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THE GENETIC STRUCTURE OF PERSONALITY I. PHENOTYPIC FACTOR STRUCTURE OF THE EPQ IN AN AUSTRALIAN SAMPLE

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Summary—The Eysenck Personality Questionnaire was completed by 4874 female and 2746 male Australian adults from the Australian Twin Register. Tetrachoric correlations between item responses were computed by maximum likelihood, and factor analysed. Stable Extraversion, Neuroticism and Social desirability ('Lie') factors were identified. In the four-factor solution, the fourth factor was clearly a Psychoticism factor, which had loadings greater than 0.2 on all but two of the items of the P scale. When more than four factors were estimated, however, this factor progressively split into Unconventional/impulsive behavior, suspiciousness, cruelty and punctuality factors. These P factors were stable across sexes and, in an oblique rotation, only moderately correlated. The factorial heterogeneity of the P scale is overlooked because of under-extraction of factors in the conventional 4-factor solution.

INTRODUCTION

The shift from the factor analysis of questionnaire scales to the factor analysis of questionnaire items has been one of the most important advances in personality description and measurement. Prior to the work of Guilford (e.g. Guilford and Zimmerman, 1956), Cattell (e.g. 1956) and Eysenck (e.g. Eysenck and Eysenck, 1969), construction of personality scales had relied heavily upon 'empirical keying' or intuition to select items for inclusion in a given scale. Factor analysis was used to explore the relations between scales, but items within a given scale sometimes correlated more highly with items from other scales than with each other. The factor analysis of questionnaire items allowed the derivation of scales which were at least factorially homogeneous.

A comparable shift is now needed in the study of the genetics of personality. With rare exception (e.g. Neale, Rushton and Fulker, 1985; Martin, Eaves, Heath, Jardine, Feingold and Eysenck, 1986), most genetic analyses of personality differences have focused upon either scale scores or factor scores, where the scales or factors have been derived by traditional phenotypic factor analysis. This approach assumes implicitly that such scales are causally, as well as factorially, homogeneous, and that there are distinct genetic and environmental factors underlying each scale. Such assumptions usually remain untested but, when tested by multivariate genetic item analysis, have sometimes been found to be false. In one recent study of self-report symptom data, we were able to confirm by conventional factor analysis the existence of separate anxiety and depression phenotypic factors (Kendler, Heath, Martin and Eaves, 1987). However, multivariate genetic item analysis revealed that most of the genetic variance in symptoms of both anxiety and depression was explained by a single common genetic factor, which could be interpreted as genetic predisposition to Neuroticism. The existence of distinct phenotypic factors was apparently environmental in origin: symptom loadings on the environmental factors were very similar in pattern to those obtained in the phenotypic factor analysis, separate anxiety and depression factors being clearly distinguishable. In such cases the genetic analysis of scale scores or factor scores derived by phenotypic factor analysis could be seriously misleading.

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Genetic analysis of individual item responses also has the potential to resolve certain controversies in personality theory which remain intractable if we restrict ourselves to conventional factor analysis. These concern the estimation of oblique versus orthogonal factors, and the choice between different mathematically equivalent, factor rotations. The choice between estimating a large number of correlated primary factors, as advocated by such personality theorists as Cattell (e.g. Cattell, 1956) and Guilford (Guilford and Zimmerman, 1956), or a smaller number of uncorrelated higher-order factors, as practised by Eysenck (e.g. Eysenck and Eysenck, 1969), can be mathematically arbitrary. The former approach involves estimating a small number of item loadings on each of a large number of factors, with many factor loadings fixed to zero; the latter approach a large number of loadings on a small number of factors, with few factor loadings fixed to zero. Neither method is necessarily superior to the other on grounds of parsimony. Under a multiple common factor model, the choice between different factor rotations (e.g. Eysenck's orthogonal dimensions of Extraversion and Neuroticism, and Gray's (1981) dimensions of Impulsivity and Anxiety, which are hypothesized to be 45° rotations of the former), is again mathematically an entirely arbitrary decision. An infinite number of rotations will predict the same phenotypic correlation matrix.

An experimental approach has been advocated as one way of deciding between mathematically equivalent solutions (e.g. Eysenck, 1950, 1981; Gray, 1981). Suppose brain lesions, drug effects, and similar experimental interventions influence responses to all items loading on a higher-order orthogonal dimension of personality (e.g. Anxiety), but no other items. This provides a basis for preferring one rotation over another, and for preferring the orthogonal solution over an oblique solution. It is more parsimonious to hypothesize that the experimental intervention is having a single effect on a higher-order dimension, rather than correlated effects on correlated primary factors. Furthermore, we can use the response to the experimental intervention to fix the factor rotation. We would expect to observe the greatest experimental effects for those items having the highest loadings on the critical personality dimension. In theory, therefore, we might use the differential impact of the experimental intervention on different items to define a target matrix for factor rotation. In practice, however, sample sizes in experimental studies are typically too small to permit such an analysis. The assumption that an experimental intervention affects one dimension of personality, and only one, is crucial, but testable (e.g. by factor analysis of change scores). If two or more dimensions are influenced, the problem of factor rotation remains unresolved.

Genetic item analysis can, under certain circumstances, be used to resolve these same issues. Until recently different personality factors have been believed to exhibit very similar patterns of familial (genetic and environmental) inheritance. Variation in the higher-order dimensions of Extraversion and Neuroticism appeared to be determined in each case by additive gene action and within-family environmental effects, with no evidence for shared family environmental effects or non-additive gene action being found (e.g. Eaves and Eysenck, 1975, 1976, 1977). Under these conditions the issue of factor rotation remains unresolvable. If, however, one dimension of personality shows a distinctive pattern of familial transmission (e.g. genetic dominance or genotype × sex interaction or genotype × age interaction), we can use this to define target loadings for that factor. In effect, we can examine the genetic architecture of responses to individual items in exactly the same way as we would examine the effects of an experimental intervention. In the case of item genetic analysis, however, our sample sizes will typically be much larger.

Recent analyses of the genetics of personality scale scores have found consistent evidence for genetical non-additivity for Extraversion, but not for Neuroticism (e.g. Martin and Jardine, 1986; Eaves, Eysenck, Martin, Heath, Jardine, Feingold, Young and Kendler, 1987). If Eysenck's model for personality (1981) is correct, we might expect to find genetic dominance for items loading on the extraversion factor, but no others. Thus in a multivariate genetic analysis of Extraversion and Neuroticism items, although the phenotypic factor solution involves two factors, there will be only a single non-additive genetic factor, for which a unique set of loadings can be obtained. If the non-additivity is due to dominance, we would expect the pattern of loadings on the corresponding additive genetic factor to be a constant multiple of loadings on the dominance factor. Under these assumptions a unique rotation of the additive genetic factors will also be defined.

The statistical methods needed for this approach have been available for many years (e.g. Eaves, Young, Last and Martin, 1978). However, it is only with the collection of extensive personality data on very large twin samples (e.g. Martin and Jardine, 1986) that application of these methods has become practical. In this first paper, we attempt to replicate the phenotypic factor structure proposed by Eysenck, using responses to the Eysenck Personality Questionnaire by twins from the Australian twin registry. In a subsequent paper (Heath, Jardine, Eaves and Martin, 1987), we shall examine the underlying genetic structure of the EPQ using genetic item analysis of these data.

METHOD

Sample

As part of a health survey, conducted by mailed questionnaire (see Jardine, Martin and Henderson, 1984), twins from the Australian NH and MRC Twin Register aged 18 years and older were asked to complete the full 90-item Eysenck Personality Questionnaire (Eysenck and Eysenck, 1975). Replies were received from both members of 3810 of the 5967 twin pairs to whom questionnaires were sent, giving a total sample of 4874 females and 2746 males. In the analyses to be presented in this paper, we shall ignore the twin structure of the sample. This implies that observations on members of a twin pair will be treated as though they are independent. When the number of pairs involved is as large as in the current study, any bias to our estimates of the factor loadings arising from this assumption will be minimal. Data were analysed separately by sex.

Data analysis

Methods of statistical analysis which are designed for continuous data are not appropriate for the analysis of responses to a series of dichotomous items. In particular, the factor analysis of product-moment correlations computed from discontinuous data can give misleading results (e.g. Olsson, 1979). No exact method exists for the factor analysis of large numbers of dichotomous variables (90 items in the case of the EPQ). We followed the approach of Olsson (1979) and Joreskog and Sorbom (1985) and used maximum likelihood estimates of the tetrachoric correlations between items as the summary statistics for factor analysis. Because tetrachoric correlations are estimated separately for every pair of items, there is no guarantee that the final correlation matrix will be positive definite. We therefore used the method of unweighted least squares to estimate factor loadings (Joreskog, 1978). Orthogonal and oblique rotations of factor loadings were performed using Varimax (Harman, 1976) and Promax (Hendrickson and White, 1964) criteria, respectively.

With large sample sizes, unweighted least squares estimation should give parameter estimates which are extremely close to the maximum likelihood values (Lee and Jennrich, 1979). A theoretical disadvantage of this approach, however, is that it gives no statistical test of the number of common factors which must be estimated to explain the item correlations. Thus we are unable to conduct any 'confirmatory' factor analysis (Joreskog, 1978). We therefore computed the proportion of variance accounted for (which, for an orthogonal solution, is given by the sum of the squared factor loadings, divided by the number of items) as a function of the number of factors extracted. Factor solutions involving estimation of 1–13 common factors were obtained. For a given factor solution, the variance explained by different factors was examined after factor rotation (which will redistribute variance between factors). A second theoretical disadvantage of unweighted least squares estimation is that it does not allow statisitical tests of heterogeneity of factor loadings across groups (e.g. sexes). To overcome this problem we have used the very approximate technique of computing correlations between factor loadings across sexes. It should be noted that in practice these limitations apply equally to maximum-likelihood estimation, since the sampling assumptions upon which the validity of statistical tests depends are so rarely satisfied (e.g. Joreskog and Sorbom, 1985).

RESULTS

The two 90×90 matrices of polychoric correlations were not positive definite, confirming the need to perform factor analysis by unweighted least squares. Figure 1 plots the proportion of variance accounted for by the common factors as a function of the number of factors estimated. Four factors were sufficient to explain 30% of the variance in item responses (29.74% in males, 30.34% in females). The improvement in variance accounted for with estimation of further factors fell off rapidly when more than four factors were estimated. Additional factors each explained less than 2% of the remaining variance. A total of 12 factors in both sexes accounted for at least 1% of the variance (before rotation). Nonetheless, because of the very large samples involved, many more factors than the 12 plotted in Fig. 1 would be needed to account adequately for the common variance of the EPQ items.

Orthogonal 4-factor solutions

Table 1 gives the item loadings for the four-factor solution, after varimax rotation (Harman, 1976). Only loadings with absolute values greater than 0.20 are given. In each sex, the four factors were readily identified with Eysenck's postulated dimensions of Neuroticism, Extraversion, Lie and Psychoticism. The Neuroticism factor had positive loadings on some of the P items, but these were generally much smaller than the loadings on the N items. Even the fourth factor. Psychoticism,

Table 1. Factor loadings (× 100) under orthogonal 4-factor solution (Only factor loadings greater than 0.20 are given)

		Female				Male			
EPQ	item	N	E	L	P	N	E	L	P
1	E1		25				27		
2	P1				−24				−32
3	N1	66				60			24
4	L1			56				56	
5	E2		66				67		
6	P2	30			−26	34			−33
7	N2	53		27		60			
8	L2			71				64	
9	P3				−22				−26
10	E3		76				74		
11	P4				−39	31			−49
12	N3	62				65			
13	L3			−51				−46	
14	E4		71				66		
15	N4	57				52			
16	L4			54				51	
17	E5		71				70		
18	P5				−35				−26
19	N5	59				62			
20	L5			−57				−52	
21	E6		−77				−75		
22	P6			36	51			32	33
23	N6	68				68			23
24	L6			60				63	
25	E7		56				59		
26	P7	29			40	28			55
27	N7	61		24		63			
28	L7			45				49	
29	E8		−63				−65		
30	P8	37			45	30			39
31	N8	69	−21			72			
32	E9		61		−23		60		
33	P9		23		45			26	51
34	N9	76				79			
35	L8			−48				−45	
36	E10		48				45		21
37	P10			−32	−33			−24	−55
38	N10	62				60			
39	L9			54				55	
40	E11		69				70		
41	N11	66				67			
42	E12		−71				−67		
43	P11				51				43
44	L10		29	50			31	52	
45	E13		74		27		77		
46	P12			24	27				28
47	N12	47				42			
48	L11			71				70	
49	E14		44	23			49		
50	P13	23			32				36
51	L12			47				49	
52	E15		80				77		
53	P14	21			−32				−47
54	N13	48				48			

Table 1 *contd*

		Female				Male			
EPQ	item	N	E	L	P	N	E	L	P
55	L13			−40				−39	
56	E16		39				39		
57	P15			−29				−24	
58	N14	56				53			
59	L14			61				63	
60	E17		40				43		
61	P16				−24			−24	−37
62	N15	56			25	53	−22		38
63	L15			65	20			63	
64	E18		27				23		
65	P17	39			35	40			33
66	N16	46				45			
67	P18				41				34
68	N17	41		25	21	44		22	20
69	L16			35	24			26	30
70	E19		71				73		
71	P19				−30				−46
72	N18	59				61	−23		
73	L18			47				40	
74	P20			29				33	
75	N19	68				63			
76	P21	35			35	39			37
77	N20	60			21	58			22
78	L18			−59				−58	
79	P22			29	29			31	27
80	N21	51				58			
81	L19			49				50	
82	E20		58				63		
83	P23	27			57	24		24	47
84	N22	40		28		41		23	
85	L20			45				55	
86	E21		72				73		
87	P24	40			35	35			39
88	N23	54		28		53		31	
89	L21			−51				−40	
90	P25	21			−30	23			−35

was clearly defined, all but two items from the P scale having loadings greater than 0.2. (The two P items with smaller loadings both related to punctuality: item 57, ' Do you like to arrive at appointments in plenty of time'; and item 74, 'when you catch a train do you often arrive at the last minute'. In our Australian sample, both these items loaded on Lie). The consistency of the factor loadings across sexes was remarkable, product–moment correlations ranging from 0.95 (for P) to 0.99 (for E).

To assess how well the N, E. L and P sub-scales of the EPQ measure the corresponding latent factors, we can compute the average proportions of variance in item responses which are explained by each factor, for each scale. These values are given in Table 2. Not unexpectedly, measurement of P presents the most difficulties. The P factor accounts for 13–15% of the variance in responses to items from the P-scale, but N, E and L account for a further 4–5%. The P factor also accounts

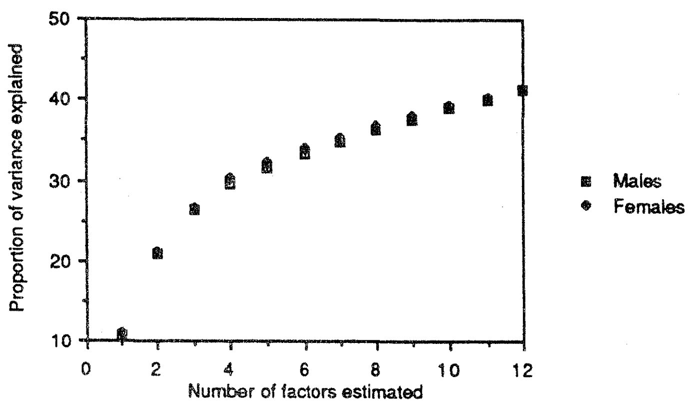

Fig. 1. Proportion of variance accounted for as a function of the number of common factors estimated.

Table 2. Average proportions of variance accounted for by latent factors, for items from N, E, L and P scales of the EPQ

	Scale							
	N		E		L		P	
	Male	Female	Male	Female	Male	Female	Male	Female
Latent Factor								
N	34%	34%	2%	1%	2%	2%	3%	2%
E	1%	1%	39%	39%	1%	1%	1%	1%
L	1%	1%	1%	1%	28%	29%	1%	1%
P	4%	4%	1%	1%	3%	3%	15%	13%

for 4% of the variance for N-scale items and 3% for L-scale items, but these are small proportions compared to the 34% and 28–29% of the variance explained by N and L respectively. Extraversion is the factor which is measured most cleanly by the EPQ.

Orthogonal 9-factor solution

In solutions involving estimation of only 5—8 common factors, correlations between factor loadings across sexes were low for at least one factor. In the 9-factor solution, however, the pattern of factor loadings showed good consistency across sexes. Such consistency would be inexplicable if we were estimating too many factors, and detecting chance associations between variables. The lack of consistency when fewer than 9 factors were extracted, in contrast, does suggest estimation of too few factors in these solutions. Sex differences in the proportions of variance accounted for by particular factors would lead to factors being extracted in different orders in the two sexes. If

Table 3. Factor loadings (× 100) of P factors under 9-factor varimax-rotated solution (only factor loadings greater than 0.2 are given)

			Females				Males			
			P1	P2	P3	P4	P1	P2	P3	P4
2	P1	Thinks things over before doing anything	−26				−34		−21	
5	E2	Talkative person			−21					
6	P2	Worried by being in debt	−25				−34			
9	P3	Locks up house at night	−25				−29			
11	P4	Upset to see child/animal suffer	−20		−80				−58	
17	E5	Enjoys meeting new people					−20			
18	P5	Insurance schemes a good idea	−47				−43			
22	P6	Would take dangerous drugs	56				36			
23	N6	Often feels 'fed up'					20			
26	P7	Enjoys hurting loved ones	37				32	24	44	
30	P8	Enemies want to harm you	29	43				55		
32	E9	Has many friends	−21							
33	P9	Enjoys jokes that can really hurt	28	24	32		21		54	
36	E10	Happy-go-lucky		28			21			
37	P10	Manners and cleanliness important	−49				−53		−31	
40	N11	Highly-strung						22		
42	E12	Mostly quiet with others		21						
43	P11	Marriage is old-fashioned	59				39	21		
45	E13	Gets life into dull party		22						
46	P12	Annoyed by careful drivers	29				20		28	
50	P13	Most things taste same	24	28			25		26	
53	P14	Worried if mistakes in work	−23				−28	−20	−26	
55	L13	Washes before meal	−23							
57	P15	Punctual for appointments	−27			−76				−73
59	L14	Ever cheated at a game							23	
61	P16	Your mother was a good woman	−26				−41			
62	N15	Often feels life rather dull					31	21		
63	L15	Ever taken advantage of someone?						21		
64	E18	Takes one more than has time for				25				
65	P17	People are trying to avoid you		51				55		
67	P18	Savings, insurances are waste of time	42				48			
69	L16	Would dodge paying taxes	26						28	
71	P19	Tries not to be rude to people	−31				−25		−40	
74	P20	Arrives late to catch train				78				74
76	P21	Friendships end easily, not your fault		41				40		
77	N20	Easily hurt when people criticize		26				29		
79	P22	Sometimes likes teasing animals			35				46	
81	L19	Has been late for appointment/work				59				60
83	P23	Would like peple to be afraid of you	43	26	34			20	50	
85	L20	Sometimes puts things off				23				30
87	P24	People tell you a lot of lies		42				43	23	
90	P25	Would feel sorry for trapped animal			−58				−53	

Table 4. Correlations of factors (× 100) under the 9-factor oblique solution

	N	E	L	P1	P2	P3	P4	N2	Sens.
1 N		−19	18	11	13	15	−05	−06	17
2 E	−17		16	−02	12	05	01	−13	−03
3 L	23	14		17	19	25	30	−10	−05
4 P1	20	05	30		28	35	−03	08	−03
5 P2	10	04	02	17		16	−03	04	−08
6 P3	01	11	13	16	19		−00	−15	−01
7 P4	01	13	31	15	−09	14		−07	21
8 N2	−02	−10	−16	00	19	−22	−13		05
9 Sens	00	03	01	00	19	−11	−05	15	

Results for males are given in the upper triangle, results for females in the lower triangle.

too few factors are extracted, this would in turn lead to apparent poor replication of one or more factors across sexes.

In solutions involving estimation of more than 4 factors, N, E and L emerge consistently as unitary factors, with high loadings on all items from the corresponding scales, even when we estimate more than 4 factors. The pattern of loadings for these factors is very comparable to the 4-factor case, the E factor being most sharply defined, and N and L both having moderate loadings on some P items. The P-factor is less robust. Table 3 gives the factor loadings of the major factors loading on the P-scale, for the 9-factor varimax-rotated solution. Only items on which at least one factor has loadings greater than 0.20 are given. Loadings of N, E and L are not given since these are highly correlated with the loadings observed in the 4-factor solution.

The P-factor observed in the 4-factor solution now breaks down into at least four distinct factors, which we have identified as P1–P4. These factors replicate reasonably well across sexes, correlations between factor loadings in the two sexes being 0.90, 0.70, 0.71 and 0.92 respectively. Factor P1 is closest to the original concept of P (Eysenck and Eysenck, 1976), but has low loadings on the Suspiciousness items of the P-scale, and moderately low loadings on some of the cruelty items. It seems to assess a disposition towards unconventional, impulsive behavior. Factor 2 is clearly a suspiciousness factor, with loadings of 0.4 or greater on the 'paranoid' items of the P-scale (Enemies want to harm you; people are trying to avoid you; friendships break up easily without it being your fault; peple tell you a lot of lies). Factor P3 is a cruelty factor. Finally, factor P4 loads most heavily on items relating to punctuality or tardiness, and arguably is a 'redundancy' factor reflecting the inclusion in the EPQ of several very similar items relating to punctuality. Factors P1–P4 explain respectively 3.3, 2.0, 1.9 and 2.0% of the variance in EPQ item responses in females, and 2.8, 2.0, 2.9 and 2.0% of the variance in males. Corresponding proportions of variance explained for the P-scale items are 10.2, 4.6, 5.8 and 5.2% in females and 8.0, 5.0, 9.3 and 4.9% in males.

The 8th and 9th factors extracted in the 9-factor solution also replicated moderately well across sexes, factor loadings correlating 0.85 and 0.80 respectively. Factor 8 ('N2') seemed to be due to redundant items, rather than substantive. This factor had especially high loadings on items such as "Would you call yourself a nervous person?", "Would you call yourself highly-strung?" and "Do you suffer from nerves?" and similar items relating to self-description, but low loadings on N items more specifically relating to symptoms. Factor 9 in females had moderate loadings (< 0.35 in all cases) on Extraversion and Neuroticism items relating to interpersonal sensitivity and shyness (E5, E8, E15; N3, N5, N18, N21), but was not very clearly defined in males. Here we have called it 'Sensitivity' or 'Sens'. We do not tabulate loadings for these two minor factors. When 10 or more common factors were extracted, no other substantive factors were identified, but the same N, E, L, P1, P2, P3 and P4 factors were obtained in each case.

Oblique 9-factor solution

Table 4 gives correlations between factors under the 9-factor solution when an oblique Promax rotation was used. The same 9 factors could be identified as in the orthogonal solution. (Factor loadings for both orthogonal and oblique 9-factor solutions are available from the authors on request). In females, correlations between factors were generally small (< 0.20), the exceptions being the correlations of L with N, P1 and P3. The correlations between P1, P2 and P3 in females were comparable in magnitude to the correlations between E, N and L. Thus the same criteria which would lead us to infer that E, N and L are roughly orthogonal to one another would also compel us to conclude that P1, P2 and P3 are also orthogonal to one another. In males, correlations of P1 with P2 (0.28) and P3 (0.35) were somewhat larger, but most correlations were again less than 0.2.

DISCUSSION

The results of our phenotypic factor analyses are consistent with Eysenck's view that Extraversion, Neuroticism and Social Desirability ('Lie'), as measured by the EPQ, are unitary traits. In the 4-factor solution, the fourth factor could clearly be identified with Eysenck's concept of P (Eysenck and Eysenck, 1976). However, when more than four factors were estimated, the P factor progressively split into separate unconventional/impulsive, suspiciousness, cruelty and punctuality factors. The single P factor obtained in the 4-factor solution may arise merely because we are extracting too few factors. (As in other cases of model-fitting, when we estimate too few parameters—as by omitting item loadings on factors P2, P3 and P4—parameter estimates will be biased). Each of the P factors had a consistent pattern of loadings across sexes, so we can have some confidence in the stability of these factors. When an oblique rotation was used, intercorrelations of the P factors were comparatively small (less than 0.2 in all cases in females, somewhat higher for P1 with P2 and P1 with P3 in males) and, in the case of females, similar in magnitude to the correlation between, say, E and N factors.

The heterogeneous nature of the items of the P scale has been remarked upon by previous investigators (e.g. Claridge, 1981). The very large sample sizes available in this study, combined with the use of statistical methods appropriate for discontinuous data, have allowed a particularly convincing demonstration of this heterogeneity at the phenotypic level. This issue we will address again when we examine the genetic architecture of P, E, N and L dimensions using item genetic analysis (Heath *et al.*, 1987).

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