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VERIFICATION OF THE GLUECK PREDICTION TABLE BY MATHEMATICAL STATISTICS FOLLOWING A COMPUTERIZED PROCEDURE OF DISCRIMINANT FUNCTION ANALYSIS

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A series of analytic multivariate analyses of data published by the Gluecks in *Unraveling Juvenile Delinquency* directed to answering several criticisms of the Glueck prediction devices are presented. The first analysis indicates that the missing observations in the Glueck data are truly random and do not influence the findings. Several reasons are proposed for the efficacy of using equal numbers of delinquents and nondelinquents in the basic research. Using the data samples produced from applying four classical methods of handling randomly missing observations, a stepwise multiple discriminant function analysis established the best analytically derived set of predictors of delinquency. The predictive ability of the analytically derived schedule was found to be almost equal to that of the best predictive deviceof the Gluecks. Almost all the variables included in various predictive devices developed by the Gluecks are in the set of best predictors developed analytically.

The paper concludes that the predictive ability and the items selected by the Gluecks for their predictive devices are those arrived at by strict analytic multivariate techniques and represent findings that cannot be faulted by criticisms of the Glueck methodology. A complete report of the findings reported here will be available in an appendix by the author in Glueck and Glueck, *Toward a Typology of Delinquency*, (in print, Grune & Stratton).

In 1950, Professor Sheldon Glueck and Dr. Eleanor T. Glueck published *Unraveling Juvenile Delinquency*,[1] a multidisciplinary, detailed comparison of 500 delinquent and 500 nondelinquent boys. In 1968 they published *Delinquents and Nondelinquents in Perspective*,[2] in which they presented the results of a follow-up of these boys until the age of 31.

In 1960, Professor Glueck, at the request of the editors of the *Journal of Criminal Law, Criminology and Police Science*, prepared a paper for the issue to commemorate fifty years of publication of that Journal.[3] In that paper, Professor Glueck answered the critics of *Unraveling Juvenile Delinquency* and presented the findings of some validation studies of the Gluecks' delinquency prediction schedules. This paper represents the most complete review and consideration of criticism of *Unraveling Juvenile Delinquency*. However, the critics neglected some very important aspects of the statistical methodology of *Unraveling*, and these are considered in the present paper.

The first of the criticisms is grounded in the fact that not all individuals used in *Unraveling* had complete observations on all 400 items involved in the original research. The reasons for these missing observations are varied. In some instances the characteristic to be measured was not observed by the psychiatrist; in others the interview with the delinquent's family did not provide sufficient information with which to evaluate some specific family environmental condition. In

[1] GLUECK & GLUECK, UNRAVELING JUVENILE DELINQUENCY, Cambridge, Harvard University Press, 1950.

[2] GLUECK & GLUECK, DELINQUENTS AND NONDELINQUENTS IN PERSPECTIVE, Cambridge, Harvard University Press, 1968.

[3] Glueck, *Ten Years of Unraveling Juvenile Delinquency*, 51 J. CRIM. L., C. & P.S. 283–308 (1960).

other cases, records were incomplete when examined by the Gluecks and their research aides. The problem of missing observations in research analyses is a very general and disturbing condition. Wherever missing observations occur, the reader must be cautious about the findings.

The nature of missing observations generally decides their impact on an experiment. There are three distinguishable types of missing observations: random, non-random, and indeterminate. Random missing observations are exclusions that result from conditions in the data collection procedure, not from particular characteristics of the respondents with missing observations. Non-random missing observations are often referred to as missing categories. A condition to be measured may not exist in a response unit. For example, the complete set of measures on a student's school performance may include the grade in an elective mathematics course. Obviously, not all students will have elected the mathematics course and will have missing observations on this datum. There are many other examples of missing categories. For example, the number of parole violations may be a missing category for someone never placed on parole, and so forth.

In many cases, it cannot be decided whether the missing observations are random or non-random. (This is the case of indeterminate missing observations.) Consider the retrieval of information from court records. The researcher may not be certain whether the extent of the data is a function of the thoroughness of the particular recorder or secretary instead of a distinguishing mark of the subject in any way. Or it may not be known whether incomplete records exist when the subject's native language is not English, in which case the missing observations can be expected to indicate other unique characteristics for that group of subjects. Most researchers presume missing observations to be random and generally avoid the issue. However, it is very important that the question of the nature of the missing observations in the Glueck data be answered.

I have proposed a method for determining the nature of missing observations.[4] The procedure is to fill in the missing observations with some estimate of the missing value. A new variable is then created that indicates which observations on the original variable are actual and which are estimated. This indicator-variable is used in the correlations and regressions to indicate whether the missing observations are random or non-random and makes the appropriate adjustment for this characteristic.

If any of the correlations of these indicator-variables with each other or with the actual variables is significant, then the missing observations are not missing randomly. This procedure was applied to the complete data reported in *Unraveling Juvenile Delinquency* and no significant correlations were found to exist between the indicators and the other variables and none were found among indicators. We may then be assured that the missing observations in *Unraveling* are random and that the assumption of randomness implied in the Glueck research is warranted.

The next area of criticism of *Unraveling Juvenile Delinquency* questions the methods used to develop tables for predicting at an early age which individuals will become delinquents and which will not. The critics chose to argue that the fact that the Glueck prediction device used equal numbers of delinquents and nondelinquents while the general population is heavily nondelinquent would distort the predictability. It was noted that even in the areas of highest delinquency the ratio of nondelinquents to delinquents seldom exceeds 9 to 1. It was argued that for accurate predictability the Glueck sample should reflect the proportion of delinquents to nondelinquents in the total population. The argument was continued to suggest that by predicting all individuals to be nondelinquent one would be at least 90% accurate. The Glueck prediction schedules were not that effective and thus, it was claimed, one could do as well as the Gluecks by stating the obvious.

I would like to take a moment to answer the issue regarding sample sizes. My principal argument is that equal populations are necessary to devise prediction schedules which can be used to predict the status of a single individual without

[4] Professor Glueck has answered the criticism involved in these words: "Of course one can assume that in a population in which the proportion of nondelinquents to delinquents is 9:1 *all* boys are nondelinquents and thereby triumphantly point out that one has guessed wrongly in only 10 percent of all cases, which is alleged to be as good as the Glueck table is able to do. But that is not the issue. The issue is whether one can *identify*, individually, the future delinquents and the future nondelinquents; otherwise one is not really predicting at all but asserting what was known, *ex hypothesi*, beforehand. . . . It seems to us that . . . the critics are confusing the counting of heads with the *weighing* of heads; a blind census with a device for *pinpointing* delinquents and non delinquents." *Ten Years*, *op. cit.*, p. 302.

presuming him to be a member of one group or the other. Without any knowledge about person X, I would assign the probability of X being female at at about 50% because this is the relative size of the group of females compared to the group of males. This is what is known as *a priori* probability, the probability before information is collected. If I know person X is over 65 years old, then the probability of X being female rises to something like 58%. The *a priori* probabilities vary depending on what subset of the total population we are dealing with.

The Glueck sample is admittedly not representative of the total population. The Gluecks have sampled among a population whose area of residence, family income, educational level, and so forth distinguishes them from the rest of the population. When we adjust our *a priori* probabilities to this sample, the equal number of delinquents and nondelinquents is not inappropriate. The Glueck prediction devices seek to classify *individuals*, all of whom have high surface potentiality for delinquency.[5]

Multivariate statistical techniques are not unmindful of the number of individuals in the groups to be discriminated. The mathematical criterion of reducing the amount of error in the eventual prediction must provide the best discrimination for the largest groups. In this respect sophisticated mathematical techniques and the casual reader will have the same bias toward stating the obvious. Little gain in statistical information is possible when groups with very different sample size are used. For this reason, it is customary to maximize information by equating the groups with respect to size, even when the *a priori* probabilities are not equal.

I suggest that the most serious criticism of the method used by the Gluecks to develop the prediction schedules might be that strictly univariate techniques produced the multivariate prediction schedules. The distinction between univariate and multivariate techniques is the concern for the relationship among the variables. Two variables that are significantly correlated contain information common to both of them. When these two variables are related to a third, each will have a relation to the third that is partly unique to that pairing and partly common to all three variables.

When two correlated variables are both used to predict a third, the information common to both is redundant. When univariate techniques are used to develop a multivariate device, it is possible that the amount of correlation among the variables will produce little unique information and much more redundant information. The device would then not be as efficient as one that maximizes unique information and eliminates redundancy. It was the Gluecks themselves who initiated the research to determine whether multivariate techniques would produce more effective prediction schedules.

As I have mentioned, the Glueck data contain missing observations. The multivariate reanalysis uses all of the classical methods of handling missing observations appropriate to the problem. Four different methods of handling missing observations were used. The first two filled in the missing observations. In one case missing observations were filled in with the mean of the sample, delinquent or nondelinquent, to which the subject belonged. The other filled in all the missing observations with the same "neutral" value. The difference between these two methods is that one takes advantage of knowing a respondent's group membership, the other does not.

The third procedure generates the correlation matrix from which the prediction equation is computed, basing each correlation on those observations which are present. This missing observations correlation matrix is then examined for inconsistencies. Briefly, correlations are inconsistent when the correlation between variables A and B is outside the bounds determined by the correlations between A and C, and B and C. This condition can occur in a missing observations matrix because the sample of individuals used to compute the various correlations can differ markedly. It is generally considered that these inconsistencies point to non-random missing observations in the data. In the case of the Glueck data no inconsistencies were found, which strengthens the claim that the missing observations are random.

If the missing observations are random then the sub-sample of cases with complete data represents a random sample of the entire experimental population. The fourth method would use just this random sample for the experiment and generalize the findings to include the entire sample. In the case of the Glueck data the pattern of missing observations was such that only a few individuals had complete data on all 111 items. It was neces-

[5] GLUECK & GLUECK, PHYSIQUE AND DELINQUENCY, New York, Harper, 1956.

sary to reduce the number of items under consideration in order to achieve a sufficiently large sample with complete data. This is the notable intrusion of the researchers heuristics into this otherwise complete analytic analysis. It was possible to eliminate some variables because of their lesser relation to delinquency. In other instances one member of a highly correlated pair of variables could be eliminated. Finally, the eligibility of the remaining variables was decided by criteria of reliability, validity, and practicality. A sample of seventy-one items with one hundred seventy-three delinquents and one hundred five nondelinquents was selected. The other three procedures employed used no such sampling. All four data sets produced by these methods of handling missing observations were submitted to the same analysis.

The multivariate device used to generate the prediction schedules is one which depends strictly on the numerical character of the items and not on any prespecified ratings of their importance, thus precluding the possibility of biasing the results with the researchers' heuristics. The technique used is a step-wise discriminant analysis.

This method is not actually the discriminant analysis that many of you are familiar with. It is a linear regression analysis which develops an equation to estimate the value of the dependent variable. When the dependent variable is coded *one* for one group and *zero* for the other, the regression analysis seeks to predict group membership and the mathematics are exactly those of the standard discriminant analysis. The procedure is called step-wise because the equation is built up adding one variable at a time. The estimation of group membership is based on an equation using variable 1. Then a second equation is developed using variables 1 and 2 and so forth. The order of the variables selected is determined by the extent to which each contributes to the estimation.

The first variable selected will be the one with the highest correlation with the dependent variable which is group membership. Correlation means the extent to which delinquents and nondelinquents are different with respect to that variable. The information that all other variables share with the selected variable is removed (usually termed partialed out) from their correlations with the dependent variable. The variable selected will be the one with the highest (now partial) correlation with the dependent variable. The process may continue until all variables are entered into the equation or the amount of information that can be added is exhausted. In practice, however, variables are added to the equation until the possible contribution to estimation of any remaining item is not statistically significant or until some practical number of items is entered. It has been shown that this step-wise method produces the best set of predictors, when the number of predictors used is small with respect to the total number of variables.

This method of constructing prediction equations is sensitive to slight differences in the relationships among variables. The selection of one of a pair of highly correlated variables may be the result of only a slight difference in their relations to the dependent variable. The selection will influence the selection of other variables and it is possible that the original small difference will produce a very different set of predictors. A reason for using several methods of estimating missing observations was to assess the stability of the items selected and provide a measure of their reliability.

The results of the application of the step-wise discriminant function procedure to the four sets of data required by the different methods of handling missing observations were uncompromisingly similar. This is exactly what would be indicated by the later analysis that specified that the missing observations were random. When observations are missing randomly the several methods used all tend to produce the same results.

Seven variables were chosen as among the ten best in all four analyses, and one variable was chosen in three of the four analyses. In the analysis using the reduced sample of data only one variable was chosen which was not selected by any of the other analyses. This assures us that the method of selecting variables and subjects from among the total was adequate to the task.

These analyses indicate a body of consistently important predictors of delinquency over all methods of handling missing observations and using the step-wise procedure for deciding importance. The variables are: *Discipline of boy by mother*, *supervision of boy by mother*, *rearing by parent substitutes*, *boy emotionally conflicted*, *nonsubmissiveness to authority*, *adventurousness*, *suggestibility*, and *mesomorphic body build*. A variable selected in two of the analyses is *discipline of boy by father*, which is highly correlated with *discipline by mother* but has the disadvantage that in many instances of the delinquent's home life the father is not a visible member of the family.

Once the set of best consistent predictors is established, it is necessary that we return to the prediction tables developed by the Gluecks to note the extent of agreement in the variables selected and also the level of efficiency in predicting delinquency that the Gluecks and the analytic multivariate methods have produced.

The procedure for classifying individuals as delinquents or nondelinquents using the multivariate prediction schedules is to get a weighted sum of the individuals' selected scores using the weights produced by the regression analysis. The weights derive from the basic metric and the extent to which each contributed unique information to the estimation of group membership. For ease of comparability, the best ten predictors in each instance were used in the prediction model. In the cases where the data were filled in, the equation was applied to all one thousand boys. The resulting scores (let's call them discriminant scores) were distributed along an axis. At the center of the axis is a region in which roughly equal numbers of delinquents' and nondelinquents' discriminant scores fall. To either side of this region are the areas of scores for predominantly one group or the other. It is noted that the size of the middle area of overlap decreases as the ability of the function to discriminate between the groups increases and vice-versa. Selecting this overlap region and counting the number of individuals in each region and noting the group to which they are members develops for us a table of efficiency of classification. Individuals in the overlap are considered unclassified. Others are correctly or incorrectly classified depending on whether they are members of the predominant group. The average accuracy of prediction for all five analyses is 88.9% correct, 5.3% incorrect, and 5.8% unclassified.

In 1966 the Gluecks reported a prediction schedule that used five items. This schedule produced 83% correct classifications. This level of accuracy is somewhat less than those reported above but uses only half the number of items. An equation was developed from the reduced sample analysis that employed only the five best items selected from the consistent predictors, not including discipline by father, for the practical reason mentioned before. Of the 778 boys classified by this analysis, 80% were classified correctly. Using discipline by father increased accuracy to 83%, which is exactly the accuracy of the Glueck schedule.

Thus, it is quite safe to say that the prediction devices developed by the Gluecks are as efficient as those developed by multivariate techniques and enjoy the advantage of wisdom about the nature of the items that the computer does not have. The danger that the univariate process which developed prediction tables had lost accuracy by being unmindful of relations among the items used is not established. There seems to be an incontrovertible maximum to the predictive efficiency to be obtained using the data of *Unraveling Juvenile Delinquency*, and the Glueck devices have reached that maximum.

The next step is to consider the variables selected by the Gluecks and by the multivariate analysis to see if they correspond. This sounds like almost too much to ask of both the analytic program and the Glueck prediction devices. In the list of nine consistent predictors of delinquency, there are four social factors: *discipline by father*, *discipline by mother*, *supervision by mother*, and *rearing by parent substitutes*. The Glueck prediction table using Social Factors and presented in *Unraveling* uses *discipline by father* (to which *discipline by mother* is an alternative and later tables use it for reasons stated before) and *supervision by mother*—effectively three out of four. This device uses *cohesiveness of family* and the Gluecks note that *broken homes* or *rearing by parent substitutes* differentiates as well between delinquents and nondelinquents but generally occurs later in life than at time of school entrance, and *family cohesiveness* is a substitute which can be measured at an earlier age.

Of the four psychiatric traits in the list of consistent predictors, three appear in the prediction device using psychiatric items and presented in *Unraveling*. The missing one is *nonsubmissiveness to authority*. It is one of the five items used in the later prediction device developed by the Gluecks and which is the best predictive device that we cited earlier. In this instance we may then claim four for four. In general the later predictive devices developed by the Gluecks sample almost exclusively from the list of best predictors developed by the multivariate procedures with the exception of *family cohesiveness*, for which the mathematical solution has substituted *rearing by parent substitutes* and *mesomorphic physique* which is difficult