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ABSTRACT

The purpose of this paper is to indicate a procedure for the analysis of data in which aptitude-treatment interactions are suspected. Procedures used in preliminary examination of data are discussed, after which the focus is on when to use analysis of covariance and aptitude-treatment interaction analysis. Finally, the steps in determining aptitude-treatment interaction are specified. (DT)

Some Basic Statistical Procedures for ATI Studies in Science Education

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The purpose of this presentation is to indicate a relatively simple procedure for the analysis of data in which aptitude-treatment interactions are suspected. As such, it is aimed at the practitioner and not meant as a rigorous statistical treatment. Aptitude-treatment interaction analysis, though appearing complex, can be explained fairly easily and carried out without much difficulty. Some computer programs exist which have the flexibility necessary to do the analyses directly. The New York Buffalo Multivariate Analysis program and SAS (Statistical Analysis System) are examples. However, BMD programs, which are perhaps the most common in use, do not yield all of the information directly, so some manual calculations are still necessary. Sometimes these programs also require knowledge of regression analysis in order to determine what is necessary in program setup and what parts of the printout are relevant. The procedures in this discussion are directed at providing information which can be utilized in a simple fashion, using concepts which are easy to manipulate and understand.

Some initial procedures are useful in preliminary examination of the data. These are the calculation of means, standard deviations, and correlation coefficients for each treatment group for all variables,

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both predictor (aptitude) and criterion. Examination of the means and standard deviations of each group for the criterion scores gives some indication of whether or not significant main effects are present. When means and standard deviations among treatment groups for each variable are examined along with the correlation cofficients of each predictor-criterion combination for each treatment group, other outcomes are indicated. Similarity between means and standard deviations for predictor and criterion among treatment groups as well as similar correlation coefficients for each of the treatment groups indicates that there are not likely any significant main effects or aptitude-treatment interactions.

Ususally, no significant differences are not quite so obvious. Main effects are easily investigated using analysis of variance. Feasibility of attempting analysis of covariance or aptitude-treatment interaction analysis can be determined by further inspection. Both of these analyses are regression techniques. The relationship between regression coefficient, correlation coefficient, and the standard deviation of the predictor and criterion is such that an examination of the emans, standard deviations, and correlation coefficients can indicate whether differences exist and the type of analysis which should be attempted. The relationship between regression and correlation coefficients is:

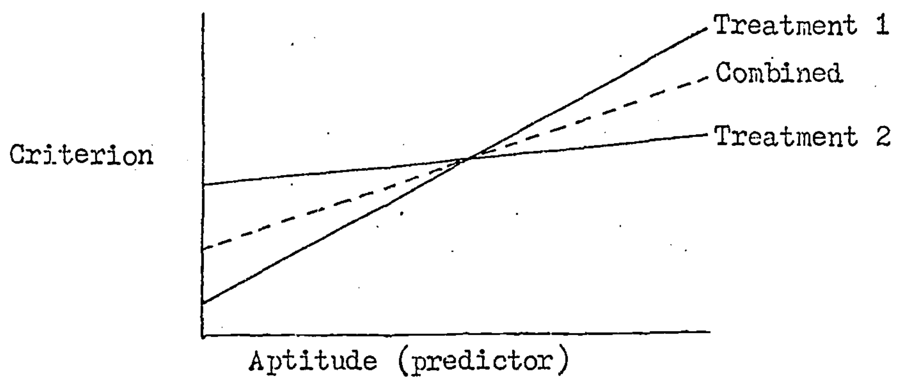
$$b = \frac{s_Y}{s_X} r_{XY} \qquad (1)$$

The regression coefficient is represented by 'b', s_Y is the standard deviation of the criterion measure, s_X, the standard deviation of the predictor, and r_{XY} the correlation between the predictor and criterion. A point to be made in examining this relationship is that if the correlation is not significantly different from zero, it can be considered as zero. In this case, the regression coefficient is also zero and the predictor does not predict the criterion. Aptitude-treatment interaction analysis or analysis of covariance is thus meaningless with correlations which are not significant.

Because relationship (1) exists, some specific considerations of the data and the descriptive statistics indicate what type of analysis may be profitable. First, if the standard deviation of the predictor and the criterion are similar as well as having similar correlations for each treatment group but having means which differ substantially between treatment groups, analysis of covariance is suggested using the predictor (or aptitude) as the covariate. Analysis of covariance assumes that the regression coefficient for each treatment group be the same, and this is indicated by the above conditions.

Second, if the standard deviation of the predictor and criterion variables differ substantially among treatment groups even though means and correlations between predictor and criterion are similar, aptitude-treatment interaction analysis is indicated because the regression coefficients for the different treatment groups will be different. In the third case, an examination of the correlations to see if the predictor-criterion pairs differ in magnitude among treatment groups also indicates the possibility of aptitude-treatment interaction. No aptitude-treatment interaction exists if the regression coefficients are the same since this equality indicates that the aptitude predicts the same performance for all groups and is dependent only on the magnitude of the aptitude score.

Aptitude-treatment interaction analysis is an attempt to determine whether or not the regression coeeficients for the different treatment groups differ significantly from one another. These coefficients represent the slope of the line which would result from graphing the relationship between predictor(aptitude) and criterion. It indicates how much the criterion increases with unit increase of the predictor. Statistically, aptitude-treatment interaction analysis can be described as testing for homogeneity of regression or the homogeneity of slopes for each treatment group. Consider diagram (2). If it is assumed that b_1 and b_2 really do not differ significantly, and that differences are due to error variance, then a regression coefficient which is the same for the two treatments combined should be as good a predictor as either regression coefficient used for the appropriate treatment. If the coefficient for each treatment predicts better, that is, that the prediction results in less error than using the combindd predictor, then the regression coefficients for the treatments differ significantly and there is an aptitude-treatment interaction.



(2)

The procedure by which it is possible to determine whether regression coefficients differ significantly requires various deviation scores. Therefore, the following are necessary:

i) the sum of the square of the deviation of predictor scores for each treatment

$$DX_i^2 = \sum_{u=1}^{n_i} (X_{iu} - \overline{X}_i)^2 = s_{X_i}^2 (n_i - 1) \qquad (3)$$

ii) the sum of the square of the deviation of criterion scores for each treatment

$$DY_i^2 = \sum_{u=1}^{n_i} (Y_{iu} - \overline{Y}_i)^2 = s_{Y_i}^2 (n_i - 1) \qquad (4)$$

iii) the sum of the product of deviation scores for the predictor and the deviation scores for the criterion for each treatment group

$$P_i = \sum_{u=1}^{n_i} (X_{iu} - \overline{X}_i)(Y_{iu} - \overline{Y}_i) = r_{XY}(s_{X_i})(s_{Y_i})(n_i - 1)^2 \qquad (5)$$

In these, i denotes the treatment group, n, the number in the treatment, X the predictor, Y, the criterion, and s, the standard deviation.

The calculations of deviation scores are not difficult to do but can be somewhat tedious. However, with knowledge of the means for all treatment groups, deviation scores and sums of squares and products can be done quickly if the sample is small. For larger samples, a computer has usually been used to get means and standard deviations for all variables in all treatment groups. In this case, equations (3), (4), and (5) indicate how the deviation scores necessary can be obtained from the standard deviations and correlation coefficients.

It is then necessary to calculate regression coefficients for each treatment group. These are obtained by taking the sum of the deviation product for that group and dividing it by the sum of the square of the deviation scores of the predictor for the treatment group.

$$b_i = \frac{P_i}{DX_i^2} \qquad (6)$$

where b_i is the regression coefficient for treatment group i. There will be as many b_i's as there are treatment groups.

The coefficient used for considering groups combined, indicated as b_T, is found by taking the sum of all of the deviation products for all treatments and dividing it by the sum of all the squares of the deviation scores for the predictors in all treatments.

$$b_T = \frac{\sum_{i=1}^{m} P_i}{\sum_{i=1}^{m} DX_i^2} \qquad (7)$$

Three different sums of squares are necessary. The first is $SS(b_i)$ which is found by taking the sum of the product of the regression coefficient squared and the sum of squared deviations of predictor scores for each treatment as shown in equation (8).

$$SS(b_i) = \sum_{i=1}^{m} b_i^2 \, DX_i^2 \qquad (8)$$

SS(b) is obtained by taking the sum of all of the sums of squared deviation scores for all treatments and multiplying it by the regression coefficient of the combined groups, b_T, squared as shown in equation (9).

$$SS(b) = b_T \sum_{i=1}^{m} DX_i^2 \qquad (9)$$

A total sum of squares, SS_{Tot}, is found by adding all of the sums of the squares of deviation of criterion scores for all groups.

$$SS_{Tot} = \sum_{i=1}^{m} DY_i^2$$

The remain der of the analysis for homogeneity of regression is shown in the table below.

Source	Sum of Squares	df	Mean Square	
Regression	$SS(b_i) - SS(b)$	$m - 1$	M_1	$F = \frac{M_1}{M_2}$
Residual	$SS_{Tot} - SS(b_i) - 2(SS(b))$	$N - 2m$	M_2	

As in the previous instances, m represents the number of treatment groups (or regression coefficients) and N the totoal number of subjects in all of the groups combined. The result obtained is an F-statistic with the degrees of freedom shown in the table. A significant F would then indicate aptitude-treatment interaction at that level of significance. Plotting the interaction is conventionally done by plotting the criterion on the Y-axis and the aptituueor predictor on the X-axis. This requires that the Y intercept be calculated by taking the mean of the criterion score for that treatment and subtracting it from the product of the mean of the aptitude score and the regression coefficient for that treatment.

$$Int_i = \overline{Y}_i - b_i\overline{X}_i$$

It is relatively easy for someone with elementary programming experience to incorporate the deviation equations given here into a program which takes raw data and calculates the F's. Alternatively, means, standard deviations, and correlations are also easily obtained and can be used. BMD regression analysis programs can also be used but 'dummy coding' (coding treatment group as a variable) is necessary in order to get the information needed. A covariance matrix is printed in this case, and the selection of appropriate parts of this matrix gives the sum of squared deviations and the sum of deviation products when multiplied by $n_i - 1$, so only a few calculations are required. Since large numbers of subjects in each treatment group are desireable in order to reduce error in prediction, computer procedures which work with raw data are best. Using means, standard deviations, and correlation coefficients does work but accuracy is dependent on carrying as many decimal places as possible.

Reference

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