DIMENSIONS OF PERSONALITY, PSYCHIATRIC SYNDROMES, AND MATHEMATICAL MODELS

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I. Introduction

It is well known that psychiatric diagnostic groupings have no claim to represent any fundamental scientific causal principle, but reflect rather the needs of administrative convenience and compromise between different theoretical orientations (Eysenck, 1960). Doubt has in fact been expressed regarding the advisability of retaining categorical divisions in a field where quantitative differences along orthogonal dimensions may be more appropriate than qualitative differences between distinct disease groups (Eysenck, 1947). The appropriate statistical method for dimensional analysis is, of course, multiple factor analysis (Eysenck, 1952) and it is possible to show relationships between factors or dimensions and psychiatric categories by giving factor scores to the subjects of the experiment and to average these scores for groups of subjects sharing a common diagnostic label (Eysenck, 1959). In this way it has been demonstrated that along the dimension of extraversion/introversion, subjects diagnosed as psychopaths tend to have particularly high extraversion scores; hysterics tend to be extraverted but not as highly as psychopaths. Patients suffering from one of the dysthymic conditions (anxiety, reactive depression, obsessional disorders), tend to have high scores on introversion. Mixed neurotics tend to be in between the other groups. All these diagnostic groups have high scores on the factor of neuroticism which is orthogonal to extraversion/introversion (Eysenck, 1957).

In recent years a new method has come to the fore which is particularly concerned with the analysis of differences between groups. This method is sometimes referred to as "canonical variate analysis", but more fittingly perhaps, the canonical analysis of discriminance. This is an extension of principal component analysis to the variation of observed differences between groups in a multi-dimensional space. Leaving out all technicalities the purpose of this method may be briefly described as follows. Assume that we have g groups and that the members of these groups have been administered m tests. We find first the mean combination of the scores on the m tests which achieves the maximum discrimination between the g groups. We then go on

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to find another combination of the m scores orthogonal to the first which maximizes the residual differences between the g groups. A third, fourth, etc., combination can be added, provided that the appropriate test of significance does not indicate that these further combinations do not add any true variance. The number of significant combinations indicates the dimensionality of the group/test combination, the only proviso being that this is a minimal and not a maximal estimate*. Applications of this method in psychology have mainly been devoted to the problem of whether psychoses and neuroses are independent dimensions or whether psychotic disorders are merely more severe expressions of the same underlying disorder as neuroses (S. B. G. Eysenck, 1956; Eysenck, 1955). In one case the analysis has been applied to the dimensionality of neurotic groups (Slater, 1947), and in another application has been made to a psychosomatic problem (Hamilton, 1950). Little has been learned about the relationship between these two methods of analysis and except for a recent theoretical and experimental paper by Slater (1960), psychologists have been left without much guidance in this matter. It is not clear under what conditions one method would be preferred to the other, and it is not always clear whether similar or different results would be expected from the use of these two methods.

Certain points are, of course, obvious. If the allocation of subjects to groups is very unreliable, or where such allocation is irrelevant to the theoretical purpose of the analysis, canonical analysis of discriminance is not to be recommended. Under conditions where reasonable reliability of allocation is present and where the relative positions of the groups and their dimensionality are relevant to the hypothesis under investigation, canonical analysis of discriminance may have considerable advantages over factor analysis in parsimony of underlying assumptions and in various other ways.

As regards a comparison between the results to be expected from the two methods, again certain points are fairly obvious. Dimensions may emerge in a factor analysis which have no counterpart in canonical analysis of discriminance, simply because the groups selected did not reflect this dimension or are in fact chosen in such a way as to rule out the influence of this factor. If we give a battery of tests to groups of hysterics, dysthymics, normals and psychotics, which have been equated for intelligence, then a canonical analysis of discriminance of these groups will not furnish us with evidence regarding the existence of the dimension of intelligence, whereas a factor analysis would do so. Quite generally Slater, in his examination of the mathematical principles underlying these methods came to the conclusion that the axes or dimensions defined by canonical analysis of discriminance "do not necessarily coincide with those found by factor analysis of the same data. There are no *a priori* reasons for expecting the most significant differences to appear in the dimensions where the variance of the individuals about their group means (or about the general mean for all groups) is widest."

* Slater (1960) puts the technical points involved most succinctly: "Canonical analysis is applicable to the measurements obtained by giving a number of psychological tests to individuals belonging to several groups. The means of the g groups form a scatter of g points in the m-space defined by the m tests, which is the dispersion between groups. The individuals' scores form scatters about their group means which can be collected to form a dispersion within groups. When the two dispersions are contracted simultaneously to the extent necessary to normalize the variance within groups in all dimensions, the between-group dispersion assumes an ellipsoidal form in a D-space which may be m-dimensional or less. Its major axis is the dimension where the most significant differences between groups are to be found, the next the dimensions where differences independent of the first are most significant, etc. The canonical analysis of discriminance is a principal components analysis applied to this contracted dispersion between groups to define its axes and test the significance of the variation there."

There are, however, conditions under which good agreement in certain respects may be expected and is indeed required by the hypothesis under investigation. This is true in particular when a battery of tests has been chosen on a rational basis to mediate the measurement of one dimension, and where groups have been chosen in such a way that rational predictions can be made from the same theory regarding their respective positions. Under these conditions, and provided that the theory is in fact correct, we would expect one dimension to emerge from the canonical analysis of discriminance, which would be similar to one specific factor emerging from the factor analysis. Such coincidence would give particularly strong support to the hypothesis under investigation because the assumptions made by one method, both mathematical and theoretical, are different from those made by the other, and coincidence would only be achieved if these assumptions were in fact justified.

II. Analysis

The data here analysed were originally collected in connection with a factorial study of extraversion/introversion by Claridge (1960). The tests used in this study were specially chosen in order to test the theory put forward by one of us postulating excessive reactive inhibition and satiation in extraverts and defective reactive inhibition and satiation in introverts (Eysenck, 1957). A number of predictions were made from this theory which have been tested experimentally at various times. Thus, it was predicted that reminiscence would be greater for extraverts than for introverts, in accordance with the well-known hypothesis that reminiscence is due to the dissipation of reactive inhibition accumulated during massed practice. Similarly, it was predicted that the after-effects of observing a rotating spiral would be more protracted for introverts than for extraverts, due to satiation of the underlying physiological processes. In regard to vigilance tests, it was predicted (*i*) that extraverts would show a greater fall off in performance with time, due to the accumulation of more reactive inhibition and (*ii*) that the introduction of a novel stimulus after a considerable degree of inhibition had been reached on the vigilance task, would lead to (*a*) inhibition of performance for introverts, and (*b*) dis-inhibition and consequently improvement of performance in extraverts. In relation to another experiment yet, namely time error, it was argued that the application of the first of a pair of stimuli would produce, in addition to the expected excitatory effect, an inhibitory process opposing the continuation of this excitation. A variable stimulus of equal intensity would then be judged greater, according to the degree to which inhibition consequent upon the first stimulus had damped down the original excitation. Extraverts, producing more inhibition as a result of the first stimulus, would be expected to show a greater tendency towards negative time errors than introverts.

Tests of this kind were given to 16 hysterics, 16 dysthymics, 16 psychotics and 16 normal subjects, all of them of roughly equal age and intelligence. Subjects were selected for these groups in terms of considerable psychiatric agreement on diagnosis. A factor analysis was performed by Claridge on 30 scores altogether; in view of the possible disrupting effect on psychotics, whose performances tend to be rather erratic, the factor analysis of the complete set of scores was repeated by using only the 48 subjects in the normal and neurotic groups and excluding the psychotics. In both analyses four factors were extracted, accounting for almost 50 per cent. of the total variance. Three of these factors are of little concern in this connection, but the fourth one was

clearly identified as extraversion; this factor had high loadings on such measures as the vigilance test (performance), vigilance test (effect of novel stimulus), spiral after-effect, reminiscence, time error, and the extraversion scale of the Maudsley Personality Inventory (Eysenck, 1959).

By and large, this research suggested that the theory underlying the selection of tests was correct, at least in part. The research did, however, leave open the possibility that that part of the hypothesis relating to the selection of groups might be mistaken. In other words, it is conceivable that hysterics and dysthymics might not emerge as the most extraverted and introverted groups respectively with regard to this factor, and the present paper presents an attempt to answer this question in two ways. (1) By the calculation of factor scores, and (2) by the calculation of canonical variates. In addition, of course, our interests will lie in a comparison of these two quite dissimilar methods of analysis.

Our method of estimating factor scores follows that of Thurstone, and two sets of factor scores were in fact calculated, derived from the two analyses mentioned above, i.e. with and without the inclusion of the schizophrenic group and deriving respectively from the 64 and 48 subjects. Mean factor scores and sigmas are given in Table I. It will be seen then that on both accounts the dysthymic groups have the lowest score on extraversion (−3·44 and −4·07 respectively), while the hysterics have the highest scores (2·27 and 2·08 respectively). The difference between the groups is about twice the size of their standard deviations, and as predicted normals and psychotics are intermediate. These results strongly support the hypothesis that the psychiatric groups do in fact represent extremes along the dimension of extraversion/introversion.

TABLE I

Factor Analysis

	N:	D:	H:	P:
Factor Scores: (64) Extraversion Factor				
Mean	1·98	−3·44	2·27	1·14
σ	2·35	1·38	1·94	2·64
Factor Scores: (48) Extraversion Factor				
Mean	1·99	−4·07	2·08	−0·16
σ	3·09	2·37	3·06	3·55

We must next turn to the canonical analysis of discriminance. Two such analyses were in fact carried out, making use of two different sets of five tests each. Each set included, as well as measures of extraversion/introversion, two tests of neurotic and psychotic abnormality, as it was thought that in this way we could assure the presence of a significant second canonical variate which would add to the interest of the analysis. The tests used are given below:

Group 1:

A1. Number of sortings on the Payne (1960) sorting test of schizophrenic thought disorder.
A2. Total score on the first part of the vigilance test.
A3. Mean length of after-effect on four trials of the rotating spiral test.
A4. Total amount of sway on the body sway test of suggestibility.
A5. Time error.

Group 2:

B1. The logarithm of the time taken on the Payne (1960) sorting test.
B2. Change on the vigilance test as a result of introducing a novel stimulus.
B3. Time judgment, i.e. judgment of elapsed time under standard conditions.
B4. The neuroticism part of the Maudsley Personality Inventory.
B5. Improvement on the pursuit rotor during the third five-minute trial. (The three trials were separated by two rest pauses of ten minutes each.)

The tests were chosen so as to give a fairly representative selection of different measures but no account was taken of the factor analysis as this had not been completed when the tests were chosen for the canonical analysis of discriminance. It would be possible now to select a group of tests having higher factor loadings than the ones actually chosen. The extraversion scale of the Maudsley Personality Inventory, while it has one of the highest factor loadings on Extraversion, was excluded from consideration as our main interest lay in *performance* tests of extraversion.

III. Results

Table II shows three latent roots extracted on the first set of tests; Table III shows the latent roots extracted from the second set of tests. Both sets agree in finding two significant latent roots; the third one falls short of significance in both analyses. Tables IV and V list the mean scores from the three canonical variates which are obtained by using the latent vectors as weights and multiplying them by the scores on the tests. (The third latent root has been retained for the sake of interest in spite of its failure to achieve statistical significance. This fact should be borne in mind in the subsequent discussion.)

TABLE II
Latent Roots
A

λ_1=0·337,973 (56·730 per cent.)	P<·01
λ_2=0·213,797 (35·886 per cent.)	P<·02
λ_3=0·043,989 (7·384 per cent.)	P=N.S.

TABLE III
Latent Roots
B

λ_1=0·578,292 (62·372 per cent.)	P<·001
λ_2=0·231,140 (24·930 per cent.)	P<·01
λ_3=0·117,740 (12·699 per cent.)	P=N.S.

On the first variate dysthymics have the highest scores and hysterics and psychotics have low scores; in the second analysis, dysthymics again have the highest scores and hysterics share the distinction of having the lowest scores with the normals. Individually the two analyses agree in singling out the dysthymics from the rest but in the one analysis the hysterics have almost identical scores with the psychotics, in the other, with the normals. As will be shown later a combination of the two analyses gives a perfect fit to our hypothesis.

TABLE IV

Mean Group Variate Scores

A

	N:	D:	H:	P:
$\bar{\gamma}_1$	35·224	41·566	27·724	26·124
$\bar{\gamma}_2$	−1·028	5·203	−0·236	6·866
$\bar{\gamma}_3$	12·024	19·860	22·559	14·746

TABLE V

Mean Group Variate Scores

B

	N:	D:	H:	P:
$\bar{\gamma}_1$	−6·353	−41·716	−11·895	−23·815
$\bar{\gamma}_2$	46·350	48·656	55·885	59·716
$\bar{\gamma}_3$	38·822	34·240	28·922	40·761

As regards the second variate we find that psychotics have the highest score in both analyses, while normals have the lowest; this is possibly to be interpreted by regarding the second variate as an approximation to the factor of psychoticism (Eysenck, 1952).

As regards the third variate, which it will be remembered did not achieve significance, we find that the two neurotic groups are opposed to the normal and the psychotic groups in both analyses. This congruence suggests that here we are dealing with a variate which is similar to the factor of neuroticism in several factor analytic studies (Eysenck, 1959). The fact that the latent roots are not significant speaks against taking them too seriously, but the agreement between the two analyses may make us incline to regard this outcome as probably non-chance. Tables VI and VII indicate the percentage of misclassification if subjects are graded according to their canonical variate scores, and this grading compared with diagnoses. It will be seen that the total percentage of misclassifications is on the average about 23; this is not a bad result considering that only one test each was included for the psychotic and neurotic dimensions and even these were not selected as being the best available. In group A, of 16 patients diagnosed as dysthymic, none were graded with hysterics, in terms of the test results; in group B the same result was found. Of the 16 hysterics one and none respectively were graded as dysthymics in terms of test results. Thus, the comparison between the two groups which are central to our study discloses only one false classification out of 64 possible errors.

TABLE VI

Diagnosis

A

	N	D	H	P	
N	*13*	1	5	1	
D	2	*12*	1	1	26·6 per cent.
H	1	0	*10*	2	misclassification
P	0	3	0	*12*	
	16	16	16	16	

TABLE VII

Diagnosis

	B				
	N	D	H	P	
N	*14*	0	2	3	
D	0	*14*	0	0	18·35 per cent.
H	1	0	*13*	2	misclassification
P	1	2	1	*11*	
	16	16	16	16	

It seems desirable to combine the first canonical variates from the two analyses in order to obtain a good general estimate of individual scores, and this was done by transforming all individual scores into standard scores with a mean of 100 and standard deviations of 10; these were then added and averaged. The same was done for the second canonical variate, which has been provisionally identified as psychoticism. The results are quoted in Figure 1.

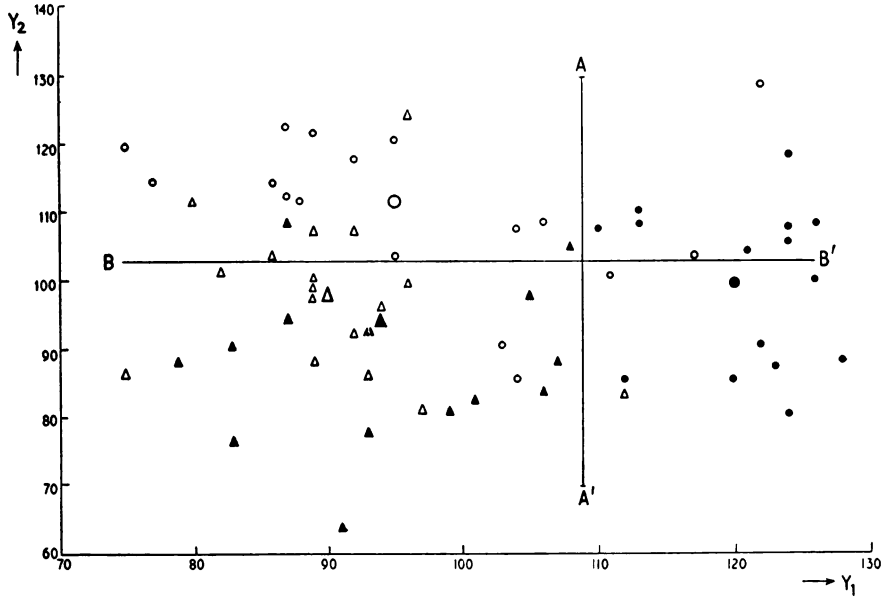

FIG. 1.—Positions of 16 normals (solid triangles), 16 dysthymics (solid circles), 16 hysterics (triangles) and 16 schizophrenic psychotics (circles) on two canonical variates. Large circles and triangles denote mean scores of respective groups.

Line A–A′ has been drawn parallel to γ_2 to show that this variate separates dysthymics from hysterics with only one misclassification; one hysteric is grouped with the dysthymics. Line B–B′ has been drawn to show the degree of separation achieved between psychotics and the other groups. Above this line there are 14 out of 16 psychotics; this success is bought at the expense of having 7 normals and hysterics diagnosed as psychotic as well as 8 dysthymics. Clearly, discrimination is best in respect of that set of groups in which our main interests lay, and for which our tests were predominantly selected.

We must next turn to a comparison of factor scores as obtained from the factor analysis with the canonical variate scores in γ_1. There is considerable

agreement between these two scores; this agreement is expressed in the terms of the correlation of +0·89, when factor scores are those derived from the total group of 64 subjects. When the factors derived from the smaller group are used, correlation becomes +0·81. It is clear that the results of the two entirely different and separate analyses give very similar outcomes.

It may be of some interest to look at the table of latent vectors for the three canonical variates. These are given in Table VIII for the two sets of tests. As these values indicate the weight which each test assumes in deriving scores for the variates, we would expect by and large that those tests intended to measure extraversion would have high figures in column X_1, those tests intended to measure psychoticism in column X_2 and those tests intended to measure neuroticism in column X_3. On the whole this expectation is borne out. For X_1 the two tests having much the highest weights are A_2 and B_2, both of which were included as tests of extraversion. A_1 and A_4, tests of psychoticism and neuroticism respectively, have the lowest values on X_1; A_4 has much the highest value on X_3 as it should. A_1, however, fails to have the highest value on X_2 as predicted; it falls into second place only.

TABLE VIII

Latent Vectors

	Test	Dimension Measured	X_1 (E)	X_2 (P)	X_3 (N)
A_1	Payne sorting; number of sortings	P	−0·027,547	−0·158,406	−0·205,837
A_2	Vigilance; total score	E	1·000,000	−0·026,706	0·433,846
A_3	Spiral after-effect	E	0·264,823	1·000,000	−0·284,795
A_4	Body sway	N	0·011,551	−0·057,418	1·000,000
A_5	Time error	E	0·284,756	−0·062,453	−0·136,360
B_1	Payne sorting; log. time	P	−0·309,036	1·000,000	1·000,000
B_2	Vigilance; change	E	1·000,000	0·389,368	−0·276,749
B_3	Time judgment	E	−0·177,192	−0·313,304	0·603,393
B_4	M.P.I. neuroticism scale	N	−0·698,485	0·333,239	−0·772,843
B_5	Pursuit rotor improvement	E	−0·193,660	0·219,790	0·279,866

As regards the second analysis, B_1 as predicted has the highest score on X_2 but also somewhat unpredictedly on X_3. B_4 which was expected to have the highest score on X_3, only has the second highest. It also has an unexpectedly high value on X_1 which is probably due to the fact that in neurotic groups B_4 (the M.P.I. neuroticism scale) shows quite high correlations with extraversion (Eysenck, 1959). By and large the values in Table VIII support our general interpretation.

IV. DISCUSSION

The results of this analysis on the whole bear out the hypothesis which was being investigated. The canonical variate analysis gives results very similar to the factor analysis as far as the relative positions of individuals and diagnostic groups are concerned. It is found that on objective laboratory tests specially selected on the basis of a theory linking extraversion with high degrees of satiation and reactive inhibition, and introversion with low degrees of satiation and reactive inhibition, hysterics are discriminated from dysthymics with almost perfect precision while normal and psychotic individuals are intermediate between these two highly extraverted and highly introverted groups respectively. These results very much strengthen two aspects of the general theory under investigation. Namely, (1) the hypothesis linking extraversion and inhibition/satiation, and (2) the hypothesis linking extraversion with

hysteria and introversion with dysthymia. It is very unlikely that factor analysis and canonical analysis of discriminance would have given results so much in agreement with each other if either one or both of these hypotheses had been seriously in error. It will also be noted that psychiatric diagnoses as used here could not be quite as unreliable as is sometimes suggested; extreme unreliability in the assignment of individuals to diagnostic groups would of necessity make the discovery of significant latent roots impossible. The reason, presumably, lies in our attempt to obtain subjects on whom there was considerable agreement among psychiatrists; the frequently observed unreliability of psychiatric diagnoses when random samples of patients are under investigation probably results from the large number of subjects whose position on the various continua involved is intermediate between those points singled out by the prevalent system of classification. This would appear to be but another argument in favour of the dimensional approach as opposed to the categorical diagnostic one.

V. Summary

A battery of objective psychological tests, selected according to a specific theory of anxiety and hysteria, was administered to groups of hysterics, dysthymics, psychotics and normals, equated for age, sex and intelligence. The results were analysed by two different methods, (1) Multiple Factor Analysis, and (2) Canonical Analysis of Discriminance. The factor analysis disclosed, as expected, a strong factor of extraversion; factor scores estimated for this factor showed hysterics to be the most extraverted and dysthymics to be the most introverted of the groups tested. The canonical analysis of discriminance revealed two significant and one suggestive factor identified as extraversion, psychoticism and neuroticism. When individuals were given scores on the first two variates it was found that hysterics had the highest extraversion scores and dysthymics the highest introversion scores. Correlations between factor scores and variate scores show considerable agreement between the two methods in placing individuals along this dimension. It was concluded that the results supported two hypotheses. 1. Hysterics are characterized by a high degree of extraversion, while dysthymics are characterized by a high degree of introversion. 2. The theory according to which the tests were selected as measures of extraversion and introversion is supported by the results of the analyses, particularly by their congruence. It is suggested that canonical analysis of discriminance is a powerful and useful method in investigating dimensional problems of nosology and may have advantages in certain circumstances over the more widely used method of factor analysis.

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