

Genetic and Environmental Contributions to Individual Differences: The Three Major Dimensions of Personality

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ABSTRACT This article deals with the contribution of genetic and environmental factors to individual differences in the three major dimensions of personality (Psychoticism, Extraversion, and Neuroticism). Twin studies indicate, and family studies confirm within limits, the strong genetic determination of these and many other personality factors, additive genetic variance accounting for roughly half the total phenotypic variance. On the environmental side, shared family environment plays little or no part, all environmental effects being within-family. Assortative mating, important in the formation of social attitudes, has little impact on personality. Dominance may be important for Extraversion. Epistasis (emergence) may account for the comparative low values of dizygotic (DZ) twins' correlations. Evidence for differential heritability of traits is present, but not very strong. It is concluded that behavioral genetics forms a vital part of the psychological understanding of the causes of individual differences in personality.

This article discusses the importance of genetic factors in personality, and it may be useful to begin with a brief definition of terms. Concepts like "personality" often mean different things to different people, and without wishing to prescribe the correct use of such terms (if there is any such correct use), it may be useful for the reader to know how such terms are used within this article. Personality in the wider sense (personality_w) may be divided into two basic categories, cognitive (in-

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telligence, mental abilities) and noncognitive (temperament, personality in the narrow sense, or personality_N) Cattell (Cattell, Eber, & Tatsuoka, 1970) clearly uses the term personality in the wider sense, because he includes intelligence, social attitudes, and other concepts in the field covered by his Sixteen Personality Factor (16 PF) Scale Strelau (1983) uses the term personality in the narrower sense, but contrasts it with temperament, which he would define as the biological and genetic basis for personality In this article I follow the usual American custom of using the term personality in the narrower sense, the genetic analysis of intelligence and ability has been described elsewhere (H J Eysenck, 1979, 1982)

Textbooks such as that by Hall and Lindzey (1970) suggest that there is no substantive area covered by the term "personality", all that the reader is given is eponymous chapters dealing with variegated theories with little in common and depending more on persuasion than on empirical demonstration However, in recent years large-scale factor analytic studies have shown convincing agreement on three major dimensions of personality, based on the intercorrelations between lower level traits (Royce & Powell, 1983) These three factors or dimensions have been variously labeled by different authors, but in the system I have originated (H J Eysenck, 1947, 1952) they are labeled Neuroticism versus Emotional Stability (N), Extraversion as opposed to Introversion (E), and Psychoticism as opposed to Super-Ego Control (P)

The Eysenck Personality Questionnaire (EPQ) (H J Eysenck & S B G Eysenck, 1975) was designed to measure these three dimensions, as well as containing a Lie Scale (L) designed to measure dissimulation This article is primarily concerned with these major dimensions of personality for two reasons First, more work has been done on the genetic analysis of P, E, and N than on any other traits or types of personality, and second, this system has some claim to constitute a budding paradigm in personality research (H J Eysenck, 1983b) The system is firmly based on a *biological* foundation, and evidence for it can be found in animal studies (rhesus monkeys, rats) where observation of social behavior, breeding studies, and experimental interventions have demonstrated similar behavior patterns to P, E, and N (H J Eysenck & M W Eysenck, 1985) Such evolutionary development strongly underpins genetic arguments

Early Studies

The empirical and quantitative study of the genetics of personality may be said to have started with the work of Newman, Freeman, and Holzinger (1937), they assigned little importance to genetic influences. In earlier work (1967) I criticized their studies in detail. In the first place, the measures used as tests of personality would not now be regarded as either reliable or valid, containing for instance the Downey Will/Temperament Test, which is essentially based on graphological principles.

In the second place, the personality tests used were primarily tests for adults, but the average age of the group of twins tested was only about 13 years, and must have included children as young as 8, or even younger. Thus the tests were quite inappropriate for the population in question.

In the third place, the statistical results obtained for some of the tests gave contradictory conclusions. Thus a Neuroticism inventory used gave an intraclass correlation of .562 for identical twins, of .371 for fraternal twins, and of .583 for identical twins brought up in separation. Note that identical twins who grow up in separation are very slightly more alike than identical twins brought up together, this suggests a very weak influence of between-family environmental factors, if any influence can be postulated at all. The difference between identical and fraternal twins suggests a heritability of about 40%, which would be greatly increased if unreliability in the measuring instrument were corrected for. It certainly would not seem reasonable to accept the very negative conclusion of Newman et al.'s (1937) book, although many textbooks of personality have done so, without considering the serious defects of the study.

I have outlined the historical development of studies of this kind (H. J. Eysenck, 1967), most of which have given positive results as far as Extraversion and Neuroticism, in particular, are concerned. This article will only comment on two or three studies before going on to more recent work using statistical methods of model fitting better equipped to deal with the complexities of the situation. The first set of studies (H. J. Eysenck, 1956, H. J. Eysenck & Prell, 1951), using twins, employed a series of objective tests of behavior, as well as inventories, and used factor analysis to isolate the factors Extraversion and Neuroticism. It was argued that factor scores derived from a multifaceted battery of

tests would give better and more valid estimates of E and N, scores on single tests are a mixture of variance due to E and/or N, variance due to other factors, specific and error variance, the factor score aggregates the "true" E or N variance and averages out the other contributions. High heritabilities were obtained for N and E in these studies, although the method of analysis was the usual, rather primitive type then prevalent.

Similar results were obtained by Shields (1962), using a self-rating questionnaire. Shields used pairs of twins who had been separated from one another in childhood, as well as a control group of twins who had been brought up together. Altogether there were 44 separated monozygotic (MZ), 44 nonseparated MZ, and 32 dizygotic (DZ) pairs of twins, of which 11 had been brought up apart. Identical twins were much more alike than fraternal twins on E and N, regardless of whether they were brought up together or in separation, as with the Newman, Freeman, and Holzinger twins, in each case twins brought up separately were slightly more alike than twins brought up together. All twins in this study were adults. In this case, as well as in several other studies (Newman et al., 1937, H. J. Eysenck & Prell, 1951), the number of pairs of twins was relatively small. The small sample size, coupled with the elementary nature of the statistics used and the absence of a proper model, detracts from the evidential value of these studies, although the studies do demonstrate at a very high level of significance that genetic factors contribute to individual variation in Extraversion and Neuroticism. What is also impressive is the agreement between the studies, some even extending to a higher intraclass correlation for identical twins separated early in life as compared with identical twins who were not separated.

Modern Studies

Six major recent studies, all of which are characterized by being based on sufficiently large numbers of twin pairs, as well as being analyzed by means of modern statistical methods, provide more reliable evidence for genetic influence on personality change (Fulker, 1981, Plomin, 1986). Historically the first of these is a series of studies (Eaves & H. J. Eysenck, 1974, 1975, 1976a, 1976b, 1977, Martin et al., 1986) dealing with the genetics of social attitudes, Extraversion, Neuroticism, and Psychoticism. These studies were reviewed by Eaves and Young (1981) and finally published in a book with many additional analyses and historical reviews (Eaves, H. J. Eysenck, & Martin, 1989). This work used

some 500 pairs of MZ and DZ twins from the Maudsley Twin Register in England, making use of the then newly developed EPQ (H J Eysenck & S B G Eysenck, 1975)

The second of these major studies was reported by Loehlin and Nichols (1976), who used 860 sets of twins in the United States, and employed the California Psychological Inventory (CPI) At my suggestion they also employed a measure of Extraversion and Neuroticism, based on selected items from the inventory

The third set of studies has been published by Martin and Jardine (1986) These were based on almost 4,000 pairs of twins, and used the EPQ, a social attitudes scale, and several anxiety and depression scales The study was carried out in Australia, thus adding another country to England and the United States for replication

A fourth study, undertaken in Sweden by Floderus-Myrhed, Pedersen, and Rasmuson (1980), used a sample of 12,898 twin pairs and a short form of the Eysenck Personality Inventory (EPI) As the analysis of the original data was rather perfunctory, the data were subsequently reanalyzed (Eaves et al , 1989)

A fifth set of studies which promises to be of particular interest is one carried out in the United States by Lykken (1982), Bouchard (1985), and Tellegen et al (1988) on twins reared apart and reared together Unfortunately the personality scales used, although similar to the EPQ, are somewhat different and a direct comparison would be difficult In addition to its substantive content, the work of this group is also important for the theoretical explanation by Lykken (1982) of the frequently found, unduly low personality correlations between DZ twins in terms of epistasis, or his rather similar concept of emergence

Sixth and last are the data from a large-scale Finnish study using 14,288 adult co-twins (Rose, Koskenvuo, Kaprio, Sarna, & Langinvainio, 1988), concentrating on the problem of shared environments and their influence on personality phenotype

This article looks primarily at the first four studies, which I refer to as the London study, the United States study, the Australian study, and the Swedish study The usual method of recruitment for these studies included the ascertainment of zygosity via questionnaires, usually validated by blood sample tests used on subgroups Models were usually fitted without sex limitation, but where necessary different models were fitted for the two sexes Studies by myself and my colleagues (Eaves et al , 1989) used five groups of twins—male MZ, female MZ, male DZ, female DZ, and mixed male/female DZ twins This last group is of

particular importance in order to study sex limitation, but such groups have often been omitted in the past

The major models tested were the following

1 *Within-family environmental factors only*— V_{EW} This is a model including only environmental differences within families, and thus excluding family resemblance. It is obviously simplistic, but was tested because to date there was no evidence for V_{EB} environmental variance, $1 e$, variance due to between-family factors, or a “shared environment” (see also Plomin & Daniels, 1987)

2 *The environmental model* This second and more promising model includes V_{EW} and V_{EB} only, $1 e$, the environmental factors associated with the within-family and between-family environmental effects

3 *The simple genetic model* This model incorporates V_A (additive genetic variance) and V_{EW} , $1 e$, it incorporates a radical assumption that *all family resemblance is genetic*, and that there is no nongenetic similarity between two twins, as would be shown by V_{EB} . The model tests whether parental influence and correlated learning experiences are affecting personality in the twins. If the model fails, then shared environmental effects may need to be considered, as described below in a fourth model

4 *The genotype-cultural model* This model includes V_{EW} , V_{EB} , and V_A , $1 e$, both genetic and cultural components of family resemblance, it is the most complicated model that can be fitted to twin data without taking sex limitations into account

5 *The dominance model* The fifth model includes V_{EW} , V_A , and V_D , $1 e$, the genetic variance due to dominance is added to the simple genetic model

6 *The competition-cooperation model* This model includes V_A , C_A , and V_{EW} . The parameter C_A represents a genotype-environment covariance generated if the same genes have a direct effect on the trait and an indirect effect on the environment of the co-twin. If the genes responsible for sibling interaction differ from those responsible for the direct effects on the trait, the effects of sibling interaction will remain undetected as long as the study employs twins alone. However, comparison with singletons may then permit further resolution of the direct and indirect effects of genes. A negative C_A implies competitive interactions since genes which increase trait expression in one twin of a pair are generating an environment which *reduces* trait expression in the other twin. The positive parameter value supports the hypothesis of cooperation or mutual reinforcement, since genes which increase the

trait value of one twin create an environment for the co-twin which tends to *increase* the trait expression

RESULTS

Methods of analysis used are discussed in detail by Eaves et al (1989), Fulker (1981), and Plomin (1986) Cattell (1982) may also be consulted for theoretical and practical points Many of these methods originated with Mather and Jinks (1971), and their usefulness and reliability is now well documented (Martin, Eaves, Kearsley, & Davies, 1978)

It would be impossible to give all the details of the analyses carried out on the data of the four studies in question Instead the general conclusions derived from the analyses are discussed, along with some of the less strong but nevertheless significant results achieved only with the larger samples, particularly the Swedish one

First, the data show that the family environment (V_{EB}), as distinct from the unique experiences of the individual, makes only a trivial contribution to personality differences (See especially Plomin and Daniels, 1987, but consider also the Rose et al, 1988, data, which suggest some possible contribution by family environment Rose and Kaprio, 1988, discuss the evidence in detail) This conclusion also emerges from the original findings of Newman et al (1937) and Shields (1962), showing that MZ twins separated at an early age are more alike in personality than MZ twins who are not separated The data base, with all relevant studies taken together, includes 106 pairs of identical twins reared apart and 5,000 identical twins reared together Intraclass correlations are .54 and .52, respectively, i e, not significantly different Similarly, for fraternal twins, the data include 20 pairs reared apart, and over 8,000 pairs reared together, with intraclass correlations of .18 and .23, respectively, also very close together If correct (and there seems little doubt about a conclusion replicated so many times, on so many large samples and using many different methods of testing and analysis), these close correlations disprove the importance of family environmental influence on personality and call into question the validity of traditional personality theories discussed by Hall and Lindzey (1970) and in personality textbooks in general Traditional theories from Freud onwards concerning the major influence on personality of the family (and associated influences such as socioeconomic status and education) now appear to be wrong This result alone necessitates a revolution in current thinking about the development of personality

Perhaps only slightly less important is the finding that genetic factors make a highly significant contribution to personality differences on all the traits and dimensions that have been analyzed hitherto. Roughly speaking, the uncorrected contribution of V_A to individual difference in personality is around .5, the question of correction for unreliability in the measuring instrument is one which is still under debate for various reasons. Any such correction would raise the contribution of genetic factors to approximately 60%.

Another important outcome of the analysis of the genetic determination of individual items on personality questionnaires was that genetic effects on personality are highly specific, even to the level of individual item responses, and not just confined to the major dimensions of personality. This strengthens my belief in the hierarchical model of personality, where P, E, and N are simply the top levels of personality description, with lower levels including many group and specific traits and factors (H. J. Eysenck, 1947).

A fourth important finding is that for some measured aspects of personality there is striking evidence that quite different genes operate at different stages of development, i.e., for younger as opposed to older people. This has always been known with respect to such items as sexual maturation, but apparently it also applies to personality dimensions and should be taken into account. The Swedish study indicates that in large samples, there is significant interaction between sex differences and genetic effects of personality, another area where new and important discoveries have been made.

Also found in the larger samples is some evidence of sibling interaction between juveniles for certain aspects of behavior, in other words, there is some evidence for the "competition-cooperation model." Equally, in some of the larger studies there is some evidence for the "dominance model," but only in relation to Extraversion, there appears to be no dominance for P and N.

From the technical point of view, it should be noted that mating is essentially random for personality differences, this is probably a counterintuitive result, but it seems to be well established empirically, and is of course important for a genetic analysis. Another point which is important is that such Genotype \times Environment interaction as might be claimed for personality on the basis of raw scores on P, E, and N, may be explained almost entirely by the properties of the scale of measurement, and removed by a transformation which assumes the equality of item difficulties and local independence. Finally, I have also found

that what many psychometricians would dismiss as "unreliability" of the scales may have a genetic component, it is this point which makes it difficult to correct for unreliability

The Swedish study, and in part the Australian study, revealed that the relative simplicity of the results obtained in the English and the American studies are due to the (relatively) small numbers used, and the large fiducial limits associated with model testing in parameter estimations in genetic studies (On the other hand, very large samples make any deviation from a model statistically significant, although the deviation may be substantively unimportant) The Swedish and in part the Australian studies show that the genetic contributions may be different for males and females, in amount as well as in consistency, and that the same is true for different age groups Finally, there is some evidence for dominance for the Extraversion variable which appears to be convincing, even though its size is relatively modest These are complexities which should not worry us too much at the moment, they do not detract in any way from the major findings outlined above However, for future work they must obviously be borne in mind and highlight the need for very large samples

Are these conclusions true only for P, E, and N, or do they apply to other personality factors as well? Henderson's (1982) review would suggest a great degree of universality, as does Cattell's (1982) book *Are personality traits differentially heritable?* Loehlin (1982) suggests a cautious "yes," Ahern, Johnson, Wilson, McClearn, and Vandenberg (1982) a cautious "no," the former conclusion being based on twin studies, the latter on family resemblances Eaves et al (1989), looking at analyses of individual item responses, find marked differences in heritability The answer to the question seems to depend on the level and type of analysis

One further point deserves mention These analyses have concentrated on twin studies, where models are easier to test and fewer qualifications arise Family and adoption studies tend to give lower heritability values (Ahern et al, 1982, Eaves & H J Eysenck, 1980, Loehlin, Willerman, & Horn, 1987), for reasons which are still being debated Eaves and H J Eysenck (1980, p 282) suggested the consideration of age-dependent genes, and some support for this view is given by Eaves et al (1989) Whatever the reason, the analyses should support cautious interpretation of the twin data (Cattell, 1982)

Comparison With Intelligence and Attitudes

It is instructive to compare the results of genetic studies on personality with those on intelligence (H J Eysenck, 1979). As Snyderman and Rothman (1987) have demonstrated in a survey of expert opinion in intelligence and aptitude testing, there is no longer any debate about the importance of genetic factors for individual differences, the average estimate of expert opinion gives a mean heritability of 60%, neatly sandwiched between Vernon's (1979) 50% and my 70% (H J Eysenck, 1979). Here there is good evidence for dominance, and on the environmental side V_{EB} is twice as important as V_{EW} . These differences demonstrate that the findings with personality are not implicit in the methodology or the method of analysis used, clearly quite different results can be obtained when ability rather than personality is at issue. There is one further difference between intelligence and personality measures, and that is the importance of assortative mating for the former, but not for the latter. This has important consequences for the amount of variance observed, the greater the amount of assortative mating, the greater the variance in the observed character.

Social attitudes also present an interesting set of comparison data for our personality research. Social attitudes probably lie between cognitive variables like intelligence and mental abilities, and noncognitive variables like personality, there clearly is a certain amount of cognition involved in the formation and formulation of social attitudes, but equally these are not uncorrelated with personality (Eaves & H J Eysenck, 1974, H J Eysenck & Wilson, 1978). Here, however, the first analyses disclosed a strong influence for V_{EB} , i.e., some influence due to shared environment, in addition to genetic factors. However, there are very high correlations between spouses for social attitudes, even higher than for intelligence, these are in stark contrast to the very small variance due to assortative mating found for P, E, and N. In fact, the degree of assortative mating for attitude is so high that its genetic consequences could account for all the additional resemblance between twins that earlier analysis had ascribed to the family environment. When the joint effects of genes, cultural inheritance, and assortative mating in the model for family resemblance and conservatism are allowed for, estimates of the cultural parameter do not differ significantly from zero. This result does not agree with my initial intuition that cultural factors are responsible for some major determinants of family resemblance and attitudes, but nevertheless these are the findings (Eaves et al., 1989).

Compound Variables

This section focuses on the degree of genetic influence on compound variables. An example of this is criminality, or generally antisocial behavior, which has been shown to be quite highly correlated with P, E, and N. This very large body of work (H. J. Eysenck & Gudjonsson, 1989) involves research carried on in many different countries such as England, Germany, the United States, and India. The finding that antisocial behavior and criminality are associated with P, E, and N, each of which is highly determined by genetic factors, would lead to the assumption that criminality too would show a high determination by heredity, and two lines of studies have supported this view. The first studies show that concordance for criminal behavior is very much greater for MZ twins than for DZ twins. The second line of evidence shows that the criminality of adopted children is determined to a very significant extent by the criminality of their true parents. The heritability of criminal conduct is estimated at about the same level as the estimates of heritability found for personality, i.e., between 50% and 60%. Thus combinations of personality traits can be shown to issue in social conduct which is very significantly influenced by genetic factors (H. J. Eysenck & Gudjonsson, 1989).

It is essential not to overinterpret this conclusion, as was done originally by Lange (1929), whose book called *Crime as Destiny* demonstrated the high concordance rates for MZ twins as far as criminality is concerned. Even as high a heritability rate as 60% would be far from endorsing a completely deterministic view, criminal behavior is certainly not the "destiny" of all those who have high scores on P, E, and N. Environmental factors have also been shown to play a very strong part (H. J. Eysenck & Gudjonsson, 1989) and under different circumstances personality traits like P, E, and N may lead to behaviors quite different from criminality, such as excellence in sports or in military service. Nevertheless, it would be foolish not to consider genetic factors in discussing the causes and cures of criminality.

Other psychosocial variables strongly influenced by genetic factors are sexual libido, satisfaction, and behavior generally (H. J. Eysenck, 1976). Here, too, the relationship seems to be mediated by personality factors P, E, and N. Psychiatric disorders like anxiety and depression are also strongly determined by genetic factors, notably P, E, and N (H. J. Eysenck, 1987). It would probably be difficult to find *any* psychosocial variable not influenced or determined to a large extent by hereditary variables and mediated by personality.

One further topic of interest here is the heritability of some of the traits which go to make up P, E, and N. Analyses have been done on impulsive and sensation-seeking behavior (H. J. Eysenck, 1983a) and on altruism and aggression (Rushton, Fulker, Neale, Nias, & H. J. Eysenck, 1986). For these lower level factors, as for P, E, and N, a combination of V_A and V_{EW} seems sufficient to account for the observed data with considerable accuracy. Here too there is no evidence of common environment (V_{EB}), so that environmental variation, insofar as it exerts an influence at all, is within-family and not between-family. Again the contribution of genetic factors, $i.e.$, V_A , is very high, falling in line with the genetic analysis of higher order factors.

Fulker (1981) suggests the interesting possibility that much of V_{EW} , after correction for unreliability, might also have a constitutional basis. His argument may be summarized as follows. He points out that this suggestion might at first appear illogical because, although genetic factors must clearly originate at a constitutional level, environmental influences necessarily arise external to the organism. However, as he goes on to state, "The effect of the environment may still be to modify the individual's constitution, especially if acting at an early developmental period, perhaps even before birth. Accidental factors affecting neural and hormonal balance during pregnancy, for instance, would most likely appear in our model as V_{EW} effects, rather than in those associated with V_{EB} . The effects of illness may similarly result in constitutional differences and be reflected in V_{EW} variation" (p. 89).

The transfusional syndrome in identical twins might be taken as a particularly good and prominent example of the constitutional but nongenetic influences that would emerge in analysis as V_{EW} . In this syndrome, the blood supply through the placenta passes through the first twin before it reaches the second, and in a number of cases is qualitatively worsened in the process, thus affecting the second but not the first twin in the direction of reducing his/her birth weight, intelligence, etc. Thus, it is important to note that while V_{EW} influences are environmental, they are not necessarily under the control of society, thus restricting even more the possibility of influencing differences in personality between people by direct social action, schooling, and so forth. This important consideration has been insufficiently taken into account in most discussions of the genetic and environmental influence on personality and intelligence, respectively.

Criticisms of the Paradigm

Some criticisms have been made of the approaches discussed in this article. The first objection, based on philosophical rather than scientific considerations, maintains that the underlying hypothesis that the behavior to be analyzed is determined exclusively by genetic, environmental, and interactional factors, is wrong, and that additional factors should be taken into account. It is never made clear what these factors might be, how they could be discovered, or what consequences could be tested that might flow from this hypothesis. Consequently, as a philosophical objection, it cannot be tested and hence is scientifically "beyond the pale." Its status might be similar to that of the Holy Ghost in scripture, whose definition has defied exegesis. No useful purpose is served in attempting to deal with criticisms of this type.

A more reasonable criticism is that MZ twins are demonstrably treated more alike (e.g., dressed alike) than DZ twins, and their similarity in intelligence and personality may be due to this treatment, rather than to genetic factors. Loehlin and Nichols (1976) have shown that when twins who are treated very much alike are compared with twins who are not treated in this fashion, similarities in intelligence and personality emerged equally for the two groups, thus showing that how twins were treated is irrelevant to the estimate of genetic and environmental influences. A recent study by Rose et al. (1988) suggests that "social contact" between twins might form an exception to this rule.

With adoption studies, it has been maintained that agencies try to fit the personality and intelligence of the baby to that of the adoptive parents, and this is certainly true to some extent. However, it is difficult to assess the personality and intelligence of babies with any degree of accuracy, and in any case the degree of success would only reduce the determination of genetic influences, by increasing the environmental correlation between adoptive parents and adopted children. Thus if there is an error involved in the methodology, it would err on the conservative side and would lead to an underestimation of heritability.

There are many complexities in the statistical treatment of the data here considered, and the possibility of misinterpretation is ever-present. However, these issues are too technical to be treated in a short article, and the reader is invited to consult Eaves et al. (1989). Minor details might be open to different interpretations, following different assumptions, but the major results of the large-scale studies discussed here are hardly in doubt, and would not be altered by any reasonable alternative assumptions on which analyses might be based.

CONCLUSION

In summary, it may be useful to repeat some of the major points discussed in this article. The biometrical genetic analysis of phenotypical data is not only concerned with the genetic aspects of causation, but equally with environmental aspects, indeed, the one has no meaning without the other, and the concern of researchers is with the analysis of the total phenotypic variance into its component parts, whether genetical, environmental, or interactional. The assessment of heritability itself is only one, and may not be the most important aim of such an analysis, which is essentially intended to reveal the architecture of the major determinants of phenotypical behavior. The methods used today require very large samples of twins and employ a method of model fitting in which various different models incorporating different genetic and environmental aspects are postulated and then tested against the observed data. Models are rejected or accepted provisionally according to the degree to which they fit the data.

General findings from the major, large-scale analyses conducted recently and analyzed according to state-of-the-art methodology verify conclusions from previous research suggesting the great importance of genetic factors in determining differences in personality, but they go well beyond these early findings in the more detailed analysis of the factors involved. On the genetic side, inherited variance (V_A) is by far the most important component, providing little evidence for assortative mating or for dominance (except in the case of Extraversion). On the environmental side, contrary to the confident expectation of most personality theorists, between-family environmental factors (V_{EB}) have almost no influence on differences in personality, whereas within-family environmental factors (V_{EW}) account for practically all the nonerror variance left over. In the case of social attitudes, the very strong degree of assortative mating may be mistakenly interpreted as evidence for V_{EW} , but in the case of the major personality factors P, E, and N, the absence of such assortative mating makes any such misinterpretation unlikely. It should be noted, however, that environmental factors due to V_{EW} may nevertheless be constitutional, i.e., not susceptible to social influences.

Students of personality have often neglected to look at genetic studies because of a lack of interest in biological factors and a desire to influence the development of children's personalities through social action. In doing so they have developed personality theories which implicate

between-family environmental factors as being responsible for the most part in causing individual differences in personality, without considering that simple parent-offspring correlations can be interpreted in alternative ways. The genetic evidence seems to be conclusive in disproving the importance of between-family environmental factors and in asserting that environmental influences are not due to shared environments, but are essentially of a unique and accidental kind clearly defined as within-family environmental variance. This finding alone makes it essential for personality theorists to consider seriously the contribution made by genetic analyses, and will certainly require a drastic reshaping of personality theories in the future. In addition, any future research in this field aimed at uncovering causal relations will need to employ the paradigms and designs of psychometrical behavioral genetics, as only they contain explicitly all the genetic and environmental influences which may determine development of personality, either singly or jointly.

Finally, it follows from this analysis that students of psychology should be taught the principles of behavioral genetics, its methods of analysis, and its major findings. If indeed genetic factors account for more than half of all the influences which shape intelligence and personality, it would be unrealistic to teach theories of intelligence and personality without providing students with the methodologies required to sort out causal influences on these variables.

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