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ABSTRACT

Based on a conceptualization of specific learning disability within a developmental rather than disease model, the longitudinal research project attempted to assess early indices of later reading disability. Kindergarten boys (N equals 474) were tested at the beginning of the school year on a number of developmental and neuro-psychological tests (predictors). At the end of the year, preliminary followup consisted of classification of the students by their teachers into High Risk and Low Risk criterion groups for potential learning disability (the true criterion would be third grade reading achievement scores). Purpose of the classification by teachers was to obtain preliminary criterion estimates of subsequent learning disability in order to determine the predictive validity of the independent variables (the tests administered earlier). Results showed high concordance between predictor measures (tests) and teacher classifications: tests correctly classified 78.4% of the children classified as High Risk, and 82.7% of the Low Risk children, suggesting that correct identification can occur even before formal reading instruction. Highest discriminating variables were Finger Localization test, socioeconomic status, Dichotic Listening total recall, and Peabody Picture Vocabulary Test. (KW)

Some Predictive Antecedents of Specific Learning Disability:

A Preliminary One Year Follow-up[1]

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Specific learning disability, particularly involving the process of reading and writing, has been recognized as a major social and educational problem of the twentieth century. The problem has been intensified in recent years by virtue of improved incidence studies and various social and economic factors which have precipitated a disproportionately high number of learning casualties in the ghetto and culturally deprived segments of society (Eisenberg, 1966). The incidence of reading difficulties has been shown to vary between 10 and 30 percent of the school population with frequency inversely related to social class (Eisenberg, 1966; Hawke, 1958). While more conservative estimates range between five and 15 percent this still means that at least four million elementary school children in the United States are disabled readers (de Hirsch, Jansky & Langford, 1966). According to Eisenberg and Gruenberg (1961, p. 361): "The magnitude of the reading problem and the shattering impact of reading disability on personal and vocational adjustment should accord proposals for its correction a major position in mental hygiene programs."

Although the incidence of reading disability is significantly influenced by deprivations in the social and environmental background of the child, there still remains a considerable number of disabled learners who have the advantages of social and educational opportunity, at least average intelligence and no evidence of gross neurological or emotional handicap. It is this particular group of children for whom incidence data and etiology are noticeably lacking. They have been distinguished from the general population of disabled readers on the basis of the preceding characteristics and have been referred to variously as cases of specific reading disability (Money, 1962), developmental dyslexia (Critchley, 1968) or educationally handicapped (Owens, Adams & Forrest, 1968). Regardless of

the diagnostic label, studies have uniformly reported a disproportionately higher incidence of males in children with these specific learning handicaps (Money, 1966).

An attempt has recently been made to explain the nature and underlying cause of this disorder (Satz & Sparrow, 1970; Satz, Rardin & Ross, 1971; Satz & Van Nostrand, 1972). These authors have postulated that specific reading disability is not a unitary syndrome but rather reflects a lag in the maturation of the brain (left hemisphere) which delays differentially those skills which are in primary ascendancy at different chronological ages. Consequently, those skills which during childhood develop ontogenetically earlier (e.g., visual-perceptual, visual-motor, directional-spatial) are more likely to be observed in <u>younger</u> children who are maturationally delayed. Conversely, those skills which during childhood have a later or slower rate of development (e.g., language and formal operations) are more likely to be observed in <u>older</u> children who are delayed maturationally. This reasoning is closely tied to Bloom's (1964) observation that variations in the environment (or CNS) have their greatest quantitative effect on a characteristic at its most rapid period of change and the least effect at the least rapid period of change. The theory, in brief, is compatible with those developmental positions which postulate that the child goes through consecutive stages of thought during development, each of which incorporates the processes of the preceding stage into a more complex and hierarchically integrated form of adaptation (Bruner, 1968; Hunt, 1961; Piaget, 1926). These stages are presumed to develop in an orderly fashion with increased age and maturation of the CNS. If, however, the maturation process is delayed, then corresponding delays in the acquisition of the developmental stages or skills are predicted.

Satz and associates (1970; 1971; 1972) have shown that the pattern of difficulties in handicapped learners indeed changes as a function of chronological age. Dramatic differences have been demonstrated between younger (ages 7 - 8) and older (ages 11 - 12) disabled readers. Generally, the younger dyslexic child, in contrast to his age-matched control, has been delayed on a number of perceptual or perceptual-motor skills which are crucial to the early phases of reading (Gibson, 1968). These same skills, in addition, have been shown to be in primary ascendency during this age period (Bruner, 1968; Thurstone, 1955). By contrast, the older dyslexic child, as opposed to his age-matched control, has not evidenced any significant delay in these earlier-developing skills, but, rather, has lagged substantially on a number of language skills which are crucial to the later phases of reading (Gibson, 1968). These same skills, moreover, have been shown to have a slower or later rate of development with primary ascendency in the 11 - 12 age groups (Bruner, 1968; Thurstone, 1955).

The preceding findings, although based on cross-sectional rather than longitudinal designs, suggest that developmental delays in the initial elementary school years may forecast different and perhaps more severe delays in language integration in later years. Although the child may lag in certain basic early skills crucial to reading (e.g., perceptual), he eventually overcomes these early lags but may then lag in those skills which develop ontogenetically later. This formulation implicitly suggests that the mechanism which underlies the maturational lag affects the rate at which the developmental milestones are reached, and therefore, early delays in the maturation process, even during pre-school, may forecast the nature and severity of later reading disability. This formulation thus conceptualizes the problem within a developmental rather than disease model (e.g., brain damage). As such, it predicts that the child who is matura-

tionally delayed will continue to "catch up" developmentally, albeit at a slower rate.

The main advantages of this theory are twofold. First, it specifies some of the early antecedents of later reading disability which may be identified during pre-school <u>before</u> formal reading instruction is begun. Second, it affords early identification at a time when the CNS is more plastic and subject to rapid growth (Lenneberg, 1967) and when the child is generally free of personality problems (Gates, 1968). The need for early identification of these "high risk" children is already recognized as one of the major problems and challenges of childhood learning disability (Money, 1966). Unfortunately, the vast majority of studies in this area have been addressed to older children who have suffered with their handicap for several years, who may now be experiencing considerable emotional distress and who may already have passed certain critical or sensitive developmental periods which could decrease their chances for remediation (Caldwell, 1968).

The optimal framework in which to assess early indices of later reading disability is longitudinal. Unfortunately, longitudinal studies in this area have been rare (Money, 1966). The most ambitious project to date is the three-year follow-up of kindergarten children (normal and premature births) by de Hirsch, Jansky and Langford (1966). Although numerous predictor tests were employed (N = 37), the study was limited by virtue of the small sample size (N = 106), the inclusion of both males and females, the large number of low income children from different races, and the utilization of univariate rather than multivariate methods of analysis. A multivariate paradigm, including factor analysis, may have afforded a reduction in the time-consuming test battery as well as an increase in the predictive validity of the instruments. Nevertheless,

the authors were able to identify a small number of high-risk children, during pre-school, who later developed severe problems in reading and writing. Of particular interest in this study was the finding that those tests which were maturation-sensitive (i.e., age-related) were uniformly more predictive by the end of second grade. The visual-perceptual and perceptual-motor tests were shown to be particularly sensitive in terms of both maturation and predictive validity, which lends indirect support to the theory previously discussed (Satz, et al., 1970; 1971; 1972). Similar findings were reported in a later study of 57 children by Sapir and Wilson (1967) which assessed the predictive validity of kindergarten measures eight and 17 months after initial testing. The highest criterion correlations (Reading Readiness Tests) were again found with the perceptual-motor instruments for both criterion periods, although the correlations for the language measures increased on the second criterion evaluation (17 months later). These findings are consistent with the theory of Satz and associates in that ages 5 - 6 mark a critical period in the primary development of perceptual skills. This longitudinal study, while predictive in terms of early identification of high-risk children, was limited for several of the reasons outlined in the de Hirsch, et al. (1966) project. The findings, however, again point out the relevance of perceptual skills in reading readiness. In fact, Weiner and Wepman (1971), using a three-year follow-up of 59 black disadvantaged children, recently showed that measures of perceptual and perceptual-motor functioning during first grade were extremely sensitive predictors of school achievement (largely language) at the end of third grade. The data from each of these studies strongly suggest that when early predictive indices are desired, criterion correlations will be increased if tests are selected which assess those skills which are in primary development at these ages. It was recently shown

(Chissom, 1971) that skills which have a much earlier rate of development (e.g., balance and motor coordination) showed a substantial correlation with academic aptitude and achievement in younger boys (first grade) but not in older boys (third grade). These findings again highlight the potential usefulness of developmental concepts in attempts to isolate some of the predictive antecedents of later learning disability.

The present chapter is addressed to a one year preliminary follow-up of a large sample of kindergarten boys (N = 474) most of whom were tested at the beginning of the school year on a number of developmental and neuropsychological tests (predictors) and who were independently classified by their teachers at the end of the year into a High Risk and Low Risk criterion group for potential learning disability. Although the time interval between test administration and criterion classification is presently small, the project was designed to circumvent many of the problems inherent in previous studies. The tests were selected on the basis of the theory outlined above; the sample, while large, was based on only boys (Caucasian) who are already at a higher risk for later reading problems; a total population was represented (i.e., 96% of kindergarten children were selected); and a linear multivariate design was employed for the factor analyses and predictive analyses.

METHOD

Subjects.

The original sample consisted of 497 white male kindergarten pupils in the Alachua County, Florida, public school system and the University of Florida laboratory school. This figure represents 95.6% of the white male population enrolled in the 20 county schools (14 urban, 6 rural) at the time of the testing. Data were collected on 86 school days between October

and March. In order to determine whether discrepant amounts of schooling affected the test battery results, Day of Testing designations, ranging from 1 through 86, were assigned each S. Ss were tested on an individual basis in an 8' x 35' trailer equipped with four testing modules which was transported to the grounds of each school. Typically, four Ss were tested in the morning, and four in the afternoon. The final analyses were based on the results from 474 Ss, 23 of the original group necessarily eliminated due to missing data. The mean age (in mos.) was 66.2; the range, 57 through 78. Low socio-economic status characterized 9.7% of the families of these Ss (see Predictor Variable No. 18 below).

A. Predictor Variables.

1. Day of Testing [DT].

2. Age (in mos.).

3. Handedness [Hand.]. Demonstration by S of the use of each of ten objects. Score: difference between the number of items for which right hand used and the number of items for which left hand used, divided by ten. Negative proportions indicate left-handed preference.

4. Finger Tapping [FT]. Timed measure of fine motor movement (Reitan, 1964) requiring S to rapidly depress a metered key with his index finger; four 10 second trials per hand, starting with preferred hand. Scores: total performance [FT_T], based upon the averaged sum of preferred and nonpreferred hand performance, and mean difference between preferred and nonpreferred hands [FT_D].

5. Peabody Picture Vocabulary Test [PPVT] (Dunn, 1959). Score: intelligence quotients.

6. Recognition-Discrimination [R-D] (Small, 1968). Visual-perceptual task requiring S to identify a geometric stimulus design among a group

of four figures, three of which were rotated and/or similar in shape to the stimulus figure. Score: percent of 15 trials correct.

7. Embedded Figures [EF] (Developed by Satz and associates in the Neuropsychology Laboratory, University of Florida). Visual-perceptual task requiring S to identify in which of three choice designs a stimulus figure was embedded. Score: percent of 15 trials correct.

8. Verbal Fluency [VF]. Modified version of Verbal Fluency Test described by Spreen and Benton (1965). S required to name in one minute as many objects as possible in each of three rooms in his home.

9. Developmental Test of Visual-Motor Integration [Beery] (Beery, 1967). Score: age equivalents (in mos.).

10. Similarities [Sim.]. Subtest of the Wechsler Pre-school and Primary Scale of Intelligence (Wechsler, 1967). Score: scaled scores.

11. Alphabet [Alph.]. Recitation of ABC's. Score: number of letters named, regardless of order in which given.

12. Right-Left Discrimination [R-L]. Ten questions measuring S's ability to make right-left discriminations on his person. Score: percent correct, half-credits for correct responses following hesitations.

13. Finger Localization [FL] (Benton, 1956). Somatosensory test consisting of five levels of performance, four of which (1, 2, 4 and 5) presumed to assess increasing levels of complexity. (1) Shielded unilateral stimulations made to the fingertips; shield removed between stimulations and S required to point to the finger touched with the index finger of his free hand. Five trials per hand, starting with preferred hand. (2) Shielded unilateral stimulations made to the fingertips; S identified each stimulated finger on a corresponding diagram of an opened hand. Five trials per hand, starting with preferred hand. (3) Shielded,

randomized series of three bilateral and ten unilateral stimulations made to the backs of S's hands; S waved hand(s) stimulated. Only bilateral trials scores. (4) Shielded unilateral stimulations made to the fingertips; S recalled the number of the finger stimulated. Instructions in the numbering of each hand given immediately before the stimulations to that hand. Five trials per hand, starting with preferred hand. (5) Shielded simultaneous bilateral stimulations made to pairs of fingertips; S recalled the number of the finger stimulated on each hand. Five pairs of stimulations, starting with preferred hand. Score: percent correct across all five levels.

14. Auditory-Discrimination [A-D]. Shortened, taped, version of the Wepman Auditory Discrimination Test (Wepman, 1958). S required to recognize on 20 trials whether pairs of words heard through earphones were the same (a single word repeated) or different (two different, but similar sounding words). Score: sum of the ratio of correct "same" responses to the total number of "same" responses and the ratio of correct "different" responses to the total number of "different" responses. Range: 2.0 - 0.0.

15. Dichotic Listening [D-L] (Satz, 1968). Measure of ear asymmetry in which S presented with disparate pairs of numbers arriving simultaneously via stereo headphones every half-second. S required to recall numbers heard. Version in this study consisted of 30 trials of three-pair digit sequences with an intertrial interval of 10 seconds for recall. Scores: total recall [DL_T] from both the right (RC) and left (LC) channels, and an ear asymmetry measure [DL_{EA}] derived from the ratio (RC - LC) / (RC + LC).

16. Auditory-Visual Task [A-V] (Birch and Belmont, 1964). Taped test requiring S to detect the visual equivalents (dots on display cards)

of patterned auditory sequences (clicks). Score: percent of 10 trials correct.

17. Behavioral Checklist [BCL]. Ratings by E on a 5-point scale (-2, -1, 0, +1, +2) of S's emotional reactivity; degree of irritability, cooperation, and dependency; duration of attention span; goal orientation; response to directions; level and nature of activity; and nature of communication. Score: absolute total of the ratings on the 10 scales; indicative only of overall deviancy, irrespective of direction.

18. Socio-economic status [S-E]. Rated by teacher on dichotomized scale as "low" (1), or "average or above" (2).

19. Maturity [MAT].[3] S's physical, emotional, and social maturity each rated by teacher as "low" (1), "average" (2), or "high" (3). Score: sum of individual ratings.

20. Activity level [ACT].[3] Rated by teacher as "low" (1), "average" (2), or "high" (3).

B. Criterion Variable.

At the termination of the school year during which testing took place, the teachers were asked to predict the likelihood that each child would encounter learning difficulty (Likelihood of Learning Difficulty = LLD) using the following four ratings: Definitely, Probable, Doubtful, and Definitely Not. On the basis of these judgments, 88 Ss were classified into a High Risk group (ratings of Definitely and Probable) and 386 Ss into a Low Risk group (ratings of Doubtful and Definitely Not). The purpose of this classification was to obtain preliminary criterion estimates of subsequent learning disability in order to determine the predictive validity of the independent variables.[4] Although this criterion classification is recognized as only a tentative and subjective approximation of the true

criterion (third-year achievement scores), it should be mentioned that predictions of learning disability based upon teacher judgments have been shown to be surprisingly accurate (Austin & Morrison, 1963; Henig, 1949; Kermoian, 1962).

Procedure.

A factor analysis which included all predictor tests and the criterion measure was executed in order to ascertain the composition of subsets of covarying variables. A reduced intercorrelation matrix (communalities in the diagonals) was computed and a principal axes solution obtained. Six factors from the resulting matrix were rotated orthogonally to varimax criterion. The four significant factors which emerged are shown in Table 1. Factor I consisted primarily of tests involving sensory and perceptual-motor functions and mnemonic abilities. The estimate of the likelihood of learning difficulty and, to a lesser extent, maturity level also loaded on this factor. The variable loadings, although generally low throughout the analysis, were highest on this factor. The percent of common variance accounted for by Factor I was 30.7. Factor II consisted of teacher evaluations pertaining to activity and maturity levels, the likelihood of learning difficulty, and socio-economic level. The sum of the squared loadings in Factor II accounted for 16.0% of the common variance. Factor III was comprised of three essentially verbal and conceptual tests (Sim., PPVT, and VF). The percent of common variance (13.4) attributable to this factor was only slightly less than the preceding factor. Finally, Factor IV represented motor measures and handedness and accounted for only 7.7% of the variance.[5]

RESULTS

I. Criterion Group Means for Predictor Variables.

The means and standard deviations of the 20 predictor variables are

presented for the High and Low Risk criterion groups in Table 2. Inspection of this table indicates that substantial differences between criterion groups were found on the vast majority of the measures employed; the Low Risk group consistently performed higher than the High Risk group. The groups did not differ significantly, however, on Day of Testing or on Age. Other measures which failed to distinguish the groups were Handedness, the Finger Tapping difference score, Right-Left Discrimination, and the Dichotic Listening ear asymmetry ratio.

Among those variables which did discriminate, the findings on the Beery were of particular interest. The Low Risk group's mean age equivalent score on this task (66.6 mos.) closely coincided with the mean chronological age of the Ss (66.3), whereas the mean age equivalent score for the High Risk group (57.1 mos.) represented an 8.5 month lag behind their mean chronological age (65.6).

II. Discriminant Function Analysis.

In order to achieve maximum differentiation between the High and Low Risk criterion groups, a discriminant function analysis (Fisher, 1936) was performed on the 20 variables presented in Table 2. The purpose of this analysis was to seek some linear combination of the variables that would maximize the "between"-group differences relative to the "within"-group differences. A composite discriminant score was computed for each S in both criterion groups based on his raw scores and the optimal lambda weightings (λ) for each variable. These discriminant composite scores (Z_i) were then averaged for each criterion group. The mean Z scores obtained for the High and Low Risk groups were $\bar{Z}_{HR} = 2.95$ and $\bar{Z}_{LR} = 3.65$, respectively. The group difference between these composite discriminant means was significant (Mahalanobis $D^2 = 3.43$, df = 20, 453; $F = 11.82$; $p < .001$), which then per-

mitted an assignment of Ss to different criterion groups.

In order to classify each S as High or Low Risk on the basis of his discriminant composite score (Z_i), an optimal cut-off score was computed (decision rule) using the ratio $(\overline{Z}_{HR} + \overline{Z}_{LR})/2$ (Satz, 1966). The composite value obtained was 3.315. Predictions of High Risk were then made for individuals whose composite scores were less than 3.315; predictions of Low Risk were made for cases in which the composite scores equalled or exceeded this value. The predictive classifications of all Ss on the basis of this decision strategy are shown in Table 3. Examination of the table reveals that 69 of the High Risk group (N=88) were classified correctly, yielding a valid positive rate of 78.4% and a false negative rate of 21.6% (19/88). Similarly, 319 of the Low Risk group (N=386) were classified correctly yielding a valid negative rate of 82.7% and a false positive rate of 17.3% (67/386). In terms of overall prediction, the discriminant function classified correctly 388 or 81.9% of the total sample (N=474).

III. Step-Wise Regression Analysis.

The purpose of this analysis was to determine the ranking of the predictor variables in terms of their discriminating power relative to the criterion measures. A ranking of the variables and their cumulative predictive classification percentages are presented in Table 4. The Finger Localization test revealed the highest discrimination ranking which accounted for 71.1% of the overall correct classifications. Socio-economic status, Dichotic Listening total recall, and the PPVT were ranked second, third, and fourth, respectively. Inclusion of these three variables along with the Finger Localization test increased the total hit-rate percentage to 80.0%. The remaining variables contributed only an additional 1.9% to the overall correct classification rate of 81.9%.

The various factors on which these four most discriminating variables loaded are also shown in Table 4. Two measures (FL and DL) loaded on Factor I (Sensory; Perceptual-Motor; Mnemonic). S-E, ranked second, contributed to Factor II (Teacher Evaluations). Only the PPVT, ranked fourth, represented the Conceptual-Verbal Factor (III). The residual variables were distributed throughout all four factors.

A separate analysis was then performed on the Finger Localization Test on the basis of its major contribution to criterion group discrimination. The analysis revealed that, as expected, criterion group differences increased as a function of complexity level. The percentages of correct responses for the Low Risk group on Levels 1, 2, 4, and 5 were 99.0, 82.0, 68.0, and 55.0, respectively. Corresponding values for the High Risk group were 98.0, 74.0, 32.0, and 19.0. The differences at Levels 2, 4, and 5 were significant ($p < .001$). Level 3 (unilateral-bilateral discrimination) also distinguished the High and Low Risk groups with respective mean percentages of 98.4 and 93.3 ($p < .001$).

IV. Classification of Ss Within Refined Criterion Groups.

An additional analysis was performed in order to examine the predictive accuracy (discriminant function) within the extreme and conservative subcategories of the High and Low Risk criterion groups. It will be recalled that the teacher evaluations of the likelihood of learning difficulty (LLD) were made on a four-point scale. Ss receiving ratings of Definitely and Probable were combined to obtain the High Risk group; those obtaining ratings of Doubtful and Definitely Not were combined to obtain the Low Risk group. In the present analysis, ratings of Definitely and Definitely Not were considered extreme, Probable and Doubtful as conservative. Table 5 presents the percentages of correct and incorrect classifications based on the dis-

criminant function within each of these four subgroupings. Inspection of this table indicates that in both the High and Low Risk groups, prediction accuracy was substantially greater in the extreme than in the conservative subcategory. In the High Risk group, the valid positive rate increased from 77.5% in the Probable category to 82.4% in the Definitely category. In the Low Risk group, the valid negative rate increased from 74.1% in the Doubtful category to 91.5% in the Definitely Not category. The overall hit rate, considering only the two extreme subgroups within each criterion classification, was 90.8%.

DISCUSSION

The present findings, while still preliminary, strongly suggest that a substantial number of High Risk children can be correctly identified during the early phases of kindergarten before formal reading instruction is begun. In fact, the discriminant function (predictor tests) correctly classified 69 of the 88 (78.4%) High Risk children (valid positives) who were identified by the teachers at the end of the kindergarten year.[6] Only 19 (22.6%) of these children were missed (false negatives). The discriminant function also correctly classified 82.7% of the Low Risk children (valid negatives) with only 17.3% being incorrectly classified as High Risk (false positives). Thus, approximately 82% of the total sample were correctly classified by the tests. These discriminant validities were even further increased when the tests were compared with more refined categories of each criterion group. Table 5 showed that in this analysis, 82.4% of the High Risk and 91.5% of the Low Risk children were correctly classified when only extreme categories of criterion teacher judgments were used. This analysis thus increased the overall hit rate from 81.9% to 90.8%, which lends further credibility to the construct validity (Cronbach & Meehl, 1967) of both predictor tests and teacher judgments.

Intuitively, the utilization of teacher judgments was felt to provide a reasonable, although tentative estimate of the true criterion (i.e., third year reading achievement). The teachers, for example, had the full kindergarten year in which to observe the children, to interact with them and to evaluate performance. Considerable efforts were also made to increase the motivation and participation of the teachers in the project. They were frequently apprised of the importance and overall objectives of the project which depended on the joint efforts of many people including the children and their parents. These factors, along with previous demonstrations of the accuracy of teacher judgments (Austin & Morrison, 1963; Henig, 1949; Kermoian, 1962), provided the rationale and opportunity to employ a preliminary criterion measure in order to evaluate the predictive validity of the independent variables.

The results were impressive for both the univariate and multivariate analyses. Approximately 75 percent of the variables revealed substantial mean differences between criterion scores on the univariate analyses. Performance on the Beery Developmental Test of Visual-Motor Integration was particularly striking in that the High Risk children lagged almost nine months behind their chronological age; this discrepancy was not observed for the Low Risk children whose age equivalent scores were nearly identical to their mean chronological age. Similar group mean differences were found for most of the remaining measures of sensorimotor, perceptual and language skill. Inspection of Table 2 revealed, however, that the mean error performance on several of the tests was still quite high for this age group of children (High and Low Risk). This finding was consistent with the authors' original purpose to select tests which assess developmental skills (some of which are in rapid ascendancy at earlier ages) which could then be readministered at later periods in the project.

The univariate analyses, while helpful in identifying those variables which differentiated criterion groups, were unable to determine the predictive validity of the tests. This evaluation was based on the results of the step-wise discriminant function analysis. Interpretation of these results, however, required the information gleaned from the earlier factor analyses. It was shown that the primary factor (Factor I) comprised most of the tests presumed to measure aspects of sensori-motor, perceptual and mnemonic skill (Table 1). The Beery and Finger Localization Tests had the highest loadings on this factor. Of interest, none of the language tasks were represented on this factor; they grouped uniformly on Factor III. The tests which loaded on Factor I represented skills which are presumed to be in rapid development during this age period (5-6), including alphabetic recitation.[7] Factor I accounted for more of the common variance than the other three factors combined, although none of the values were particularly high.

The results of the step-wise discriminant function analysis revealed that two of the four most discriminant variables loaded on Factor I (Finger Localization and Dichotic Listening); in fact, Finger Localization had the highest ranking of all the variables and classified correctly 71.1 percent of the total sample. This classification percentage was increased to 80 percent by adding the next three highest discriminator variables (Socio-economic level, Dichotic Listening, Peabody Picture Vocabulary Test, respectively). Inclusion of the remaining tests merely increased the overall hit-rate by an increment of 1.9 percent (81.9 percent). Thus, in terms of predictive validation, Factor I had the major contribution to criterion group discrimination, followed by Factor II (S-E) and Factor III (PPVT).

The effect of Socio-economic level (Factor III) was particularly surprising in that only six of the 20 elementary schools were rural and only

9.7 percent of the children were estimated to come from low socio-economic backgrounds. When S-E status was examined for each criterion group, however, it was found that the percentage of low socio-economic children was nearly five and a half times higher in the High Risk group (28.4%) than in the Low Risk group (5.4%). A possible confounding between predictor and criterion variables, however, may have occurred in that both estimates were based on teacher judgments. This relationship would tend to spuriously inflate the effects of S-E status as a predictor variable. Whether true or not, it should be apparent that the majority of the High Risk children were still represented in the middle to upper-middle socio-economic level. This fact should underscore the need to identify variables other than S-E status in attempts to account for and predict the occurrence of specific learning disability.

The present findings, in summary, lend convincing support for some of the predictive antecedents of later learning disability. Although final criterion specification is still lacking, the concordance between the predictor measures (assessed at the beginning of kindergarten) and criterion teacher classifications (assessed at the end of kindergarten) was high, if not impressive. The predictive classification of the variables at least strengthens the construct validity of the tests and teacher judgments. Only time can determine the true validity of these measures.

The results also lend further indirect support to the theory which guided selection of the present tests (Satz & associates, 1970; 1971; 1972). Those tests which assess skills presumed to be in rapid development during ages 5-6 were particularly discriminating. Many of the High Risk children were shown to be <u>lagging</u> already as much as eight-nine months during kindergarten (e.g., Beery). Performance on the Finger Localization Test was also much lower in the High Risk children and their performance became progressively

worse as complexity level increased. These findings again suggest that a lag mechanism may retard the developmental rate at which these children acquire hierarchically more complex levels of skill. Consequently, earlier delays (which may be less severe) may forecast later delays which may alter both the nature and degree of the behavioral pattern (Lenneberg, 1967; Satz and Van Nostrand, 1972). The present findings revealed a primary lag in sensori-motor, perceptual and mnemonic skill in the High Risk children. There was also a corresponding, although less striking, delay on some of the language measures (PPVT). Only follow-through investigation will determine whether the delay in language competence increases over time as the children gradually overcome their sensorimotor and perceptual handicaps. The theory predicts that this behavioral pattern will occur. If so, it warrants even further attention to the critical problems of early detection and intervention.

Lastly, the present design, while longitudinal in scope, illustrates the importance of linear multivariate models in the early prediction of specific learning disability. These methods provide a more powerful quantitative approach to predictive validation than is possible with univariate models. They also help to determine the minimal number of tests necessary for maximal criterion group differentiation. As such, the investigator is provided with greater design economy which permits fewer tests and greater opportunities for increasing sample size in order to offset attrition problems. The present study represents an application of these methods to an appropriate clinical problem.

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3
Included in factor analysis but not discriminant function analyses (see below).

4
Within the framework of the longitudinal design, teacher assessments will eventually be used as a predictor variable along with test performances against a final criterion of second grade achievement.

5
The six principal axes factors used in the orthogonal rotation were also subjected to an oblique factor analysis. The resulting primary factors were virtually identical in content with those obtained from the orthogonal analysis. An intercorrelation of .59 was shown to exist, however, between Factors I and III.

6
The 88 children who were predicted by the teachers to be High Risk for later learning disability represent approximately 20 percent of the total sample. This percentage, while consistent with previous incidence estimates (Eisenberg, 1966) may actually be too low because the present study included only boys who are already known to be at a higher risk than girls (Ingram, 1970). If a conservative ratio of 4:1 was used, this would mean that 16 out of every 20 children expected to develop reading disability would be boys (4:1) which would increase the incidence rate from 20 percent in mixed sex samples to 32 percent in male samples. Thus, in the present project, one could conservatively predict that 32 percent or 152 children would eventually develop signs of specific reading disability. It is interesting to note that the discriminant function classified a total of 136 children as High Risk which more closely

approximates this expected value. The true incidence, of course, will only be known after the third year reading achievement tests are given.

7 More puzzling was the loading of teacher criterion judgments (LLD) on this factor. The relatively high inverse correlation suggests that their predictions of High and Low Risk were based in part on observations of sensorimotor and perceptual performance during school.

Table 1

Rotated Orthogonal Factor Loadings[a]

Factors			
I Sensory; Perceptual-Motor; Mnemonic (30.7)[b]	II Teacher Evaluations (16.0)	III Conceptual-Verbal (13.4)	IV Motor (7.7)
Beery (.72)	ACT (.62)	Sim. (.63)	FT_D (.59)
FL_T (.64)	MAT (.57)	PPVT (.61)	FT_T (.44)
R-D (.57)	LLD(-.48)[c]	VF (.37)	Hand. (.38)
Alph. (.55)	S-E (.42)		
LLD (-.53)[c]			
A-D (.50)			
EF (.46)			
DL_T (.41)			
MAT (.40)			

[a] Variables loading ≧ .37 included in listings.

[b] Percent of common variance for which factor accounted.

[c] Loading negative because of way in which code numbers assigned to LLD ratings: Definitely = 4, Probably = 3, Doubtful = 2, and Definitely Not = 1.

Table 2

Means and Differences between Criterion Groups on the Predictor Variables

Variables	Criterion (Teacher Judgment)				
	High Risk (N = 88)		Low Risk (N = 386)		F
	Mean	SD	Mean	SD	
1. DT	47.6	27.5	42.7	23.6	2.86
2. Age	65.6	4.4	66.3	4.0	1.93
3. Hand.	0.7	0.6	0.6	0.6	0.15
4. FT_D	1.8	3.2	2.3	3.4	1.47
5. FT_T	45.2	7.1	47.8	8.2	7.91*
6. PPVT	93.9	16.5	107.1	14.0	59.65*
7. R-D	50.7[a]	18.0	67.3[a]	18.0	62.34*
8. EF	31.3[a]	18.7	40.6[a]	25.0	14.23*
9. VF	18.7	6.5	23.0	6.7	29.47*
10. Beery	57.1[b]	8.6	66.6[b]	9.9	69.13*
11. Sim.	10.8	3.0	12.6	2.7	29.30*
12. Alph.	15.2	9.0	21.8	7.1	56.16*
13. R-L	54.0[a]	27.0	61.0[a]	31.0	3.18
14. F	61.0[a]	17.0	78.5[a]	16.5	80.77*
15. A-D	1.0	0.5	1.3	0.4	33.79*
16. DL_T	56.7	17.6	70.7	14.2	62.98*
17. DL_{EA}	- 0.0	0.3	0.0	0.3	1.04
18. A-V	34.0[a]	18.0	39.0[a]	15.0	8.08*
19. BCL	3.5	3.4	2.0	2.5	22.22*
20. S-E	1.7	0.5	1.9	0.2	47.26*

[a] Percent correct

[b] Age equivalents (in mos.)

* $p \leqq .005$, df = 1,472.

Table 3

Predictive Classification of Children into Criterion Groups based on Discriminant Function Test Scores

Interval Composite Discriminant Function Test Scores	Criterion (Teacher Judgment) High Risk (N = 88) $\bar{Z}$ = 2.95	Low Risk (N = 386) $\bar{Z}$ = 3.65
1.815 - 2.114	4	1
2.115 - 2.414	9	0
2.415 - 2.714	10	6
2.715 - 3.014	22	11
3.015 - 3.314	24	49
3.315 - 3.614	14	82
3.615 - 3.914	4	133
3.915 - 4.214	1	88
4.215 - 4.514	0	15
4.515 - 4.814	0	1

[a]Composite cut-off score: $Z \geq 3.315$; overall hits = 81.9%; valid positives = 17.3%.

Table 4

Step-wise Regression Analysis of
Discriminant Function Composite Scores
by Test and Factor Loading

Ranked Variables	Factor	Cumul. % Correct Classification	Cumul. % Misclassification
1. FL	I	71.1	28.9
2. S-E	II	75.7	24.3
3. DL_T	I	78.3	21.7
4. PPVT	III	80.0	20.0
5. Residual Tests	I-IV	81.9	18.1

Table 5

Predictive Classification (percent) within Extreme and Conservative Subcategories of High and Low Risk Criterion Groups

Discriminant Function Composite Scores	Criterion (Teacher Judgment) High Risk Definitely[a] (N = 17)	High Risk Probable (N = 71)	Low Risk Doubtful (N = 197)	Low Risk Definitely Not[a] (N = 189)
Z < 3.315 (positives)	82.4	77.5	25.9	8.5
Z ≧ 3.315 (negatives)	17.6	22.5	74.1	91.5

[a]Extreme subcategories