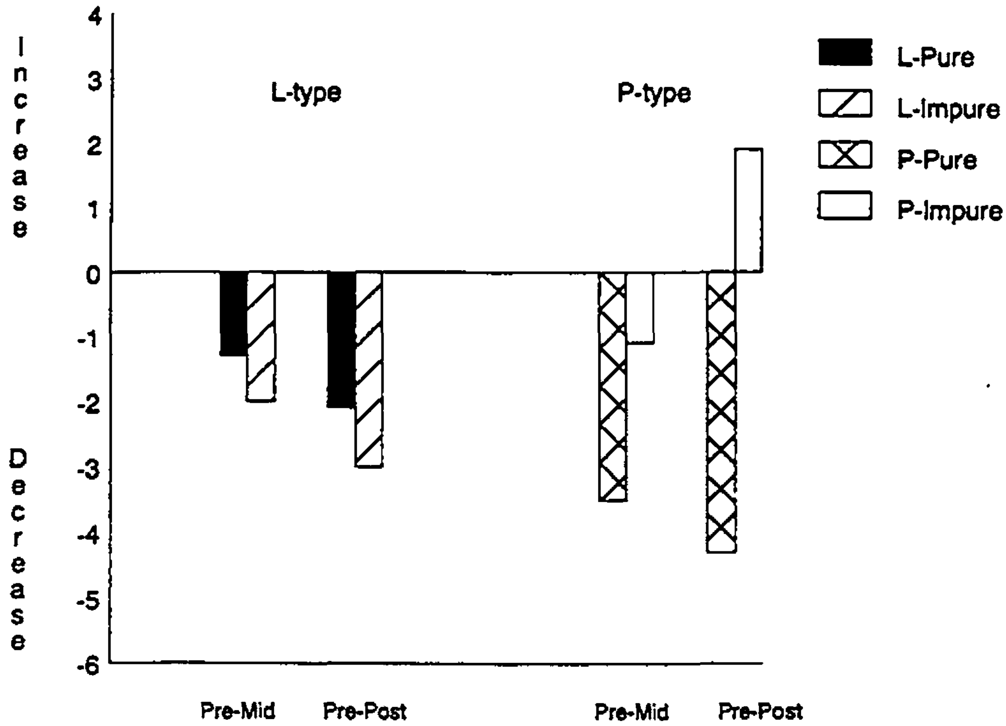

Figure 38. Changes in percent TCE: Pure vs impure types

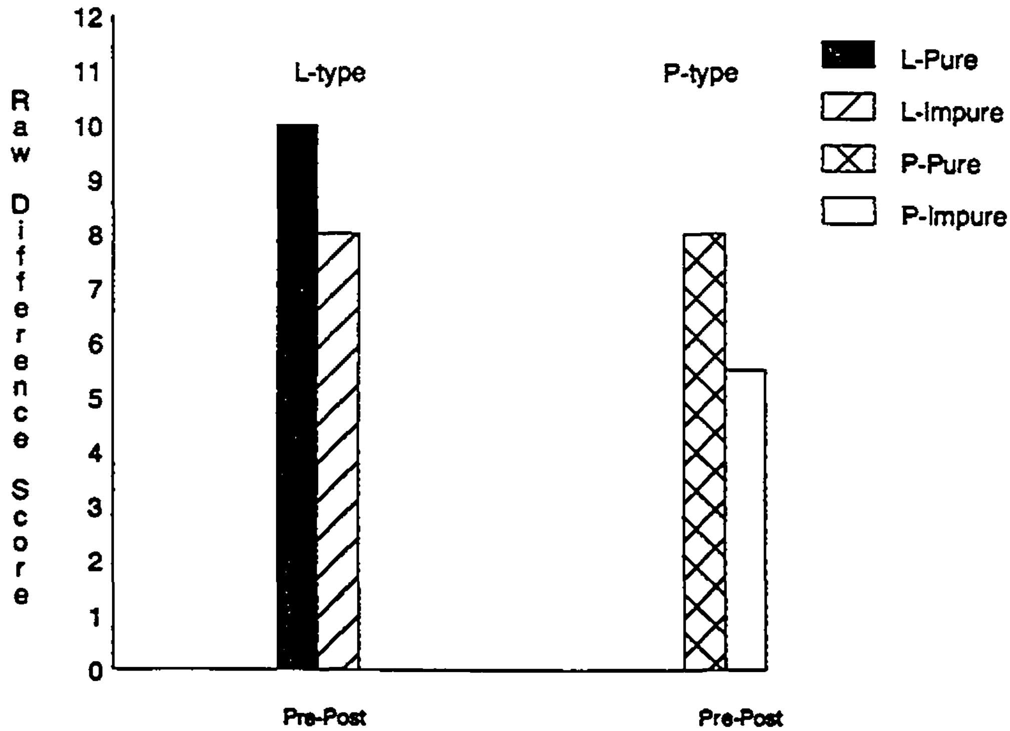

Figure 39. Changes in FWT: Pure vs impure types

Except for WRAT-R measures of Reading and Spelling, "Pure" subjects tended to show greater improvement than "Impure" subjects over time on all measures. Among the most dramatic differences were those involving substantive and time-consuming errors. These two measures can be considered the most sensitive measures of improvement because HSS is designed specifically to counteract substantive and time-consuming errors in L-types and P-types respectively.

BHD changes in ERP amplitude for L-types and P-types are presented in Figures 40 and 41 respectively. On the P300 temporal component, Pure L-types demonstrated rightening of brain activity in contrast to leftening of activity demonstrated by Impure L-types. In P-types the opposite effect was evident on the P300 Temporal component: Pure P-types showed leftening of activity; Impure P-types showed rightening of activity.

Due to the small N involved in this exercise, these results are put forth cautiously and are meant to be viewed only in speculative terms.

Subjects' Rating of HSS

On a 5-point scale, subjects' ratings of HSS (N=13) averaged to a mean of 3.53 (SD: 1.4, Range: 1-5). Seven subjects reported that they found HSS to be enjoyable and an interesting way to improve their reading ability (e.g., " It

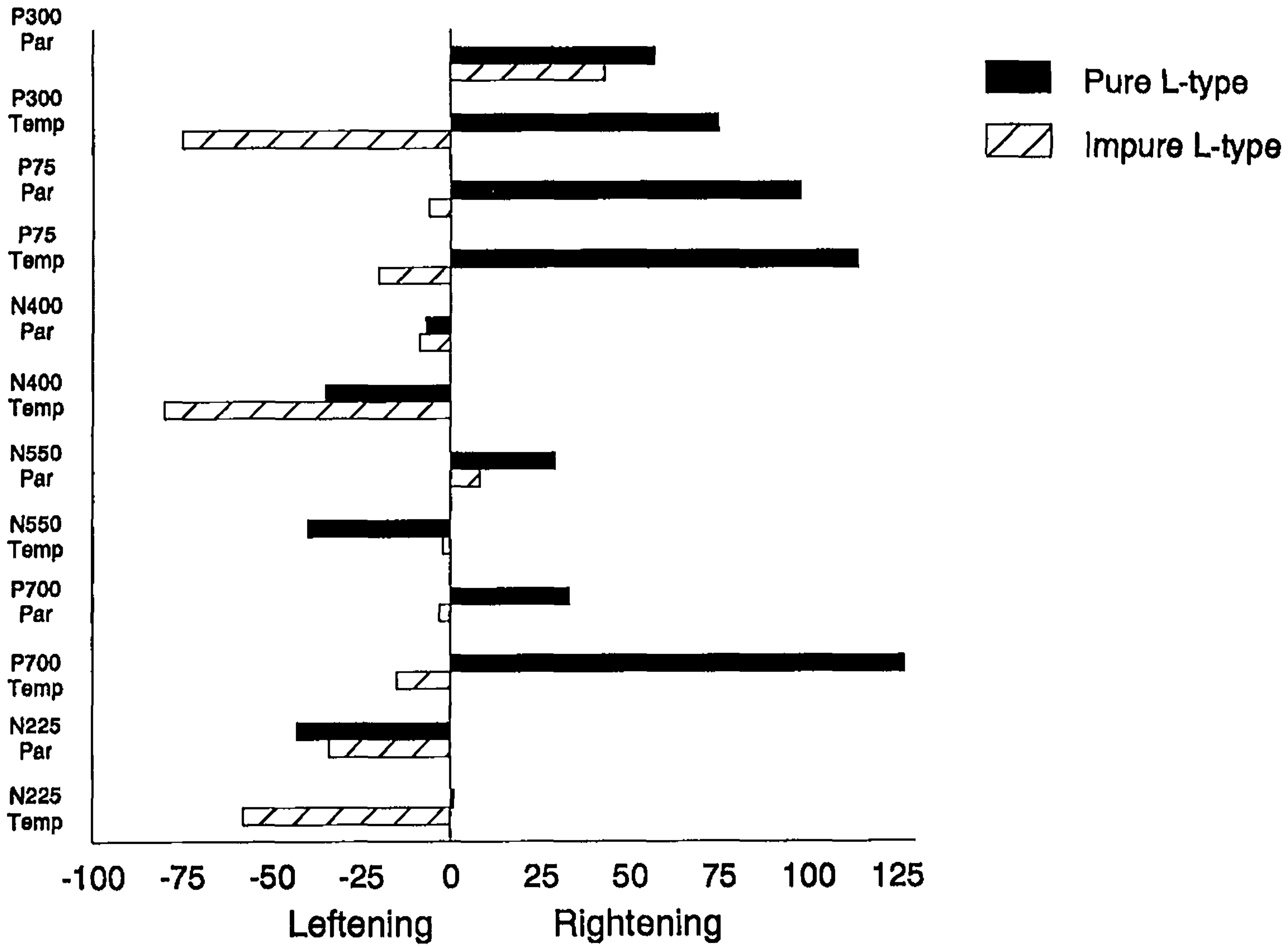

Figure 40. Changes in ERP Amplitude: Pure vs Impure L-types

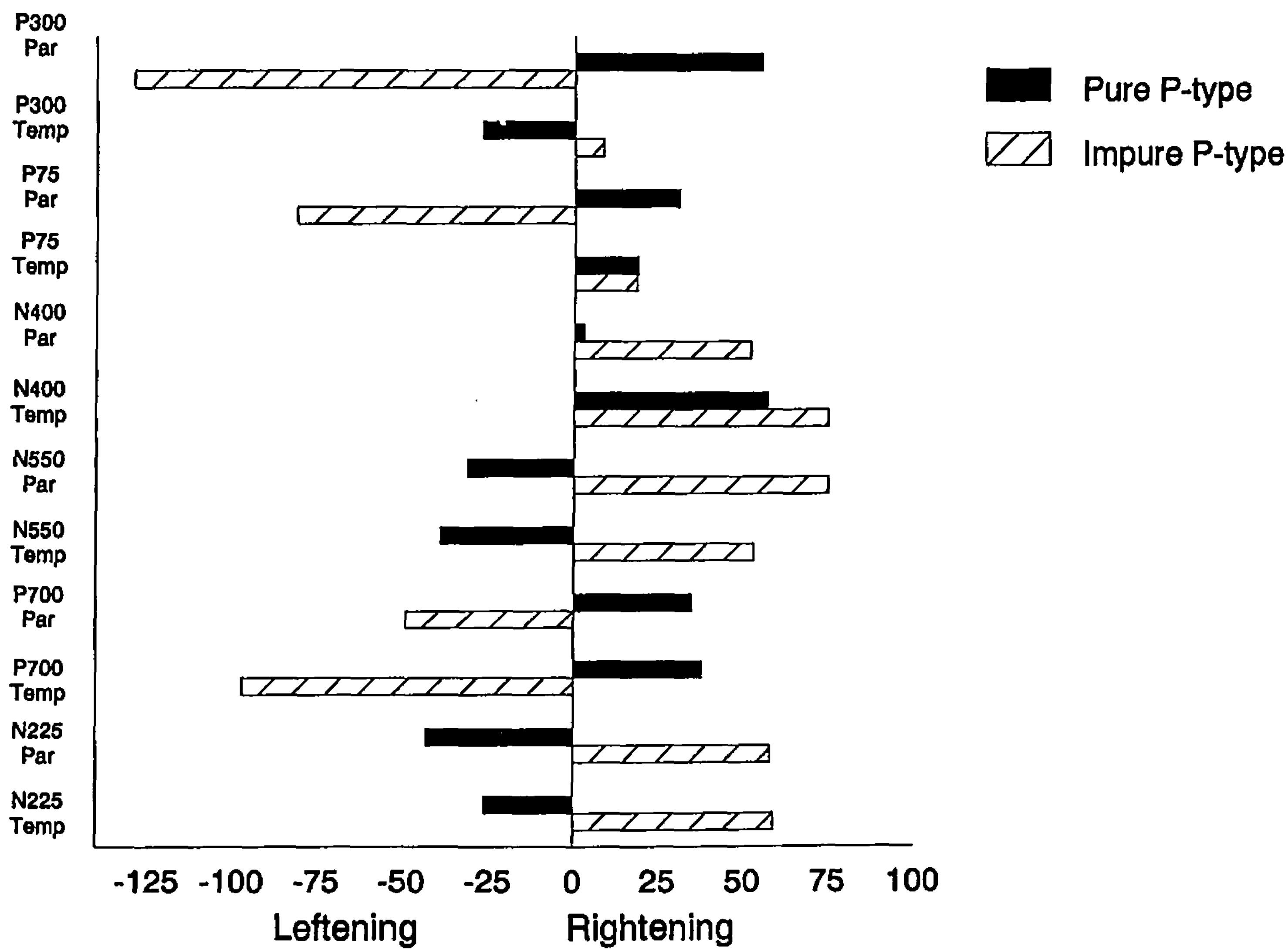

Figure 41: Changes in ERP amplitude: Pure vs Impure P-types

was neat.", "Great way to learn", "It was fun.", "I really liked it."). Four subjects were not overly impressed with HSS but regarded it as acceptable (e.g., "It was O.K.", "I liked it more than I hated it."). Only two subjects rated the method in the most negative direction (e.g., "It was awful and boring.").

CHAPTER FOUR

Discussion

The present study was designed to replicate the findings of Bakker and Vinke (1985) and concomitantly test a set of three hypotheses about HSS based on Bakker's theory. These hypotheses predicted that HSS would result in (a) improvements in reading and spelling, (b) specific changes in BHD for each group, and (c) moderately high and significant correlations between BHD changes and reading/spelling improvements. A comparison of the present study with that of Bakker and Vinke on the significant findings for each of these three areas is presented in Table 11 (L-types) and Table 12 (P-types). Reference to Figure 1 may be useful for the reader to become reacquainted with the groups of L- and P-types used by Bakker & Vinke (1985).

In terms of academic changes, Bakker and Vinke found significant improvements for Group L1 in SE and spelling as well as a reduced reading speed. These improvements were not replicated in the present study. In contrast, the present study found L2 to show greater improvement in SE and GORT Reading than did L1 from pre- to mid-testing. The only measure in the present study on which L1 showed a greater improvement than did L2 (p < .10) was on the FWT, a finding not described

Table 11

Significant Findings for L-types in the Present Study and in Bakker & Vinke's Study

Bakker & Vinke	Present Study
1. Changes in Academic Performance	
Within	Within
- (L1) Decrease in Words Attempted	- (L1) Increase in SE (pre-mid)
- (L1) Decrease in SE	- (L2) Decrease in SE (pre-mid)
- (L1) Increase in Spelling	
Between	Between
- L1 improves more than L2 in SE ($p < .10$)	- L1 improves less than L2 in SE (pre-mid)
	- L1 improves less than L2 on GORT Reading (pre-mid, $p < .10$)
	- L1 improves more than L2 on FWT ($p < .10$)
2. P250/P300 BHD Changes	
Within	
- (L2) Parietal Leftening	
- (L5) Parietal Leftening ($p < .10$)	
Between	Between
- L1: Rightening; L2: Leftening (Parietal)	- L1: Leftening; L2: Rightening (Temporal)
3. Correlations	
- More SE associated with Parietal P250 Leftening ($p < .10$)	- Improvement on GORT Comp associated with Temporal P300 Rightening
- More Words Attempted associated with Temporal P250 Leftening	- Less TCE associated with Parietal P300 Rightening

Note: $p < .05$ unless otherwise stated

Table 12

Significant Findings for P-types in the Present Study and in Bakker & Vinke's Study

Bakker & Vinke	Present Study
1. Changes in Academic Performance	
Within	Within
- (P1) Decrease in Words Attempted	- (P2) Increase in SE (pre-mid)
Between	Between
- P1 shows a greater decrease in Words Attempted than P5 ($p < .10$) - P1 improves more than P5 on FWT ($p < .10$)	- P1 improves more than P2 on FWT - P1 improves more than P2 on WRAT-R Reading (pre-mid, $p < .10$) - P1 improves more than P2 in SE (pre-mid, $p < .10$)
2. P250/P300 BHD Changes	
Within	Within
- (P1) Parietal Leftening - (P5) Parietal Rightening	- (P1) Temporal Leftening ($p < .10$) - (P2) Parietal Rightening ($p < .10$)
	Between
	- P1: Leftening; P2: Rightening (Temporal)
3. Correlations	
- More SE associated with Parietal P250 Leftening ($p < .10$) - More Words Attempted associated with Temporal P250 Leftening	- Improvement on GORT Read associated with Parietal P300 Rightening - Less TCE associated with Parietal P300 Rightening
- More errors on FWT associated with Temporal P250 Leftening	- Less errors on FWT associated with Temporal P300 Leftening

Note: $p < .05$ unless otherwise stated

by Bakker and Vinke. For P-types, only one similarity in results exists between the two studies: P1 improved to a greater extent than did P2 on the FWT (nonsignificant tendencies in both studies). The finding of a relatively greater decrease in reading speed in P1 as compared to P5 (Bakker and Vinke) was not replicated. Unlike Bakker and Vinke's results, the current findings included non-significant tendencies indicating that Group P1 improved relatively more than P2 on WRAT-R Reading and SE (pre- to mid-testing).

Thus, in general, the achievement test results of the present study do not replicate those of Bakker and Vinke. Although there was a general improvement for all groups over time on most measures, the experimental groups did not perform significantly better than controls on important measures of reading and spelling. The only significant ($\underline{p} < .05$) result in support of Bakker's work was that P-types given HSS performed significantly better than controls on the FWT.

Given the slow nature of P-types' reading style, this subtype might be expected to be very poor prior to treatment at identifying words seen for only a fraction of a second. However, with repeated practice of this skill, it is not inconceivable that a significant improvement in performance would result. Unfortunately, in the case of the present study, the improvement in reading appears to be quite specific to reading flashed words, a task rather far removed from "real-life" reading.

Comparison of the two studies on P250/P300 BHD changes yielded no more similarity than did the comparisons of academic performance. Unlike Bakker and Vinke, who found L1 to show a preclusion of leftening and L2 and L5 to show leftening at the parietal location, the current study revealed a significant difference between L1 and L2 at the temporal location with L1 and L2 showing relative leftening and rightening respectively. With P-types, more similarity existed between the results of the two studies: P5 in Bakker and Vinke and P2 in the present study (comparable groups) both showed rightening of parietal activity. In addition, leftening occurred for P1 in both studies but at different locations (parietal in Bakker and Vinke, temporal in the present study). As well, the present study found a significant between-group difference at the temporal electrodes indicating relative leftening for P1 and relative rightening for P2. Therefore, for L-types, the hypothesized electrophysiological changes in BHD did not occur and findings were inconsistent with those of Bakker and Vinke. However, for P-types, the predicted changes did occur and these were generally consistent with the ERP changes found by Bakker and Vinke.

Although the achievement test results differ, the ERP results for L- and P-types may be construed as consistent with

Bakker's theory. One might expect that trained L-types who did not improve more academically than controls and who, in one area, improved significantly less than controls would show a leftening of their activity, indicating an even greater reliance on an inappropriate left-hemispheric strategy. In contrast, trained P-types in this study tended to perform better than controls on three measures of reading. Therefore, the leftening and rightening effects shown by Groups P1 and P2 respectively are logically anticipated.

Correlations between BHD changes (P300) and academic changes emphasize further the characteristic relations between academic performance and hemispheric electrophysiology in the present study. For L-types, improvement on GORT comprehension and on TCE was associated with rightening of activity, a predicted finding. For P-types, improvement on the FWT was associated with leftening, also to be expected. It is interesting that Bakker and Vinke found the opposite, unexpected relation, i.e., more errors on the FWT were associated with leftening in P-types.

Unfortunately, the results of the present study do not completely replicate those of Bakker and Vinke. The present study found no clinically significant improvement in dyslexic children receiving HSS. Trained L-types in fact appeared to fare worse with HSS than did their matched controls not receiving the treatment. Given that the academic results were not replicated, one would therefore expect differences between the two studies in the ERP findings if Bakker's theory is valid. Such an outcome occurred: the ERP results of the present study, although at odds with those of Bakker and Vinke, are consistent with the predictions of Bakker's theory of electrophysiological changes in L- and P-types.

Unlike Bakker and Vinke's study, which found the greatest improvement in L-types, the present study found P-types to benefit most, albeit in a subtle manner, from the treatment. In contrast, L-types tended to get worse in certain areas after HSS. Although the explanation for this discrepancy in results is not clear, it appears that some element in the L-type HSS was promoting rather than hindering a continued left-hemispheric strategy. A technique involving the flashing of words might logically promote fast reading which would benefit particularly P-types and encourage even faster reading speed (and less accurate reading) in L-types. However, although such an explanation can account for the results of the present study, it does not explain why Bakker has achieved the opposite result.

It is possible as well that any of the differences between the two studies listed in Chapter Two could have played a causative role ` this discrepancy. A scrutiny of these differences does not lead to any obvious conclusions of a contributory role of any of these differences to the promotion of a left-hemispheric strategy. Nonetheless, one difference between the studies, the utilization of the earphone method during HSS, might be considered further. For L-types, the paradigm involves presenting the right ear with classical music and the left ear with the voices of the subject and trainer. This set-up is reversed for P-types. This technique was used in Bakker and Vinke's study, but was not used in the present study. Van den Honert (1977) reported dramatic results after using a combined visual and auditory technique to "re-lateralize" dyslexic readers. Although her technique was based on incorrect information, and her results are based only on anecdotal information, it was interesting that she found dramatic improvement only when both the visual and auditory set-up was used and not when either the visual or auditory paradigm was used alone. Her results therefore suggest a possible explanation for the lack of replication in the current study.

In addition to the three hypotheses discussed, four other questions were posed prior to the study. The first hypothesis was that the relative electrophysiological activity between the right and left hemispheres would differ for L- and P-types at the pre-test time. Results for the P300 component indicated that L-types showed a right-hemisphere advantage for both parietal and temporal locations, the opposite result of that predicted. In P-types, no significant differences were found.

Furthermore, results were unchanged after subjects were re-classified according to the Errors Only system. In sum, this analysis provided no support for the pre-treatment ERP differences in L- and P-types shown previously by Bakker and colleagues.

Second, the use of three testing times in the present study allowed for the examination of academic change over time. Interestingly, all changes were most prominent from the pre-test to mid-test time. Several quadratic trends in the data indicated that subjects' performance decreased slightly on several measures from the mid-test to post-test time. This effect is consistent with Bakker's (1990) suggestion that improvement reaches maximal value after only 10 sessions followed by a levelling off. One explanation for the lack of further progress at post-test time in the present study concerns a situational factor. That is, post-testing occurred in June, at a time when the school year is winding down and children are typically excitable and distractible. Testing scores at such a time could therefore encompass a much higher degree of error involving mainly underestimation of performance.

The third supplementary issue that was investigated concerned the subjects' subjective opinions about HSS. In general, most subjects appeared to like the technique or at least find it acceptable. The two exceptions to this general consensus were among the most difficult subjects in the project; they exhibited management problems upon several occasions. Due to the requirement of fairly long periods of sustained attention and restricted physical activity, HSS would not be an effective technique for children who have behavioural, attentional, or hyperkinetic disturbances.

The fourth issue involved an investigation into the reliability of Bakker's classification system. This topic will be discussed in depth at a later point in this chapter.

In attempting to explain why the present findings did not replicate those of Bakker and Vinke (1985), one may consider at least three possible explanations: (a) The present study did not provide an adequate test of the efficacy of HSS; (b) Bakker's model of dyslexia and/or his classification system is in need of revision and the use of HSS with the model or system in the flawed state results in unreliability and a reduction in power (increase in Type II error); and (c) Bakker's theory and system are valid, but HSS is not an effective training technique. Much of the remainder of this chapter will focus on the first two possibilities. In relation to the first explanation, methodological limitations specific to the present study are considered. Following this section, a large portion of this chapter will deal with the second possibility as a viable choice. For example, one possibility that will be explored in detail is that several subjects were incorrectly classified with the consequence of incorrect treatment provided to these subjects. Finally, suggestions for future research into the balance model and HSS are proposed.

Limitations of the Present Study

There are a number of difficulties and limitations specific to the present study which should be pointed out. Future research in HSS should attempt to avoid these shortcomings:

1. The number of subjects was limited, especially for P-types due to three limiting factors of number of trainers available, equipment availability, and availability of reading-disabled children.

2. Two of the subjects were left-handed (one untrained L-type, one trained L-type). Left-handedness is a concern because it increases the probability that an atypical or reversed pattern of hemisphere specialization exists. Because Bakker's treatment paradigm assumes a definite pattern of cerebral organization, treatment might be invalid for an atypical subject. It is unclear how Bakker deals with the issue of handedness in HSS; he has not addressed this issue in his work thus far.

3. The ratio of boys to girls was 1.89 to 1 in the present study. This ratio appears somewhat low in comparison to those cited in the literature. This discrepancy may reflect subjects

in the present study who have a non-specific reading disability. In addition to the possibility of this confounding factor, there is some suggestions that the neural substrate of dyslexia may differ between males and females (Witelson, 1977).

4. The age-range of the children was quite broad (8 to 12 years). Although experimental and control groups were matched for age, controlling the between-group variance, the lack of homogeneity within the groups contributed to high error variance within groups. HSS with an 8-year-old subject may be a very different process with different effects than with a 12-year-old subject.

5. A limitation of the present study with respect to the DLT was the use of only one pre- and post-trial. Reliability of the DLT would be improved with more than one administration of the test (Bakker, 1990). The subject of the reliability and validity of the DLT will be discussed further in the another section.

6. In order to ensure that the typefaces used for L-types in a HSS study act to stimulate the right hemisphere, some pilot work would seem to be necessary. Bryden and Allard (1976), in a study of visual-hemifield advantages using 10 different typefaces, found that only two of these produced left visual-field advantages. One of the dimensions that appeared most related to left visual-field effects was the script-to-print dimension, i.e., typefaces that resembled handwriting

were more likely to produce a left visual-field advantage. Because the typefaces used in the present study were not tested specifically for visual-field advantages, it is possible that few or none of the typefaces actually acted as primers of the right hemisphere.

As in any type of research, a "negative finding" is never conclusive. Thus, a failure to replicate does not automatically imply that the phenomenon under study cannot be replicated. It would therefore be presumptuous and incorrect to conclude that HSS is of no value in the treatment of dyslexic children. With the present results, it is possible to comment about the value of HSS only under the very specific parameters used in the present study. The efficacy of HSS might have been much improved if the treatment were modified or lengthened for example. An unqualified statement about the efficacy of HSS could be made only if HSS was tested under all conceivable conditions and remained unsuccessful.

Beyond the results of the current study, the study was heuristic and informative in pointing out the virtues and flaws of Bakker's model. In the next section, I will present a critical analysis of Bakker's model of dyslexia.

Critical Appraisal of the Balance Model of Dyslexia

The rationale underlying HSS is Bakker's balance model of dyslexia. As described in Chapter One, the balance model is based on a developmental theory and it attempts to explain the normal learning-to-read process and how this process can be disrupted in dyslexia. In the model, Bakker explicitly posits two subtypes of dyslexic readers - L-types and P-types. A critical analysis of HSS first necessitates an evaluation of the validity of the model and of the theory upon which the treatment is based.

That there are at least 16 learning disability typologies (Spreen, 1989b) suggests that such taxonomies are relatively easy to generate. However, as with a scientific theory, a classification scheme, which is often based upon a theory, should undergo an empirical process of verification. Skinner (1981) stated that "classification should be viewed as a scientific theory that is open to empirical falsification" (p. 69). Empirical methods of validation should follow as a matter of course after the theoretical formulation stage. Therefore, once a typology is created, the important question becomes "Is it reliable and valid?"

Skinner (1981) proposed a three-stage paradigm as a common framework for the integration of classification theory with empirical methods. The first component is theory formulation which involves the specification of the underlying theoretical foundation of the classification scheme as well as a precise definition of each subtype including its developmental origin, etiology, prognosis, and amenability to treatment. All hypotheses generated by the theory should be open to empirical falsification.

The second component, internal validation, refers to the development of an operational definition for the classification system, and to the assessment of its internal properties including reliability, coverage, and homogeneity. These standards are similar to those used to assess the psychometric properties of psychological tests. Skinner states that these requirements should be satisfied before a classification system is used in a clinical setting.

External validation, the third component, is the most neglected component in classification research (Skinner, 1981). It refers to validity in its traditional sense, and suggests the question: Does this typology represent what it purports to represent (Kavale & Forness, 1987)? External validity involves an ongoing series of studies that seek to demonstrate that subtypes can be discriminated by techniques not used in the original classification.

Under the rubric of external validity are predictive, descriptive, and clinical validity. Predictive validity refers to the clinical and prognostic usefulness of a diagnostic system, i.e., does the system allow one to make accurate statements of prognosis and decide upon an appropriate treatment approach? Descriptive validity includes both convergent and discriminant aspects of validity. In terms of convergent validity, the question is asked, can individual L- and P-types be classified similarly across measures not used in the original system? Discriminant validity deals with evaluating the distinctiveness between subtypes across measures different from those used originally. Clinical validity refers to the perceived acceptance of the system, i.e., the clinical relevance and meaningfulness of the diagnostic system to clinicians who may potentially utilize the system. In addition to these three major forms of external validity, the concept of generalizability falls under the heading of external validation.

As Skinner's theoretical framework provides an excellent structure for a critical evaluation of a classification model, this framework will be used in the following evaluation of the balance model of dyslexia.

Internal Validity of the Balance Model

With respect to the internal validity of Bakker's typology, I will now consider the issues of reliability, coverage, and homogeneity.

Perhaps the most fundamental requirement for a diagnostic system is reliability. On the most basic level, repeated testing of the same subject after a brief time should consistently yield the same classification. Bakker has not addressed this type of reliability; therefore I investigated this question in the present study. Upon examination of the reliability of L- and P-type classification (employing ear advantage, reading speed, and type of reading error) in control subjects, it was found that this system was quite unreliable (6 of 13 subjects were re-classified after 9 weeks). However, an alternate system, employing reading errors only, was found to be considerably more reliable than the original system.

I will discuss two possible explanations for the unreliability of the original system in the present study. The first explanation concerns developmental changes within types. Due to developmental changes, it is conceivable that subtypes may not remain stable over time (Fletcher & Satz, 1985). However, on the other hand, it is unlikely that such developmental change would occur over a relatively brief period of 9 weeks.

A second reason for unreliability involves the argument that the three different criteria in Bakker's system, each of which involves a range of error, could contribute to an additive end result of large total error variance. Using such reasoning, it is more likely that a system with three criteria would show less stability than a system with only one criterion. On the other hand, if all three criteria are reliable and valid measures of important characteristics of dyslexic subtypes (as they ideally should be), then classification reliability should be higher because chances are increased that correct classification has occurred in all testing sessions. Reliability of a typology depends to a large extent upon the reliability and validity of the measures used to assess subject characteristics. Unreliable tests contribute to a high degree of error variance which can seriously obscure results and consequently hinder the progress of classification research.

One of the key instruments central to Bakker's subtyping procedure is the DLT. The concept that perceptual asymmetry as measured by the DLT and visual half-field tasks is a reflection of functional hemispheric asymmetry has been well-known since Kimura's (1961) early studies (e.g., REA and LEA for verbal stimuli goes with left and right hemispheric control of language respectively). Although some investigators (e.g., Bakker, 1979b) judge the validity of the DLT as acceptable through the external criterion of speech dominance found through unilateral intracarotid injections of sodium amytal, other investigators have criticized the DLT (see Clark, 1981; Lezak, 1983; Satz, 1976) for being a poor measurement index of functional cerebral asymmetry. For example, Satz (1976) has questioned the assertion that right-hemispheric specialization for language is reliably predicted from LEA for speech stimuli. Using Baye's theorem on conditional probabilities, he demonstrated that the likelihood of such a relation is extremely low. Satz (1976) concluded that the implicit assumption of a perfect relationship between ear advantage and hemispheric speech dominance is "unwarranted and reckless" (p. 291). As mentioned earlier, confounding attentional factors have been noted also as a problem with the DLT (see Clark, 1981).

In conclusion, due to its questionable validity, the use of the DLT as one of Bakker's key criteria for classification may contribute to the poor reliability of subtypes, limiting the internal validity of his typology. An additional problem with Bakker's use of the DLT will be discussed in the section on external validity.

The idea of consistency in methodology and results within Bakker's own work can be considered another type of reliability. This topic was touched upon briefly in Chapter One, and the conclusion derived was that there exists some degree of inconsistency within Bakker's own work, particularly in the realm of classification procedure. Although the balance model clearly delineates three classification criteria (i.e., ear advantage, reading speed, and type of reading errors), in Bakker's three published studies of HSS, he has not been consistent in using these criteria. Rather, a different system has been used in all three studies. For example, in Bakker & Vinke (1985), the authors do not use reading speed as a criterion. This is surprising because speed is one of the cardinal features of the typology (e.g., P-types are slow, L-types are fast). The understanding of what constitutes an L- and P-type does not appear solid enough to warrant such variable criteria. It has certainly not been established that an L-type chosen by the methods in one study is equivalent to an L-type chosen by different methods in another study.

Another issue subsumed under internal validation is coverage. Coverage refers to the percentage of the sample that can be classified by the system. Ideally, a typology should classify all dyslexic readers, or at least classify 80 percent of the sample. Bakker (1990) has reported his coverage to be 60 percent. He has admitted that this low rate of classification indicates that the system is in need of improvement.

Homogeneity is another important internal feature of a typology and involves two components. First, subtypes should exhibit minimal overlap, i.e., they should be sufficiently different from each other. Second, within each subtype, subjects must be maximally similar. In the case of a clinical-inferential typology, the question can be asked: do the criteria used for categorization discriminate well between the types and result in highly similar subjects within each subtype?

The homogeneity of Bakker's subtypes has not been formally investigated. However, a careful consideration of his criteria for classification suggests that homogeneity may be poor. For example, in regard to type of reading error, Bakker's operational definition of an L-type states that SE must be more than the mean number of SE and TCE must be less than the mean number of TCE across all subjects. Hypothetically, if the mean number of SE and TCE is 8.2 and 7.5 respectively, then a subject with 8.3 SE and 7.4 TCE would be considered an L-type. Similarly, a subject with 8.1 SE and 7.6 TCE would be labelled as a P-type. Such a "thin" boundary between types fails to adequately discriminate between types. The other two variables of reading speed and ear advantage suffer from the same problem. Each variable is treated as a continuum with an arbitrary line drawn in the middle of each continuum, implying discreteness on either side. This type of classification acts to dilute the purity of the individual subtypes. For example, an L-type whose scores lie closer to the demarcation lines may be quite different from an L-type whose scores lie at the far end of the continuums (see Figure 42).

Furthermore, due to the "and/or" clause in the definition (i.e., an L-type exhibits REA <u>and</u> demonstrates average or fast reading <u>and/or</u> a greater percentage of SE than the grand mean across all subjects), an L-type need not satisfy all three criteria to become classified as such. Thus, a subject who has REA and reads quickly would be considered an L-type even if type of reading error is primarily of the time-consuming

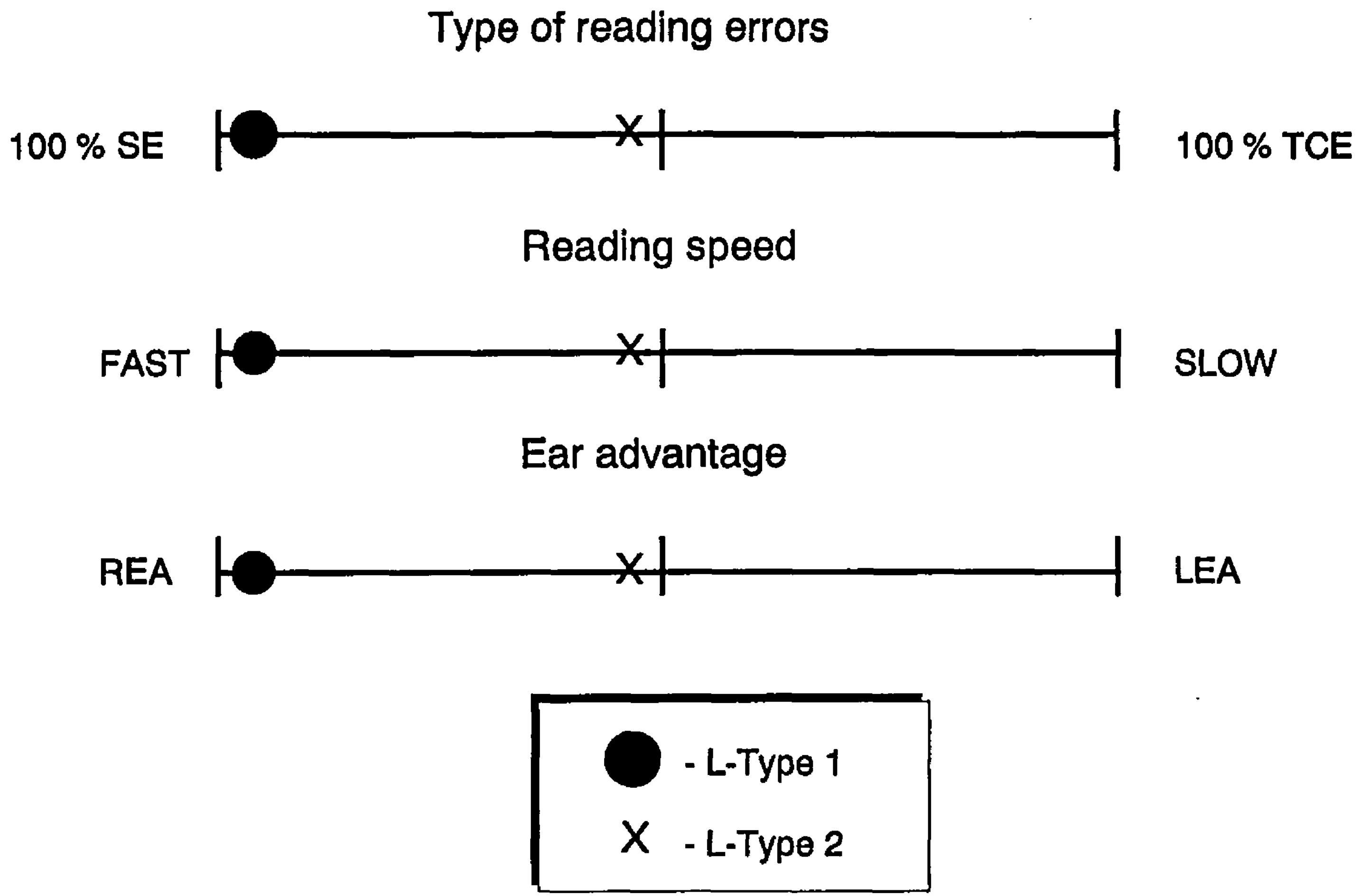

Figure 42. Illustration of the potential heterogeneity within the L-type classification

variety. Clearly, the "and/or" clause contributes further to heterogeneity within subtypes.

Some evidence for the preceding criticisms was gathered in the present study. A post-hoc comparison of "Pure" and "Impure" L- and P-types demonstrated differences between these types in academic and electrophysiological changes after HSS. Pure subjects (i.e., those trained subjects whose original classification remained the same after re-classification with the Errors Only system and who met all 3 criteria) tended to show greater improvements in reading ability over time than Impure subjects (i.e., those trained subjects whose classification changed under the Errors Only system). Thus, subjects classified on the basis of reading error showed greater improvement than those whose type of reading error was inconsistent with their classification. Furthermore, Pure L-types showed rightening of brain activity (P300 Temporal) as predicted by Bakker's theory whereas Impure L-types demonstrated a leftening effect. Although these results are based on only a few subjects, they are compelling and suggest that Bakker's original classification system may be in need of revision. Specifically, the use of error type as a primary classification criterion may be more reliable and valid than ear advantage.

These results suggest a logical reason (i.e., misclassification) why as a group, L-types in the current study did not show improvement and predicted rightening of electrophysiological activity. Indeed, it is possible that L-type HSS for the misclassified individuals was actually counterproductive.

If the characteristics of L- and P-types exist along a continuum, perhaps it would be appropriate to propose a third subtype, that of a mixed L-P type. Such a subtype would describe the subject who has characteristics of both types and who may benefit from a combined HSS treatment program. The creation of a third mixed type would help to preserve the distinctiveness and homogeneity of L- and P-types. As illustrated, without a mixed group, the distinctiveness of groups can become diluted due to the inclusion of subjects with combined L- and P-type features.

This idea has been noted previously. For example, a similar argument for a mixed subtype has been put forward by Boder (1973) in support of her mixed subtype. Along the same lines, Stanovich (1988) offered his belief that dyslexia can be conceptualized as a disorder on a multidimensional continuum of reading-relevant abilities. He noted that there is considerable evidence that dyslexia does not represent a discrete pathology (like the measles) as Rutter and Yule (1975) suggested when they described a "hump" at the low end of the reading distribution. Rather, evidence now points to a graded continuum of reading disability similar to the condition of obesity. Furthermore, although Stanovich agrees that heterogeneity exists within the dyslexic population, he does not believe that subtypes of dyslexic readers form discrete clusters or homogeneous subgroups. Rather, boundaries are recognized as highly arbitrary and can be imposed anywhere on the continuum to isolate groups of normal readers, dyslexic readers, or subtypes of dyslexic readers. Thus, with this kind of framework in mind, a mixed typology would be a natural middle transition between the extreme far ends of the continuum.

Another argument against the use of a dichotomy of dyslexia is that a typology with only two subtypes may be overly simplistic, and increase the possibility of erring on the out-dated unitary syndrome side of dyslexia theory. It is clear that dyslexia is a complex, heterogeneous disorder. Therefore, any model or theory attempting to explain it must be sufficiently complex and multidimensional (Petrauskas & Rourke, 1979). A dichotomous subtype structure with a corresponding dichotomous treatment paradigm is analogous to trying to force all dyslexic readers into one of two procrustean beds (an L-bed and P-bed). Such a practice may be too simplistic and nonspecific to be of any practical or effective use. That many researchers today appear to be aware of this issue is reflected by the fact that most of the typologies described have included more than two subtypes.

In summary, one of the possible explanations for the results of the current study and the lack of robust effects in Bakker's studies is that Bakker's classification system does not allow for accurate classification of L- and P-types. Bakker (1990) himself admits that the classification system is in need of improvement and the current measurement tools are not as accurate as he would like them to be.

In addition to the problems with internal validity already noted with the L-P system, there is one additional conceptual difficulty that could be construed as significant. This problem concerns the use of ear advantage for subtype differentiation of L- and P-types. Bakker's balance model specifies that L-types have left hemispheric speech (reflected by REA) and P-types have right or bilateral hemispheric speech (reflected by LEA or lack of ear advantage; Bakker, 1979b, 1981a; Bakker, Teunissen & Bosch, 1976). Indeed, it is due to this feature that P-types comprise the minority of dyslexic readers because children with LEA are relatively rare. Assuming that the DLT is indeed a reliable and valid index of cerebral asymmetry (a questionable assumption), is the side of hemispheric language specialization a logical criterion for distinguishing between L- and P-types? The following argument proposes that both L- and P-types can have left-hemispheric subservience of speech. This modification of the balance model does not invalidate the rest of the model and in fact improves the logic of HSS within types.

Bakker asserts that L-types have left-hemisphere language, but lack the right-hemisphere reading strategies necessary to process effectively the perceptual features of script. P-types can be regarded as also having left-hemisphere language, albeit with poor development of left-hemispheric reading strategies such as phonetic analysis. Thus, P-types could have "normal" language organization, but have deficient functioning of left-hemisphere reading strategies. Their right hemispheres, on the other hand, may be relatively more capable, resulting in a tendency to make heavier use of perceptual strategies in the reading process.

Another interpretation which is consistent with the idea of left-hemispheric speech in P-types is suggested by the research of Witelson (1976). She suggested that although most dyslexics demonstrate REA, many of these children might possess a bilateral representation of spatial functioning (proposed due to their lack of normal left visual-field superiority for spatial processing). Therefore, on a reading task which requires both left and right hemisphere processing, these dyslexics may favour primarily a spatial-holistic strategy in preference to a phonetic-analytic one.

Given these alternate interpretations, the possibility to be considered is that Bakker's criterion of LEA for P-types may be a red herring. If so, misclassification of subjects would be the major repercussion. If the preceding argument in correct, then the ratio of P- to L-types would dramatically increase, perhaps to the extent that P-types would form the majority subtype. This state of affairs would certainly be more consistent with the views of subtypes in the literature.

Modifying the theory to allow P-types to have REA improves the logic of HSS as well. Using Bakker's original model, HSS in P-types is designed to stimulate their RVF (left hemisphere). However, this procedure is not logically sound considering that P-types' functional and anatomical home for language resides in the right hemisphere according to Bakker. If, on the other hand, P-types are granted left-hemispheric control of language, P-type HSS is logical.

Despite the importance of this potential flaw in logic, Bakker has not directly addressed this issue. However, he has chosen to de-emphasize the criterion of ear advantage in his more recent work. For example, Bakker (1990) explains that L- and P-types are identified on the basis of type of reading errors. He states that reading speed might be considered as an alternate method and one "might wish" (p. 22) to administer a DLT. In his most recent HSS study (Bakker, Bouma, & Gardien, in press), neither ear advantage nor reading speed was employed. Bakker does not offer an explanation for his variable use of his three fundamental criteria for distinguishing L- and P-types.

In concluding this section on internal validity, it is clear that Bakker's classification system is in need of formal revision. The classification scheme appears to fall short of accurate representation of the proposed theoretical differences between L- and P-type dyslexic readers. As Bakker admits, a standardized approach to L-P classification that is both reliable and valid must be developed.

External Validity of the Balance Model

External validity can be considered a "higher" dimension beyond the more basic dimension of internal validity. External validity goes beyond the basic internal properties of a model or theory and addresses the outside evidence that exists to support it. A number of studies done by Bakker and other investigators have provided external validation of the balance model. Other studies, however, have resulted in conclusions of questionable validity. This section will review the studies that address external validation of Bakker's work.

Much of the evidence in support of the balance model comes from Bakker's research. He is one of the few investigators who has attempted to supply external validation for his theory. This highly commendable effort is sadly lacking in the field of dyslexia treatment and cognitive rehabilitation in general.

Specifically, Bakker has taken two routes to provide external validation for the L-P system. First, he has demonstrated electrophysiological brain differences between L- and P-types (discriminant validity). These changes have been shown to be inherent within types prior to HSS (Bakker, 1990). In addition, he has shown that HSS acts to enhance the electrophysiological activity in the right hemisphere for L-types and the left hemisphere for P-types (Bakker & Vinke, 1985). The present study found some support for the latter finding but not for the former one. Also using the electrophysiological paradigm, Bakker and colleagues have gathered support for the developmental proposal in the theory, i.e., that novice readers learn to read with a right hemispheric strategy.

The second means of external validation that Bakker has employed is the development of a specific treatment paradigm (i.e., HSS) and the subsequent empirical research into its efficacy (predictive and clinical validation). Studies of subtype by remediation interactions are rare and are required to establish clinical meaningfulness of the model. Despite this commendable attempt at validation, I have illustrated that the results from efficacy studies of HSS, in particular the present study, have not been overly supportive of HSS.

Descriptive validity of the L-P classification would be indicated if the subtypes elucidated by different investigators using different methods were similar to L- and P-types. If the balance model is a valid and reliable method of describing and representing dyslexia, then it follows logically that L- and P-types should resemble the subtypes of other typologies.

Despite the lack of consensus on one definitive classification scheme of dyslexia, there exists a basic similarity and overlap between numerous classification systems (Spreen & Haaf, 1986; Thomson, 1984). Bakker's typology is not inconsistent with this general trend, and upon first glance, Bakker's subtypes are quite similar to several other typologies of reading disability. These typologies include those of (a) Johnson and Myklebust (1967), (b) Boder (1973), (c) Kinsbourne and Warrington (1963), (d) Mattis et al. (1975), (e) Ingram et al. (1970), and (f) Lovett (1984).

The basic similarity between the above mentioned systems is that all describe two general subtypes. One subtype can be considered, through neuropsychological findings, to have left-hemisphere dysfunction (Rourke, 1978a). This subtype has audiophonological language difficulties such as confusion of vowel sounds, consonant substitution, and mispronunciation of diphthongs (Benton, 1978; Thomson, 1984). This subtype is often further subdivided into types that exhibit specific and distinct clusters of psycholinguistic deficits, possibly reflecting differential dysfunction of specific areas within the left cerebral hemisphere (Rourke, 1978a).

Under the rubric of this "left-hemisphere" subtype falls the auditory dyslexic of Johnson and Myklebust (1967), the audiophonic type of Ingram et al. (1970), the language retardation (Group I) type of Kinsbourne and Warrington (1963), the dysphonetic type of Boder (1970, 1973), and the language-disordered type of Mattis et al. (1975). Bakker's P-type would fit well among this crowd.

The other general subtype is thought to have primarily right hemisphere dysfunction (Rourke, 1978a), resulting in poor visuospatial and/or visuomotor skills in the context of relatively intact psycholinguistic abilities. Children with this problem may confuse words and letters on the basis of their visual configuration (Benton, 1978; Thomson, 1984). The counterparts of the typologies noted above represent this "right-hemisphere" type, e.g., visual dyslexia (Johnson & Myklebust, 1967), visuospatial type (Ingram et al., 1970), Gerstmann Group (Group II; Kinsbourne & Warrington, 1963), dyseidetic dyslexia (Boder, 1970, 1973), visuospatial perceptual disorder (Mattis et al., 1975), and Bakker's L-type.

Although Bakker (1983, 1990) has correctly pointed out the obvious similarities between his subtypes and those of others, there remains one important difference. This difference involves the proportion of subjects falling within each subtype in a given sample. Of the typologies mentioned previously that include a comment about proportion, without exception, all have described the left-hemisphere dysfunction subtype as comprising by far the largest group and the right-hemisphere dysfunction type as representing a small percentage of the sample. For example, Boder (1973) reported that dysphonetic and dyseidetic types comprised 67% and 10% of the sample respectively. This observation, that the left-hemisphere dysfunction type represents the majority of dyslexic children, has been noted by several investigators (e.g., Petrauskas & Rourke, 1979; Stanovich, 1988; Thomson, 1984; Warrington, 1967, cited in Yule & Rutter, 1975; Witelson, 1977).

That the majority of dyslexic readers exhibit a cognitive profile of "intact and overused spatial, holistic processing combined with deficient linguistic sequential processing" (Witelson, 1977, p. 311) is further substantiated by many years of unsuccessful research devoted to the elucidation of basic visual-perceptual processing deficiencies in dyslexics (see Benton, 1975; Hynd & Semrud-Clikeman, 1989). Additional evidence for visuospatial deficits being less common than linguistic deficits in dyslexia comes from a lack of correlation between severe visuospatial deficits (e.g., as in Turner's syndrome) and dyslexia in children (Rutter, 1978). In contrast, research findings have widely supported the notion that deficits in semantic-linguistic memory processes and poor phonological analysis are prominent in dyslexia.

Bakker's research, in direct contrast to this arsenal of literature to the contrary, indicates that L-types comprise a much larger proportion of any given sample, whereas P-types are relatively rare. These results imply that one of the most prevalent deficiencies underlying dyslexia is poor visuo-perceptual ability. This conclusion is, of course, unsupported by the literature.

Although Bakker's classification system is not entirely congruent with other systems at the level of subtype, Bakker's developmental theory of reading and dyslexia is quite consistent with several other well-respected developmental theories. These theories include those of Fletcher and Satz (1980), Rourke (1982), and Goldberg and Costa (1981).

As briefly discussed in Chapter One, the developmental theory proposed by Satz and colleagues (e.g., Fletcher & Satz, 1980; Satz, Rardin, & Ross, 1971; Satz et al., 1978) stated that the deficits responsible for reading problems differ on the basis of age. Visual-motor integration is of primary importance during the early stages of learning to read (e.g., ages 7 to 8) whereas verbal-conceptual skills become important at the more advanced stages of reading development (e.g., ages 11 to 12). Bakker has postulated a very similar developmental shift in normal reading, and he expands on this idea to suggest that an arrest at the first stage results in a P-type, whereas an omission of this step results in an L-type.

The theory of Goldberg and Costa (1981, see Chapter One) postulates a similar idea involving a developmental transition from right- to left-hemisphere processing, consistent as well with the balance model.

Finally, Rourke (1982, see also Rourke & Fisk, 1988) proposed a model of central processing deficiencies which is compatible with Bakker's view. In his model, Rourke emphasizes differences between right- and left-hemisphere systems, and explains that specific dysfunction of each hemisphere is correlated with particular learning difficulties. As an example to illustrate his model, Rourke described two learning disability subtypes which are reminiscent of L- and P-subtypes.

In conclusion, Bakker's theory of reading development is consistent with those of others in the field. This similarity demonstrates some degree of external (descriptive) validation for the theory. That L-and P-types are similar to numerous other subtypes indicates external validity as well. However, further "fine-tuned" comparison of Bakker's subtypes with those of other investigators demonstrates serious differences.

There are, of course, several other avenues of research that could provide validational support for Bakker's theory and typology. One area in particular that would be important for the credibility of his typology would be to show that L- and P-types can be identified and distinguished by other means (convergent and discriminant validity). This endeavour would be important because the examination of only one or few variables (such as the three criteria used by Bakker) can result in masked heterogeneity within subgroups that are assumed to be homogeneous.

In the current literature on dyslexia, there appear to be two general methods for classification of subtypes. One is grounded on the analysis of errors in reading and/or spelling (e.g., the systems of Boder (1973) and Ingram et al. (1970)). Bakker's system best fits into this category. The other system is based on the analysis of deficits in cognitive abilities including oral language, motoric skill, perception, and short-term memory (e.g., the system of Mattis, French, & Rapin (1975)). There are few dyslexia typologies that have been developed or validated around both of these systems. However, it would be beneficial and progressive if these two systems were used jointly (Benton, 1978).

To obtain a realistic and valid idea of subtype differences, it is necessary to measure a comprehensive set of skills and abilities (Fisk & Rourke, 1983; Kavale & Forness, 1987; Rourke, 1989). Although dyslexia can potentially be correlated with a wide range of interacting dimensions, most researchers in the field have utilized only one part of this global picture. The use of a single dimension does not do justice to the complexity of variables actually present. A seemingly homogeneous subgroup may contain a host of heterogenous variables that interact with treatment approaches in an unpredictable manner. Therefore, the consideration and integration of all relevant content domains (e.g., reading and spelling errors, neuropsychological deficits, genetic factors, socioemotional functioning, birth history, etc.) can only aid in the comprehensive description and understanding of each subtype in a typology.

In regards to Bakker's typology, the cognitive dimension is in need of exploration, i.e., the underlying neuropsychological characteristics of L- and P-types. Studies of neuropsychological deficits in learning-disabled children have been used frequently to distinguish between learning disability subtypes (see Rourke, 1989). Many researchers believe that in the classification of reading disabilities, it is most fruitful to use a large number and breadth of measures known to be sensitive to CNS dysfunction (Petrauskas & Rourke, 1979) because dyslexia is far more complex than a deficit in reading. Neuropsychological studies are needed because it is not firmly established that L-types require right-hemisphere stimulation because they are poor in perceptually-related abilities and P-types require left-hemisphere stimulation because they are poor at phoneme-grapheme associations. Alternatively, L-types who read quickly and make many SE could do so because of deficits in verbal labelling or anomia rather than visuo-perceptual deficiencies. Similarly, P-types may exhibit their characteristic reading problems due to receptive difficulties in speech-sound discrimination and sequencing or expressive deficiencies in motor-speech co-ordination (Mattis et al., 1975). The suggestion here is that information provided from detailed neuropsychological studies of the two subtypes may shed informative light on the typology.

Van Strien, Bakker, Bouma, & Koops (1988) have begun to look into this area in their study of the familial antecedents and cognitive correlates of L- and P-type boys. In their abstract, the authors briefly reported that L-type boys were better at verbal tasks and worse at spatial tasks than P-type boys. This pattern was evident in the parents of these subjects as well, i.e., parents of P-type dyslexics performed better on some spatial tasks than did parents of L-type dyslexics.

Using the same argument for a comprehensive and integrative set of methods for classification, the two major methods for classification - the phyletic (clinical-inferential) and phenetic (statistical) approaches - should be considered complementary and therefore be used jointly (Adams, 1985). Along these lines, Bakker's system, based on a phyletic approach, could be enriched by the use of quantitative (phenetic) approaches such as cluster analysis. Given the criticisms of the "subjective" a priori approach (e.g., Fletcher & Satz, 1985), the use of a multivariate classification technique would provide a means for gathering additional evidence (i.e., convergent validity) for the balance model.

Suggestions for Future Research

On the basis of the above critical analysis of the balance model, a number of suggestions for future research into this area are relevant. Some of these suggestions are of a general nature and are applicable to dyslexia research in general. Other suggestions are more specific to future studies of the balance model and HSS. The suggestions are hierarchical in nature such that, ideally, each suggestion should be implemented before the next one is approached.

1. Specification of the Population The first logical step concerns the refinement of a definition of the dyslexic population from which L- and P-types are chosen. Use of a teacher's rating that a child's major difficulty is with reading is not adequate for this purpose. Notwithstanding the criticisms of exclusionary definitions from a clinical viewpoint, such an exclusionary approach from the research viewpoint is advantageous to attain as homogeneous a group of dyslexic subjects as possible. Therefore, non-specific reading disability must be excluded by the assessment or screening of subject variables such as general intelligence, educational opportunity, vision and audition, and emotional stability.

A finer level of distinction beyond the broad "specific-nonspecific" distinction may also be considered, again for the purpose of increased homogeneity. This level would involve the exclusion of dyslexic subjects who manifest severe difficulties in other academic areas such as mathematics. This refinement would contribute further to reduction of heterogeneity within the dyslexic sample which in turn would facilitate the investigation of causes and correlates of subtypes. Increased specificity would logically improve upon the plethora of contradictions and inconsistencies known in past research (Benton, 1975).

2. <u>Refinement of Bakker's Classification System - Improving Internal Validity</u>

(a) Due to the illogical reasoning mentioned earlier, the criterion of ear advantage should be altered such that all subjects (both L- and P-types) should demonstrate REA to reflect left-hemispheric speech.

(b) In future studies of HSS, only right-handed subjects should be used to reduce error variance and to prevent the confounding of results.

(c) A mixed subtype should be added to the typology to allow for a more realistic representation of the dyslexic continuum as well as to aid in increasing the homogeneity of each subtype.

3. Establishing External Validity

(a) Once the above changes are implemented, further investigation into the characteristics of L- and P-types must be carried out. This can be accomplished with both neuropsychological and psycholinguistic approaches. A neuropsychological study is needed to explore the neuropsychological correlates of each subtype. All levels of analysis should be examined (e.g., level of performance, pathognomonic signs, differential scores, and comparisons of performance on the two sides of the body). In psycholinguistic terms, more detailed information about the reading characteristics of L- and P-types would be useful. This knowledge could be attained through a full psycholinguistic analysis (e.g., assessment of various dimensions of reading skills from oral reading to comprehension to spelling; Benton, 1978; Spreen, 1978). The information gleaned from such projects might provide fuel for the development of a standardized test for L- and P-type classification.

(b) The developmental dimension should be examined within the context of 3a. For example, are young P-types similar to older P-types on neuropsychological indices?

(c) A longitudinal study is necessary to determine the stability of the L- and P-type system.

(d) In terms of HSS, session variables such as frequency and length of sessions should be manipulated in future HSS studies.

(e) In the investigation of the developmental dimension, the variable of age must be controlled more stringently. For example, it has not yet been determined whether or not HSS is more effective at a particular age or stage of the learning-to-read process. Another potential goal might be to predict L- and P-type problems in pre-school children, and administer the appropriate treatment during the learning-to-read process.

(f) Comparisons of HSS with other remediation techniques must be carried out.

(g) Follow-up studies are also necessary to assess the degree of permanency of improvement in reading after HSS.

Conclusion

In the previous discussion of internal and external validity, numerous criticisms of Bakker's classification system have been put forth. The most serious problem concerns the internal properties of the system. The L-P system is not reliable, it is questionable whether it results in homogeneous groups, and it yields poor coverage. Furthermore, it is not entirely clear what the L-P classification is because Bakker has defined it differently with each use. It is clear that more work on this basic issue is necessary before further efforts in external validation can continue with accuracy.

The failures at external validation mentioned above cannot be taken at face value due to the difficulties with the internal properties of Bakker's classification system. Attempts at external validation are hindered and results are made ambiguous and confusing if a theory is not internally valid. Thus, it is my opinion that an acurate appraisal of HSS in the present study was precluded by reduced power resulting from a diagnostic system that did not allow for accurate classification of L- and P-type dyslexics.

In spite of the flaws and pitfalls described, the balance model is not unfounded. As noted, there exist numerous studies of various sources that support the external validity of Bakker's theory and basic typology of the balance model. The present study provided some support as well in that the ERP results were consistent with Bakker's theory of electrophysiological changes in L- and P-types.

The considerable effort put forth in the present thesis to carefully study and critique Bakker's work speaks to its value. Bakker is one of the few researchers to attempt to supply external validation of his subtypes in the form of specific remediation for each subtype. Furthermore, his work is pioneering in the sense that it strives to examine not only the behavioural effects of the treatment, but also the physiological changes that might occur in the brain as a result of the treatment. Thus, Bakker has endeavoured to examine all aspects of the brain-behaviour relationship, and in doing so, he has bridged the gap between brain and behaviour. Such a comprehensive approach is to be highly commended. Although we have not yet reached the goal described so many years ago by Hinshelwood, we have progressed in our understanding of dyslexia and its treatment due to the work of investigators such as Bakker. Further research into the L-P classification system and the balance model is certainly warranted due to its potential usefulness and important clinical implications for dyslexic children.

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Appendix A

Sample Letter and Consent Form Sent to all Parents at Beginning of Study

February 19, 1988

Dear ________________________:

As a parent of a child with reading problems, you are probably all too familiar with the need for new and effective treatments. I would like to ask your help in my study of the effectiveness of a promising new type of treatment for children with reading problems. The study is being conducted under the supervision of members of the University of Victoria, Psychology Department. I am the doctoral student in charge of the testing and training. Full permission and cooperation has been obtained from Oaklands school and the School Board. Your child's teacher is also enthusiastic about this project.

The first part of the study will involve giving your child some tests of reading ability and school achievement. These tests will be given at the school to find children who are likely to be good candidates for the training method to be used. This new method works best with children who have certain types of reading problems, which are shown by about 3 out of 4 reading-disabled children. At the end of the study, you will be provided with a brief report outlining your child's performance on the tests whether or not your child is selected. If your child is selected, the following will occur:

1. We will ask you to bring your child down to the Royal Jubilee Hospital, where I will record your child's brain wave activity. This procedure takes about an hour, and most children find it interesting and fun.

2. Your child will then receive 20 special training sessions at school (twice a week for 10 weeks) using a micro-computer. Because we have limited equipment and staff for training, we will be able to train only half of the selected children. Also, because this procedure is new, it is essential that we compare children who are trained with those who do not receive training. However, if the treatment proves to be effective, we are hoping to carry out another study next September, and if your child is not chosen to be trained in this study, we will give your child first priority in the next study.

3. Finally, after the training sessions, we will re-test your child to see if any improvements in reading have occurred. We will also do another recording of your child's brain wave activity to see if any changes have occurred.

Your cooperation in this project is purely voluntary, and you have the freedom to remove your child from the study at any time for any reason. The results of your child's testing and training will be treated with strict confidentiality. Your child's teacher will have access to the results only if you sign the appropriate place on the consent form.

Although your child's involvement in this project will require some effort on your part (e.g., you will have to bring your child to the Royal Jubilee Hospital on two occasions), we would like to emphasize the potential benefit that the training procedure may have for your child's and other children's reading ability. In addition, as mentioned earlier, you will receive a report outlining your child's test results.

I have attached a more detailed description of the project in case you are interested. If you have any questions or would like more information about the project, please call me at 721-7525 (office) or 386-7801 (home). Please fill out the consent form attached to this letter, and have your child return it to his or her teacher.

Thank you for your time and consideration.

Sincerely,

Gloria M. Grace, M.A.
Ph.D. Student in Psychology

CONSENT FORM

To Parent: Please fill in the requested information if you wish your child to participate in the project. If you do not want your child to be part of this study, please sign the space at the bottom of this form. Please have your child return this form as soon as possible to his or her teacher.

Child's Name:____

Child's Birthdate:____

Home Address:____

Telephone Number:____

I agree to let my child participate in the project entitled: "Effects of Hemisphere-specific Stimulation on Reading Performance and Event-related Potentials in Reading-Disabled Children". I understand that this will involve testing in my child's school, brain wave recording at the Royal Jubilee Hospital, and up to 20 special training sessions. The child and I have the right to withdraw from the study at any time. I will receive a report of the test results at the end of the study.

____

Signature of Parent/Guardian

____

Date

I further agree to allow my child's teacher to have access to the testing results.

____

Signature of Parent/Guardian

****

I do not wish to let my child participate in the project.

____

Signature of Parent/Guardian

PROJECT DETAILS

As a doctoral graduate student at the University of Victoria, I am conducting a project investigating the effects of a new treatment technique for reading problems in children. As you may be aware, despite the high prevalence of reading disability, there has been very little research done concerning the treatment of the disorder. This new treatment approach was originally developed in Amsterdam, Netherlands, and has been found to be quite successful with certain types of reading disabled children. However, these findings have not yet been replicated in North America. During this past summer, I conducted a preliminary study with reading disabled children in the summer school program in Victoria. The results from this study were very encouraging, showing that the children who received training improved much more than those who simply attended the summer school reading class. Because of the important practical potential this treatment offers, we would like to carry out a larger study in Victoria using this technique with children who have reading problems.

The study will involve three parts:

1. PRE-TESTING

This part of the study will take place in late February and March, 1988.

a) First, your child will be given some basic psychological tests of cognitive ability and school achievement. This will take place at your child's school and takes approximately one and a half hours. It is important to note that not all children given this initial screening will be suitable for the project (for example, some children may not fit our criteria for reading disability). However, whether or not your child is suitable, we will provide you with a brief report outlining your child's performance on the tests, including his or her cognitive and intellectual strengths and weaknesses. Thus, even if your child is not chosen for the study, you will be provide with a mini-assessment service supervised by Dr. Otfried Spreen, an experienced psychologist, which may provide you with helpful information about your child's capabilities.

b) Second, if your child meets our criteria for the study, we would set up an appointment to do a recording of your child's brain wave activity in the form of event-related potentials. This process would be carried out at the Electrodiagnostic Services department of the Royal Jubilee Hospital. It is important to emphasize that this procedure involves only the recording of the child's brain wave activity, and poses no physical or psychological risk. In fact, most of the children in the summer school study appeared to find this procedure interesting. This recording takes approximately one hour.

2. TRAINING

The training sessions will take place at your child's elementary school twice weekly during a 10-week period over April, May, and early June. Each training session is approximately 45 minutes in duration. Arrangements will be made with your child's teacher as to the best times to schedule these sessions.

The training sessions involve the use of a micro-computer. Children will be asked to identify words and letters (of varying lengths and difficulty) that are flashed onto either the right side or left side of the computer screen. In addition to identifying the words or letters, the children will also be asked to process the words in other ways, such as forward and backward spelling, rhyming, etc. The children who were trained with this procedure in the summer appeared to find this computerized method of practicing with words a fun way to learn.

Of all the children who are pre-tested and found to fit the criteria for this study, only half will receive training. Part of the reason for this is limited equipment and staff available for training. We are also interested in comparing the children who are trained with those who do not receive the training. Therefore, if your child undergoes the pre-testing phase of the study, we cannot guarantee that he or she will be involved in the training phase. However, if the training proves to be effective, we are hoping to carry out another study next September, and if your child is not chosen to be trained in this study, we will give your child first priority in the next study. In addition, whether or not your child is trained, we will provide you with a report on your child's testing results.

3. RE-TESTING

Re-testing will allow us to evaluate the success of the training sessions, and involves the same two components discussed under pre-testing, namely the psychological and school achievement testing, and the recording of the child's brain wave activity. The reading tests will again be given in the school and you will again be asked to bring your child down to the Royal Jubilee Hospital (during the month of June). The re-testing results will also be included in the report prepared for you at the end of the study.

Appendix B

Sample Feedback Reports
Sent to Parents at Completion of Study

A. Sample report for a Trained Subject

B. Sample report for an Untrained Subject

Gloria M. Grace
Department of Psychology
University of Victoria
P.O. Box 1700
Victoria, B.C.
V8W 2Y2

September 7, 198

Dear Mr. and Mrs. ________________:

Thank you for allowing Sean to participate in my study of elementary school students with reading difficulties. He was very pleasant and cooperative, and I very much enjoyed working with him. As you know, Sean was given 18 training sessions (twice a week for 9 weeks) which were designed to improve his reading ability. Sean was also given several tests in order to evaluate his intellectual and academic achievement abilities before and after the training. As promised, I would like to describe to you his performance on these tests that I gave to him on March 11, 1988 (pre-test) and on June 15, 1988 (post-test) at Gordon Head School.

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

This battery of tests is made up of 10 different subtests which together provide a measure of a child's general intellectual ability. Half of the subtests measure verbal intelligence (i.e., how well a child interacts with the world through language). The other half of the subtests measure nonverbal intelligence (i.e., how well a child understands the world through seeing and perceiving). The WISC-R therefore allows for measurement in three areas: 1) overall intelligence; 2) verbal intelligence; and 3) nonverbal intelligence. Please note that the WISC-R results as well as the other test results are subject to change. They can be interpreted with confidence only during the current year, and no conclusions should be drawn for future years. The WISC-R test battery was given during the pre-test session only.

On the basis of our test results, Sean's overall level of intelligence at the time of testing was in the average range. There was little difference between his verbal and performance scores which were also in the average range. However, when comparing Sean's performance on individual subtests, there was considerable variation in the test scores. For example, Sean's highest score was at the 84th percentile (i.e., 84 percent of children his age would perform more poorly than Sean) on two nonverbal tests. One of these tests required Sean to identify what was missing in a given picture, and measures visual discrimination and perception. The other test that Sean performed very well on involved the construction of short puzzles and requires good visual perception of part to whole relationships. In contrast, Sean's lowest score (9th percentile) was on a verbal arithmetic test in which he was asked to respond verbally to oral math questions. All other subtest scores were between these two percentile values.

2. Wide Range Achievement Test-Revised (WRAT-R)

This test of academic achievement was used to measure Sean's ability in the areas of spelling and oral reading of words.

Pre-Test Results: On the spelling test, Sean's score was at the beginning Grade 3 level, which was within the low-average range for his age. His performance on the reading test was at the mid Grade 2 level (far below-average range).

Post-Test Results: On the June 15th testing, Sean showed some improvement in spelling ability (end of Grade 3 level, still low-average range). Similarily, he showed some improvement in his ability to read single words (beginning Grade 3 level, below-average range).

3. Gilmore Oral Reading Test (GORT)

This is an oral reading test in which a child reads aloud several paragraphs of varying difficulty. After the paragraphs are read, questions about them are asked to assess comprehension.

Pre-Test Results: Sean's oral reading accuracy score was at Grade 2.7, which is considered below-average for his grade level at the time of testing. His rate of reading was average, and his comprehension of what he read was below-average.

Post-Test Results: On the June 15th testing, Sean showed an improvement in his accuracy of reading (Grade 3.1, below-average range). Sean's level of reading comprehension also improved to the average range, and his rate of reading remained in the average range.

Please note that results on the WRAT-R and GORT are compared to those of children from the United States (Canadian norms do not exist for these tests), and therefore may not accurately reflect Sean's ability in his school grade at the time of testing.

4. <u>Dichotic Listening Test</u>

This test is designed to determine which side of the brain (left or right hemisphere) is better at processing language. The child wears a set of earphones which presents numerous pairs of words simultaneously in both ears. For example, if the child identifies more words heard in the right ear, this suggests that the left side of the brain (the opposite side) is dominant for language.

In both pre- and post-testing, Sean identified many more words heard through his right ear, suggesting that his language abilities are in the left hemisphere of his brain, as they are for most people.

In addition to the four tests described above, Sean's brain wave activity was also sampled through a visual evoked-potential test at the Royal Jubilee Hospital. The results from this test were normal.

I hope that these results are clear and informative. Thank you once again for supporting this research project.

Sincerely,

Gloria M. Grace, M.A.
Ph.D. Student in Neuropsychology

Gloria M. Grace
Department of Psychology
University of Victoria
P.O. Box 1700
Victoria, B.C.
V8W 2Y2

September 5, 1988

Dear Mrs.__________________ :

Thank you for allowing Scott to participate in my study of elementary school students with reading difficulties. As promised, I would like to describe to you his performance on the tests that I gave to him on February 29, 1988 (pre-test) and on June 17, 1988 (post-test) at Oaklands School. Although Scott was not in the training group of the study, the test results may be of interest to you for other reasons. Scott was given several tests designed to evaluate his intellectual and academic achievement abilities.

1. <u>Wechsler Intelligence Scale for Children-Revised (WISC-R)</u>

This battery of tests is made up of 10 different subtests which together provide a measure of a child's general intellectual ability. Half of the subtests measure verbal intelligence (i.e., how well a child interacts with the world through language). The other half of the subtests measure nonverbal intelligence (i.e., how well a child understands the world through seeing and perceiving). The WISC-R therefore allows for measurement in three areas: 1) overall intelligence; 2) verbal intelligence; and 3) nonverbal intelligence. Please note that the WISC-R results as well as the other test results are subject to change. They can be interpreted with confidence only during the current year, and no conclusions should be drawn for future years. The WISC-R test battery was given during the pre-test session only.

On the basis of our test results, Scott's overall level of intelligence at the time of testing was in the average range. There was little difference between his verbal and nonverbal scores which were also in the average range. However, when comparing Scott's performance on individual subtests, there was considerable variation in the test scores. For example, Scott scored at the 75th percentile (i.e., 75 percent of children his age would perform more poorly than Scott) on a verbal subtest measuring moral judgement, social awareness, and common sense. However, Scott's lowest score (at the 9th percentile) was on an oral arithmetic test in which he was asked to respond verbally to oral math questions. All other subtest scores fell between these two extremes.

2. Wide Range Achievement Test-Revised (WRAT-R)

This test of academic achievement was used to measure Scott's ability in the areas of spelling and oral reading of words.

Pre-Test Results: On the spelling test, Scott's score was at the beginning Grade 3 level, which is within the low-average range for his age. His performance on the reading test was at the end of the Grade 2 level (below-average range).

Post-Test Results: On the June 17th testing, Scott showed no change in spelling ability (beginning Grade 3 level, low-average range). However, he showed some improvement in his ability to read words, scoring at the beginning Grade 3 level (still within the below-average range).

3. Gilmore Oral Reading Test (GORT)

This is an oral reading test in which a child reads aloud several paragraphs of varying difficulty. After the paragraphs are read, questions about them are asked to assess comprehension.

Pre-Test Results: Scott's oral reading accuracy score was at Grade 4.1, which is considered below-average for his grade level at the time of testing. His rate of reading was slow, and his comprehension of what he read was average.

Post-Test Results: On the June 17th testing, Scott showed slight improvement in accuracy of reading (Grade 4.8, below-average range). Scott's level of reading comprehension remained at the average level, and his rate of reading improved to the average level.

Please note that results on the WRAT-R and GORT are compared to those of children from the United States (Canadian norms do not exist for these tests), and therefore may not accurately reflect Scott's ability in his school grade at the time of testing.

4. Dichotic Listening Test

This test is designed to determine which side of the brain (left or right hemisphere) is better at processing language. The child wears a set of earphones which presents numerous pairs of words simultaneously in both ears. For example, if the child identifies more words heard in the right ear, this suggests that the left side of the brain (the opposite side) is dominant for language.

In both pre- and post-testing, Scott identified more words heard through his right ear, suggesting that his language abilities are in the left hemisphere of his brain, as they are for most people.

In addition to the four tests described above, Scott's brain wave activity was also sampled through a visual evoked-potential test at the Royal Jubilee Hospital. The results from this test were normal.

I hope that these results are clear and informative. Thank you once again for supporting this research project.

Sincerely,

Gloria M. Grace, M.A.
Ph.D. Student in Neuropsychology

Appendix C

Word Stimuli used in ERP Procedure with Frequency and Concreteness Ratings

Word Stimuli used in ERP Procedure
with Frequency and Concreteness Ratings

Word	Frequency *	Concreteness Rating **
1. LORD	AA	4.18
2. LOVE	AA	1.80
3. TOOL	40	6.80
4. IDEA	AA	1.42
5. FIRE	AA	6.66
6. HIDE	A	5.45
7. FACT	AA	3.31
8. WIFE	AA	6.52
9. ROCK	AA	6.96
10. DOLL	46	6.94
11. ARMY	AA	6.55
12. DUTY	AA	2.32
13. SHIP	AA	6.93
14. GOLD	AA	6.76
15. CITY	AA	6.41
16. BODY	AA	6.58
17. STAR	AA	6.73
18. POLE	A	6.93
19. NAIL	A	6.96
20. CASH	46	6.28
21. GIRL	AA	6.83
22. DEED	A	4.19
23. KISS	AA	6.13
24. CORN	A	6.90
25. BOWL	A	6.90
26. FATE	A	1.46
27. POET	A	6.35
28. TIME	AA	2.47
29. JOKE	32	3.80
30. DAWN	A	5.83
31. LIFE	AA	2.96
32. BIRD	AA	6.96
33. MEAT	AA	6.93
34. CAMP	AA	6.56
35. CELL	A	6.63
36. SOUL	AA	1.87
37. HOME	AA	6.25
38. SEAT	AA	6.79
39. HALL	AA	6.72
40. IRON	AA	6.87

Word	Frequency *	Concreteness Rating **
41. SKIN	AA	6.96
42. TREE	AA	7.00
43. GIFT	A	5.95
44. PIPE	A	6.90
45. WINE	A	6.96
46. FORM	AA	4.08
47. KING	AA	6.34
48. BOOK	AA	6.96
49. HOUR	AA	2.93
50. SOIL	AA	6.87
51. COST	AA	3.41
52. HOPE	AA	1.18
53. LAWN	36	6.96
54. COIN	A	6.90
55. BABY	AA	6.90
56. FLAG	A	6.94
57. LAKE	AA	6.90
58. DOOR	AA	7.00
59. MIND	AA	2.60
60. DUST	A	6.67

* Frequency according to Thorndike & Lorge (1944)
where 35 = 35 occurences per one million words
A = > 50 occurences per one million words
AA = > 100 occurences per one million words

** Concreteness values according to Paivio, Yuille, & Madigan (1968). Values range from 1.18 to 7.00.

Appendix D.

Word Sets used in HSS for L- and P-types

Word Sets used in HSS for L- and P-types

1. L-type Single Word Sets

	Set 1	Set 2	Set 3	Set 4	Set 5
1.	q	no	sea	kid	jar
2.	r	is	tie	lad	mob
3.	t	we	ear	tea	van
4.	p	he	oil	key	ink
5.	i	be	war	fur	dye
6.	o	me	dry	hit	hen
7.	k	my	hot	gas	gem
8.	y	us	arm	wet	wax
9.	x	up	eye	net	rat
10.	f	if	run	cat	dew
11.	a	it	bag	bar	ant
12.	h	at	hat	cow	dot
13.	e	by	lip	nod	sew
14.	m	do	box	gun	hay
15.	d	go	air	cap	dad
16.	b	or	dog	bee	axe
17.	g	so	ice	row	toy
18.	v	in	cup	map	owl
19.	s	oh	men	log	mud
20.	c	to	can	bow	bud

	Set 6	Set 7	Set 8	Set 9	Set 10
1.	tire	lock	horn	goal	kick
2.	word	milk	lamp	earl	heap
3.	gold	tone	team	lamb	mule
4.	play	king	hero	dart	gasp
5.	yard	face	feed	barn	belt
6.	fair	iron	goat	fork	jury
7.	inch	girl	fold	rice	sole
8.	baby	wolf	wine	worm	whip
9.	hair	rock	park	jail	knot
10.	suit	duke	coin	echo	joke
11.	back	acre	aunt	mast	puff
12.	home	east	dish	acid	beer
13.	land	salt	rail	palm	robe
14.	cent	head	gift	bath	chin
15.	army	deck	card	cage	doll
16.	edge	bear	band	twig	tomb
17.	knee	sign	sand	hawk	lace
18.	door	page	maid	unit	veil
19.	meat	news	lion	gown	mist
20.	city	cake	bark	hoof	lawn

	Set 11	Set 12	Set 13	Set 14	Set 15
1.	moss	knit	sway	music	human
2.	plum	dive	vine	nurse	enemy
3.	vein	pool	lane	uncle	prize
4.	link	cord	soup	judge	dozen
5.	file	boot	wrap	fruit	bread
6.	lark	hood	host	heart	grass
7.	herd	tide	pear	fight	smile
8.	weed	wink	boss	woman	wheel
9.	soap	poem	lime	river	noise
10.	colt	fort	trap	devil	field
11.	bait	reed	cape	alarm	queen
12.	diet	beam	monk	earth	beast
13.	stem	sore	pump	sword	sugar
14.	item	buck	clay	giant	chair
15.	cash	claw	bean	color	crowd
16.	bite	moan	grin	blood	train
17.	tube	lump	pond	table	light
18.	rack	vest	drum	plane	voice
19.	pony	leaf	seal	ocean	knife
20.	brow	pant	crew	cloud	money

2. L-type Double Word Sets

	Set 1	Set 2	Set 3
1.	up-up	job-job	job-boy
2.	by-be	eye-dye	hot-hot
3.	ox-on	pan-pat	rib-rib
4.	or-on	die-dig	gay-say
5.	in-is	bed-bed	box-box
6.	oh-oh	get-let	mud-mud
7.	me-me	toe-toe	top-top
8.	as-as	win-wit	who-why
9.	us-us	off-off	our-out
10.	he-ha	fan-fan	ear-eat
11.	at-it	ray-ray	see-see
12.	it-it	ale-all	arm-art
13.	we-he	she-shy	sir-sit
14.	no-on	bid-big	cat-cat
15.	go-go	cut-cut	fit-fix
16.	be-be	far-war	use-use
17.	my-my	leg-leg	new-new
18.	to-no	vow-vow	yea-tea
19.	so-so	kid-did	law-lap
20.	do-go	now-not	pig-pig

	Set 4	Set 5	Set 6
1.	son-son	van-van	pull-bull
2.	six-sin	try-dry	real-deal
3.	hop-hop	lad-led	your-tour
4.	pea-pea	saw-saw	once-once
5.	you-you	way-way	gave-save
6.	gem-gem	key-key	moon-moon
7.	lot-lot	old-old	join-join
8.	boy-bay	bid-did	tune-tune
9.	ice-ice	man-man	upon-upon
10.	ran-raw	two-too	ease-east
11.	cry-cry	cow-cow	area-area
12.	gay-pay	net-met	fact-fact
13.	oak-oat	red-red	vest-test
14.	dad-bad	day-bay	lake-lame
15.	ago-age	add-add	drop-drop
16.	fun-fur	ash-ask	blow-slow
17.	met-wet	pot-pet	wood-wood
18.	egg-egg	fur-for	tame-came
19.	own-own	sum-sun	spot-spot
20.	beg-big	gun-gun	cart-dart

	Set 7	Set 8	Set 9
1.	quit-quit	show-slow	seat-seat
2.	near-neat	view-view	talk-tall
3.	vain-gain	duck-duck	jury-jury
4.	meal-meal	glow-plow	pain-pain
5.	high-sigh	your-your	them-them
6.	list-list	coal-coat	fool-tool
7.	jest-best	hood-hoof	hind-hint
8.	wall-wall	bold-bolt	been-been
9.	skin-skin	fell-felt	trip-trap
10.	dust-dust	read-read	read-reed
11.	away-away	cave-save	cost-cast
12.	into-into	hill-hill	hero-hero
13.	tend-send	lazy-lazy	lash-lash
14.	keen-keep	even-ever	book-hook
15.	cold-colt	ache-ache	able-able
16.	beak-beak	born-born	fail-fail
17.	urge-urge	jump-jump	knit-knot
18.	rang-hang	bent-best	down-dawn
19.	pony-pond	nest-next	make-male
20.	boil-soil	flew-flew	cell-cell

3. P-type Word Sets

	Set 1	Set 2	Set 3	Set 4	Set 5
1.	q	no	lie	has	sit
2.	r	is	may	end	the
3.	t	we	sky	nor	yes
4.	p	he	law	die	out
5.	i	be	far	big	how
6.	o	me	ill	got	low
7.	k	my	get	say	job
8.	y	us	use	was	you
9.	x	up	off	met	sir
10.	f	if	day	few	for
11.	a	it	act	now	are
12.	h	at	due	any	her
13.	e	by	put	old	way
14.	m	do	had	but	let
15.	d	go	cry	did	fit
16.	b	or	and	see	buy
17.	g	so	sat	lay	why
18.	v	in	not	try	ask
19.	s	oh	new	joy	too
20.	c	to	bad	lot	cut

	Set 6	Set 7	Set 8	Set 9	Set 10
1.	sad	put	eye	some	less
2.	gay	rid	for	time	many
3.	ate	win	son	hate	that
4.	fun	own	red	pain	kind
5.	beg	his	way	want	free
6.	mix	our	dye	glad	join
7.	rob	led	ate	last	good
8.	vow	yet	him	been	wish
9.	dig	try	you	idea	poor
10.	mad	get	tow	quit	each
11.	raw	and	pee	call	area
12.	aid	him	two	keep	fast
13.	ray	use	due	near	rush
14.	bit	may	led	dark	here
15.	fix	fly	not	also	dear
16.	dim	big	see	fool	best
17.	tax	why	boy	make	seem
18.	odd	see	won	fair	only
19.	sin	shy	our	once	nice
20.	won	cut	ant	easy	come

	Set 11	Set 12	Set 13	Set 14	Set 15
1.	such	real	most	safe	just
2.	took	sick	give	slow	kind
3.	hurt	said	soon	more	size
4.	past	obey	find	pure	hope
5.	well	gone	came	know	easy
6.	hard	meet	long	need	hate
7.	lean	heat	wait	loud	fast
8.	both	warm	take	what	weak
9.	into	true	size	upon	nice
10.	rate	else	high	full	calm
11.	care	able	than	busy	also
12.	just	felt	born	harm	dark
13.	none	very	vain	wide	past
14.	deep	late	down	much	good
15.	away	dead	even	evil	blue
16.	gave	bold	your	cool	away
17.	lost	will	pair	save	rich
18.	feel	tell	mind	told	mind
19.	over	stay	next	sure	late
20.	ever	cold	ruin	date	best

	Set 16	Set 17	Set 18	Set 19	Set 20
1.	mild	vain	reach	range	juice
2.	mood	here	short	score	legal
3.	type	lead	heard	royal	verse
4.	luck	dear	order	pause	sauce
5.	glow	high	those	worry	error
6.	lazy	fair	given	fancy	inner
7.	help	aunt	young	major	glide
8.	urge	buoy	began	awake	waist
9.	pity	blue	judge	yours	piano
10.	dumb	pain	peace	quick	dirty
11.	bend	wood	large	limit	amaze
12.	fond	meet	march	owner	ditch
13.	rare	made	count	quiet	ranch
14.	fade	know	wrong	birth	hello
15.	damp	need	above	ahead	crazy
16.	bind	hare	force	event	boast
17.	risk	four	visit	match	sadly
18.	ours	soul	every	drove	nerve
19.	neat	bear	north	usual	moist
20.	cure	weak	dream	climb	clasp

Appendix E

Grade Scores for each Subject on Reading, Spelling, and Comprehension Measures

Grades Scores for each Subject on
Reading, Spelling, and Comprehension Measures

Subject	Grade + Placement	WRAT-R Reading	WRAT-R Spelling	GORT Accuracy	GORT Comprehension
L1 4	6	3B ***	2E ****	3.9 **	5.1 *
L1 6	6	3B ***	2E ****	4.2 **	4.2 **
L1 11	5	3B **	3E **	3.9 *	6.7
L1 19	4	2M **	3B *	2.7 **	2.3 **
L1 20	6	4B **	4B **	4.3 **	5.4 *
L1 21	6	2M ****	2E ****	3.1 ***	2.8 ***
L1 24	6	2E ****	2E ****	3.0 ***	3.4 ***
L1 31	5	2E ***	2M ***	4.1 *	4.1 *
L2 1	7	3E ****	3B ****	3.6 ****	3.8 ***
L2 3	6	2E ****	3B ***	4.1 **	7.1
L2 12	5	3B **	3E **	2.9 **	7.1
L2 16	3	2E *	2M *	2.8	4.8
L2 18	6	4B **	3E ***	4.8 *	4.8 *
L2 22	5	3B **	3E **	4.1 *	4.8
L2 23	5	4B *	3B **	4.2 *	4.1 *
L2 34	3	2B *	1E **	1.5 **	1.8 *
L2 36	4	2E **	3E *	3.4 *	3.8
P1 2	7	3E ****	3B ****	3.9 ***	7.1
P1 10	6	2E ****	3B ***	4.6 **	8.0
P1 15	4	3B *	3B *	3.0 *	5.1
P1 25	4	1E ***	2B **	2.2 **	5.1
P1 35	3	2M *	2B *	1.7 **	1.0 **
P2 7	7	3B ****	3B ****	3.9 ***	4.8 **
P2 26	5	2E ***	2E ***	3.1 **	4.8
P2 29	3	2E *	2M *	3.1	3.8
P2 33	4	2B **	2B **	1.7 ***	3.4 *

* At least 1 year below current grade placement
** At least 2 years below current grade placement
*** At least 3 years below current grade placement
**** At least 4 years below current grade placement

\+ All Subjects were tested approximately 7/10 way through the school year.