LEARNING DISABILITIES: A MULTIVARIATE SEARCH FOR SUBTYPES

By

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For Mary, with love

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The purpose of this study was to conduct a systematic search for subtypes within the learning disabled population. Cluster analytic techniques were applied to the WRAT reading, spelling and arithmetic scores of 236 boys with a mean age of 130 months. This relatively unselected original sample included children at all levels of achievement. The initial analysis obtained 9 distinctive patterns of WRAT scores. These subgroups were then compared through a multivariate analysis of variance on measures of verbal fluency, WISC Similarities, the Developmental Test of Visual-Motor Integration and a recognition-discrimination task. Peabody Picture Vocabulary Test estimates of IQ, teacher ratings of socioeconomic status and neurological ratings were also analyzed for subgroups.

As expected, there was a general trend for low-achievement groups to perform more poorly on all variables. However, no subgroup obtained a mean Peabody IQ of less than 90. One subgroup with average reading but depressed arithmetic scores showed large decrements in perceptual-motor performance. The differences between the two lowest achievement subgroups were largely in degree of substandard performance. Both these subgroups showed an extremely high proportion of children rated "affected" on neurological examination. By virtue of their markedly deficient WRAT achievement scores these subgroups were identified as a learning disabled population.

For purposes of further analysis the low-achievement groups were combined (N=89). A second cluster analysis utilizing the two language and two perceptual-motor variables generated four unique cluster-subtypes. No significant differences in WRAT achievement, socioeconomic status or neurological ratings existed between subtypes. However, differences in performance on the perceptual-motor and language tasks were both statistically significant and heuristically meaningful. The children of subtype 4 were clearly those with both impoverished language and perceptual-motor skills. They were the only subtype to obtain less than average Peabody IQ scores. Subtype 2 was characterized by generally average scores except in verbal fluency where their performance was significantly impaired. Subtype 3, on the other hand, showed substantial deficits only on the perceptual-motor variables. Subtype 1 constituted an enigma, as these children performed at levels which equalled or exceeded the original sample mean (N=230) on every variable. Comparisons on the 14 factor scores of the Children's Personality Questionnaire failed to support the hypothesis that motivation problems or debilitating psychopathology were responsible for the poor achievement of this subtype.

The results of this study point out the need for greater definitional precision and specificity in the application of hypotheses in research on the highly heterogeneous learning disabled population. Finally, implications for future investigations are discussed.

CHAPTER I
INTRODUCTION

One of the fortuitous consequences of the growing human potential and civil rights movements has been an increased awareness and sensitivity to the effects of learning difficulties upon a child's development. Learning disabilities now constitute a major educational and social problem of the modern era. As incidence survey techniques and measurement have improved, knowledge of the scope and depth of the problem has increased. Some studies (e.g., Kline, 1972) have suggested that at least 15 percent of all children in school suffer from severe reading deficiencies. Additionally, preliminary results from longitudinal research suggest the relationship of learning disability to a surprising number of behavioral and emotional disorders, extending even to the magnitude of schizophrenia (Robins, 1966). Studies linking reading failure and adult criminal behavior (Wright, 1974) further underscore the importance of the remediation of this disorder to the maintenance of a productive society.

Although there can be little doubt that learning disabilities are extremely common in almost every educational setting, there have been certain difficulties in obtaining accurate estimates of the prevalence of the disorder. Gaddes (1976) has pointed out that ambiguity results from the application of imprecise definitional criteria to the variety of learning disorders. Definitions and classifications may differ dependent upon whether medical, psychological or educational models are employed. Thus, while one of the few encouraging trends in the field of learning disabilities has been the interest of a variety of professional disciplines, another consequence of this interest has been a proliferation of conceptual models and diagnostic labels. This does not generate either a unitary body of knowledge about the disorder, nor a comprehensive, coherent theory. Satz (1977) has bluntly concluded that "the present state of affairs is such that there can be no assurance that a diagnostic study will be accurate nor that remedial instruction will be sufficient to meet a child's needs" (p. 11).

Conceptual Issues

Applebee (1971) has identified two major deficiencies which have contributed to the lack of success in research on reading retardation. A major source of confusion has been an historical tendency to construct restricted conceptual models which emphasize the role of variables of interest to a single professional discipline (usually medical, educational or psychological). A related problem has been a lack of specificity and precision in defining the population identified as reading disabled. Typically, the target population is defined through the use of several exclusion criteria; selected variables on the resulting group are then examined for unique patterns of deficits. There has been an implicit, if erroneous, assumption of homogeneity for these populations.

A second class of problems results when there is a lack of correspondence between the statistical model used in analyzing the data and the actual structure of the data. Applebee lists six models in current usage. The simplest model proposes a single causal defect for reading problems. Use of models of increasing complexity (e.g., multiple regression models) may reflect a growing awareness of the heterogeneity of the learning disabled population. In the sixth model, for example, the assumption is made that there are several independent syndromes, each dependent upon particular patterns of critical variables. Applebee speculates that different models may be appropriate for different target populations.

Doehring (1976), citing the works of Applebee (1971) and Wiener and Cromer (1967), has advanced the possibility that multiple processes are involved in learning to read. He cautions that when a single-cause model for learning disability is used, only a single syndrome may be investigated, since the variability introduced by the presence of other syndromes may confuse the interpretation of results. His review of the literature reveals that the assumption of homogeneity for the learning disabled population is probably unwarranted.

In his own studies Doehring compared children on measures related to processing of letters, letter patterns, syllables, words and syntactically-semantically related groups of words. Although the study did not find distinguishing profiles for different groups of reading disabled children, it did appear that the normal readers' performance on the component skills measures conformed to a hierarchical model, while the reading disabled children, in their "spotty" performance, seemed to fit more in accordance with an assembly model.

Doehring's multiple process position closely parallels that of Zigler (1967a, 1967b, 1969) in the field of mental retardation. Zigler has reviewed the conceptual bases of three distinct types of theories of mental retardation (difference, defect and developmental models).

A difference theory states that a clinical population has more (or less) of a certain attribute. A defect theory states that the population lacks the attribute. Finally, a developmental theory proposes that the discrepancies between normal and pathological populations are related only to the rate of acquisition and the limit of achievement that each may approach. Zigler concludes that the mentally retarded population is not homogeneous, even though it may be defined by a single criterion (e.g., an IQ less than 70). He proposes that an initial distinction at least be made between the organic subgroup of retardates and the developmental-familial group.

Wiener and Cromer (1967) applying similar concepts to the reading retarded population have identified four assumptions which determine how one conceptualizes reading disability. If one assumes a defect as the cause of the disorder, a neurological explanation is most easily suggested. An assumption of deficiency draws attention to such areas as phonetic skills or general language ability. A disruption model lends itself to consideration of emotional factors. Finally, a difference model emphasizes the mismatch between the behavior patterns of the individual and those required by his environment. These assumptions lead to investigation of three kinds of factors: sensory-perceptual (physiological), experiential-learning (educational), and personality-emotional (psychological). Through the relationships of the factors with each other, different types of disabled readers may be produced.

Benton (1975), after a thorough review of current evidence, concludes that such evidence is too contradictory and inconsistent to support the assumption that all dyslexic children suffer the same basic deficiency. Benton cautions that, in order to make meaningful statements about reading failure, it is necessary to specify carefully the type of behavior which constitutes the failure, as well as the level of the failure. Silverberg and Silverberg (1977), for example, have demonstrated that different reading tests may produce different estimates of a child's reading level.

Benton next proposes locating the cognitive and functional correlates associated with the faulty reading performance. Ultimately, the search for the neurological-genetic substrate which subsumes these correlates may then be conducted. Benton proposes that a classification system at least distinguish between poor readers with no accompanying problems and those with concomitant deficiencies in other skill areas. This distinction would then be a first step toward the definition of more homogeneous classes of disabled learners.

Specific Developmental Dyslexia

While the evidence has persistently pointed to multiple determinants of reading disability, investigators have most often concentrated their attention on a population identified by the World Federation of Neurology as exhibiting specific developmental dyslexia. The disorder has been defined as one ". . . manifested by difficulty in learning to read despite conventional instruction, adequate intelligence and sociocultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin" (Waites, 1968, p. 16). Various labels have been applied to this hypothetical disorder including specific reading disability, strephosymbolia, congenital word blindness, reading retardation and unexpected reading failure. The World Federation definition hints that the disorder is a unitary one, yet membership in the classification is based upon exclusion criteria which imprecisely delimit it. A vague unproven etiology is also implied, but no clue to possible mechanisms involved is given. Under such circumstances the homogeneity of the group certainly becomes suspect.

A preliminary study (Taylor, Satz and Friel, 1977) was recently completed which attempted to determine whether there was any clinical utility to the diagnosis of specific developmental dyslexia. Taking particular pains to satisfy definitional requirements, they sought to compare "dyslexic" with "non-dyslexic" disabled readers, and both groups with normal readers. The measures selected for the comparisons included: (1) severity of reading failure, (2) parental reading and spelling competency, (3) neurological rating, (4) math skills, (5) neuropsychological performance, (6) reversal errors in reading and (7) personality traits. The tasks uniformly failed to differentiate between the two disabled groups, but differentiated the total group of disabled readers from the group of normal readers. The results challenge the traditional notion of dyslexia as being easily dissociated from other reading problems. The investigators, while not rejecting the concept of the existence of specific subgroups of disabled readers, stress the need to operationalize definitions and trim surplus meaning from concepts in the area. They call for further studies to discover clinically useful groupings, perhaps based on patterns of deficits, neuropsychological performance, the kinds of errors in reading and spelling, and even according to prognosis.

Classification Systems

Historically the efforts of most researchers have been directed toward the isolation of the "essential nature" of what has been regarded as a homogeneous disorder. It is interesting, therefore, to note in retrospect that Monroe (1932) performed a study well ahead of its time in its suggestion of the involvement of multiple determinants of learning disability. This well-designed study tentatively identified subgroups based on the source and nature of the referral. One group of children was referred for assorted problems in development and behavior. Another group was identified by teachers and parents as having specific difficulties in reading. The final group was composed of children with borderline or defective intelligence. Monroe obtained a reading index based on the comparison of a composite reading grade with chronological age, mental age and an arithmetic score. She then classified the errors made in reading into ten types. It was found that patterns of types of errors did emerge, but that different "causes" could produce the same profile. Monroe discussed the various defects which could give rise to reading disability, the pattern of errors thay may result and the remediation methods recommended for children with each type of error pattern.

Robinson (1946) similarly utilized the skills of a team of specialists representing the different professions to investigate the proposition of multiple determinants in learning disabilities. The causal factors he identified are similar to those of Monroe (1932). Both studies emphasize that visual maladjustments are commonly associated with reading problems. For example, Robinson's close scrutiny of 30 reading disabled children showed 73 percent to have visual difficulties, although the visual handicap was judged as causal in only one-third of these cases. Additional causes identified were neurological compromise, auditory and speech difficulties, physical deficiencies, intellectual deficiency, emotional and personality deviancy, social and environmental handicaps, endocrine abnormalities and perhaps, problems of cerebral dominance. The foresight of these studies is quite remarkable and undoubtedly they have not received the attention they deserve.

Blom and Jones (1970) have sought to divide classification systems into four major types. One group of systems focuses on "descriptive reading behaviors" (a useful approach for teachers and educators since one or more of the symptoms can usually be observed in students). Distinctions may, for example, be made between children who show difficulties in oral reading and those with poor silent reading. Other descriptive-behavior systems might differentiate children according to the sensory modality impaired (visual, auditory, etc.).

A second group of systems is based on etiology. One of the simplest is that of Eisenberg (1966), who dichotomizes factors in reading disability into sociopsychological sources (for example, defects in teaching or deficiencies in motivation), and psychophysiological sources (defects in intellect, sensory processing, brain functioning or general ability).

Blom and Jones next point out that most theoretical systems develop classifications consistent with their theories. This third type includes, for example, models based upon psychoanalytic ego theory, upon statistical constructs and upon psycholinguistic theory.

Finally, some systems attempt to exhaust all possibilities and compile a complete nosological system (e.g., that of Blom and Jones, 1970).

Many researchers have hypothesized that the two major origins of reading difficulties are neurological defect and genetic predisposition. A rudimentary classification system may be drawn if this dichotomy is accepted. Rugel and Mitchell (1977) predicted that one group of reading disabled children would show symptoms of minimal brain dysfunction including hyperactivity, distractibility and perceptual-motor problems. It was anticipated that the children of the other group would show difficulties in auditory sequential-memory, auditory discrimination and visual-spatial perception, factors felt to be inherited. A twenty item behavioral rating scale, a test of auditory vigilance and measures of skin conductance were employed as dependent measures. The data seemed to show some support for their hypothesis, but the authors speculated that there may be a need for two categories of the familial poor readers — those with MBD symptoms and those without.

Silver (1971) notes that the distinction between learning disability and minimal brain dysfunctions is often poorly drawn. In a study of 556 children he attempted to identify familial patterns among children with neurologically based learning disability. On the basis of his data he concludes that it is necessary to specify both the particular type of learning disability (e.g., perceptual-motor, memory, motor, etc.) as well as the etiology. Silver's data showed that in his neurological population familial patterns were present in 30 to 40 percent of the cases.

One of the more common classification systems in both formal and informal usage distinguishes between children whose learning problems are but one manifestation of a more general impairment and those who show more circumscribed learning disturbance. The distinction between secondary and primary reading retardation advanced by Rabinovitch and associates (Rabinovitch, Drew, DeJong, Ingram and Whithey, 1954; Rabinovitch, 1968) represents an early approach for specifying subgroups of reading disabled children. Conceptually the primary reading retardation group fits the criteria for the definition of specific developmental dyslexia. Secondary reading retardation implies that the disorder is the result of other pathology or condition — encephalopathy, emotional disturbance, poor language experience or motivational/opportunity factors. This group of children was shown to have a better prognosis than the primary reading retardation group who were hypothesized to suffer from a basic disturbed pattern of neurological organization.

Ingram, Mason and Blackburn (1970) examined 82 children selected for a two-year discrepancy between mental age (as measured by the Stanford-Binet) and reading age. Elaborate pre-, peri- and postnatal histories were obtained along with detailed medical and neurological examinations. Data on reading, personality, perceptual-motor skills and speech were also collected. While an earlier study by Ingram (1966) had found evidence for a three-way classification, the data on these 82 children suggested two subgroups: those with a general disorder and those with a specific learning disturbance. The two groups did not differ significantly in severity of reading failure nor in incidence of family history of reading difficulties. Examination of the "general" group, however, revealed a greater frequency of abnormal births and developmental histories, as well as positive findings on neurological examinations and abnormal EEG's. The "specific" group showed a higher percentage of audiophonic difficulties and tended to make more primitive types of errors in reading. The authors concluded that severe reading difficulty can be present without brain abnormality and, significantly, is likely to be part of more general educational problems.

Keeney (1968) also accepted the primary-secondary classification but argued that, even with limited etiological knowledge, an attempt should be made to form a more comprehensive classification system. He proposed three additional major divisions. His category "slow readers" is employed to distinguish those children whose reading difficulties stem from visual handicaps, auditory impairments or hypothyroid states. "Acquired dyslexia" covers the somewhat rarer cases where there are lesions of the dominant hemisphere, angular gyrus or splenium. Finally, he proposed a "mixed" category to account for children with positive profiles fitting two or more of the other classifications.

Yule and Rutter (1976) have used more powerful techniques for differentiating "general reading backwardness" from "specific reading retardation." Responding to the need to operationalize definitions and concepts used with reading handicapped children, these researchers defined "unexpected reading failure" as a discrepancy of 2-years 4-months or more between reading level and an expectancy score derived from chronological age and assessed intellectual level. Their "general" group was defined simply on the basis of performance 2-years 4-months below chronological age, irrespective of intellectual level. These groups, of course, had many members in common. Additional power for this study was provided by the examination of an entire population of children. The "specific" group obtained higher intelligence scores, was more likely to be male, typically showed delays in development of speech and language and tended to be more refractory to attempts at intervention. The "general" group had a higher incidence of manifest neurological conditions, motor and praxic difficulties, and left-right confusion. These latter children tended more frequently to come from lower class families and to show generally greater academic improvement in all subjects except arithmetic.

Significantly, no core group fitting the definition of developmental dyslexia was able to be isolated in this study. By contrast the concept of "specific reading retardation" can theoretically be applied to children at <u>any</u> level of intellectual ability as long as reading ability is not commensurate with IQ. This concept does not carry any implication for etiology, whether genetically or socially transmitted. Yule and Rutter's concept of specific reading retardation does not correspond to the unitary syndrome idea often associated with the term dyslexia. Rather, specific reading retardation is viewed as the result of the complex interaction of multiple factors.

While some investigators (e.g., Taylor, Satz and Friel, 1977) have questioned the existence of a distinct dyslexic syndrome, others have sought to identify, within the dyslexic population, subgroups defined by different patterns of deficits. Mattis, French and Rapin (1975) have reviewed the literature concerned with neuropsychological parameters of learning disability. They found that previous investigations have related the presence of learning disability to (1) the development of perceptual stability and the ability to transfer information between sensory modalities, (2) the development of language and speech fluency, (3) the acquisition of gross and fine motor coordination and (4) the development of lateral awareness and dominance. With these guidelines, Mattis et al. compared the performance of brain-damaged children with normal reading, on a variety of neuropsychological measures. It was found that these measures did not discriminate groups of dyslexics (brain-damaged versus non-brain-damaged). However, on the basis of inspection, three patterns of deficits seemed to emerge, accounting for about 90 percent of the poor readers.

The language disorder was characterized by verbal retrieval problems (anomia), intact visuo-constructional skills, and lowered vocabulary scores. These children often produced lower WISC Verbal IQ's than Performance IQ's, although this relationship was not diagnostic in and of itself. The investigators noted that children who show anomia after age 8 seem to be at exceptionally high risk for learning disability.

The motor speech disorder (labelled the articulation and dyscoordination syndrome) was defined by specific deficits in the production of sounds and words. The dyspraxia present in these children was more likely to be of the buccal-lingual than of the dental-palatal type. Verbal and Performance IQ's for the group were more nearly equal.

Children classified as suffering from a visual-perceptual disorder appeared to have failed to establish a stable and reliable association between sounds and letters. Notably, this disorder was not manifested on constructional tasks, although on tasks of visual integration and complex perception significant impairment was observed.

On the basis of this evidence the principal processes critical to reading were concluded to involve the adequate development of language symbolization, intact visual-spatial perception and the ability to produce fluent speech. The distribution of the three syndromes was different for the brain-damaged and non-brain-damaged dyslexics. A language disorder was most common in the brain-damaged dyslexics, followed by a motor-speech disorder and to a significantly lesser extent a visual-perceptual disorder. In the non-brain-damaged dyslexics the motor-speech disorder and the language disorder were reversed in frequency.

Denckla (1972) has identified three clinical syndromes (a specific language disturbance, a specific visuo-spatial disability and a dyscontrol syndrome) which roughly correspond to those of Mattis et al. (1975). Denckla, however, found that approximately 70 percent of disabled learners either produced mixed deficits or did not fit into any of the three categories. Denckla's dyscontrol syndrome is further distinguished by the presence of both poor muscular coordination and increased levels of activity (hyperkinesis).

Numerous other studies have suggested the existence of subgroups with either primary language deficits or primary visuo-spatial deficits. Cole and Kraft (1964) divided their 36 subjects into five groups which included these, along with (1) dyslexics without general language <u>or</u> visuo-spatial defect, (2) dyslexics with mixed defects and (3) specific learning disability without dyslexia. This latter group was quite heterogeneous and contained children with apraxic difficulties, specific spelling disability, with dysgraphia but without apraxia, and with abnormal speech development. Although the reliability of this categorization is questionable owing to the small number of subjects in each group (e.g., the visuo-spatial group contained only 4 members) and the methods used to classify the children, it represents an attempt to recognize additional patterns of disability among these children.

Among their subjects the language disorder was easily the most common, followed by the mixed group. Cole and Kraft found a high incidence of both abnormal neurological examinations (86 percent) and family history for learning problems (50 percent) among all of the groups, a finding common in many studies.

A comprehensive study of learning disability in children and their siblings was undertaken by Owen et al. (1971). The broad objectives of the project were to identify the characteristics of different learning disabilities and to attempt to isolate causal and familial patterns. Using an inspection technique five groups of the educationally handicapped population were preselected and they and their siblings were compared with matched controls and their siblings. Subjects were compared on 87 variables. Unfortunately the classification system was based on criteria which yielded overlapping, confabulated categories. Three of the five groups were based on WISC performance patterns (high Full Scale IQ, low Full Scale IQ and relatively higher Performance than Verbal IQ). The fourth category reflected etiological criteria (high incidence of medical and neurological abnormality) and the final category was based upon behavioral dimensions (social deviancy). Less than half of the children could be placed in a single category. The familial, neurological, intellectual and performance characteristics reported for each of the groups must be regarded as highly tentative because of these difficulties. The higher-Performance IQ group, for example, showed great similarity to the medical-neurological group along a number of performance dimensions, although the former group was in other ways the purest.

The study produced more significant findings regarding the characteristics of their dyslexic group as a whole. In their group there were very few gross neurological abnormalities noted on either physical examination or EEG. However, these children were judged to be more neurologically immature and showed greater deficits on neuropsychological tasks including right-left discrimination, auditory tapping and simultaneous tactile perception. Although these dyslexic children performed more poorly on psychomotor tasks, they were as capable of perceiving their errors as the control group. Both parents of these children were found to have performed less well in high school English. While the dyslexic children's fathers obtained lower overall WRAT scores than fathers of the control group, the dyslexic group's mothers had obtained poorer math grades in high school than mothers of the control group.

Finally, the study addressed the often-raised issue of whether reliable WISC subtest score relationships exist which distinguish children with learning disabilities. The data suggest that dyslexic children tend to produce relatively depressed scores on the Arithmetic, Digit Span and Coding subtests and relatively elevated scores on Picture Completion. The disabled children were found to have a greater incidence of higher WISC Performance IQ's than Verbal IQ's. In addition, reading and spelling scores (WRAT) were found to be less highly correlated for this group.

In his review of the evidence regarding WISC subtest patterns, Huelsman (1970) found that there was general but weak support for the hypothesis that disabled readers tended to show lower Verbal IQ's than Performance IQ's. There appeared to be a strong need to identify operational subtypes before making generalizations regarding WISC subtest patterns. Huelsman's own subjects obtained a "believable difference" between PIQ and VIQ in only 20 percent of the cases. It was found that no patterns of WISC subtest scores (including the often-reported lowered Arithmetic, Coding and Information scores) reliably identified reading disabled children.

A different approach to subtyping is exemplified in the works of DeHirsch and Jansky (1968), Boder (1968, 1970, 1971) and Doehring and Hoshko (1976). The defining characteristics in these classification systems derive from single or multiple performance measures as, for example, achievement test scores, school grades or reading skills scores.

DeHirsch and Jansky (1968) retrospectively examined the protocols of kindergarten children and followed their reading progress. They scrutinized standardized test scores and developmental histories, as well as measures of language and perceptual-motor ability. On the basis of reading performance the children were divided into high achievers, slow starters and failing readers. The reading failure children in this study were observed to be more immature, have diffuse deficits in oral language, unstable auditory and visual perception and inferior perceptual-motor skills. Hyperactivity was observed to occur with greater frequency in this group. At the year's end these children continued to show widespread deficits in contrast to the slow starters, who had largely made up their initial failure.

Boder (1968, 1970, 1971) has long argued that it is of importance to know <u>how</u> a child reads as well as at what level. She noted that some children exhibited difficulties in associating sounds with appropriate symbols. In her earlier work (1968) these children were called "visile" while a second group with visualizing difficulties were identified as "audile." A third group was included for those with mixed deficits.

In her later works Boder (1970, 1971) integrated these conceptual divisions with actual test performance on diagnostic reading and spelling tasks. Those children who demonstrated adequate sight vocabulary but impaired word attack skills and poor phonics (the visile children) were labeled as "dysphonetic." Other children were successful in approximating unknown words through phonetic sounding, but were deficient in recognizing words that should have been in their sight vocabulary. These children formed the "dyseidetic" group. (In the classroom such children tend to read very laboriously but possess near normal word attack skills.) The remaining group who demonstrated both patterns of deficits and overall poor reading were classified as "alexic." Camp and Dolcourt (1977) linked this latter group to those children identified in other systems as having generalized learning difficulties or non-specific reading problems.

Doehring and Hoshko (1976) utilized more advanced statistical methods in classifying children with reading handicaps according to their performance on 31 tests of reading-related skills. These tests required rapid matching responses to simple sets of letters, syllables, words and sentences. The method used to group the children is a variation of factor analytic procedure known as "Q-technique." The "Q-technique" is an "inverted" method which groups together individuals who show similar patterns of test scores. A factor is defined in this technique by the performance of individuals who have high loadings on that factor. In this case subgroups of children were defined on the basis of reading performance, and the profile of each subgroup was examined. Two samples were drawn. The first was composed of children whose primary difficulties were in reading, while the second sample included children with more general learning disorders, language disorders and mental retardation. The number of subjects in each sample (34 and 31 respectively) was uncomfortably small for analyses of this sort.

Three principal factors emerged for the first and second samples and four for the combined samples. In both samples three major subgroups were found. In the reading retarded sample the first subgroup of children performed well on visual and auditory-visual matching but poorly on oral reading tests involving words and syllables. The second subgroup was characterized by good visual scanning but very poor auditory-visual matching and poor oral reading. The last subgroup showed good visual and auditory-visual matching of single letters (but not of words and syllables) and poor oral word, sentence and syllable reading skills.

The first two subgroups of the second sample resembled those of the first sample. The remaining subgroup was characterized by slow visual matching. The authors attempted to relate their statistically derived groups to those proposed by previous investigators - none of whom used multivariate correlational procedures. Their results are difficult to interpret in light of the complex patterns of the constituent variables obtained by the analyses. However, it was concluded that the use of statistical classification techniques could greatly facilitate the achievement of a consensus regarding the number and the types of developmental reading disabilities.

A recent study by Rourke and Finlayson (1978) examined patterns of academic performance in relationship to neuropsychological variables. An earlier study (Rourke, Young and Flewelling, 1971) demonstrated that differential patterns of WRAT subtest performance could be related to particular patterns of WISC Verbal IQ-Performance IQ discrepancies. The earlier study found that performance on the WRAT Arithmetic subtest was more dependent upon visual-spatial skills than upon abilities of a verbal nature. The current project sought to determine whether children who exhibited varying patterns of academic abilities would also exhibit unique, meaningful and consistent patterns of visuo-spatial and verbal behaviors.

Children were placed into three groups. One of the possible weaknesses of the study was the composition of these groups. Group 1 was labeled as deficient in reading, spelling and arithmetic when WRAT performance on all tasks was at least 2 years below expected grade level placement. Group 2 was selected on the basis of their WRAT spelling and reading scores falling at least 1.8 years below their WRAT arithmetic scores. It should be noted, however, that this arithmetic performance still represented a deficit of some magnitude (mean grade level=4.86) in relation to the mean age for the group (143.67 months). The mean arithmetic score for Group 2 was significantly higher than for Group 1. However, when Group 3 was selected, arithmetic scores similar to those of Group 2 were then considered deficits, and were, in fact, the basis for identification of this group. Group 3's reading and spelling scores were significantly better than either Group 1 or 2, who did not differ significantly on these tests. Given these relationships between groups, the identity of each group is somewhat obscured by the confabulation of absolute criteria (as, for example, in the selection of a two-year deficit cut-off) with criteria based on relative performance (as, for example, used in the definition of Group 2). In their defense the authors argue that their results suggest patterns of performance rather than levels of performance are the more critical dimension.

Differential hypotheses were advanced concerning the expected performance on visuo-spatial, visuo-perceptual, auditory-perceptual and verbal measures. On nine of the 10 verbal and auditory-perceptual measures, the performance of Group 3 was found to be significantly superior to that of Groups 1 and 2. Groups 1 and 2 did not differ from each other on any of the variables, but were superior to Group 3 on the visuo-perceptual and visuo-spatial measures. Additionally, Groups 1 and 2 showed significantly lower Verbal IQ's and higher Performance IQ's compared to Group 3, although the Full Scale IQ's for the three groups did not differ.

The authors conclude that their results are consistent with the view that deficiencies in arithmetic are due to difficulties in visual-spatial organization and integration, abilities believed to be dependent upon the integrity of the right cerebral hemisphere. Similarly, Groups 1 and 2 appeared to perform in a fashion similar to that expected were they to have a relatively dysfunctional left cerebral hemisphere.

The authors speculate that differences between Groups 1 and 2 may not lie along the particular dimensions examined in their study. They call for further studies to compare the motor, psychomotor and tactile-kinesthetic performance of their subgroups in order to investigate possible alternative dimensions, as well as to provide further data on the role of the right and left cerebral hemispheres in academic performance.

CHAPTER II
STATEMENT OF THE PROBLEM

The preceding review suggests that most investigators working in the field of learning disabilities recognize the heterogeneity of that group of children whose academic performance falls below that of their age peers. Various schema have been devised attempting to account for the considerable variance exhibited by these children on almost all variables. The assumption is often made that, through the discrimination of subgroups within the general learning disabled population, greater precision in the identification of causal factors would be obtained. Ultimately, the application of differential treatment methods could take place. More accurate prognostic statements could then be made for children who exhibit particular types of learning difficulties. In light of the potential importance of identifying subtypes within the learning disabled population, there is a surprising lack of systematic investigation in this area.

In current usage the term "dyslexic" is often applied to any child who is behind in reading. Thus, there is little agreement regarding prevalence or epidemiology, much less the underlying mechanisms involved. Some researchers have attempted to conform to the World Federation of Neurology's definition of "specific developmental dyslexia" (Waites, 1968) on the assumption that a homogeneous sample is being selected. Recent studies (e.g., Taylor, Satz and Friel, 1977) fail to support this assumption, and the empirical utility of the concept appears to be suspect.

Many studies that have addressed the subtype problem as a primary issue (rather than as a "nuisance" parameter) have imposed *a priori* schema upon the data, sympathetic to a particular theoretical position. Thus, children have been sorted according to such criteria as neurologically impaired versus familial history of learning disability, or according to a certain pre-determined pattern of test performance. The validity of such classification schemes is too often treated as assumption rather than as hypothesis. Frequently, the method of assigning children to these categories is based solely upon inspection of quite complex data sets, rather than upon more rigorous systematic statistical methods. The study by Doehring and Hoshko (1977) stands as a notable exception to the "inspection" approach. Unfortunately, the precision of their sorting technique failed to reduce the complex patterns of performance to readily interpretable dimensions.

The need for systematic, rigorous studies to delineate subtypes is dictated both by the practical and theoretical implications of such discoveries, and by the present rather dismal lack of success (or at least agreement) in this area.

CHAPTER III
METHOD

Subjects

The subjects for the study were those children who participated in the longitudinal study of Satz and associates (1973, 1974, 1977) who were administered the Wide Range Achievement Test (WRAT) in year 6 (grade 5) of their schooling. The children in the original standardization sample of the Satz and Friel (1973) study consisted of 497 white male kindergarten pupils in the Alachua County, Florida, public school system and the University of Florida Laboratory School. This number represented 96 percent of that population enrolled in 20 county schools. A second group of children, identified as the cross-validation sample (N=181) was initially tested in 1971. The total sample for the present study (N=236) was drawn from these two groups. The mean age of these children at time of administration of the WRAT was 130.0 months (SD=3.9) with a range of 124 to 143 months.

The Satz studies utilized white males exculsively, in an attempt to provide a more homogeneous sample of children who would be at higher risk for developmental dyslexia (boys), and who would be less likely to be culturally disadvantaged (whites). The large sample size was felt to insure that subgroups of failing readers could be identified and studied in subsequent years.

Major follow-up examinations of the children were conducted in years 3 and 6 of the study. Teacher ratings and standardized achievement tests (administered through the school system) were obtained in intervening years. For the present study data from these previous examinations were available.

Procedure

In the initial phase of the present study the relatively unselected sample of 236 children was sorted into naturally occurring subgroups according to achievement test scores. These subgroups were next surveyed to determine if there were patterns of performance on intellectual, language and perceptual-motor tasks which further distinguished these groups. Attention was then directed towards the central question of the study, the identification of subtypes within the population of learning disabled children.

The first step in the process consisted of the application of cluster analytic techniques to Wide Range Achievement Test (WRAT) reading, spelling and arithmetic scores. These scores were entered in the form of discrepancy scores which were derived by comparing a child's chronological age with the age-equivalent score obtained on each subtest. Thus, a discrepancy score of "-24" in reading would indicate that the performance was 24 months behind that expected on the basis of the child's chronological age.

Cluster analysis is a set of procedures whose most common use is to form a classification system from a data set. This is accomplished by grouping together individuals most similar to each other on the component cluster variables.

Phase I

All clustering procedures used in this study were contained in the CLUSTAN 1C program (Wishart, 1975). For the WRAT data a hierarchical, agglomerative, average-linkage method employing a squared euclidean distance similarity coefficient was selected. The average-linkage method combined with the euclidean distance measure is more likely to permit clusters to emerge which do not fit the general trend of the data. It was known that WRAT reading, spelling and arithmetic scores are highly correlated for the general population (Jastak and Jastak, 1976). Therefore, it was anticipated that there would be a strong tendency to form clusters composed of reading, spelling and arithmetic scores at the same level (e.g., high, low or average). The structure of the data would then be largely that of a linear scale from lowest to highest achievement. Some other methods and similarity coefficients (e.g., those which minimize an error sum of squares) would be more likely to form spherical clusters and to obscure any deviations from the major trends of the data.

After the completion of the initial clustering, the composition of these clusters was then re-examined using Procedure Relocate (Wishart, 1975) in order to generate a local optimum solution. The rationale behind this latter procedure as well as the method used to determine the optimum number of clusters present in the data is discussed in the Appendix.

Phase II

Phase I established a preliminary classification system. To confirm the validity of the cluster solution a multivariate analysis of variance (MANOVA) was applied to the WRAT reading, spelling and arithmetic scores to test for the effects of subgroups. Subgroups were then compared again utilizing MANOVA, on two language measures, WISC Similarities scaled scores (Wechsler, 1949) and Verbal Fluency (Satz and Friel, 1973). They were additionally compared on a perceptual task, Recognition-Discrimination (Small, 1968), and a perceptual-motor developmental index, the Developmental Test of Visual-Motor Integration (Beery, 1967). Utilizing chi-square tests for independence additional comparisons were made on a teacher's rating of socioeconomic status (low versus average or above) and a rating of neurological status (normal, equivocal or affected) rendered by qualified physicians. Finally, Peabody Picture Vocabulary Test (Dunn, 1965) IQ's for the subgroups were subjected to an analysis of variance. These measures were selected in an attempt to determine if the groupings were associated with distinctive patterns of development, background, constitution or abilities and, additionally provided an external check on the classification system.

All multivariate and univariate analyses were conducted using the General Linear Models (GLM) procedure of the Statistical Analysis Systems (SAS) program (Barr, Goodnight, Sall and Helwig, 1976). The MANOVA procedure is the multivariate analogue of the univariate analysis of variance and was considered appropriate to the present data in order to decrease the probability of a Type I error which might result from the repetition of individual univariate analyses for each of the multiple dependent variables. When significant effects were found for subgroup in the MANOVA, individual variables were subjected to univariate analyses. Individual means were compared using post hoc Duncan's Multi-Range Tests (Winer, 1971).

Phase III

While the first two parts of the study surveyed a broad range of achievement levels, this phase of the study concentrated on those children whose performance was substantially lower than that of their age peers. The two lowest scoring subgroups (N=89) were combined into a single group to be reanalyzed. The reading, spelling and arithmetic scores for these groups, as indicated in Table 1, are sufficiently depressed to suggest that these children suffer significant difficulties in learning.

The combined group of low achievers was then reclustered on the basis of WISC Similarities, Verbal Fluency, Developmental Test of Visual-Motor Integration and Recognition-Discrimination scores in an attempt to identify subtypes within the learning disabled population. Again a hierarchical, agglomerative method was applied. However, because these variables were not as highly correlated as the reading, spelling and arithmetic scores of Phase I (Table 2), the method which assigns individuals to clusters in a manner which minimizes the error sum of squares (minimum variance method) was now appropriate for use. As in Phase I a local optimum solution was then sought through Procedure Relocate.

The resulting clusters were tentatively identified as subtypes of the learning disabled population. A MANOVA search for differences between subtypes on WRAT reading, spelling and arithmetic scores was made. In order to establish the statistical validity of the subtypes, the clusters were then examined through a multivariate analysis of variance of the clustered variables. Individual analyses of variance followed by post hoc tests (Duncan's Multi-Range Tests) were applied as in Phase II. Similarly, chi-square statistical tests for independence were computed for the socioeconomic status and neurological measures. Finally, an analysis of variance of Peabody Picture Vocabulary Test scores for the groups was conducted.

TABLE 1

Mean WRAT Discrepancy Scores For Achievement Subgroups

SUBGROUP NUMBER	N	READING*		SPELLING*		ARITHMETIC*	
1	13	42.8	A	24.9	A	11.8	A
2	16	40.7	A	5.9	B	- 9.6	D
3	25	25.2	B	4.3	B	2.6	C
4	25	10.8	C	- .2	C	-12.7	E
5	12	2.5	D	-14.9	E	-23.2	G
6	11	1.0	D	- 8.5	D	6.4	B
7	39	- 5.7	E	-16.5	E	- 8.6	D
8	56	-20.5	F	-26.7	F	-16.7	F
9	33	-31.2	G	-34.7	G	-27.4	H
10	3	56.6		61.7		-10.0	
11	1	66.0		86.0		8.0	
12	2	74.0		67.5		26.0	
Total Sample	236	.6		-11.2		-11.0	

* Means followed by the same letter are not significantly different within variables (Duncan's Multi-Range Test, Alpha level = .05).

TABLE 2

Variable Correlations for Total Sample

	WRAT READING	WRAT SPELLING	WRAT ARITHMETIC	PPVT	SIM	VF	VMI
WRAT SPELLING	.87	-	-	-	-	-	-
WRAT ARITHMETIC	.65	.66	-	-	-	-	-
PPVT	.56	.47	.34	-	-	-	-
SIM	.60	.54	.47	.63	-	-	-
VF	.49	.49	.40	.46	.44	-	-
VMI	.48	.47	.48	.32	.43	.34	-
RD	.37	.34	.33	.44	.35	.37	.45

Note: All correlations (Pearson Product-Moment Correlations) are significant at p .001.

Measures

Wide Range Achievement Test (WRAT)

This test was first standardized in 1936 (Jastak and Jastak, 1976). Since that time it has gained widespread acceptance as an economical and reasonably accurate estimate of a child's level of school achievement in reading, spelling and arithmetic. Criticisms of the instrument have noted that the subtests tap only a limited range of behaviors. For example, the reading subtest is a measure based solely on word recognition. However, studies by Rourke and Orr (1977) suggest that the WRAT is as powerful a discriminator of normal and disabled readers as are the Reading, Word Knowledge and Word Discrimination subtests of the Metropolitan Achievement Test. Validation studies cited by Jastak and Jastak (1976) generally point to moderately high correlations with the Stanford Achievement Test, the Woody-Sangren Silent Reading Test as well as other frequently used reading assessment instruments.

Language and Perceptual Motor Measures

These measures were selected for their presumed ability to measure performance in the important areas of cognitive-language and perceptual-motor development. In the longitudinal studies of Satz and associates (1973, 1974, 1977) WISC Similarities and Verbal Fluency were found to load highly on a factor identified as verbal-conceptual ability. These measures contributed heavily to the discriminative power of this factor to identify children at high and low risk for learning problems, in the age range examined in the present study.

Among the tests of non-verbal abilities administered in the Satz predictive battery, the Developmental Test of Visual-Motor Integration and Recognition-Discrimination showed the highest loadings over time on the factor labeled sensori-perceptual-motor. As of year 6 of the study they demonstrated their ability to predict future reading success from year 1 (predictive validity), as well as their ability to discriminate between groups at year 6 (concurrent validity). However, this factor reportedly had less power at year 6 than the verbal-conceptual factor (Satz et al., 1977).

WISC Similarities (SIM). The composition, scoring and validity of the Similarities subtest of the WISC Verbal Scale is generally well known and accepted (Wechsler, 1949, 1974). In the present study, scaled scores (Mean=10) were used throughout.

Verbal Fluency (VF). This is a modified form of the Verbal Fluency test developed by Spreen and Benton (1965). A child was required to name as many words as possible that begin with the letters F, A and S, allowing one minute per letter. Scores were the total number of words produced across all trials.

Developmental Test of Visual-Motor Integration (VMI). The VMI was devised as a measure of the degree to which visual and motor behavior are integrated in young children (Beery, 1967). It consists of a series of 24 geometric forms to be copied with pencil and paper. The forms are arranged in order of increasing difficulty. The copying of geometric forms is stated to be well suited to the purpose of measuring visual-motor integration because of the close correlation between visual perception and the motoric expression that is required, and because, unlike letter forms, geometric forms are equally familiar to children of varying backgrounds. For purposes of this study an age-equivalent score (in months) was used.

Recognition-Discrimination (RD). This visual-perceptual task created by Small (1968) requires the child to match a geometric stimulus design to one of four test figures. Three of the four were rotated and/or similar in shape to the stimulus figure. The maximum score for this task was 24.

Peabody Picture Vocabulary Test (PPVT). Dunn (1965) designed this test to provide an estimate of a child's verbal intelligence through the measurement of "hearing vocabulary." He points to substantial correlations of the PPVT with other measures of intelligence including WISC Verbal, Performance and Full Scale IQ's, Stanford-Binet IQ's and California Test of Mental Maturity IQ's. Accuracy for a wide range of mental abilities and for normal clinical groups is claimed on the basis of a large number of studies.

However, recent evidence suggests that IQ scores for certain groups, including disadvantaged children and, perhaps, the learning disabled, may show marked changes over time. A comprehensive longitudinal study by Van De Riet and Resnick (1973) examined the effects of an early childhood intervention program upon the development and achievement of children from poverty backgrounds. On two measures of IQ (WISC-R and Stanford-Binet) children who had participated in a "learning to learn" program showed mean improvements of greater than 15 points over the course of 5 years. This finding seems to support, in part, the widespread clinical practice of "adding points" to obtain best estimates of the IQ's of culturally deprived, emotionally disturbed and educationally handicapped children. Dunn (1965) acknowledges that while the PPVT has considerable face validity as a measure of "hearing vocabulary" or even expressive language, its items do not provide a comprehensive measure of intellectual functioning.

Therefore, when a test having the characteristics of the PPVT is used to generate IQ scores, caution must be exercised in interpreting the results. In the present study the IQ scores should be regarded more as an estimate of current verbal-intellectual performance than of the more abstract concept of an innate ability.

Socioeconomic Status (SES). The measure of socioeconomic status was obtained from teacher ratings on a dichotomous scale and was scored as either (1) low, or (2) average or above. This is admittedly a crude measure, of questionable validity and reliability, but suitable for discerning gross differences in cultural background.

Neurological Examinations (Neuro). These examinations were given by pediatric residents under the direction of Dr. John Ross of the University of Florida during year 4 of the longitudinal study of Satz et al. (1977). It consisted of the following: (1) a general exam which assessed cranial nerves, motor responses, sensation, reflexes and cerebellar functioning; (2) a special exam to evaluate fine and gross motor functioning, right-left discrimination and eye tracking; and (3) an examination of gross body anomalies or stigmata of the head, eyes, ears, mouth and feet. Each examination was conducted without concurrent data on the child and assignment was made to one of three categories (affected, borderline-equivocal or normal) on the basis of overall clinical judgement and component numerical scores.

CHAPTER IV
RESULTS

Phase I

The initial cluster solution was obtained by examining the composition of individual clusters at each stage of the clustering process. As the analysis decreased the total number of clusters by fusing the most similar entities two at a time, inspection of the mean reading, spelling and arithmetic scores revealed the character of each cluster. In this analysis it was found that a 12-cluster solution yielded the most distinctive pattern of subgroups.

Tracing the clustering process exposed the trend of the data to form clusters, which, by virtue of their mean reading and spelling scores, could be arranged in scalar fashion. Mean arithmetic scores for the clusters proved more variable. Solutions with more than 12 clusters served only to generate clusters with additional intermediate mean values for reading, spelling and arithmetic scores. Solutions consisting of less than 12 clusters resulted in the absorption of clusters of potential interest because of their unique patterns of scores. Additionally, a further reduction in the number of clusters caused the range of achievement patterns to begin to regress towards the overall sample mean.

Subjecting the initial cluster array to the relocation and fusion procedure improved the clarity of individual clusters and confirmed that the 12-cluster solution was near optimal for this study. Table 1 contains the 12-cluster solution in the form of the mean WRAT reading, spelling and arithmetic scores for each cluster and for the total sample.

The small number of individuals who made up clusters 10, 11 and 12 (N=6) led to considering these clusters as "outliers." The component individuals all obtained extremely high (and deviant) reading scores. Examination of the cluster fusion process revealed that no other entities were clustered with any of these clusters. Similarly, these "outliers" resisted incorporation into larger clusters until the 4-cluster solution. Following the recommendation of Everitt (1974), these individuals (N=6) were dropped from further analysis.

Phase II

The remaining clusters (achievement subgroups) were then examined for statistical differences on the clustering and dependent variables. An analysis of variance revealed no significant age differences between subgroups, F (8, 221) = .57, $p > .81$.

WRAT Scores

Although the total sample reading mean closely approximated the WRAT standardization mean (Table 1), means for spelling and arithmetic were 11 months below standardization norms (Jastak and Jastak, 1976). As predicted, reading, spelling and arithmetic scores were highly correlated for the total sample (Table 2).

A multivariate analysis of variance (MANOVA) on WRAT reading, spelling and arithmetic scores obtained an overall significant effect for subgroup (Hotelling trace = 16.01, $F_{approximation}$ (24, 653) = 145.22, $p < .001$). This finding justified the application of univariate analyses for each of the variables. Individual analyses of variance yielded significant effects for subgroup on WRAT reading, F (8, 221) = 199.76, $p < .0001$, on WRAT spelling, F (8, 221) = 157.59, $p < .0001$, and on WRAT arithmetic, F (8, 221) = 148.00, $p < .0001$.

Means for each WRAT variable are reported by subgroup in Table 1. Tests of significance for differences between means revealed that in only two instances for reading, and two for spelling, were pairs of means not significantly different from each other (Duncan's procedure, $\underline{p} < .05$). For arithmetic scores only one pair of means did not significantly differ. These comparisons tend to confirm the appropriateness of the cluster solution and point to the unique character of individual subgroups.

Subgroups 1 and 2 both obtained superior scores in reading, but subgroup 2 exhibited only average performance in spelling and was further distinguished by below-average scores in arithmetic. Subgroup 3 achieved high reading scores and average spelling and arithmetic scores. Subgroup 4 emerged as a group with adequate reading and spelling scores, but substandard performance in arithmetic. Subgroup 5 constituted a unique group by virtue of its average reading, below average spelling and severely depressed arithmetic scores. Subgroup 6's performance in all areas was, perhaps, the most nearly average of all the subgroups.

At the lower end of the achievement spectrum, subgroups 7, 8 and 9 each contained a large number of children. Reading and spelling scores for these subgroups could be arranged according to decreasing levels of performance. Arithmetic scores were below average for all three groups, although the mean scores of other subgroups (2, 4 and 5) were in several instances as deficient. The overall achievement of subgroups 8 and 9 was sufficiently depressed as to suggest that at least these children suffer significant difficulties in learning.

Peabody Picture Vocabulary Test

An analysis of variance revealed a significant effect for subgroup F (8, 217) = 10.46, p <.0001. Post hoc comparisons of IQ means (Duncan's procedure, p <.05) showed a strong ordering effect on the subgroups, in much the same manner as the WRAT reading scores (Table 3). Subgroup PPVT means formed a chain from highest to lowest with adjacent means not differing significantly from each other. Notably, no subgroup obtained a mean IQ less than 90 and the total sample mean (102.69) closely approximated the mean value reported for the PPVT standardization sample.

Language and Perceptual-Motor Variables

Pearson product-moment correlations of all variables are presented in Table 2 for the total sample. A multivariate analysis of variance on WISC Similarities, Verbal Fluency, Test of Visual-Motor Integration and Recognition-Discrimination revealed an overall significant effect for subgroup (Hotelling trace = .76, $F_{approximation}$ (4, 225) = 42.94, p <.0001). Individual analyses of variance yielded significant effects for subgroup on all dependent variables: WISC Similarities, F (1, 228) = 114.53, p <.0001, Verbal Fluency, F (1, 228) = 54.18, p < .0001, Test of Visual-Motor Integration, F (1, 228) = 73.52, p <.0001 and Recognition-Discrimination, F (1, 228) = 29.96, p < .0001.

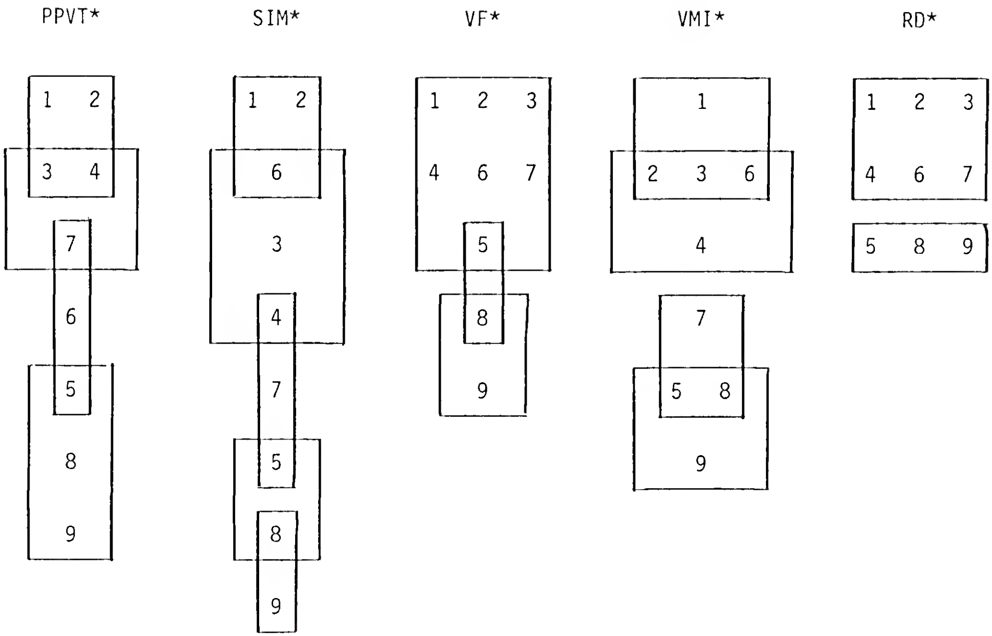
Similarities. Subgroup means for Similarities scaled scores along with Duncan's Multi-Range Tests (p <.05) are reported in Table 3. The relative performance of the subgroups is graphically represented in Figure 1. While the highest and lowest reading groups tended also to obtain the highest and lowest Similarities scores respectively, subgroup 6's performance was not statistically distinguishable from the two

TABLE 3

Mean PPVT, WISC Similarities, Verbal Fluency, VMI and Recognition-Discrimination Performance by Achievement Subgroups

SUBGROUP	N	PPVT*		SIM*		VF*		VMI*		RD*	
1	13	116.77	A	14.77	A	35.23	A	135.08	A	19.61	A
2	16	117.93	A	15.13	A	30.81	A	121.56	AB	18.88	A
3	25	110.27	AB	12.44	B	32.84	A	125.20	AB	19.84	A
4	25	110.12	AB	12.04	BC	30.08	A	117.24	B	18.68	A
5	12	99.08	CDE	10.58	CD	28.42	AB	87.25	CD	16.42	B
6	11	102.64	CD	13.73	AB	30.64	A	119.00	AB	18.64	A
7	39	103.15	BC	10.85	C	30.05	A	102.10	C	18.69	A
8	56	96.66	DE	8.88	DE	23.79	B	95.27	CD	16.80	B
9	33	90.52	E	8.00	E	19.79	C	87.18	D	16.30	B
Sample	230	102.69		10.90		27.65		105.74		17.96	

* Means followed by the same letter are not significantly different within variables (Duncan's Multi-Range Test, Alpha level = .05)



* Subgroups within the same box did not differ significantly for that variable.

Figure 1. Configuration of Achievement Subgroup Means for PPVT, WISC Similarities, Verbal Fluency, VMI, and Recognition-Discrimination

highest groups. Subgroups 8 and 9 produced the lowest levels of performance on this variable.

Verbal Fluency. Subgroup means for the Verbal Fluency variable with post hoc tests are presented in Table 3. Inspection of Figure 1 for this variable reveals a large number of subgroups with statistically similar means (subgroups 1, 2, 3, 4, 6 and 7). Subgroup 5 was characterized by performance which fell between that of this large group and that of subgroups 8 and 9. The uniquely poor performance of subgroup 9 was particularly striking.

Test of Visual-Motor Integration. The VMI mean developmental age-equivalents for subgroups, with post hoc comparisons, are reported in Table 3. The relationship of subgroup means is depicted in Figure 1. While the association of subgroups 1, 2 and 3 with higher scores and subgroups 8 and 9 with the lowest scores persisted, subgroup 6 again performed in a manner similar to the highest subgroups. In contrast, subgroup 5 obtained scores among the lowest for the sample. The total sample mean of 105.74 months represents a value substantially below that expected for the sample whose mean age was 130.01.

Recognition-Discrimination. Inspection of Table 3 and Figure 1 reveals a significant difference between the performance of subgroups 1, 2, 3, 4, 6 and 7 and that of subgroups 5, 8 and 9. This dichotomous division suggested the similarity of,subgroup 5 to that of the lowest achievement groups.

Socioeconomic Status

The chi-square test applied to the frequency distribution of this variable reflected a significant relationship between socioeconomic status and subgroup, $X^2 = 28.14$, $p < .0004$. Only 18 percent of the children of the total sample were rated as having low socioeconomic status. Subgroups 8 and 9 showed greater representation of the low ratings (34 percent each). The distribution of "low" versus "average or above" ratings is presented in Table 4.

Neurological Status

The chi-square test for the independence of the distribution of neurological status by subgroup confirmed the significant relationship between these variables, $X^2 = 74.92$, $p < .0001$. Inspection of Table 5 reveals that the academic achievement of subgroups was generally associated with frequency of positive neurological findings. The two subgroups with the lowest achievement scores (subgroups 8 and 9) also had the highest percentage of "affected" neurological ratings. Subgroup 9, in fact, included no children who were judged "normal." The percentage of "affected" and "equivocal" ratings for subgroup 5 suggested the similarity of this group to the two lowest achievement subgroups with respect to frequency of neurological symptoms.

The total sample showed an overall high proportion of neurological examinations rated "affected" (48 percent). However, it should be noted that there were 68 missing values from the distribution and that some cells were only sparsely represented. Therefore, all results pertaining to this variable must be interpreted with caution.

Phase III

Cluster Analysis

The 89 children of subgroups 8 and 9 were selected for further examination by virtue of their overall low achievement scores. The mean WRAT reading, spelling and arithmetic discrepancy scores for the combined subgroups were sufficiently depressed that they could legitimately be regarded as learning disabled (Table 6).

TABLE 4

Socioeconomic Status by Achievement Subgroups

SUBGROUP	N	MISSING VALUE	LOW		AVERAGE OR ABOVE	
			Frequency	% of Subgroup	Frequency	% of Subgroup
1	13	0	0	0	13	100
2	16	0	2	12	14	88
3	25	0	0	0	25	100
4	25	0	3	12	22	88
5	12	1	2	18	9	82
6	11	0	1	9	10	91
7	39	0	3	8	36	92
8	56	0	19	34	37	66
9	33	1	11	34	21	66
Sample	230	2	41	18	187	82

TABLE 5

Neurological Ratings by Achievement Subgroups

SUBGROUP	N	MISSING VALUE	NORMAL		EQUIVOCAL		AFFECTED	
			Frequency	% of Subgroup	Frequency	% of Subgroup	Frequency	% of Subgroup
1	13	3	5	50	4	40	1	10
2	16	7	7	78	2	22	0	0
3	25	7	16	88	1	6	1	6
4	25	11	7	50	4	29	3	21
5	12	3	2	22	2	22	5	56
6	11	2	3	33	2	22	4	45
7	39	16	7	30	6	26	10	44
8	56	18	4	11	5	13	29	76
9	33	8	0	0	4	16	21	84
Sample	230	68	51	33	30	19	74	48

TABLE 6

Mean PPVT, WISC Similarities, Verbal Fluency, VMI and Recognition-Discrimination Performance by Learning Disabled Subtypes

SUBTYPE	N	PPVT*	SIM*	VF*	VMI*	RD*
1	15	105.73 A	10.93 A	35.87 A	108.20 A	19.53 A
2	14	101.79 A	10.14 A	18.50 C	110.43 A	18.71 A
3	23	97.35 A	9.78 A	24.21 B	83.52 B	16.88 B
4	32	86.84 B	6.31 B	18.06 C	86.47 B	14.96 C
Outliers	5	74.20	5.60	10.60	71.00	8.00
Total Sample	230	102.69	10.90	27.65	105.74	17.96

* Means followed by the same letter are not significantly different within variables (Duncan's Multi-Range Test, Alpha level = .05)

Clustering these 89 children on the basis of their WISC Similarities, Verbal Fluency, Developmental Test of Visual-Motor Integration and Recognition-Discrimination scores resulted in a 5-cluster optimum solution. The solution was identified by tracing the value of the total similarity coefficient through each stage of the clustering process and by examining the composition and "N" of each cluster at each stage. A dramatic shift in the rate of change of the total similarity coefficient occurred during the transition from 5 to 4 clusters. This shift suggested that two relatively heterogeneous clusters, while the most similar of those clusters remaining, had been forced together. Inspection of the 5 and 4-cluster solutions confirmed that two relatively large clusters (N's of 15 and 19) had been fused to generate the 4-cluster solution. In contrast a 6-cluster solution contained an additional cluster with only 3 members.

Subjecting the 5-cluster solution to the relocation procedure resulted in the formation of 4 clusters with a significant number of members (15, 14, 32 and 23). The fifth cluster of only 5 individuals was not altered by any of the relocation passes, nor was it able to be combined with any other cluster. These individuals, because of their small number and because of their extremely deviant low scores on the clustering variables (Table 6), were designated as "outliers" for purposes of further analysis. The 4 remaining clusters were tentatively identified as subtypes of the learning disabled population.

WRAT Scores

The reduced sample of learning disabled children (N=84) obtained a mean reading score of -24.06 months (SD=9.07), a mean spelling score of -29.56 months (SD=6.49) and a mean arithmetic score of -20.55

(SD=6.29). A multivariate analysis of variance did not yield a significant effect for subtype (Hotelling trace = .20, $F_{approximation}$ (9, 230) = 1.72, p >.08). Thus, subtypes could not be differentiated on the basis of academic performance.

Peabody Picture Vocabulary Test

An analysis of variance yielded a significant effect for subtype, F (3, 80) = 9.87, p <.0001. Post hoc tests (Duncan's procedure, p <.05) revealed that only subtype 4 produced a significantly deviant mean (Table 6). The other three subtypes obtained means which approximated both the total sample mean as well as the national norm.

Language and Perceptual-Motor Variables

A multivariate analysis of variance showed a significant effect for subtype on WISC Similarities, Verbal Fluency, Developmental Test of Visual-Motor Integration and Recognition-Discrimination (Hotelling trace = 4.77, $F_{approximation}$ (12, 227) = 30.09, p <.0001). Individual analyses of variance confirmed the significant effect of subtype on each of these measures: WISC Similarities, F (3, 80) = 31.98, p < .0001, Verbal Fluency, F (3, 80) = 48.65, p <.0001, Test of Visual-Motor Integration, F (3, 80) = 22.15, p < .0001, and Recognition-Discrimination, F (3, 80) = 25.51, p < .0001.

WISC Similarities. Means and Duncan's procedures, p < .05, for subtypes may be examined in Table 6. Subtypes 1, 2 and 3 obtained statistically indistinguishable mean scaled scores, which were consistent with the overall sample mean of 10.9, as well as the WISC standardization value of 10. In contrast, subtype 4 showed a substantially deficient performance (Mean=6.31).

Verbal Fluency. The results of post hoc comparisons between subtype means (Duncan's procedure, $p < .05$) revealed a diversity of performances (Table 6). Surprisingly, subtype 2 produced low scores not significantly different from those of subtype 4. Equally surprising was the superior mean score of subtype 1, which was comparable to the means of the highest achievement groups of the total sample of 230. Subtype 3 obtained scores which were nearly average.

Developmental Test of Visual-Motor Integration. Subtype means and tests of significant differences between these means (Duncan's procedure, $p < .05$) are reported in Table 6. On this variable subtypes 1 and 2 obtained means approximating the total sample mean and not significantly different from each other. The means of subtypes 3 and 4 were likewise statistically equivalent. However, the performance of these two latter subtypes suggested pronounced deficits in visual-motor skill development.

Recognition-Discrimination. The means for subtypes 1 and 2 were not significantly different as determined by the post hoc tests (Table 6). Their scores were substantially higher than the total sample mean suggesting that these subtypes were unimpaired on this task. Subtypes 3 and 4 obtained mean scores substantially below that of subtypes 1 and 2, as well as below that of the total sample mean. On this variable subtype 4 scored significantly below even the mean of subtype 3.

Socioeconomic Status

A chi-square test for independence of the subtype and socioeconomic status variable distributions was non-significant, $X_3^2 = 4.42$, $p > .21$. Thus, subtypes could not be differentiated from each other on the basis of SES, although, as noted earlier, the learning disabled sample as a whole showed a significantly greater number of low status children than the higher achievement sample.

Neurological Status

The relationship of subtypes to neurological status was also found to be non-significant, $X^2_3 = 8.55$, $p > .20$. While there was a high incidence of "affected" ratings among all subtypes, Table 7 raises the possibility that subtype 1 tends to be less neurologically impaired. This hypothesis must remain speculative because of the large proportion of missing values.

TABLE 7

Neurological Ratings by Learning Disabled Subtypes

SUBTYPE	N	MISSING VALUE	NORMAL		EQUIVOCAL		AFFECTED	
			Frequency	% of Subtype	Frequency	% of Subtype	Frequency	% of Subtype
1	15	6	1	11	3	38	5	56
2	14	2	2	17	2	17	8	66
3	23	6	0	0	2	12	15	88
4	32	11	1	5	1	5	19	90
Subtype Sample	84	25	4	7	8	14	47	79

CHAPTER V
DISCUSSION

A critical appraisal of research on learning disabilities must conclude that there is a lack of consensus concerning almost every aspect of this problem except its importance. Some reviewers (e.g., Benton, 1975; Applebee, 1971) have suggested that one major source of the present state of theoretical disarray has been the unwarranted assumption that learning disabled children constitute a homogeneous population. Their position is supported by the diversity of reported correlates of learning disability found in the current literature. Similarly, no one of the numerous competing theories has been able to account adequately for the myriad of defects present in these children.

Most researchers acknowledge that the end result of substandard school achievement may be produced by such conditions as gross neurological defect, severe cultural or educational deprivation, impaired intellect, or debilitating psychopathology. However, those learning disabled children who suffer from none of these handicaps have defied accurate classification, other than to consider them as cases of learning difficulties of unknown origin. One approach toward reducing the ambiguity presented by these children has been to subsume them all under a single label as, for example, "specific developmental dyslexia." An alternative solution has been to group children according to a set of predetermined, sometimes arbitrary, criteria. Both approaches appear to force a premature structure upon the often complex patterns of performance produced by these individuals. The present study represents a preliminary effort to return to a basic stance of exploration in the search for naturally-occurring subtypes among the learning disabled.

An endeavor of discovery should be as free from a priori restrictions as possible, while still proceeding in systematic fashion. This project had as its primary goal the identification of subtypes through empirical means. As such, no attempt was made to employ a single set of theoretical constructs or constraints, nor to examine a select group of children. The 236 children available for the study represented the wide range of achievement occurring in the general school population. While the ultimate focus was to be on learning disabled children, the initial phases of the study sought to examine the performance characteristics of children of all levels of academic ability. Learning disability was here defined operationally by those children who clustered together on the basis of similarly low achievement scores. The sample size, one of the largest reported in the current literature, was felt to provide ample opportunity for a variety of distinctive groupings to emerge.

Similarly, the measurement of academic performance was not confined solely to reading competency. Although the vast majority of studies have singled out reading disability as representative of problems in learning, there is no firm evidence to suggest that failure in other academic areas is not equally as significant. For example, the findings of Rourke and Finlayson (1978) suggest that relatively deficient performance in arithmetic is associated with a unique pattern of neuropsychological deficits. These deficits contrast with those displayed by children whose reading and spelling scores are relatively inferior. The authors speculate that differential patterns of academic achievement may reflect differences in the integrity of the cortical mechanisms which ultimately subserve them. At the same time, there is not sufficient evidence to conclude that reading disability consistently occurs as a singular deficit. Several studies (e.g., Cole and Kraft, 1964; Ingram et al., 1970) have demonstrated that reading disability is most frequently accompanied by other educational handicaps.

One of the most powerful features of the present study was the manner in which subgroups were identified in the initial phase. With the exception of Doehring and Hoshko (1977) most investigators have relied upon the process of inspection alone or the use of "cut-off" scores to select their disabled samples. When more than one criterion measure is used, as was the case with the reading, spelling and arithmetic scores employed here, the resulting complexity of the data set effectively rules out the use of inspection techniques. In contrast, the cluster analytic procedures employed in this study permitted the data themselves to dictate the nature of the groupings that emerged. Cluster analysis represents a method tailor-made to discriminate similarities of individuals along a variety of dimensions. While an investigator must ultimately exercise judgement in determining which cluster solution is empirically useful, he can be assured that a particular cluster array has been systematically and impartially derived.

Examination of the statistically generated clusters revealed a configuration which could be regarded heuristically as a preliminary achievement-based classification system. Since the final value of a classification system rests upon its utility, it was necessary to establish both the statistical and empirical validity of the subgroups. Thus, analyses were conducted to determine if individual clusters were associated with particular patterns of scores on the developmental, intellectual, cultural or neurological variables. Through these analyses the search for meaningful achievement-subgroups was conducted in a particularly rigorous manner.

While the total sample size was certainly adequate (N=236), this number represents only slightly more than a third of the original population of 678 subjects studied in the longitudinal project of Satz et al. (1977). Although no systematic selection process was applied beforehand in choosing the subjects for this study, there is evidence to suggest that they constitute a somewhat unusual sample. One indication of the deviancy of this group is the relatively substandard spelling and arithmetic mean scores for the sample. Reading scores, on the other hand, closely approximated the national norms reported by Jastak and Jastak (1976). The mean discrepancy scores of -11.2 months and 11 months in spelling and arithmetic respectively clearly represent deficient performance, although not necessarily of pathological significance.

One likely explanation for this finding is that the inferior scores reflect the effects of differences between local educational standards and those of the national standardization sample. However, if this explanation is accepted, the question arises why the mean reading score for the local sample was not also lower. The significant correlational values between reading, spelling and arithmetic scores reported in Table 2 for the total sample compare favorably with those found for this age by Jastak and Jastak (1976). The sum of this evidence suggests that the relationships among scores were stable across the range of achievement and that a particular child's spelling and arithmetic performance was likely to be inferior to his reading performance.

An immediate consequence of the sample's depressed mean spelling and arithmetic scores is the dilemma of assigning descriptive labels to individual achievement subgroups. Assignment of a label is contingent upon whether local or national norms are used. For example, the children of subgroup 5 could be classified according to local sample means as roughly average in reading and spelling with an arithmetic deficiency. According to national norms these same children would show average reading, depressed spelling and severely impaired arithmetic performance. There are valid arguments for each position. On the one hand it could be claimed that these children certainly have not achieved on a par with their national peers in spelling or arithmetic; therefore, they represent a deficient group. On the other hand it could be speculated that these children performed at an average level (in spelling) given their educational and cultural opportunity. It is, perhaps, more judicious to avoid the use of labels which imply absolute levels of performance, particularly in the middle ranges of achievement.

Another disturbing finding of the present study is the large number of children who showed significantly depressed scores in one or more areas of achievement. Regardless of which interpretation is made concerning the sample mean scores in spelling and arithmetic, the performance of subgroups 8 and 9, and probably subgroup 5, can clearly be classed as deficient. The 89 children of subgroups 8 and 9 alone represent almost 38 percent of the total sample. This figure testifies to the significance of learning disabilities to public education. Undoubtedly, this figure is increased by the inclusion of the additional areas of spelling and arithmetic. This fact may, in part, account for the discrepancy between the 38 percent found here and more conservative estimates of approximately 15 percent (e.g., Kline, 1972) in studies in which only severe reading disability was considered.

Accompanying the depressed scores in two of the three academic areas there are two other significant characteristics of this sample in need of discussion. First, the mean developmental-age scores of the total sample obtained by the Test of Visual-Motor Integration (105.70 months) represented a deficit in expected performance of greater than 2 years relative to the mean chronological age of the sample (130.01 months). No satisfactory explanation is suggested by these data and any interpretations must remain highly speculative. However, the possible association of depressed arithmetic and spelling scores with inferior visual-motor performance is certainly worthy of further study in light of the findings of Rourke and Finlayson (1978).

A final major feature of the sample was the high incidence of "affected" neurological ratings (approximately 48 percent). Taking into account that the bulk of these ratings were obtained by children from the large low-achievement subgroups, this percentage is, nonetheless, considerably higher than estimates reported in most other current research. Cole and Kraft (1964), for example, found that only 50 percent of their learning disabled subjects showed evidence of neurological abnormalities. It is noteworthy that nearly a third of the subjects in the present study did not receive neurological examinations. Furthermore, the type of examination conducted included extensive procedures designed to detect even subtle impairments in neurological performance, thereby enhancing the chances for the assignment of an abnormal rating. Thus, while there is not reason to conclude that the ratings were inaccurate, it is probable that their significance is not equivalent to that of other studies.

Within the total sample, the 9 subgroups generated by the cluster analysis each exhibited a unique configuration of WRAT reading, spelling and arithmetic scores. It is unlikely that any two subgroups could be merged without losing potentially valuable information concerning the structure of the achievement data. The children of subgroup 1 were clearly superior, not only in their reading, spelling and arithmetic achievement, but also in their performance on each of the language and perceptual-motor tasks. None of these children were judged to have low socioeconomic background and only one child was given an "affected" neurological rating.

Subgroup 2 was characterized by a dramatic discrepancy between their excellent reading scores and their undistinguished spelling and arithmetic scores. However, this group's performance on the dependent measures was not statistically different from that of the most superior group. There was some suggestion of a trend toward relatively lower perceptual-motor scores (e.g., on the VMI), although the meaning of this trend is difficult to ascertain.

The achievement scores of subgroup 3 identified them as good readers with no other demonstrable academic deficits. Similar to subgroups 1 and 2 on most tasks (Verbal Fluency, VMI and Recognition-Discrimination), their lower Similarities scores implied a slight decrement in verbal-abstractive abilities relative to the two higher groups. The lower arithmetic scores (compared to spelling and reading) of subgroup 4 resulted in a pattern similar to subgroup 2, but at a lower achievement level. Again there was the hint of a relationship between depressed arithmetic scores and perceptual-motor performance. At the same time their above-average reading scores were accompanied by performance on the

PPVT and language measures which was not significantly different from subgroup 3.

The performance of subgroup 5 is worthy of careful scrutiny. These children obtained average reading scores, but showed depressed spelling and severely retarded arithmetic scores. It is the performance of this group of 12 children which cautions against limiting the study of learning disabilities to children with reading problems. Obviously, this group would not be singled out for special attention on the basis of their reading scores and yet in several respects their performance is indistinguishable from the two lowest groups of achievers. While their PPVT, Similarities and Verbal Fluency scores were nearly average, this subgroup obtained extremely low scores on both VMI and Recognition-Discrimination. Although there were statistical similarities of this subgroup to subgroups 8 and 9 in all areas, the pronounced deficits on these perceptual-motor tasks clearly identifies these children as suffering from significant developmental problems. By way of confirmation 55 percent of these children were assigned ratings of "affected" upon neurological examination. The combination of depressed spelling and arithmetic scores exemplifies the interpretive dilemma referred to earlier. While the mean arithmetic score certainly represents a deficit of some magnitude, the spelling scores must be evaluated in light of the overall sample spelling mean. Speculation regarding the underlying mechanisms involved would be hazardous at this point. However, future studies would do well to consider such children in addition to the poor readers.

The reading, spelling and arithmetic scores of subgroup 6 were the most nearly average and unremarkable of all the subgroups. However, on

4 of the 5 dependent measures their performance closely resembled that of the two superior subgroups. Subgroup 6 differed significantly from subgroups 1 and 2 only in their mean PPVT IQ's. The scores of subgroup 7 on all dependent test measures most closely approximated the means for the total sample. It is likely that both their reading, spelling and arithmetic achievement, and their developmental performance represents an intermediate value between those of the average and deficient achievement subgroups.

The differences in achievement between subgroups 8 and 9 were largely ones of degree. Both subgroups are readily recognizable as experiencing serious difficulties in all three academic areas. Their performance on the language and perceptual-motor tasks confirmed that these subjects suffered serious deficiencies across a range of developmental skills. These findings coupled with the unusually high proportion of positive neurological examinations and greater number of "low" socioeconomic ratings underscore the pronounced vulnerability of these children to difficulties in all facets of their educational lives. It is significant that these problems emerged in the absence of grossly substandard IQ scores. Both subgroups 8 and 9 obtained PPVT IQ's which fell within the "average learners" category relative to the national norms.

Data provided by the Phase I and II analyses raise serious questions regarding current methods in research involving disabled children and, inferentially, the assumptions which underlie these methods. The failure of the analyses to identify a unique reading-spelling group (or even a group deficient in both reading and spelling) suggests that "dyslexia" as an isolated syndrome, may be a rarer occurrence among children than previously supposed.

The failure to find an isolated reading-disabled group among the achievement subgroups is not surprising upon close inspection of the Rourke and Finlayson (1978) sample. These investigators were readily able to identify their Group 3 children on the basis of "average or above" reading scores and relatively deficient arithmetic performance. In contrast, their Group 2 children were only relatively adept in arithmetic compared to their performance in reading and spelling. Group 2's level of arithmetic achievement was substantially depressed. Furthermore, Group 2 children did not differ from Group 1 children (who showed deficiencies in all 3 areas) on any of the 16 dependent measures. Thus, it is doubtful that Rourke and Finlayson were able to isolate a "pure" verbally-deficient group in the manner of Groups 1 and 3.

Both the subgroup 5 children of this study and the Group 3 children of Rourke and Finlayson (1978) displayed impaired development of important non-verbal skills, though they had acquired adequate language skills. While deficient perceptual-motor performance effectively distinguished subgroup 5, no such differential pattern was found for the large numbers of children in subgroups 8 and 9. Rather, these children tended to perform poorly on all measures of development. It should be emphasized that these results were obtained through sampling at a single age and, therefore, cannot be comprehensively applied to a number of developmental issues. However, these results tend to challenge the "lag" hypothesis encountered in some current theories (e.g., Satz et al., 1977) which predicts that learning disabled children eventually "catch up" on certain earlier developing skills, (e.g., visual-perceptual and cross-modal sensory integration). The magnitude of the deficits on the VMI and Recognition-Discrimination variables for subgroups 8 and 9 suggest that at an age when language-conceptual difficulties should begin to predominate, significant perceptual-motor problems tend to persist.

However, it should be recalled that most developmental theories of learning disability have been based on and applied to what is potentially a quite heterogeneous population. In the example cited above, it is conceivable that within subgroups 8 and 9 certain children could show deficits exclusively in language, having made up deficits in other areas. Other children may have demonstrated deficient language and perceptual-motor skills throughout their development. The final phase of this study was designed to provide a preliminary basis for further investigation into these possibilities. If it could be demonstrated that certain distinctive patterns of deficits exist at the age addressed in this study, efforts could then be directed toward examining the developmental processes which produced these patterns.

The simultaneous emergence of the four cluster-subtypes in the final cluster analysis constituted one of the unique findings of this study. It appears that no previous classification systems have adequately encompassed the range of logically possible combinations of deficits which may be represented in the learning disabled population. The present data suggest that not only are such combinations possible, but that they actually occur. Thus, the final cluster configuration included: (1) children who showed deficits in neither language nor perceptual-motor development; (2) children with impairment in both areas; (3) children with language-related deficiencies; and (4) children with deficits in perception and perceptual-motor integration.

The differences between these subtypes were not found to be associated with the severity of their academic failure. For example, the relatively superior IQ and Verbal Fluency scores of subtype 1 did not save these children from the same dismal achievement as that of subtype 4, who demonstrated considerably more limited resources in these areas. Neither could individual subtypes be discriminated on the basis of their impoverished socioeconomic background, although the measure employed in this study was admittedly crude. Similarly, the high rate of abnormal neurological findings for the total group precluded indentification of any single "neurological subtype" (c.f. Owen et al., 1971). This finding is in accordance with Mattis et al. (1975) who found that their dyslexic subjects could not be differentiated on the basis of presence or absence of brain damage. Nonetheless, the subtypes delineated in this analysis exhibited statistically significant differences along dimensions which have considerable relevance to current research and theory.

Little controversy surrounds the existence of subtype 4. This group of children typically obtains the lowest scores on almost all proficiency measures employed in the classroom. Denckla (1972) has estimated that fully 70 percent of the learning disabled population should be classified in the "mixed or unclear" category. In the present study the 32 children of this subtype represented within the reduced sample the poorest performers on all variables. Their performance produced the only IQ's to fall outside the average range. On no language or perceptual-motor variable did their performance approach the mean of the total sample (N=230).

In many respects subtype 4 resembled the children categorized by Yule and Rutter (1976) as suffering from "general reading backwardness." Both these groups showed depressed IQ scores, demonstrated inferior perceptual-constructional abilities and exhibited significant speech and language impairment. The children in the "general reading backwardness" group tended to have a higher incidence of neurological problems and social disadvantage than the group identified as "specific reading retarded." However, they also showed a better prognosis for future academic achievement in all areas except arithmetic. This latter finding by Yule and Rutter cautions against prematurely discriminating against these children in terms of the focus of future research, as well as intervention.

Subtype 2 emerged as a distinctive group by virtue of significantly depressed Verbal Fluency scores. This deficient performance was highly circumscribed and did not extend into other language measures, including WISC Similarities or the Peabody Picture Vocabulary Test. Neither was there evidence that these children experienced lags in perceptual-motor skill acquisition. Only in verbal fluency did their scores fall substantially below the means of the total sample.

Benton (1975) has identified generalized language disability as one of the persistent defects reported in reading disabled children. He points to the large number of studies which have noted difficulties in verbal production as a crucial obstacle to the development of adequate reading skills. In the classification system of Cole and Kraft (1964) a group described as "dyslexia with general language defect" contained the largest number of individuals. The criteria which defined their group were (1) a history of retarded speech development and

(2) abnormalities of expressive or receptive speech. Interestingly, the group was composed entirely of boys and fully 84 percent had a positive family history of learning difficulties.

Mattis et al. (1975) similarly stressed the importance of verbal retrieval problems in both the brain-damaged and nonbrain-damaged dyslexics who composed their "language disorder" group. Like the children of subtype 2, the "language disorder" children showed impeded verbal production, but intact visuo-constructional skills. In contrast to the Mattis results, subtype 2, characterized by deficiencies in verbal fluency in the present study, was the least common of the four subtypes. Subtype 2 also resembled the category of "specific reading retardation" identified by Yule and Rutter (1975) as exhibiting deficits only in speech and language. Both groups obtained remarkably similar mean IQ estimates falling solidly in the average range.

There appears to be a strong consensus regarding the existence of a group of children whose deficiencies lie almost exclusively in the area of language development. However, it is presently unclear whether the disorder is manifested from earliest childhood or is developmentally preceded by deficiencies in sensory, perceptual or motor skills. Likewise, the evidence is inconclusive as to which specific language-speech functions are compromised. For instance, some studies (e.g., Cole and Kraft, 1964) suggest that the disorder encompasses both receptive and expressive language dimensions.

Benton (1975) in his review of the defects reported to be associated with learning disability has commented that the role of visuo-perceptive factors has been overrated. Part of his rationale rests on the observation that these defects do not generally persist into adulthood.

Nonetheless, numerous studies (e.g., Cole and Kraft, 1964; Ingram, 1966; Denckla, 1972; and Mattis et al., 1975) have concluded that a small but persistent group of children suffer relatively circumscribed deficits in perceptual-motor development including the specific problems of visuo-spatial agnosia, constructional apraxia, graphomotor dyscoordination and poor visual-motor integration. Such a population was represented in the present study by subtype 3.

In contrast to the majority of other studies, subtype 3 accounted for a relatively large proportion of the learning disabled subjects (approximately 27 percent). These children exhibited strikingly inferior performance on both the VMI and the Recognition-Discrimination task. Their PPVT and Similarities mean scores were not significantly different from those of subtypes 1 and 2, nor from those of the original achievement sample.

The emergence of subtype 3 as a distinctive and well-established group again presents a serious challenge for explanation to "developmental lag" theories which predict that perceptual-motor deficits are characteristic of much younger disabled learners. These youngsters purportedly should make up these deficits only to lag behind in later years in language skill development. Although developmental trends are more appropriately addressed through longitudinal designs, the present results suggest that language and perceptual-motor decrements in performance may be present separately, or together (as in subtypes 2, 3 and 4) at the same chronological age.

Perhaps the most surprising group to emerge in the analysis was subtype 1. While their poor achievement was not distinguishable from the other subtypes, its source is difficult to infer because there appeared to be no functional correlates to their disabilities. With the possible exception of the VMI their scores on each variable were at least average. Although the proportion of "affected" neurological ratings was not statistically different from that of other subtypes, the 56 percent figure for subtype 1 is comparable to the total sample mean of 48 percent and to that of achievement subgroup 5. On the basis of verbal-conceptual development the children of subtype 1 would be difficult to suspect of having learning problems. In fact because of their superior verbal fluency, they might create an initial impression in educational situations of having far greater general abilities.

The significance of the mean VMI score for subtype 1 (108.20 months) is difficult to assess. On the one hand this value reflects nearly a 2-year lag behind chronological age. On the other the subtype 1 mean slightly exceeded the mean for the total sample. In the context of the present design it could be argued that relative to other disabled subtypes (3 and 4) subtype 1 performed demonstrably better.

Since none of the developmental, intellectual or neurological measures clearly discriminated subtype 1, it was hypothesized that perhaps this subtype was composed of individuals who suffered from significant psychopathology or motivational problems. Numerous investigators have postulated the close association of reading disability with emotional disturbance and personality dysfunction (e.g., Owen et al., 1971; Rourke, 1975). The clinical impressions of Rabinovitch et al. (1954) suggest that the nature of these associations may vary with the type of reading difficulty. The administration of the Children's Personality Questionnaire (Porter and Cattell, 1972) permitted the measurement of 14 independent factors, or traits, presumed to underlie the normal personality.

These 14 raw factor scores, employed as dependent measures in a multivariate analysis of variance, provided a basis for comparing the subtypes. However, the analysis failed to reveal differences between subtypes along any of the 14 dimensions (Hotelling trace = .59, $\underline{F}$ approximation (42, 167) = .78, $p > .82$).

Confronted with the sum of this puzzling evidence, subtype 1 must be considered as composed of children with truly "unexpected learning difficulties." The current research literature has not addressed this subtype and contains few clues to the deficiencies which account for the failure of this substantial number of children. It remains for future studies to explore additional areas of childhood development in the search to validate and, ultimately, to explain their retarded achievement.

Overall, the results of the present study demonstrate the need for investigators studying the learning problems of children to specify carefully the populations selected for scrutiny. Ultimately, the particular achievement subgroups identified here may not prove to be definitive. However, there can be little doubt that a considerable variety of achievement-score relationships are represented by significant numbers of children. Such patterns are to be found at all levels of achievement from superior to disabled. Further study of all achievement levels may provide insight into the general principles and component skills involved in the mastery of material from different academic areas. The conclusion of Rourke and Finlayson (1978), that patterns, rather than levels of achievement, are the salient feature in the production of learning disability, may well be validated through such studies. It should then be possible to generate hypotheses regarding possible underlying mechanisms of learning disability with far greater precision.

The emergence of four unique and meaningful subtypes supports the position advanced by some investigators that the population of disabled learners is quite heterogeneous. In accordance with Applebee's (1971) model it appears that poor achievement may be simultaneously associated with each of several different patterns of deficits. The data from this study admit the possibility that substandard learning achievement may occur in the presence of (1) verbal fluency difficulties alone, (2) deficient perceptual-motor development alone, (3) deficits in neither skill or (4) defects in both skills. Hypotheses which address only one of these dimensions are likely to yield inconclusive results when applied indiscriminately across all groups. For instance, a theory which stresses exclusively the role of language defects in learning disabilities will be hard-pressed to account for the performance of children of subtypes 1 and 3.

Building upon the foundation of the present project, future research can next address the developmental parameters which may characterize each of the subtypes. In the manner of Zigler (1969) it might be found that some subtypes conform most nearly to a lag model, others to a defect model and still others to a difference model. One approach to this issue might be to trace the performance of the present individual subtypes across age ranges and to compare their developmental characteristics with those of a "normal" control group.

Another avenue of exploration would be to utilize cluster analytic procedures to identify learning disabled children who showed similar patterns of development, as reflected by their scores on selected performance variables at different chronological ages. The composition of the resulting clusters could then be examined to determine which characteristics distinguished each group. These subgroups could then be compared with normal or superior achievement groups using multivariate procedures.

It is apparent that the use of modern clustering techniques greatly facilitates the examination of the hidden structure of complex data sets. This capability, applied to the search for the multitude of dimensions which underlie children's learning problems, offers considerable promise for solid advances in the understanding of this crucial social and educational problem.

APPENDIX
CLUSTER ANALYSIS

Cluster analysis is a statistical procedure which facilitates the creation of a classification scheme. Succinctly stated, the task is to group _N_ objects or individuals into _g_ classes, given that each object is measured on each of _p_ variables. Everitt (1974) has identified at least seven possibilities for the use of clustering techniques including: (1) finding a true typology, (2) model fitting, (3) prediction based on groups, (4) hypothesis testing, (5) data exploration, (6) hypothesis generating and (7) data reduction. However, the flexibility and scope of cluster analytic methods have not been matched as yet by their precision or power. Blashfield (1976) has examined the accuracy of four agglomerative heirarchical methods and found that there was considerable variance in the adequacy of cluster solutions generated by these methods. He acknowledges that the literature on cluster analysis is still in its infancy and suggests caution in the adoption of a particular classification result.

Although cluster analysis was originally proposed some years earlier the procedure did not gain widespread notice until the advent of high speed computers. One of the earliest works was a book on numerical taxonomy in biology by Sokol and Sneath (1963). Blashfield's (1976) review of the relevant literature reveals a veritable explosion of research addressing the theory and application of cluster analysis since the early sixties. He concludes that no single theory or method has gained ascendancy.

Perhaps the most popular methods in current use are the hierarchical procedures. Hierarchical methods attempt to form homogeneous groups by systematically analyzing a similarity/dissimilarity matrix. The matrix is constructed by computing the similarity of every entity to every other entity. Various measures are available to indicate similarity including the squared euclidean distance measure used in both clustering phases of this study. Examples of other measures frequently used are product-moment correlations and error sum of squares.

Following the formation of a similarity matrix, the individuals are then assigned to clusters using one of several linkage methods. Linkage methods refer to the mechanism used to join entities to form clusters. For Phase I of this study an average linkage method (sometimes called the "unweighted pair-wise group mean average linkage method") was selected for its property of allowing "nonconformist" clusters to form (Blashfield, 1976). This method requires that before an entity can join a cluster it must achieve a given level of similarity with the average of the members already belonging to the cluster.

In Phase III a minimum variance method (Ward's method; Wishart, 1975) was employed. Although not suitable for all applications (as in Phase I) this method has the advantage of optimizing an objective statistic (the error sum of squares among the members of each cluster) and is, perhaps, the most generally reliable and accurate of available methods.

Two problems present themselves in connection with the hierarchical clustering methods. The first results from the process by which clusters are formed in hierarchical fashion. An individual, once placed in a given cluster, is not able to be reassigned to a later-forming cluster, even if its similarity to the latter cluster is greater. To circumvent this difficulty, i.e., to maximize a cluster solution, Procedure Relocate of the CLUSTAN 1C program (Wishart, 1975) was applied subsequently to each of the initial cluster analyses. During each relocation scan, each individual is statistically removed from its parent cluster and its similarity to all other clusters is computed. If its similarity to another cluster is greater the individual is placed in that cluster and the centroids (cluster centers) are immediately recomputed. The process continues for each individual for the specified number of scans. An option available in this procedure allows for the fusion of cluster, thereby reducing the number of clusters after each relocation scan. The final cluster array which resulted after Procedure Relocate was felt most likely to reflect the closest approximation of the actual structure of the data.

The second major problem encountered with the use of clustering techniques is that of determining when an optimum number of clusters has been reached. In the heirarchical agglomerative methods each object initially forms a cluster of one. Objects are joined two at a time until all objects belong to a single cluster. The decision to halt the clustering process is largely based on external considerations, there being no generally accepted test statistic currently available able to estimate when the number of clusters accurately reflects the underlying structure of the data. Everitt's (1974) review of current practices suggests that, while there have been attempts to employ advanced statistical measures (e.g., minimization of "trace (W)" techniques), most often the cluster array must be evaluated on the basis of whether the solution makes heuristic sense, given what is known about the data a priori or upon other external criteria. It is then most prudent to validate the classification system by examining the relationship of the clusters to other relevant variables not used in the clustering.

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BIOGRAPHICAL SKETCH

Roy Otto Darby III was born August 22, 1945, in Columbia, South Carolina. He lived in Savannah, Georgia, Oak Ridge, Tennessee, and Columbia, South Carolina, where he graduated from A.C. Flora High School. He was graduated with a B.S. in Psychology from the University of South Carolina, and was commissioned an Ensign, United States Navy, in June, 1967. After a tour as Gunnery Officer, Legal Officer, Officer of the Deck and Command Duty Officer on a destroyer, he was assigned as Senior Naval Advisor to a Vietnamese Coastal Group (Junk Force). As a Full Lieutenant he received the Bronze Star, Combat Action Ribbon, Vietnamese Honor Medal (First Class) and Vietnamese Cross of Gallantry with Silver Star.

After discharge he entered the University of Florida Graduate School in Clinical Psychology. He received the Molly Harrower Psychodiagnostic Award and the Master of Arts degree in 1974. From 1974 to 1976 he was employed as the psychological evaluator for the Jackson (Mississippi) Mental Health Center. His residency year was served at the University of Texas Health Sciences Center at San Antonio. He returned to the University of Florida where he received the Ph.D. degree in clinical psychology in December, 1978.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul Satz, Chairman
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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