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The Estimation of Psychological Genetic Differences Between Classes and Races

By P. A. P. MORAN

For genetic characteristics controlled by a single locus which are such that the degree of dominance is not dependent on the environment, statistical methods of determining the mode of inheritance and the gene frequencies are now well understood in principle. If, however, there is incomplete penetrance, depending on the environment (taken in the wide sense), the problem becomes much more difficult, especially in human genetics. The situation is even worse if the character is dependent on several or many loci and such characteristics are often very dependent on environmental factors. This seems to occur in man in some psychiatric diseases and is certainly the case for intelligence. The genetical analysis of such phenomena is very difficult, and it is essential that the mathematical and statistical bases of such investigations be carefully understood by anyone who undertakes such work.

A review of recent studies on possible genetic differences in intelligence between races and classes has been made by S. Scarr-Salapatek (1971). She introduces a useful distinction between 'castes' and '(social) classes'. This is not always an absolute distinction, nor is the latter an exact concept, but they are useful in analysing the problems involved. Moreover the distinction is closely analogous to the one made in population genetics between 'demes' and 'clines', and the word 'caste' is preferable to 'race' in human studies because the latter often has non-scientific connotations.

A human population is said to be divided into 'castes' if it is divided into two or more identifiable groups between which there is little or no migration or mating, or which are such that the offspring of such mating can be readily identifield (and thus eliminated from the sample used for investigation). Black and white Americans can thus be regarded, to a first approximation, as constituting two castes.

Social classes, although their definition by sociologists has a fair degree of conventionality, do correspond to something real in society, but have a high degree of intermobility and intermarriage, both of which are themselves dependent on genetic factors. For the purposes of statistical investigation it is convenient to use the Registrar General's classification into five classes based on occupation, although within each of these mating is certainly not at random and the distribution of psychiatric disorders within each is not at all uniform. In spite of all this, there is a rough gradation in class which corresponds to the 'clines' observed in plant and animal populations.

Suppose that we have some genetically based characteristic, dependent on a number of loci, which can be readily measured, and suppose that we measure it on two different castes. Then we may ask if there is a difference in the averages of the genetic values of the individuals in the two castes. Suppose that the phenotypic values of randomly selected individuals from each of the two castes are x_1 and x_2. Then, assuming as a first approximation additivity of genotypic value and environmental effects and lack of interaction (not true in general), we may write $x_1-x_2 = g_1-g_2+e_1-e_2$, where g_1, g_2 represent the genotypic values of the individuals, and e_1, e_2 represent quantities whose difference is the difference between the effects of the two environments. Then, taking averages over all the members of the castes and denoting these averages by capitals, we can write $X_1-X_2 = G_1-G_2+E_1-E_2$. Notice that this equation does not require the e_i and g_i to be uncorrelated but only that there is no interaction, i.e. they are additive. In many cases, such as for intelligence,

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we can estimate the left hand side of this equation by observation, whilst the scientific problem is to estimate G_1-G_2. To do this we must estimate E_1-E_2 and subtract it from the observed X_1-X_2.

Since E_1 and E_2 are not known directly, we might consider proceeding as follows. By observations within each caste we try to find what measurable components of the environment affect the x's. From these, by statistical methods, we attempt to construct an index, I, of such environmental variables, and the partial regression of the x_i on I (i.e. with the effect of any correlation of I with g_i removed). Let the regression coefficient be β as estimated from within each caste (unfortunately this may be different in the two castes, but for simplicity we assume it to be the same). Then we estimate G_1-G_2 by $X_1-X_2-\beta(I_1-I_2)$.

The first difficulty is to estimate β. We cannot do this by comparing the two castes, since their observed difference also contains G_1-G_2 which is not known. β would therefore have to be estimated from comparisons within the castes. In practice this is very difficult but might be possible in principle by studying identical twins brought up together and brought up apart. No estimate is possible from other familial correlations, because e_i and g_i are usually correlated in the population (they certainly are for intelligence and possibly for some psychiatric disorders).

However, as far as intelligence is concerned, there is an insuperable difficulty in the above procedure. We have assumed that a suitable index, I, of environment can be constructed. This may be true within a caste. However, in comparing, say, the intelligence of white and black people in the U.S.A. it is certain that some of the components of the environment which are relevant to the difference between the two castes are different from those relevant within each caste. Such components include the social and intellectual traditions of the two groups (compare for example the relative contributions to American science of Americans born in America of Irish and Jewish origin respectively), and the self-image of the two groups as they compare themselves with each other. Thus the construction of an adequate I and the estimation of β does not seem possible.

In spite of these difficulties, attempts have been made to measure the sign and size of a possible difference between the average genotypic value for intelligence in white and black Americans. Many measurements of I.Q. have been made, and taken all together they suggest that a reasonable average estimate of x_1-x_2 is that the white Americans score about 15 points higher than black Americans.

Shuey (1966) has described a series of investigations in which, instead of using a regression on an index of environment, comparisons were made between groups which were matched for a number of environmental variables. These suggest that if the above methods could be used the estimated difference would be reduced by something between a quarter and a half of the observed value, and also that the value of β differs in the two groups (which is not surprising since the environmental difference between the two groups certainly depends on other variables). Shuey's method of matched samples is statistically a close approximation to using regression methods (except for the possibility of non-linearity) and suffers from the same invalidity that is described below.

The residual difference of about 7 to 12 points may be compared with the known estimated phenotypic difference of 8·2 points between biochemists and social scientists holding teaching and research positions in the University of Cambridge, England, in 1965 (Gibson and Light, 1967). This is based on a small sample and is one of a number of comparisons, but considered by itself is significant at the 1 per cent level.

The above considerations suggest that, although the problem is very difficult and not yet solved, it might be possible to solve it in principle if we could make a better evaluation of the environmental differences between the two groups. Unfortunately, the whole procedure outlined above is vitiated in practice by a fundamental statistical fallacy which does not seem to have been pointed out in the literature dealing with the problem and which makes it insoluble in our present state of knowledge.

This is the fact that although covariance analysis, as used to remove the part of the observed differences between groups due to

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some known factor, is a valid technique in a randomized experiment, it is invalid and gives a biased answer when applied to observational data unless: (a) the covariate is an exact measure of the whole of the effect due to factors other than the one being investigated; and (b) this covariate is measured without error. The bias is due to both (a) and (b) and is removed by randomization in a randomized experiment. If (a) is false the bias may be in either direction, but if (b) is false the denominator in the estimate of β is inflated and the magnitude of the regression underestimated. Exactly the same considerations apply to matched samples. This means that the true value of $G_1 - G_2$ may be positive, zero, or negative. The situation is very similar to the standard statistical error of confusing a structural relationship with a regression (for a survey of the theory, see Moran (1971)). The error of using this method on observational data (either with regression or with matched samples) has been discussed by Cochran (1968) in several papers.

Those considerations may also apply to variations between classes in a single community or caste with respect to any characteristic which is partially dependent on both genetic and environmental factors. This is of great importance in the study of psychiatric diseases, especially schizophrenia which has a very large difference in the observed class distribution of patients. As we are here dealing with a cline and not a set of castes, the problem arises as to whether this observed difference is due to a difference in the environment of the individuals concerned, to a difference in gene frequency in the different classes, or to a downward migration of those who develop or are about to develop the disease. An extensive controversial literature exists on this subject which will not be reviewed here. For the early literature see Hare (1962), and for later work see Hare, Price and Slater (1972). In the corresponding case of intelligence it is clear that phenotypically more intelligent individuals are more likely to move upwards in the social scale than other individuals with the same background. It should also be noted that if schizophrenia is, say, dependent on a single locus, as some psychiatric geneticists believe, then the estimates of gene frequency and penetrance will both be biased by the existence of any cline in the gene frequency, and by any variation in the population of any environmental effect, if such exists and is more similar in related individuals. For a short theoretical discussion see Moran (1972). A further complication is that, contrary to what usually happens in plants and animals, the genetic and environmental components, g_i and e_i, of any individual are likely to be correlated positively, which has the effect of inflating familial correlations over what they would have been otherwise. In Fisher's (1918) original treatment he ignored this fact completely.

For reasons unknown to me the confusion about the estimation of possible differences in average genetic levels between races has been further compounded by attempts to calculate the 'coefficient of heritability', h^2, and to use this in some way as a means of determining the effect of environment. The origin of this concept lies in the fundamental paper of Fisher (1918) who first showed that the discrete model of early Mendelian genetics could be used to explain the observed inheritance of continuous characters by supposing that the latter are the sum of the effects of a number of different loci, and the interaction (epistasis) between them. He first considered the effects of two possible alleles at a single locus, and showed that this could be represented as the sum of a linear component and a component due to dominance deviations, these components being uncorrelated and their separate variances therefore additive. He next showed that this idea could be extended to the case where alleles at different loci interacted, and defined an interaction term which was uncorrelated with the two previous components. Then the average in the population is the mean from which the additive components are measured, the average of the latter and the two other components being zero. However, the variance in the population is the sum of the variances of the three components. There are, however, further complications. The first of these is the effect of homogamy, i.e. assortative mating. Fisher constructs a model for this which leads to a further term in the sum of variances. However there are other more plausible models for human assortative mating

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which cannot be represented in this way and can actually lead to a decrease in the variance. These have been investigated in a series of papers in course of publication by Dr. Susan R. Wilson. In humans assortative mating appears to be quite large in respect of e.g. stature and intelligence, and cannot therefore be neglected. It presumably also plays some part in psychiatric genetics. In what follows we shall, however, ignore it. Finally there are the environmental effects and the covariance of these with the genetic component in a family. The former merely inflate the total variance if the latter is absent. In animal and plant genetics the covariance of environment and genetic effects can usually be ignored, but in human genetics they are important and may also considerably inflate the numerator of a correlation coefficient between members of the same family thus leading to biases in estimation.

Following Fisher's work, most geneticists are accustomed to define a 'coefficient of heritability', h^2, as the ratio of the variance due to the additive component to the total variance. This is a useful tool in animal and plant breeding (but not in human genetics), since it gives an indication of the size of the effect that can be expected from first order selection. Psychologists, however, tend to define heritability as the ratio of the total genetic variance to the total variance. We denote this by h_p^2. Since the numerator contains the dominance and epistatic components this cannot throw any light on the effect of selection, since the additive component could be zero. It is easy to construct a simple model in which $h_p^2 = 1$ and no amount of selection will have any effect at all on the population. The important fact about heritability, as measured by h^2 or h_p^2, is that it is not a property of an individual, or a population, but of a population living in a specified variable environment. Thus these coefficients have no relevance to any differences between castes and classes, and it is something of a mystery to understand how anyone came to think that they did.

To make the situation clear we might consider two different varieties of apple trees such as Granny Smiths and Cox's Orange Pippins, grown on their own roots in controlled environments in a phytotron (an apparatus for growing plants in controlled conditions). Instead of apples we might consider any vegetative varieties which can be grown by vegetative propagation. Populations of such varieties are, as is well known, clones, i.e. all the individuals have exactly the same genotype but are usually quite heterozygous.

Then if we grow two such varieties in a phytotron under exactly the same set of variable environmental conditions, including soil, the difference between the means of the two varieties will be almost entirely genetic in origin, but in each population h^2 and h_p will be practically zero.

Alternatively we might grow two populations of the same apple varieties in two different varying sets of different environmental conditions such that the mean effect of one is different from that of the other. Then $h^2 = h_p^2 = 0$ as before, but the difference is entirely environmental in origin.

Now suppose that the two varieties are crossed and large numbers of the offspring are grown. Then these will be highly heterogeneous in the genotypes. We grow two groups randomly selected out of the offspring, each in uniform but different environments. Then h_p^2 will be unity, or nearly unity in each, and h^2 probably fairly high. Yet the difference between the groups will be entirely environmental in origin, except for sampling variations. Similarly if we take two populations produced by self-crossing the two varieties and grow the two sets of offspring in the same environment we can have (approximately) $h_p^2 = 1$ in each, h^2 possibly high, and the difference entirely genetic. Thus h^2 and h_p^2 do not throw any light at all on the difference between human castes and attempts to calculate them are quite irrelevant.

As there has been a considerable amount of controversy in problems of this kind in relation to both intelligence and psychiatric disease, this note has been written in the hope of clarifying some of the statistical difficulties involved. I am indebted to Dr. S. R. Wilson for some helpful criticism.

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