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ABSTRACT

While the WISC and Bender-Gestalt are widely used for differential diagnosis, there is a need for empirically determined criteria for classification. Multivariate techniques seem especially promising in classification problems. This study determined the extent to which such an approach can classify children into rational, a priori categories of learning disorder. Two discriminant functions were obtained and found to be highly significant. Six predictors within each function were identified as optimum. The efficiency of the functions in predicting criterion group status was demonstrated. Educational implications are discussed. (Author)

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A MULTIVARIATE ANALYSIS OF RATIONALLY DERIVED CATEGORIES OF LEARNING DISORDER[1]

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INTRODUCTION AND BACKGROUND

The literature indicates there have been numerous problems in diagnosing the group of children with average or near-average intelligence, but with learning disabilities, language and/or perceptual-motor deficits. While many psychological instruments are allegedly capable of differential diagnosis, the Bender Visual-Motor Gestalt Test (Bender, 1938) seems to be the most frequent choice of diagnosticians. This is especially the case when questions of organicity are raised (Schulberg and Tolor, 1961).

A major source of difficulty in using the Bender-Gestalt for differential diagnosis of children, however, is the selection of criteria for classifying a youngster "learning disabled." Research has shown no single independent variable to be consistently accurate in predicting learning disorders (Billingslea, 1963). However, a single study showed that children who were diagnosed as learning disabled on the basis of "soft signs" on psychoeducational evaluations, and placed in a classroom especially designed to meet their individual needs, manifested "hard signs" of CNS dysfunction on subsequent neurological examination (Hertzig, 1969).

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In addition to the Bender-Gestalt, the Wechsler Intelligence Scale for Children (Wechsler, 1949) is also frequently used for classification purposes (Hartlage, 1966). Beck and Lam (1955), investigating the efficacy of the WISC in predicting organicity in children whose IQ was less than 80, found that 31 of 42 Ss—previously diagnosed "organic" on the basis of psychometric data—were subsequently diagnosed organic on the basis of neurological examination. Beck and Lam suggested that the probability of organicity increases considerably as the WISC IQ drops below the 70-80 range.

Tolor and Schulberg (1963) called for criteria which are more empirically determined for diagnostic groupings, and which more distinctly differentiate among levels or categories of behavior to be predicted. As Tatsuoka (1971) has asserted, the need for application of multivariate techniques to such classification problems is pressing.

Weiner (1966) investigated the WISC and the Bender-Gestalt as predictors of minimal neurological impairment in 822 Ss, 8-10 years of age. Using multiple regression analyses, Weiner sought to differentiate between groups of subjects with varying degrees of CNS deficit. Several Bender-Gestalt scoring criteria were found to predict diagnoses of neurological dysfunction ($R=.22$). Significant predictors included inability to reproduce curves and angles, and gross motor or perceptual distortions. Controlling for WISC Verbal IQ and race, total Bender scores significantly discriminated neurological groups. A discriminant function analysis was employed with conflicting results. White children were best classified by Bender scores, while neurologically impaired Black Ss were best classified by WISC Performance Scale IQ. Weiner called for further research using multivariate techniques, into the underlying processes or constructs involved in the Bender-Gestalt.

Burgess and his colleagues (1970), using a multiple regression technique to predict organicity in neurological and psychiatric Ss, concluded that behavioral measures, particularly visual-motor indices, can signficantly differentiate these subjects. These researchers called for the use of multivariate prediction in future investigations of differential diagnosis.

Haring and Ridgway (1967) used a related procedure, principal components analysis, to determine whether kindergarten children, who were identified by teachers as "potentially learning disabled," received standardized test scores indicating discernible common traits. Teachers nominated 106 children as "high risk" candidates, based upon deficits in areas considered basic to academic success. These Ss were then administered the Stanford-Binet and three WISC subtests. Results indicated that, of the 31 predictor variables considered, the most signficant were language-related, accounting for 20% of the commonality in principal components analysis. The second principal component accounted for only 7%, while the remaining components did not adequately account for a significant percentage of the total variance. Haring and Ridgway found that those Ss selected by teachers and later tested had few common identifiable learning patterns. That is, there were no significant distinctions between the standardized test performance of their Ss and a typical population of children. It was felt that differences in performance apparently were "masked" when data were treated as a group. Nonetheless, these authors concluded that when given structured guidelines, kindergarten teachers can select children with potential future learning problems.

Ackerman, Peters and Dykman (1971) administered the WISC to 82 elementary age children diagnosed as "learning disabled" and to 34 "normal" controls. The exact criteria for the diagnosis were not specified, but the learning disabled group included reading as well as other learning disorders. Using a discriminant function, five selected WISC subtests were found to be as reliable as ten in discriminating controls from "learning disabled" Ss. Using these five subtests, a discriminant analysis accurately identified 76% of those Ss previously diagnosed as "disabled." However, "severely disabled" readers could not be distinguished from "mildly disabled" readers, or from adequate readers with other disabilities. Moreover, a discriminant analysis using ten WISC subtests could not separate (a) a group of neurologically-positive and "equivocal" learning-disabled Ss, from (b) a group of neurologically-negative and control Ss.

A related approach was used in earlier studies (Wheeler, et al., 1963a, 1963b), in which discriminant functions were applied to behavioral indices in predicting organicity in adult psychiatric patients. It was found that, in all cases, the discriminant function more accurately predicted subjects' status than did neurological criteria. It was concluded that the discriminant function has practical value in predicting organic impairment from behavioral tests.

The need is great for applying such multivariate techniques to the classification of learning-disabled school children. As Sawyer (1966) convincingly demonstrated, "clinical" prediction rarely betters statistical (including multivariate) prediction. With such definitive evidence, it is surprising that many researchers, physicians, and school psychologists continue to use exclusively clinical judgments when diagnosing learning disorders.

As the literature has indicated, there is a need to determine the efficacy with which behavioral predictors can classify children into a priori categories of learning disorder.

The purpose of this research, then, was to investigate two major objectives:

I. To determine whether intellective and visual-motor predictors can classifu elementary school children into rational, a priori categories of learning disorder, and

II. To determine the accuracy and practical value of multiple discriminant analysis in categorization of learning disabilities.

METHODS AND/OR TECHNIQUES

Data were analyzed by means of a multiple discriminant analysis technique, and significant discriminant functions were derived (Finn, 1968). The computer program used to compute the analyses treated each of the significance test (one for each predictor variable) on a given discriminant function as nonorthogonal. In so doing, it partialed out in a step-down fashion the effects of all preceding significance tests on the same dependent variable. Thus, the alpha level remained constant and the probability of Type II errors did not increase with each consecutive significance test for a given discriminant function. These significant discriminant functions were then applied simultaneously to the sample in an effort to compare the empirically derived classifications with the a priori diagnoses of judges. Frequencies of hits and misses in classification of criterion groups were computed using the minimum chi square procedure described by Tatsuoka (1971). Finally, the independent dimensions were named, and discriminant function centroids were plotted to indicate how the dimensions separate the criterion groups. Dimensions were then analyzed in terms of the amount of canonical variance accounted for.

DATA SOURCE

SUBJECTS. The sample for the study consisted of 225 elementary school children (6-7 years of age) in a suburban Northeastern community in 1971. All Ss had been nominated to attend "Pre-Primary" (learning disabilities) classes, and each was given an individual psychological evaluation. Based upon the psychological assessment, children were clinically categorized into one of five groups: intellectual deficit, emotional dysfunction, perceptual dysfunction, any combination of the prior groupings, and no dysfunction. Four school psychologists were used to make the clinical categorization. Interrater agreement, estimated by means of Cronbach's coefficient alpha, was .86.

MEASURES. Twenty three predictor variables were derived from the psychological evaluations, and are shown in Table 1. These included such standard measures as full scale and subtest scores from the WISC, Bender-Gestalt subscores and discrepancy scores. In addition, sex and age-in-months were included as predictor variables.

Insert Table 1 about here

RESULTS AND DISCUSSION

A one-way multivariate analysis of variance (MANOVA) was employed with five criterion groups for the 23 original predictors. The F ratio for the multivariate test of the equality of mean vectors indicated that the five groups differed ($F_{92,766} = 4.65$; $p < .0001$).

Table 1 contains the results of the discriminant analysis for the 23 variables. Raw and standardized coefficients are presented for the two significant derived functions. The first discriminant function accounted for 78 percent of the canonical variation (chi square [d.f.=92] = 359.96; $p < .0001$), while the second discriminant function accounted for 15 percent of the canonical variation (chi square [d.f.=66] = 115.97; $p < .0002$).

On the basis of the F values and the standardized coefficients in Table 1, nine optimal predictors were selected for further analysis; five came from the first function and eight from the second. Four of these predictors were common to both functions. Therefore, a set of nine optimal predictors was used for further analysis. The F ratio for the multivariate test of equality of the mean vectors indicated that the five groups differed ($F_{36,779} = 11.10$; $p < .0001$).

Table 2 contains the results of the discriminant analysis for these nine predictor variables. Raw and standardized coefficients are presented for the two significant discriminant functions. For this predictor set of nine variables, the first discriminant function accounted for 82 percent of the canonical variation (chi $square_{d.f.=36} = 329.57$; $p < .0001$), while the second discriminant function accounted for 14 percent of the canonical variation (chi $square_{d.f.=24} = 84.55$; $p < .0001$).

The most heavily weighted predictors in the first discriminant function reflected perceptual-motor abilities (WISC Performance IQ and Bender Discrepancy score). The second discriminant function showed the most heavily weighted variables to be associated with overall intellectual ability (WISC Performance IQ and WISC Verbal IQ). Group centroids on the two discriminant functions are presented in Table 3. A graphical representation of the criterion groups in the bivariate space is shown in Figure 1.

It can be seen from Table 1 that variables 8, 13, 14, 20, and 23 have the largest standardized coefficients on the first discriminant function, while variables 7, 8, 10, 11, 14, 20, 22, and 23 have the largest standardized coefficients on the second discriminant function. These variables seem to be of two broad types, one of general psychomotor ability (discriminant function I) and the other of overall intellectual ability (discriminant function II). As such, they seem to form two continuua or dimensions, along which extreme criterion groups may be discriminated.

It should be pointed out that the WISC Performance IQ was the most heavily weighted predictor variable on both discriminant functions. However, because of the very high relationship between Performance IQ and the WISC Full Scale IQ ($\underline{r}$ = .89; Weschler, 1949), it seems appropriate to assume that the second function actually defines the measurement space as general intellectual functioning. It is of interest to note that seven of the eight predictors of discriminant function II are psychomotor in nature. This finding may reflect one or both of two interpretations: (a) the children used in this research were all nominated to attend learning disabled classes, and the nominations may have been primarily based on psychomotor deficits; or (b) the judges making the classifications of Ss into categories may have generally based their diagnoses more on information from psychomotor predictors than on verbal data.

Figure 1 indicates that the perceptual continuum (discriminant function I) separates the group of Ss having no apparant disfunction from those Ss considered to have any combination of learning disorder. The dimension characterized as overall intellectual ability (discriminant function II), also shown in Figure 1, seems to separate Ss diagnosed as intellectually deficient from those Ss considered to have a perceptual dysfunction.

EDUCATIONAL IMPLICATIONS OF STUDY

This study demonstrated the feasibility and efficiency of using behavioral predictors to classify children into a priori categories of learning disorder. The practical value of such a finding rests in the ability to characterize a child's learning problem as early and as accurately as possible. This, in turn, would hopefully lead to earlier placement of the child in an educational program suited to his particular needs.

This study, moreover, can be considered a validity investigation into the underlying psychological dimensions at work when judges make assignments to categories of learning disability. Thus, the study was involved with construct validation, using discriminant analysis in the attempt to explain judges'. behavior. As such, the study accomplished two related goals: (1) Data reduction, or the parsimonious explanation of classification of young children into categories of learning disorder; and (2) construct validation, or the examination of the underlying dimensions upon which judges assigned students to such categories.

Limitations of this study are being investigated in current research in an attempt to answer three crucial questions: (1) What is the predictive accuracy of the discriminant functions when empirically classifying Ss into categories of learning disorder? In other words, what are the percentages of hits and misses of predictions within and across categories? (2) Would the same discriminant functions or dimensions be obtained with a new sample of Ss? That is, do the functions hold up under cross-validation? Finally, (3) How would using a new sample of judges but the same functions affect the percentage of hits and misses?

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TABLE 1

ORIGINAL PREDICTOR VARIABLES

	Variable WISC:	Step Down F	P Less Than	I Raw	I Std.	II Raw	II Std.
				Disc. Funct. Coeff's.			
1.	Inform.	3.80	.0053	-.047	-.135	-.071	-.204
2.	Compr.	6.18	.0001	.025	.070	-.073	-.206
3.	Arith.	5.15	.0006	-.015	-.045	-.003	-.008
4.	Simil.	1.36	.2507	.011	.052	.036	.163
5.	Vocab.	2.29	.0612	.013	.039	-.023	-.067
6.	Digits	3.41	.0100	-.025	-.053	.054	.118
7.	P. Comp.[2]	12.99	.0001	-.028	-.068	.130	.311
8.	P. Arr.[1,2]	5.92	.0002	-.129	-.332	.173	.445
9.	Blocks	9.92	.0001	-.082	-.174	-.043	-.092
10.	Obj. As.[2]	3.11	.0163	-.109	-.255	.144	.336
11.	Coding[2]	4.21	.0027	-.108	-.297	.165	.453
12.	F.S. IQ	1.40	.2370	.024	.168	.006	.050
13.	Bender:[1] Error Score	26.51	.0001	-.274	-.752	-.087	-.238
14.	#Rotat's.[1,2]	3.39	.0104	.295	.498	.259	.438
15.	Persever's.	.37	.8304	.209	.185	.137	.121
16.	Integration	1.21	.3086	.155	.208	.081	.109
17.	Age in mos.	.91	.4600	-.001	-.008	-.015	-.097
18.	Sex	.65	.6310	-.201	-.099	-.166	-.082
19.	Distortions Bender[1,2]	.24	.9164	.163	.272	.043	.072
20.	Discrepancy	4.05	.0036	-.228	-.509	.239	.537
21.	V-P Differ.	1.23	.3000	-.007	-.051	-.029	-.228
22.	Verbal IQ[2]	.40	.8114	.020	.195	.069	.669
23.	Perf. IQ[1,2]	1.00	.4079	.135	1.16	-.061	-.523

1 Optimal predictors for Discriminant Function I
2 Optimal predictors for Discriminant Function II

TABLE 2

OPTIMAL PREDICTOR VARIABLES

Variable	Step Down F	P Less Than	Disc. Funct. Coeff's. I Raw	I Std.	II Raw	II Std.
WISC:						
P. COMP.	19.22	.0001	-.027	-.066	-.180	-.431
P. ARR.	10.10	.0001	.065	.167	-.215	-.555
OBJ. AS.	6.72	.0001	.044	.103	-.153	-.357
CODING	3.24	.0133	.035	.097	-.200	-.551
BENDER:						
Error Score	32.61	.0001	.137	.375	.053	.146
# ROTAT's.	2.60	.0375	-.109	-.185	-.215	-.364
DISCREP. Score	5.79	.0002	.185	.415	-.264	-.590
VIQ	9.39	.0001	-.029	-.287	-.065	-.626
PIQ	5.28	.0005	-.095	-.817	.087	.754

TABLE 3

GROUP CENTROIDS ON THE TWO LARGEST DISCRIMINANT FUNCTIONS

	Function 1	Function 2
Intellectual Deficit	-7.69	-4.4[illegible]
Emotional Dysfunction	-8.69	-5.28
Perceptual Dysfunction	-7.65	-6.97
Any Combination	-6.02	-5.96
No Dysfunction	-9.45	-6.15

FIGURE 1

CENTROIDS OF DYSFUNCTION IN BIVARIATE DISCRIMINANT SPACE