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Pegnato Revisited: Using Discriminant Analysis to Identify Gifted Children

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Abstract

The purpose of this paper is to provide an overview of discriminant analysis and an illustrative example of how this powerful technique can maximize the effectiveness and efficiency (Pegnato and Birch, 1959) of screening procedures for identifying intellectually gifted students. The best predictors of scores on an individually-administered intelligence test were scores on group IQ and achievement tests.

Key words: Identification, Giftedness, Discriminant analysis

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The identification of gifted students remains a controversial issue in gifted education (Feldhusen & Jarwan, 2000; Hany, 1993; Heller & Feldhusen, 1986; Jarwan & Asher, 1994). In addition to lack of agreement about the nature of giftedness, the practical issue of how to implement an identification system that combines multiple sources of information is a source of debate. In many instances, the definition and operationalization of giftedness is legislated. Although there are many ways that one can be gifted (Marland, 1971), giftedness is often operationalized solely in terms of an arbitrary IQ cut-off score on an individually-administered intelligence test. Since the cost of administering this test is very expensive, many school systems implement one or more screening procedures to determine which students should receive the individual intelligence test.

Effectiveness and Efficiency

A seminal article in the gifted education literature is Pegnato & Birch's (1959) report of the effectiveness of screening approaches in gifted education, which was based on Pegnato's (1958) dissertation. Pegnato & Birch (1959) introduced the concepts of "effectiveness" and "efficiency" of screening procedures for identifying gifted children. In the context of a school system, the effectiveness of a screening procedure is the ratio of students identified by a procedure to the total number of gifted students in the school system. Unless a school system administers the criterion measure to all of the students in the school system, the number of identified gifted students becomes the estimate for the total. The efficiency of a screening procedure is the ratio of the number of students identified by a screening procedure to the number of students referred by a screening procedure. Pegnato and Birch (1959) reported that teachers in their study were able to identify 41 of 91 intellectually gifted students (those with Stanford-Binet IQ scores above 136), resulting in an effectiveness ratio of 45.1%. To find these 41 students, teachers had to nominate 154 students, resulting in an efficiency ratio of 41/154 or 26.6%. There is a trade-off between effectiveness and efficiency. A group IQ cut-off score of 115 was found to be 92.3% effective in identifying intellectually gifted students. However, the efficiency score was only 18.7%. Raising the group IQ cut-off to 130 increased the efficiency ratio to 55.5% at the expense of effectiveness, which dropped to 21.9%. Preference for one approach depends upon a person's role in gifted education. Advocates for gifted children want to ensure that every gifted child is identified and served, so advocates are more concerned with effectiveness. Since the cost of administering individual intellectual assessments is expensive, school administrators and school psychologists lean toward efficiency. The purpose of this paper is to provide an overview of discriminant analysis and an illustrative example of how this technique can maximize the effectiveness and efficiency of procedures for identifying intellectually gifted children.

Discriminant Analysis

Developed by Fisher (1936), discriminant analysis is a multiple regression technique that seeks to find the best linear weighting of predictor variables to maximize the differences among two or more groups. Variables that contribute most to the prediction of group membership in relation to other variables are given the highest weights. This permits the maximum prediction of group membership. Prediction is made on the basis of discriminant function scores. An individual discriminant function score takes the following form:

$$\mathbf{D = d_1z_1 + d_2z_2 + d_3z_3 \ldots d_pz_p}$$

where $\mathbf{d_1}$ to $\mathbf{d_p}$ represents weightings of $\mathbf{z_1}$ to $\mathbf{z_p}$ predictor variables in standard score form.

Discriminant function scores for groups can be averaged to determine group means or "centroids." The closer an individual's disciminant function score falls to the group centroid, the more likely it is that the individual is a member of the group. Prediction is also enhanced if the base rates or prior probabilities of group membership are known.

Huberty (1994) made a distinction between predictive discriminant analysis and descriptive discriminant analysis. The purpose of predictive discriminant analysis is to develop a linear equation for predicting group membership and to evaluate its effectiveness in correctly classifying group members. The purpose of a descriptive discriminant analysis is to explain group differences on the response variables. Descriptive discriminant analysis is the preferred post-hoc procedure to follow-up significant effects in a multivariate analysis of variance (MANOVA) because this procedure incorporates the intercorrelations among response variables (Bray & Maxwell, 1982). Since computer programs provide information for both predictive and descriptive discriminant analyses, features of both are often reported in the literature (Huberty & Hussein, 2002). This brief explanation of discriminant analysis can be enhanced through consultation with more technical sources such as Bray & Maxwell (1982), Cooley & Lohnes (1971), Huberty (1975, 1994), Pedhazur (1997), Tabachnick & Fidell (1996), and Tatsuoka (1971).

Pegnato Revisited: A Case Study Using Discriminant Analysis

Procedure

Pegnato's (1958) dissertation, *An Evaluation of Various Initial Methods of Selecting Intellectually Gifted Children at the Junior High Level* was obtained from UMI Dissertation Services. This study examined the effectiveness and efficiency of eight potential screening methods (group IQ tests, achievement tests, teacher nomination, placement on the Honor Roll, special abilities in arithmetic, leadership, art, and music). Although a comprehensive study of each procedure, Pegnato's study did not use multivariate techniques to weight the various screening methods. Complete data was available for 155 individuals from the original Pegnato study. Eighty-Seven individuals met Pegnato's criterion of giftedness, having an IQ of 136 or higher (top 1%) on the Stanford-Binet. Sixty-Eight individuals had IQ scores below this criterion.

Data Analysis

A predictive discriminant analysis (Huberty, 1994) was performed using the DISCRIMINANT subprogram (Klecka, 1975) in SPSS for Windows 11.0 to determine the optimum weighting of the predictors used in Pegnato & Birch's study to distinguish group membership (gifted or average-ability). The METHOD=Direct option was to specify the criteria by which the independent variables would be included in the discriminant analysis. This procedure enters all the variables into a prediction equation simultaneously. Standardized discriminant function coefficients and structure coefficients (the correlation between the discriminant function and the predictor variables) were requested together with a jackknife classification analysis. This analysis provides results based on repeated random sampling of all but one subject.

Results

Standardized discriminant function and structure coefficients are shown in Table 1. Bartlett's (1947) *Chi Square Test*, which was performed to investigate the significance of Wilks' *lambda*, a measure of group separation indicated that the two groups were significantly separated by the discriminant function. The mean discriminant function score for the average-ability group was -.92. The mean discriminant function score for the gifted group was .72. Examination of both the standardized discriminant function and the structure coefficients indicated that subjects who score high on group IQ tests and achievement tests are likely to meet the criterion of giftedness on an individually-administered intelligence test. When the discriminant scores were used to predict group membership, it was found that 71 of the 87 gifted students were correctly classified. To find these 71 students, 89 would have been referred for testing. Overall, 78.10% of the subjects were correctly classified.

Table 1:
Standardized Discriminant Function and Structure Coefficients

Variable	**Standardized Discrimant Function Coefficient**	**Structure Coefficient**
Group IQ	.55	.79
Achievement	.52	.81
Honor Roll	.21	.55
Teacher Nomination	.17	.42
Arithmetic Ability	-.08	.41
Leadership Ability	-.09	.11
Artistic Ability	.05	.08
Musical Ability	-.11	.01

Discussion

Discriminant analysis permits a sophisticated view of the effectiveness/efficiency question. The weighting of the linear composite(s) is performed in such a way as to maximize both efficiency and effectiveness. In the present study, effectiveness was 81.61% (71/87) while efficiency was 79.77% (71/89).

These results are consistent with other discriminant analysis studies comparing gifted and average-ability students. Glasnapp, Eros, Isaac, Hitz, & Carlton (1981) obtained effectiveness and efficiency ratios of 89% and 87% respectively when using a combination of teacher ratings and cognitive measures. Pyryt (1986) obtained effectiveness and efficiency ratios of 78% and 72% respectively using subscales of the Piers-Harris Self-Concept Scale to predict group membership based on scores on a group IQ test. It should be noted that the optimum classification cut-offs can be modified to improve either effectiveness or efficiency. Glasnapp et al. (1981) recommended a cut-off score of -.5 for the discriminant function obtained in their study. This cutting score resulted in effectiveness and efficiency ratios of 95% and 71% in their original study. Upon cross-validation, this cutting score resulted in effectiveness and efficiency ratios of 90% and 41%.

It should be noted that the reported results are somewhat optimistic and need to be cross-validated. Although the jackknife classification analysis provides a better estimate of classification results than exact fitting of results to the data, true cross-validation is necessary.

It should also be noted that there are several options for entering predictor variables: direct entry of all variables as in the present study, hierarchical entry of one or more variables, and stepwise. If there is a strong rationale for specifying a certain order of entry, hierarchical approaches can be informative. Most researchers who perform discriminant analysis tend to let the computer choose the order of entry through the stepwise approach. The problem with the stepwise approach is the likely capitalization on chance due to multiple statistical tests used to determine the order of entry. In the present study, direct entry was specified because there was no compelling a priori ordering of predictors. The present study incorporated all of the predictors used by Pegnato and Birch. Researchers are generally advised to be judicious in the selection of predictors.

Some of the discriminant function weights are negative. Since these variables' zero-order correlations with the criterion are positive, the negative sign is an indication of suppressor effects. Although such effects might improve prediction, it is best to remove these variables and rerun the analysis to obtain robust results that are more likely to generalize.

Finally, it should be noted that the Pegnato and Birch study used an IQ definition of giftedness. The findings in the present example only relate to this conception of giftedness.

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