Psychoticism as a Dimension of Personality: A Multivariate Genetic Test of Eysenck and Eysenck's Psychoticism Construct

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In this study, we applied multivariate genetic analysis, a generalization of factor analysis and behavior genetic analysis, to responses to items of the Psychoticism scale of the Eysenck Personality Questionnaire by 2,903 adult same-sex Australian twin pairs. Item loadings on genetic, shared environmental, and nonshared environmental common and specific factors were estimated. The genetic factor structure differed considerably from the environmental structures, particularly in men. The genetic correlation between suspiciousness items and items reflecting unconventional or tough-minded attitudes or hostility to others was negative, but the environmental correlation was positive. Thus, conventional behavior genetic studies that have reported significant heritability of psychoticism, on the basis of analyses of scale scores, are misleading as to what trait is being inherited.

In the Eysenckian personality scheme (H. J. Eysenck, 1981; H. J. Eysenck & S. B. G. Eysenck, 1976; H. J. Eysenck & M. W. Eysenck, 1985), psychoticism constitutes the third personality dimension, orthogonal to extraversion and neuroticism. It is conceptualized as a continuum of liability to psychosis (principally schizophrenia and bipolar affective disorder) with "psychopathy" (i.e., anti-social behavior) defined as "a halfway stage towards psychosis" (H. J. Eysenck & S. B. G. Eysenck, 1976, p. 203). Thus, schizophrenics, bipolars, and psychopaths are viewed by H. J. Eysenck and S. B. G. Eysenck (1976) as being different only in degree, rather than qualitatively, from normals, with the single personality dimension of psychoticism differentiating normals from psychopaths (intermediate in psychoticism) and from schizophrenics and bipolars (extreme in psychoticism). Self-report questionnaire scales have been developed (H. J. Eysenck & S. B. G. Eysenck, 1975, 1976; S. B. G. Eysenck, H. J. Eysenck, & Barrett, 1985), including a children's version (H. J. Eysenck & S. B. G. Eysenck, 1975), that attempt to measure psychoticism. High scorers on the Psychoticism (P) scale are conceptualized as "cold, impersonal, lacking in sympathy, unfriendly, untrustful, odd, unemotional, unhelpful, antisocial, lacking in insight, strange, with paranoid ideas that

people were against him" (H. J. Eysenck & S. B. G. Eysenck, 1976, p. 47). Prisoners, schizophrenics, alcohol and drug abusers, and children reporting many antisocial behaviors have all been reported to show elevated P scores (reviewed in H. J. Eysenck & S. B. G. Eysenck, 1976).

Key evidence cited by H. J. Eysenck and S. G. B. Eysenck (1976) in support of the psychoticism construct is derived from genetic studies. Family and adoption studies (e.g., Heston, 1966; Kety, Rosenthal, Wender, & Schulsinger, 1968; Mednick, Schulsinger, Higgins, & Bell, 1974; Odegard, 1963) have found increased risk of psychopathy, criminality, alcoholism, various personality disorders, not just schizophrenia in the biological relatives of schizophrenics. Unfortunately, such data are open to alternative interpretations. H. J. Eysenck and S. G. B. Eysenck's interpretation is that they provide evidence for a common dimension of genetic predisposition to psychosis and psychopathic or antisocial behavior and that it is this dimension of heritable liability that is assessed by the P scale. Equally plausible is the interpretation that predispositions to schizophrenia, antisocial personality, and other disorders are biologically independent but that there is cross-assortative mating (e.g., an increased likelihood that a schizophrenic woman will become pregnant by an antisocial man; Gottesman & Shields, 1976; Mednick, 1974).

The assumption of a single personality continuum that determines liability to psychopathy, schizophrenia, and bipolar disorder; the heterogeneous nature of groups scoring high on the P scale; and the relatively weak evidence that schizophrenics obtain higher scores have stimulated considerable criticism of the P scale (Bishop, 1977; Block, 1977a, 1977b). Nonetheless, when traditional factor analytic and behavioral genetic methods, as commonly applied in personality research (e.g., Eaves, Eysenck, & Martin, 1989; Fulker, 1981), have been used with the P scale, results have been broadly consistent with H. J. Eysenck and S. B. G. Eysenck's predictions. Factor analyses of the Eysenck Personality Questionnaire (EPQ) that estimate four common factors are usually able to recover a fourth factor with

loadings consistent with the psychoticism construct (e.g., H. J. Eysenck & S. B. G. Eysenck, 1976; S. B. G. Eysenck et al., 1985; Heath, Jardine, Eaves, & Martin, 1988): suspiciousness ("paranoid") items, tough-minded or hostile ("antisocial") items, and items relating to unconventional attitudes and behavior all have positive loadings on the Psychoticism factor. It is only when more than four factors are extracted that psychoticism breaks down into several factors, which are only modestly correlated in an oblique solution (Heath et al., 1988). The large-sample twin studies that have obtained data on the P scale have reported that P scores are moderately heritable (Eaves & H. J. Eysenck, 1977; Eaves & Young, 1981; Eaves et al., 1989; Fulker, 1981; Martin & Jardine, 1986; Young, Eaves, & Eysenck, 1980). Thus, conventional psychometric and behavioral genetic studies of the P scale using general population samples have shown results that appear consistent with the psychoticism construct formulated by H. J. Eysenck and S. B. G. Eysenck.

Conventional genetic studies of personality traits, including the previously cited studies of psychoticism, compute correlations between twin pairs or other relatives for scale scores, obtained as the weighted (or unweighted) sum of responses to a number of items (e.g., Eaves et al., 1989; Fulker, 1981). Implicit in this approach is the assumption that the observed ("phenotypic") personality structure and the underlying genetic and environmental structures are not qualitatively different. More precisely, it is assumed that phenotypic common factor loadings and corresponding genetic common factor loadings differ only by a scale factor (Heath, Neale, Hewitt, Eaves, & Fulker, 1989). To the extent that such differences are present, they must be taken into account in any discussion of the heritability of psychoticism. In the extreme case, the underlying genetic and environmental structures may differ so markedly that the genetic common factor loadings and the environmental common factor loadings are uncorrelated. Under those conditions, the concept of heritability would no longer be applicable at the trait level, only at the item level.

Genetic item analysis has been proposed as an alternative to the traditional methods for analyzing the influence of heredity on personality. Most applications have involved univariate analyses of individual items (Heath, Jardine, Eaves, & Martin, 1989; Horn, Plomin, & Rosenman, 1976; Jardine, 1985; Loehlin, 1965, 1986; Loehlin & Nichols, 1976; Neale, Rushton, & Fulker, 1986). Genetic analyses of responses to single items of the P scale (Heath, Jardine, Eaves, & Martin, 1989; Jardine, 1985; Neale et al., 1986) have confirmed significant heritability of most—but not all—of the items that constitute the P scale, and thus they appear to lend support to the psychoticism construct. Differences in item heritability can arise, however, through differences in item reliability, in item loadings on one or more underlying genetic common factors, or in item-specific genetic influences (Heath, Jardine, Eaves, & Martin, 1989). Univariate genetic item analysis, because it ignores the information contained in the intertwin, interitem correlations about genetic and environmental correlations between item responses, cannot resolve these different possibilities. Support for the psychoticism construct from such analyses is therefore only indirect.

Multivariate genetic analysis (Eaves, Martin, & Eysenck, 1977; Martin & Eaves, 1977), a generalization of factor analysis

and behavior genetic analysis, permits the estimation of separate genetic and environmental common and specific factor loadings from data on twin pairs or other genetically informative relatives. When applied to items rather than scale scores (e.g., Kendler, Heath, Martin, & Eaves, 1987), this method does use all of the information contained in the intertwin and the intratwin (i.e., phenotypic), interitem correlations and thus avoids some of the pitfalls of univariate genetic item analysis. It also relaxes the strong assumptions about the underlying genetic and environmental factor structures implied by the conventional genetic analysis of scale scores.

In this study, therefore, we applied multivariate genetic item analysis to the largest available data set, that of Martin and Jardine (1986), which consists of the responses of 2,903 adult same-sex twin pairs to the items of the P scale. We attempted to replicate the phenotypic factor structure predicted for these items by H. J. Eysenck and S. B. G. Eysenck (1976) and to examine whether this phenotypic factor structure reflects similar underlying genetic and environmental factor structures. Our results show a marked lack of correspondence between the dimensions of genetic variation that are influencing the P scale and the personality construct *psychoticism*, particularly in men. These findings illustrate how conventional behavioral genetic analyses of personality scores and conventional univariate genetic item analyses can sometimes be misleading.

Method

Sample

Health questionnaires, including the Eysenck Personality Questionnaire (H. J. Eysenck & S. B. G. Eysenck, 1975), were mailed to 5,967 adult twin pairs (minimum age of 18 years) registered with the Australian National Health and Medical Research Council Twin Registry. Replies were received from both members of 3,810 pairs (64% pairwise response rate). The pairs comprised 1,233 monozygotic (MZ) female, 567 MZ male, 751 dizygotic (DZ) female, 352 DZ male, and 907 unlike-sex pairs. We determined zygosity on the basis of responses to a brief two-item questionnaire. Use of such questionnaires has been found to give a misclassification rate of less than 5% when compared with the results of blood typing (e.g., Martin & Martin, 1975; Nichols & Bilbro, 1966). Because the twins were, with rare exception, reared in the same household, there is always the possibility of special twin environment effects that could limit the generalizability of our findings. For personality variables, however, reasonable agreement has been found between the results of studies of twins reared apart, twins reared together, adoptees, and intact nuclear families (e.g., Eaves et al., 1989; Eaves & Young, 1981; Scarr, Webber, Weinberg, & Wittig, 1981; Tellegen et al., 1988), implying that such effects are not of major importance.

Data Summary

We computed summary statistics separately for each same-sex zygosity group. Computing resources were insufficient to permit either use of the unlike-sex pairs or simultaneous analysis of the male and female data in the multivariate genetic analysis. For each twin pair, there were 51 observations: the responses of the first twin to each of the 25 items of the EPQ P scale, the responses of the second twin to these items, and the age of the twin pair. Twins were designated as first and second members of a pair either on the basis of reported birth order or, when this information was lacking, at random. We computed tetrachoric cor-

relations (Jöreskog & Sörbom, 1985; Olsson, 1979) between every pair of observations (excluding age) using maximum-likelihood analysis. Biserial correlations (Jöreskog & Sörbom, 1985; Olsson, Dragsow, & Dorans, 1982) were computed between age and every other observation. Thus, the data summary for each twin group consisted of a 51 × 51 matrix of tetrachoric and biserial correlations.

Estimation of tetrachoric and biserial correlations implies the assumptions that the dichotomous observed response distribution for a given P scale item is determined by an underlying latent personality variable whose distribution is continuous and normal and that the distribution of the latent personality variable in twin pairs is bivariate normal. This is consistent with Eysenck's personality theory (Eaves & H. J. Eysenck, 1977; H. J. Eysenck, 1981; H. J. Eysenck & S. B. G. Eysenck, 1976), which assumes that the population distribution of the psychoticism construct is continuous and normal. Because of the low endorsement frequency of some P scale items (H. J. Eysenck & S. B. G. Eysenck, 1976), our estimates for some of the tetrachoric and biserial correlations may be biased, even with the large sample sizes available in our study (Olsson, 1979; Olsson et al., 1982). This is potentially a problem for correlations involving Items P4, P7, and P16, for which endorsement frequencies in the "high P" direction were less than 5% in both sexes (Jardine, 1985).

Data Analyses

For comparison with other factor analytic studies, a conventional one-factor model was fitted initially, separately for men and for women, ignoring the twin structure of the data. For these analyses, four 25 × 25 matrixes of phenotypic (i.e., within subjects) tetrachoric correlations (for first vs. second members of MZ vs. DZ twin pairs) were used. A single set of factor loadings was estimated from the four matrixes of correlations, using LISREL (Jöreskog & Sörbom, 1985), by unweighted least squares. As an additional index of the phenotypic heterogeneity of the P scale, we rescored all items so that a positive response was associated with high psychoticism, and the mean and range of the interitem correlations was computed: A low mean interitem correlation and a large range would indicate possible heterogeneity (Briggs & Cheek, 1986).

Multivariate genetic models were fitted to the full 51 × 51 matrixes of correlations by unweighted least squares (Jöreskog & Sörbom, 1985) using a user-written program that permits constrained optimization. Model fitting by unweighted least squares provides no test of the goodness-of-fit of a model. We therefore fitted models separately to the male same-sex and to the female same-sex data so that replication (or failure of replication) across sexes would provide a gross indication of the robustness of any findings. Multivariate genetic analysis may be viewed as a generalization of genetic analysis (e.g., Eaves & H. J. Eysenck, 1975; Jinks & Fulker, 1970) and of factor analysis (e.g., Harman, 1976), which permits simultaneous estimation of genetic and environmental factors (Eaves et al., 1977; Kendler et al., 1987; Martin & Eaves, 1977). Whereas a conventional factor analysis uses only within-subjects (phenotypic) correlations, multivariate genetic analysis exploits the additional information contained in the correlations and cross-correlations between item responses of MZ and DZ twin pairs.

Figure 1 illustrates a simple multivariate genetic model, called by convention the one-factor model. As in a conventional genetic analysis, the model distinguishes between genetic effects, environmental effects shared by twins reared in the same family, and unique environmental effects (i.e., effects not shared by twins in the same family, which therefore makes one twin different from his or her cotwin). As in a factor analysis, the model also distinguishes between common factors, which contribute to the correlations between items, and item-specific factors, which contribute to the variance in an item but not to its covariance with other items. Genetic and environmental loadings are constrained

to be the same in first and second twins from each pair and in twins from MZ and DZ twin groups; however, the correlation between corresponding latent genetic factors in first and second twins will be unity in MZ twins who are genetically identical and .5 in DZ twins who on the average share half of their genes (Kendler et al., 1987; Martin & Eaves, 1977). Changing the genetic correlation between DZ twins to .5 implies the assumptions of purely additive gene action, which is consistent with the results of our univariate genetic analyses of the P scale items (Heath, Jardine, Eaves, & Martin, 1989) and random mating for psychoticism. Whereas the latter assumption is not strictly correct, the low marital correlations (<.20) that have been observed for P scores (Eaves et al., 1989; Young et al., 1980) would imply a slight effect of assortative mating on family resemblance for psychoticism.

We estimated item-specific loadings rather than item-specific variances, thus constraining the genetic, shared environmental, and unique environmental item-specific variances to be nonnegative. For our purposes, the item-specific loadings may be regarded as nuisance parameters: Our primary interest was in those genetic and environmental influences that the items of the P scale share and that supposedly relate to the psychoticism construct (i.e., in the genetic, shared environmental, and unique environmental common factor loadings). In the analyses that we report, we obtained zero estimates for the item-specific genetic loading for some items and for the item-specific shared environmental loading for other items for each sex. A zero estimate of an item-specific genetic loading would imply that the residual MZ twin correlation for that item, after partialing out the genetic and environmental common factor variance, is equal to or less than the residual DZ twin correlation. A zero estimate of an item-specific shared environmental loading would imply that the residual MZ twin correlation is greater than or equal to one half of the residual DZ twin correlation and would raise the possibility of item-specific genetic dominance or epistasis for some items (e.g., Eaves, 1970; Heath, Jardine, Eaves, & Martin, 1989; Martin,
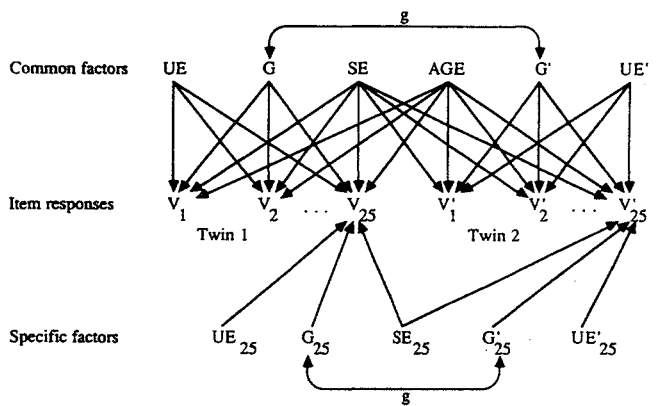
Figure 1. One-factor multivariate genetic model for twin data. (V = item response of first twin of each pair. V' = item response of second twin. Subscript numerals [e.g., 1, 2, $\cdots$ 25] = items on the Psychoticism scale. UE = unique environmental common factor of first twin. G = genetic common factor of first twin. SE = shared environmental common factor. UE' = unique environmental common factor of second twin. G' = genetic common factor of second twin. AGE = age common factor. g = Correlation between genotypes [for monozygotic pairs, g = 1; for dizygotic pairs, g = .5]. UE_{25} and G_{25} denote unique environmental and genetic specific factors for Item 25 of the first twin. SE_{25} = shared environmental factor for Item 25. G'_{25} and UE'_{25} denote genetic and unique environmental specific factors for Item 25 of the second twin. Specific factors are included for the 25th item only in order to simplify the diagram.)

Eaves, Kearsey, & Davies, 1978). In a multivariate genetic analysis, the genetic and shared environmental item-specific loadings are estimated with less precision than are the common factor loadings: Information about the latter is principally derived from the $n(n-1)$ intertwin, inter-item correlations for each twin group (where there are n items in a scale), but information about the item-specific loadings depends heavily on the univariate twin correlations for each item. Thus, the zero-specific loadings we obtained for some items may merely reflect the imprecision of our estimates of the univariate twin tetrachoric correlations for those items. We refitted the one-factor model, estimating item-specific genetic and environmental variances instead of loadings, relaxing the constraint that these variances be nonnegative. This produced a negligible change in the common factor loadings (less than ± .02 in all cases for the female pairs, less than ± .03 in all cases for the male pairs), so the results of these analyses are not presented here.

In addition to item loadings on common and specific genetic, shared environmental, and unique environmental factors, we estimated simultaneously loadings on an "age" factor, on which age has a loading fixed to unity, in order to permit concurrent age correction of the data (Neale & Martin, 1989). Published factor analyses of the EPQ have ignored this problem of age correction (e.g., H. J. Eysenck & S. B. G. Eysenck, 1976), but because some items of the P scale exhibit marked changes in endorsement frequency with age, we considered it important to control for these effects.

As in a factor analysis, it is possible in a multivariate genetic analysis to estimate two or more sets of common factors simultaneously (i.e., two genetic, two shared environmental, and two unique environmental common factors). Because estimation of too few common factors will lead to biased parameter estimates, we compared results from one-, two-, and three-factor solutions. In the three-factor solution in women, genetic and environmental loadings had to be constrained to ensure a non-negative specific environmental variance for one item ("Was your mother a good woman?"). This may result from overextraction of factors, or alternatively, it may reflect the imprecision of the estimated tetrachoric and biserial correlations involving that item (which was one of the three items with an extremely low endorsement frequency in the high-P direction). We did not attempt to obtain estimates with four or more sets of common factors. In analyses involving estimation of two or more sets of common factors, genetic, shared environmental, and unique environmental common factors were separately rotated according to varimax criteria (Harman, 1976).

Results

Phenotypic Analyses

Table 1 shows the factor loadings obtained when a traditional one-factor phenotypic factor model was fitted, ignoring the twin structure of the data. The sign of the factor loadings predicted by H. J. Eysenck and S. B. G. Eysenck (1976) is also given in the table. In both sexes and for all items, the sign of the observed factor loadings was in the predicted direction. Items with the highest loadings on the factor were those relating to tough-minded attitudes and hostility toward others (i.e., "upset to see child/animal suffer"; "Enjoys hurting loved ones"; "Would like people to be afraid of you") and unconventional attitudes and behavior (i.e., "Would take drugs with strange or dangerous effects"; "Good manners, cleanliness matter"; "Marriage old-fashioned"; "Mother a good woman"). Suspiciousness items (e.g., "Enemies want to harm you"; "Several people avoiding you"; "Friendships break up easily"; "People tell you a lot of lies") also have the predicted positive loadings on the factor. Loadings for Items P4, P7, and P16, which have very low en-

dorsement frequencies, which in turn could lead to biased estimates of tetrachoric correlations involving these items, appear comparable to other items having higher endorsement frequencies.

Interitem phenotypic correlations were somewhat low for the P scale (Ms = .14 and .15 for men and women, respectively). The lowest correlations were −.12 and −.13; the highest correlations were .67 and .70. These values were higher than the .10 average correlation that Fiske (1971) reported for the typical personality test. (Note, however, that we are reporting polychoric correlations, which will take somewhat higher values than the product–moment correlations that have usually been reported.) Out of the 25 items that constitute the P scale, 6 had phenotypic factor loadings less than .3 in both sexes (P1, P2, P3, P13, P15, and P20), and 2 had a low loading in one sex (P5 and P14). Some of these 8 items have questionable relevance to H. J. Eysenck and S. B. G. Eysenck's (1976) psychoticism construct, and several (P3, P5, and P20) have indeed been deleted in a subsequent revision of the P scale (S. B. G. Eysenck et al., 1985). Deletion of the 8 items raises the phenotypic inter-item correlations to an "acceptable" value for a personality scale (Briggs & Cheek, 1986), of .21 in women and .18 in men.

Genetic Analyses

Also shown in Table 1, for comparison with our multivariate results, are the individual item heritabilities, which were derived from univariate genetic item analyses, reported for this same data set by Jardine (1985; Heath, Jardine, Eaves, & Martin, 1989). All items yielded positive heritability estimates with the exception of P9 and P16 (men only). There was a modest, nonsignificant correlation between the absolute loading of an item and its heritability in the Australian sample (rs = .21 and .31 in men and women, respectively).

Table 2 shows the loadings on genetic and environmental common and specific factors in the one-factor multivariate genetic solution. In both sexes, we observed distinct patterns of item loadings on the genetic, shared environmental, and unique environmental common factors. Each pattern of common factor loadings showed good consistency across sexes. In interpreting these loadings, remember that because we were partitioning phenotypic variance into genetic, shared environmental, and nonshared environmental sources, genetic and environmental common factor loadings will generally be smaller than those observed in the conventional phenotypic factor analysis. Indeed, for some items the estimated loadings were surprisingly small.

The genetic common factor had negative loadings on suspiciousness items and also had negative (not positive) loadings on items relating to cautious, conforming behavior and punctuality, and conventional or tender-minded attitudes and lack of hostility. This pattern was seen most clearly in men. Four of the five items with the highest negative loadings on the genetic common factor in male subjects related to suspiciousness (i.e., "Several people avoiding you"; "People tell you a lot of lies"; "Enemies want to harm you"; "Friendships break up easily"). Items relating to worry about being in debt, concern for a child or animal that is suffering, conventional attitudes (e.g., "Good manners, cleanliness matter"), punctuality, and cautious behavior (e.g., "Locks up carefully at night") also had substantial neg-

Table 1

Factor Loadings Under One-Factor Solution, Predicted Sign of Loadings, and Item Heritability Estimates

Psychoticism (P) scale item	Predicted loadings	Male loadings	Female loadings	Item heritability %
P1 Thinks things over before doing anything	—	−29	−22	32
P2 Would be worried if in debt	—	−22	−20	33
P3 Locks up carefully at night	—	−25	−17	23
P4 Upset to see child/animal suffer	—	−39	−54	59
P5 Insurance schemes good idea	—	−18	−34	26
P6 Would take drugs with strange or dangerous effects	+	38	58	71
P7 Enjoys hurting loved ones	+	64	55	51
P8 Enemies want to harm you	+	49	51	37
P9 Enjoys hurtful practical jokes	+	43	53	0
P10 Good manners, cleanliness matter	—	−57	−43	52
P11 Marriage old-fashioned	+	37	54	54
P12 Annoyed by careful drivers	+	30	35	40
P13 Most things taste same	+	23	27	39
P14 Worried if mistakes in work	—	−31	−17	28
P15 Arrive at appointments in good time	—	−28	−25	46
P16 Mother a good woman	—	−58	−38	F = 41, M = 0
P17 Several people avoiding you	+	36	41	39
P18 Against savings and insurance	+	30	42	35
P19 Tries not to be rude to people	—	−42	−31	33
P20 Arrives at last minute for train	+	25	25	53
P21 Friendships break up easily	+	36	31	44
P22 Sometimes likes teasing animals	+	32	38	32
P23 Would like people to be afraid of you	+	59	66	43
P24 People tell you a lot of lies	+	37	33	50
P25 Would feel sorry for animal caught in trap	—	−30	−33	51

Note. Predictions are by H. J. Eysenck & S. B. G. Eysenck (1976). Heritability estimates are as reported for this sample by Jardine (1985). F = heritability in females and M = heritability in males in items for which a sex difference in heritability was found. Decimal points have been omitted.

ative loadings on the genetic common factor. Yet, under H. J. Eysenck and S. B. G. Eysenck's (1976) hypothesis, the loadings of these items should be opposite in sign to the loadings of the suspiciousness items. The sign of items loading on the genetic factor in women paralleled, with rare exception, that observed in men, again contrary to what would be predicted under H. J. Eysenck and S. B. G. Eysenck's (1976) hypothesis. Loadings of the suspiciousness items were somewhat smaller in absolute value in women than in men (−.19 to −.33 for women compared with −.35 to −.50 for men). Loadings of items reflecting conventional attitudes (i.e., "Good manners, cleanliness matter"; "Marriage NOT old-fashioned"), cautious and conforming behavior ("Would NOT take drugs with strange or dangerous effects"; "Insurance schemes a good idea"; "NOT against savings and insurance"), and punctuality were somewhat higher in absolute value in women than in men, but once again negative and thus of the same sign as the suspiciousness items.

As a gross measure of the similarity of the phenotypic factor structure (see Table 1) and the underlying genetic factor structure (see Table 2), we computed product–moment correlations between the phenotypic common factor loadings and the genetic common factor loadings. In male subjects, the correlation between phenotypic factor loadings and genetic factor loadings

was effectively zero ($r = .10$), confirming the marked difference between the phenotypic factor structure and the underlying genetic structure. In female subjects, this correlation was much stronger ($r = .60$). It is principally the genetic loadings of the suspiciousness items that were inconsistent with the phenotypic factor structure, as can be seen by comparing the sign of the loadings in Table 2 with the predicted sign in Table 1.

The *shared environmental* common factor was a tough-minded hostility factor. In both sexes, items concerning indifference to suffering (i.e., "NOT upset to see child/animal suffer"; "Would NOT feel sorry for an animal caught in a trap"; "Sometimes likes teasing animals") and hostility toward others ("Enjoys hurting loved ones"; "Would like people to be afraid of you"; "Enjoys hurtful practical jokes"; "Rude to people") had high loadings. In both sexes, the item "Was your mother a good woman?" had a strong negative loading on this factor. In female subjects, the suspiciousness items also had moderately high loadings on this factor, with suspiciousness being positively associated with tough-minded hostility. In male subjects, loadings of the suspiciousness items were in the same direction but were much smaller (.14–.22 for men compared with .24–.42 for women). Loadings of the P items on the shared environmental common factor were somewhat closer to the pattern predicted

Table 2

Genetic and Environmental Factor Loadings Under One-Factor Solution

	Male loadings and specifics							Female loadings and specifics						
	Genetic		Shared environmental		Unique environmental			Genetic		Shared environmental		Unique environmental		
Psychoticism (P) scale item	Common	Specific	Common	Specific	Common	Specific	Age	Common	Specific	Common	Specific	Common	Specific	Age
P1 Thinks things over before doing anything	−15	0	−19	32	−25	88	6	−15	55	−10	0	−22	78	−8
P2 Would be worried if in debt	−37	0	−11	42	−13	80	14	−33	21	−8	42	−2	80	13
P3 Locks up carefully at night	−24	59	−1	21	−20	67	24	−26	24	−7	53	−7	77	−5
P4 Upset to see child/animal suffer	−31	33	−56	0	−9	68	14	−20	0	−70	0	2	66	18
P5 Insurance schemes good idea	−9	35	5	53	−34	69	−1	−29	22	−5	60	−47	53	−8
P6 Would take drugs with strange or dangerous effects	14	0	4	69	24	55	−38	38	60	23	0	34	44	−36
P7 Enjoys hurting loved ones	−11	0	54	0	22	66	−46	13	57	50	0	21	59	−14
P8 Enemies want to harm you	−46	0	22	34	41	65	−19	−19	24	42	0	49	69	−11
P9 Enjoys hurtful practical jokes	5	0	26	50	22	74	−28	2	0	41	47	24	70	−27
P10 Good manners, cleanliness matter	−26	44	−17	0	−44	62	36	−49	0	−22	52	−14	62	21
P11 Marriage old-fashioned	−1	36	9	57	28	63	−25	26	37	23	49	47	50	−14
P12 Annoyed by careful drivers	4	31	6	44	25	79	−14	14	59	7	5	25	70	−25
P13 Most things taste same	4	63	25	0	28	67	12	−8	31	24	0	27	87	10
P14 Worried if mistakes in work	−12	40	−26	0	−18	84	16	−20	45	−12	0	−9	85	−4
P15 Arrive at appointments in good time	−22	0	15	34	−25	78	39	−43	49	8	0	−19	69	25
P16 Mother a good woman	−8	0	−50	57	−31	50	26	−7	69	−43	49	−17	27	3
P17 Several people avoiding you	−50	37	16	1	29	68	−22	−28	0	35	38	44	67	−6
P18 Against savings and insurance	17	42	−2	37	46	67	−3	29	0	8	51	54	60	3
P19 Tries not to be rude to people	−2	49	−34	19	−24	73	12	−11	30	−19	0	−17	91	6
P20 Arrives at last minute for train	17	52	−24	0	25	65	−39	33	57	−10	0	19	68	−23
P21 Friendships break up easily	−35	44	14	0	28	72	−25	−29	56	24	0	39	63	−8
P22 Sometimes likes teasing animals	−3	42	22	48	13	70	−20	−5	34	25	47	12	68	−36
P23 Would like people to be afraid of you	−23	37	27	0	38	70	−33	3	9	46	0	40	68	−39
P24 People tell you a lot of lies	−49	0	16	43	35	64	−15	−33	53	30	12	41	58	−3
P25 Would feel sorry for animal caught in trap	−22	58	−32	0	−6	70	13	−20	73	−33	16	4	73	11

Note. Decimal points have been omitted.

by H. J. Eysenck and S. B. G. Eysenck (1976) than were the genetic common factor loadings, except that loadings relating to conventional attitudes, cautious and conforming behavior, and punctuality were small and in some cases close to zero. Shared environmental common factor loadings were highly correlated with the phenotypic factor loadings (rs = .80 and .88 in men and women, respectively).

The pattern of loadings on the *unique environmental* common factor was again much closer to that predicted under H. J. Eysenck and S. B. G. Eysenck's (1976) hypothesis than was the case for the genetic common factor loadings. For all 25 items in male subjects and all except 2 items in female subjects, the sign of the loading on the unique environmental common factor was in the direction predicted. Suspiciousness items had high positive loadings. So, too, did items expressing unconventional attitudes or behavior, including items expressing opposition to insurance and savings schemes. Only the items concerning indifference to suffering had loadings that were low in both sexes. Unique environmental common factor loadings were again highly correlated with the phenotypic common factor loadings (rs = .92 and .85 in men and women, respectively).

Item-specific genetic, shared environmental, and unique environmental loadings were substantial for many items. Measurement error will contribute to the unique environmental loadings, which we therefore expected to be sizable, but the substantial genetic and shared environmental specific loadings were unexpected. This implies either that the number of common factors had been underestimated or that much of the genetic and shared environmental variance was indeed item specific, perhaps because responses to individual P items were being determined by a variety of different personality traits.

For some items, zero estimates of the item-specific genetic or shared environmental loadings were obtained. As can be seen from Table 2, items having zero estimates of the item-specific genetic loading are not consistent across sexes, suggesting that the cause is imprecision in the original estimates of the univariate twin tetrachoric correlations for those items. Items having a zero estimate for the shared environmental item-specific loading showed greater consistency across sexes (e.g., Items P4, P7, P13, P14, P20, P21, and P23), implying that there may be item-specific genetic dominance or epistasis for these items.

We have also included in Table 2 loadings on the "age-correction" factor. The associations of some of the P scale items with age were substantial. Older respondents gave fewer tough-minded or hostile responses, were more punctual and more cautious and conforming in their behavior, and were more conventional in their attitudes. Older respondents, particularly men, were also somewhat less likely to endorse suspiciousness items, but age effects for these items were less pronounced than for tough-minded, unconventional items.

In multivariate genetic analysis, the pattern of results that we have observed in the one-factor solution, with different genetic and environmental factor structures (as well as substantial specific loadings), can sometimes arise through estimation of too few common factors. However, examination of results in the two-factor and three-factor solutions did not support this interpretation for these data. Common factor loadings from the varimax-rotated three-factor solution are given in Table 3. (Note that specific factor loadings have been omitted.) We caution

against overinterpretation of the fine detail of these results because the P scale was not designed to assess multiple factors. In both sexes, the first genetic common factor had positive loadings on items describing suspicious, punctual, cautious, and conforming attitudes and behavior; the first shared environmental common factor was a tough-minded hostility factor with positive loadings also on suspiciousness items. Thus, factors similar to those obtained in the one-factor solution still emerged. The first unique environmental common factor had high loadings on suspiciousness and hostility items and insurance items (women only) but relatively low loadings on other items and thus was narrower in content than the P factor obtained in the one-factor solution. We found no evidence for a tough-minded hostility genetic factor with positive loadings both on tough-mindedness and hostile items and on suspiciousness items. The second and especially the third common genetic factors showed only moderate replication across sexes (particularly if we excluded the two items relating to insurance and savings, which did have high loadings on the second genetic factor in both male and female subjects). The second and third shared environmental common factors and the second and third unique environmental common factors likewise replicated poorly across sexes. The three-factor solution did not give any better support to the psychoticism construct than did the one-factor solution.

Discussion

Our analyses of the phenotypic interitem correlations, ignoring the twin structure of the data set, revealed that the EPQ P scale is an imperfect instrument (S. B. G. Eysenck et al., 1985). When a single phenotypic factor was estimated, 8 out of 25 items had factor loadings of less than .3 in at least one sex. Interitem correlations averaged less than .2 in both sexes, raising doubts about whether the scale is measuring a single homogeneous construct (Briggs & Cheek, 1986). Nonetheless, all item loadings were of the sign predicted by H. J. Eysenck and S. B. G. Eysenck (1975, 1976). Nothing in the phenotypic analyses prepared us for the etiologic heterogeneity uncovered by the multivariate genetic analyses.

Conventional analyses of twin data using scale scores have shown that the Eysenckian construct of psychoticism, as assessed by the P scale, is moderately (36–50%) heritable (Eaves & H. J. Eysenck, 1977; Martin & Jardine, 1986; Young et al., 1981). In their analysis of this same data set, Martin and Jardine (1986) reported the heritability of psychoticism to be 36% in female subjects and 50% in male subjects. The methods used in those analyses have been routinely employed in behavior genetic studies of personality as well as of cognitive and attitudinal variables (see reviews by Eaves et al., 1989; Fulker, 1979, 1981). Univariate genetic item analyses of the P scale have confirmed the heritability of most items of the P scale (Heath, Jardine, Eaves, & Martin, 1989; Jardine, 1985; Neale et al., 1986): Only Items P9 and P17 (in men) in the Australian sample (Heath, Jardine, Eaves, & Martin, 1989; Jardine, 1985; see Table 1) and Items P2 and P17 in the smaller English sample of Neale et al (1986) have yielded no evidence of genetic influence. The univariate genetic analyses failed to identify homogenous subgroups of P scale items, differing in average heritability, that

Table 3
Genetic and Environmental Common Factor Loadings Under Three-Factor Varimax-Rotated Solution

Psychoticism (P) scale item	Male loadings Genetic			Shared environmental			Unique environmental			Female loadings Genetic			Shared environmental			Unique environmental		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
P1 Thinks things over before doing anything	7	−1	−10	−1	1	−30	−8	37	−7	−2	−1	−7	1	13	0	−7	−34	22
P2 Would be worried if in debt	27	1	−8	−2	21	−1	12	43	−13	14	−14	−23	6	11	3	1	1	37
P3 Locks up carefully at night	22	−13	9	1	13	3	−7	14	−14	9	−6	−7	3	19	17	−2	−18	18
P4 Upset to see child/animal suffer	−5	−1	24	−7	45	−16	−1	45	31	1	−9	−14	68	24	−13	1	−16	−19
P5 Insurance schemes good idea	−7	−57	−2	−3	−1	18	1	31	3	7	−42	−5	−12	17	−10	−32	−13	10
P6 Would take drugs with strange or dangerous effects	−16	27	−8	10	−6	0	11	−5	8	−5	47	2	−6	−23	6	2	44	2
P7 Enjoys hurting loved ones	2	13	3	57	−24	25	21	−5	−11	0	11	2	−50	−9	12	15	32	−4
P8 Enemies want to harm you	29	−4	6	32	−8	−17	61	0	20	18	−1	13	−21	−30	29	41	20	27
P9 Enjoys hurtful practical jokes	0	14	−9	−5	−11	27	38	3	3	9	−1	6	−32	−13	14	20	23	−14
P10 Good manners, cleanliness matter	31	−19	0	−22	10	−9	−27	35	−7	22	−24	−5	5	41	−2	5	−16	33
P11 Marriage old-fashioned	−6	34	12	22	−17	−12	15	2	9	4	52	20	−10	−8	27	17	30	−1
P12 Annoyed by careful drivers	−5	18	−6	2	10	21	20	−6	4	−8	4	−13	−4	0	12	8	40	−6
P13 Most things taste same	10	9	1	2	−5	51	18	−15	14	14	−3	−4	−13	−12	13	18	21	−4
P14 Worried if mistakes in work	−10	1	1	−3	22	−19	11	41	−37	4	−9	−11	4	7	−15	−7	4	51
P15 Arrive at appointments in good time	41	−14	44	−23	−7	6	−3	7	−24	72	−2	−5	−2	0	−28	−3	−31	3
P16 Mother a good woman	9	−15	9	−51	51	−16	−19	14	−1	−4	−22	73	36	44	−14	−26	9	5
P17 Several people avoiding you	38	3	−10	44	−1	−16	24	1	30	27	−30	15	−10	−39	20	46	20	16
P18 Against savings and insurance	−2	55	−2	−4	−6	−11	9	−33	11	−9	38	3	13	−21	8	54	6	−21
P19 Tries not to be rude to people	0	−16	−5	−19	6	25	−30	18	25	−10	−17	−5	14	0	−5	−3	−26	14
P20 Arrives at last minute for train	−48	10	−45	19	27	1	4	2	40	−56	−3	2	3	−1	16	6	32	6
P21 Friendships break up easily	33	13	−12	37	12	5	7	−9	20	26	−3	7	−11	2	34	33	11	12
P22 Sometimes likes teasing animals	24	4	−42	−15	−12	20	27	3	4	2	−5	0	−26	11	15	21	11	−10
P23 Would like people to be afraid of you	10	−2	−6	28	5	16	58	−12	−2	3	12	−4	−34	−10	37	28	25	−5
P24 People tell you a lot of lies	40	2	−6	30	10	5	33	−2	27	30	−4	−2	−9	−11	35	41	2	9
P25 Would feel sorry for animal caught in trap	0	14	48	2	40	1	−17	28	22	17	3	0	47	11	22	−11	−14	12

Note. Specific factor loadings and age factor loadings have been omitted.

might have suggested underlying genetic heterogeneity. Only the lack of association that we found between individual item heritability estimates and the item phenotypic factor loadings raised the possibility of the etiologic heterogeneity confirmed by the multivariate genetic analyses.

The results of the multivariate genetic item analysis show that in the case of the EPQ P scale, the conventional analysis of scale scores is misleading. The analyses that we have presented confirm that there are genetic effects common to many (but not all) items of the P scale. It appears, however, that what is inherited bears little relation to the psychoticism construct or even to tough-mindedness (an alternative descriptor of what the P scale measures, offered by H. J. Eysenck & S. B. G. Eysenck, 1975). The pattern of loadings on the first genetic common factor (see Table 2) revealed a combination of suspiciousness, cautiousness, conventional and conforming behavior and attitudes, punctuality, tender-mindedness, and lack of hostility toward others. This combination of traits is perhaps better described as a precursor of paranoid behavior (Claridge, 1981; Claridge & Chappa, 1973) rather than general psychotic behavior.

The shared environmental factor structure of the P scale is different from the genetic factor structure and somewhat different from the unique environmental factor structure. Shared environmental effects would include effects of family background, schooling, peers, and other influences shared by both members of a twin pair. We found no paranoid-predisposing shared environmental common factor to parallel the genetic common factor. Rather, the first shared environmental common factor was a tough-minded hostility factor. Suspiciousness items did have moderate loadings on this factor, but we may suspect that for the individual who endorses the tough-minded, hostile items of the P scale (e.g., "NOT upset to see a child/animal suffer"; "Enjoys hurting loved ones"; "Would like people to be afraid of you"), endorsements of suspiciousness items such as "Are there several people who keep trying to avoid you?" probably have a firm basis in reality. Unexpectedly, even in the two- and three-factor solutions, we failed to obtain a genetic factor having a pattern of loadings similar to the tough-minded, hostile shared environmental common factor.

The unique environmental common factor in the one-factor solution had loadings that were most consistent with the predictions of H. J. Eysenck and S. B. G. Eysenck (1976). Unique environmental effects would include all of the environmental effects that are not shared by members of a twin pair, including measurement error. Thus, it is conceivable that this pattern of loadings reflects merely measurement errors that are correlated across items. Without test–retest data on twin pairs, we were unable to test this possibility.

Several potential artifactual explanations of these findings can be excluded. Differences in heritability of different items or differences in the effects of shared environment or nonshared environment cannot explain the different genetic and environmental structures observed. In univariate item analyses, we were unable to demonstrate differences in overall heritability or in mode of inheritance between different groups of P items (e.g., suspiciousness items vs. tough-minded or hostility items; Heath, Jardine, Eaves, & Martin, 1989; see also Table 1). Furthermore, such differences in item heritability cannot explain why suspiciousness items and items reflecting tough-minded or

unconventional attitudes and behavior or hostility have loadings of the same sign on environmental common factors but loadings of opposite sign on genetic common factors. Biases in the estimated tetrachoric or biserial correlations also do not seem to be a likely explanation of these findings. Sample sizes were large, and loadings of those items having very low endorsement frequencies (i.e., P4, P7, and P16) in the phenotypic factor analysis were in the predicted direction. Furthermore, it was only the genetic common factor loadings, not the phenotypic or environmental common factor loadings, that were in marked disagreement with the predictions of H. J. Eysenck and S. B. G. Eysenck (1976).

In univariate data on twin pairs reared together, estimates of additive genetic and shared environmental parameters are highly negatively correlated, that is, changes in the value of one or the other twin correlation arising through sampling variation alone will tend to inflate one parameter and deflate the other. Resolution of genetic and shared environmental effects in twin data therefore requires large sample sizes of the magnitude used in the present study (Martin et al., 1978). In contrast, the estimate of unique environmental variance is almost uncorrelated with estimates of either the additive genetic or shared environmental parameters (Martin et al., 1978). The problem of correlations between additive genetic and shared environmental parameter estimates will apply a fortiori in multivariate analyses. It does not appear, however, that the correlation between parameter estimates can explain the apparent differences in genetic and environmental structures. If H. J. Eysenck and S. B. G. Eysenck's (1976) hypothesis were correct, we would expect some items to exhibit high genetic common factor loadings and low shared environmental common factor loadings, and others to show the reverse, due to sampling variation alone. There would be no reason, however, to expect that it would be specifically all of the suspiciousness items that load in an idiosyncratic fashion and certainly no reason to expect that these items would have substantial loadings opposite in sign to what had been predicted. Furthermore, if the correlations between parameter estimates were the cause, we would expect not only the genetic factor structure but also the shared environmental common factor structure to differ markedly from the unique environmental structure, contrary to what was found.

Thus, it appears that the structure of genetic influences on the items of the P scale is genuinely different from the structure of environmental influences. This etiologic heterogeneity provides an explanation for the results of analyses of these data where we constrained the genetic and environmental common factor loadings to differ only by a scale factor (Heath, Eaves, & Martin, 1989). In those analyses, we did obtain a pattern of loadings consistent with the psychoticism construct, but the heritability of psychoticism was estimated to be zero both in male and in female subjects. Very different genetic and environmental structures would be expected to produce precisely this result in the constrained analysis, even though there are indeed common genetic effects on the P items.

The heterogeneity of the P scale, confirmed by the analyses in this article, has been criticized by many (e.g., Bishop, 1977; Block, 1977a, 1977b; Claridge, 1981). It is perhaps not surprising, in view of this heterogeneity, that we have uncovered different underlying genetic and environmental structures. The

etiologic heterogeneity of the P scale provides one possible explanation of the diversity of the groups that have been identified as high P scorers. Groups of prisoners, schizophrenics, and alcohol and drug abusers may each have elevated scores, compared with controls, for different reasons. One group may be differentiated genetically, another in family background risk factors. Without information about which items within the P scale discriminate between which groups, differences in overall score will be essentially uninterpretable.

These results do not strictly invalidate H. J. Eysenck and S. B. G. Eysenck's (1976) psychoticism construct. Whether the inheritance of schizophrenia involves one gene (e.g., Kidd & Cavalli-Sforza, 1973; Sherrington et al., 1988) or, as H. J. Eysenck and S. B. G. Eysenck assumed, whether it is multifactorial (e.g., Gottesman & Shields, 1982), and whether it is possible to identify and measure an underlying continuum of liability to schizophrenia remain unresolved. Our findings do contradict the notion that the EPQ P scale, as presently constructed, is able to assess the hypothesized dimension of heritable liability to psychopathy and psychosis: Loadings of tough-minded or hostility items and loadings of suspiciousness items on the genetic common factor are opposite in sign, contrary to the prediction of H. J. Eysenck and S. B. G. Eysenck (1976).

There have been few applications of multivariate genetic item analysis to personality data. For the Extraversion and Neuroticism scales of the EPQ, the phenotypic factor structure does appear similar to the underlying genetic structure, and hence for these variables the results of conventional genetic analyses of scale scores are not misleading (Heath, Eaves, & Martin, 1989). The extent to which other personality measures will exhibit the lack of similarity of underlying genetic and environmental structures that we have uncovered for the P scale remains to be determined.

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