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Part I.—Original Articles.

THE INHERITANCE OF NEUROTICISM: AN EXPERIMENTAL STUDY.*

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(1) INTRODUCTION.

It is commonly believed that heredity plays a considerable part in the determination of an individual's personality. If we accept the well-known definition of personality as " the integrated organization of all the cognitive, affective, conative and physical characteristics of an individual as it manifests itself in focal distinctness to others," we might expect that much research endeavour would have been dedicated to the discovery of hereditary influences on the cognitive, affective, conative and physical characteristics of the individual. A certain amount of such research there has been, but its emphasis has been curiously lopsided ; we have some studies into inheritance of physical characteristics, and numerous studies into the inheritance of cognitive characteristics, but there has been little worth-while research into the conative and affective sides of personality.

The most favoured method of investigation has been the so-called " twin-method " developed in Germany (Siemens, 1924), which consists in comparing the average resemblance of identical twins with that of fraternal twins. The difference between identical twins, due to environment alone, is compared with the difference between fraternal twins, due to both heredity and environ-

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ment; if differences between fraternal twins are much greater than between identical twins, heredity appears to be a powerful causative factor, while if differences are small or non-existent, the influence of heredity as a causative factor in individual differences is discounted. It is possible to give mathematical expression to the estimated contribution of heredity and environment to the variance of any given test, as well as of the interaction of heredity and environment (Shuttleworth, 1935), provided we are ready to make the assumption that the environment is as similar for a pair of fraternals as for a pair of identicals.

The large amount of research done along these lines into the inheritance of intelligence has been summarized adequately by Verschuer (1939), Schwesinger (1933), Newman, Freeman, and Holzinger (1937), Gottschaldt (1939), and Woodworth (1941). The fairly universal conclusion has been that "inter-family environmental differences account for a much smaller proportion of the variance in intelligence than do hereditary differences" (Shuttleworth, 1935). No equally comprehensive generalization has hitherto been made in the affective and conative fields if we except the rather negative conclusions arrived at by Newman, Freeman and Holzinger (1937) who say: "In most of the traits measured the identical twins are much more alike than the fraternal twins, as indicated by higher correlations. This is true of physical dimensions, of intelligence, and of educational achievement. *The only group of traits in which identical twins are not much more alike consists of those commonly classed under the heading of personality.** . . . The difference in resemblance of the two classes of twins is not the same in the different groups of traits. In general, the contrast is greater in physical traits, next in tests of general ability (intelligence), less in achievement tests, and least in tests of personality or temperament. In certain instances, viz. . . . tapping, will-temperament and neurotic disposition, the correlations of identical twins are but little higher than those of fraternal twins."

A brief review of such experimental and observational data as are available will indicate some of the reasons for this failure to achieve positive results comparable to those achieved in the cognitive field, and will also make us familiar with certain dangers in twin research which have invalidated many conclusions confidently drawn from methodologically inadequate data.

(2) Review of Literature.

Much the most extensive work on the inheritance of personality has been done in the field of mental illness, where twin studies of psychotic (and occasionally neurotic) patients have been widely accepted as a method for elucidating the influence of heredity on pathology. The work of Rüdin (1930), Rosanoff *et al.* (1935, 1941), Essen-Moeller (1941), Luxenburger (1928, 1930, 1933, 1934, 1935, 1940), Kallmann (1941, 1946) and Kallmann and Barrera (1942) leaves little doubt that concordance in identical twins is considerably more frequent than in fraternal twins, although still far from perfect. This type of work inevitably suffers from the subjectivity of psychiatric diagnoses, and the lack of reliability associated with all rating methods.

* Italics not in original.

A quite different field, which also has attracted some attention, is that of criminal tendency. Lange (1931), Stumpfl (1936), Kranz (1936) and Borgstroem (1939) have shown that identical twins are more concordant in their criminality than are fraternal twins, even when complete separation has taken place. Popenoe (1936) concludes from a review of this material that " we must ascribe to heredity a more important role in the production of crime than has hitherto been the case."

When we come to the more definitely experimental type of study, we find that the relevance of the experiment to the question of heredity of personality is usually contingent on the theory of personality held by the investigator. Conditioning experiments appear important to the followers of Pavlov ; eidetic imagery to those who agree with Jaensch's system ; handwriting is studied by the " expressive movement " school ; autonomic patterns are investigated by the physiological experimenters ; perseveration and fluency by the Spearman school ; projective techniques are employed by the followers of Rorschach and Freud.

Much work has been carried out in the field of handwriting, both along subjective, interpretative lines and along objective, quantitative lines. The picture is somewhat confused. Bracken (1940*a* and *b*) found no hereditary determination for differences in handwriting pressure in 42 pairs of twins, while Carmena (1935*b*) and Miguel (1935) came to the opposite conclusion after experimenting on 50 pairs of twins each. Writing speed was found to be determined largely by heredity in Bracken's (1939*a*) study of 38 sets of twins, a conclusion confirmed in a later study by the same author (Bracken, 1940*a*) on 42 pairs of twins. Thelen (1939) conducted matching experiments which showed hereditary factors to be prominent in handwriting, while Hartge (1936) found handwriting to be of no diagnostic value in individual diagnosis of monozygoticity. Nicolay (1939) and Hermann (1939) agree in finding little hereditary determination in handwriting, with the exception of the writing angle. Saudek and Seeman (1932, 1933) emphasize both heredity and environment in the determination of writing and drawing. Newman, Freeman and Holzinger (1937) support Galton's original finding that there is surprisingly little resemblance between handwritings of identical twins. The one exception to this appears to be the quality of the handwriting (*cf.* also Kramer and Lauterbach (1928)).

Closely related to handwriting studies are three investigations of the Downey Will-Temperament test, which is based essentially on handwriting characteristics. Tarcsay (1939) reports negative conclusions, while Bakwin (1930) is more positive. Freeman, Newman and Holzinger (1937) report findings which definitely disprove the hypothesis that heredity determines individual differences in reaction to this test ; the intraclass correlations on the four scales of this test are higher for fraternal than for identical twins ! (The actual values are ·69, ·36, ·53 and ·51 as against ·45, ·31, ·51 and ·48.)

Perceptual factors in the personality of twins have been studied by Bracken (1939*c*), Hofstetter (1948) and Smith (1949). Eidetic imagery, which, according to Jaensch's theories is closely connected with personality type, was shown by the last-named author to be strongly determined by hereditary factors, as

was also reaction time. The other authors show that in the production of after-images, in the extent of visual illusions, and in accommodative convergence heredity plays a powerful part.

A beginning has been made in the study of conditioning in twins by Kanaev (1934, 1938, 1941), who used the Krasnogorsky modification of Pavlov's method to show remarkable similarities between identical twins. He links this approach to Pavlov's theories of personality, which are based on conditioning experiments, and it is unfortunate that his suggestive work has been left in a relatively undeveloped state, where no certain conclusions can be drawn.

Another physiological variable which has been studied on the hypothesis that it might be found to be correlated with personality differences is the brain wave pattern. Lennox *et al.* (1945), Elmgren (1941), Davis and Davis (1936) and Gottlober (1938) have shown remarkable similarities between identical twins and less marked similarity between fraternal twins; in the absence of any satisfactory theory linking brain-wave patterns to personality, however, it is difficult to interpret these findings.

Of more definite relevance to personality are three studies of yet a third physiological variable, viz. the psycho-galvanic reflex. The important monograph by Wenger (1948) has definitely established the close connection between neuroticism and autonomic imbalance, and has shown that the P.G.R. is a good measure of autonomic imbalance. Carmena (1934, 1935*a*), working on 60 pairs of twins, showed that the P.G.R. is strongly influenced by heredity. Jost and Sontag (1944) supported this finding by using, in addition to the P.G.R., pulse pressure, salivation, heart period, respiration rate, vasomotor persistance time, and other autonomic measures. They conclude that an autonomic constitution may be at least partially inherited.

Ratings along the lines of the Vineland Social Maturity Scale have been carried out by Bracken (1939*b*), Troup and Lester (1942), and Wilson (1941); there is considerable agreement that whatever is measured by this scale is influenced to a considerable extent by heredity. While it is believed that the Social Maturity Scale measures personality factors additional to intelligence, it has not hitherto been possible to identify them, and therefore it is difficult to interpret the findings.

Motor skill has been studied by Brody (1937) and by McNemar (1933). Both authors find identical twins much more alike than fraternal twins, and conclude that the hereditary hypothesis is the most plausible explanation of individual differences in motor skills. This finding is relevant to personality research because it has been shown by Eysenck (1947) that motor skills correlate quite highly with neuroticism, so that hereditary determination of individual differences in skill gives presumptive evidence for hereditary determination of individual differences in neuroticism.

Related to this work are the studies by Becker and Lenz (1939) and Pauli (1941) showing that differences in work curves are more pronounced in fraternal than in identical twins. Irregularities in work curves have also been shown to be diagnostic of neuroticism (Eysenck, 1947), so that this finding, too, supports the tentative hypothesis that neuroticism may be based on an hereditary foundation.

Perseveration has been studied by Yule (1935) and by Cattell and Molteno (1940). The former, using 115 twins, showed that on a battery of p tests of Stephenson type heredity played an important part ; the latter, using 84 pairs of twins, found that p tests gave no evidence of hereditary influence. Tests of F (fluency of association) were also given by Cattell and Molteno, who concluded that family-environmental differences " are about 8 times as important as hereditary segregation of genes in accounting for individual differences in fluency." This conclusion links up with the work of Carter (1938, 1939) and Sorensen and Carter (1940) on association in twins ; it was found that identical twins are slightly more alike with respect to speed of association.

Most of the studies mentioned so far have had only tangential relevance to personality ; more directly relevant might be work on questionnaires and projective tests. Carter (1933, 1935) has reported on the use of the Bernreuter Personality Inventory as applied to 133 pairs of twins. Identical twins were markedly more similar than fraternal twins with respect to neurotic tendency, self-sufficiency and dominance. This conclusion does not agree with the results published by Newman, Freeman and Holzinger (1937) with respect to another neuroticism questionnaire. The Rorschach technique has been used by Troup (1938), Eckle and Ostermeyer (1939), Marinescu *et al.* (1934), and Kerr (1936). Results are conflicting, Kerr's being essentially negative, Marinescu's positive, while the other reports are somewhat intermediate. No clear picture emerges from the combined results, however.

Certain techniques have been used by one investigator only, and while the connection between the test used and personality is not always clear, the results illustrate a point in methodology which we want to stress in the discussion. Szondi (1939) found greater similarity in identical twins when he applied the test that bears his name to 97 pairs of twins. Petö (1946) used psycho-analysis as his method of investigation, finding surprising identity of symptom in two identical twins. Malan (1940) found spatial orientation to be an inherited trait. Hunt and Clarke (1937) showed marked differences in the startle pattern of a pair of twins. Carter (1932) found occupational interests to be due in part at least to hereditary causes. Frischeisen-Köhler (1933) reports that personal tempo is definitely conditioned by heredity. Thompson (1943) showed determination of play-behaviour by heredity. Waardenburg (1929) shows greater similarity between identical twins with respect to likes and dislikes. Zilian (1938) found less variability for identical twins on imaginal and motor factors. Steif (1939) found great similarity in scribbling between identical, little similarity between fraternal twins, a result similar to Luchsinger's findings with respect to voice range (1940).

Certain obvious characteristics emerge even from this very brief review of the literature dealing with twin studies in personality research. (1) Objectively oriented investigations are mostly very limited in scope, dealing with traits of a low order of complexity, such as scribbling, angle of handwriting, eidetic imagery, reaction times, or spatial orientation. (2) When an attempt is made to study higher-order concepts, such as criminality or psychosis, the concepts chosen are of a sociological-ethical, or psychiatric rather than of a psychological nature, and the investigation proceeds along lines far removed

from the objectivity of psychometric testing procedures. (3) While on the whole most authors agree that identical twins are more alike than fraternal twins on most of the tests used so far, there are many inexplicable contradictions (e.g. the studies of perseveration, of questionnaire tests, and of the Rorschach). (4) Most personality tests have such low reliabilities that results are almost bound to be disappointing; correction for attenuation is seldom attempted. (5) Even when results are clear-cut, they are often difficult to interpret, due to our lack of knowledge of precisely what it is a given test is measuring.

Some of the conflicting results reported may be due to technical faults, which vitiate many of the studies reported. Results are often stated as impressions, rather than being reported as objectively scored and statistically validated conclusions. Choice of twin-pairs to be tested is often based on faulty sampling practices, fraternal twins which look unlike each other being overlooked in favour of those who resemble each other. (Correct procedures are suggested by Verschuer (1939) and Rosanoff *et al.* (1937)). Diagnosis of monozygoticity or dizygoticity has often been faulty, even where the procedures adopted have been described in full. These and other technical faults are easily overcome by experimenters of reasonable competence. Two other criticisms are more fundamental, and must be discussed in some detail.

(1) In passing, we have noted that the whole procedure of twin research rests on the assumption that the environment is as similar for a pair of fraternal twins as it is for a pair of identical twins. Stocks (1930), Holmes (1930), Bracken (1933, 1934*a*, 1934*b*, 1935, 1936), Wilson (1934) and Jones and Wilson (1933) present reports indicating that identicals are treated more alike than are fraternals, a fact which would appear to invalidate this assumption. Bluekersken (1935), Lohmeyer (1935), and Misbach and Stromberg (1941) on the other hand, show that often the very fact of the identicals' similarity leads to different development in the sense that they take on complementary roles. Schiller (1937) and Newman *et al.* (1937) have confirmed this point. Meumann (1935) and Bouterwek (1936) have shown a tendency for identical twins to select different occupations. Woodworth (1941) comments that "such differentiations of roles as has been observed would probably cause identicals to differ in certain special abilities and personality traits . . ." In any case, as Wilson (1934) has emphasized, while in many respects the identical pairs live under more similar conditions than the fraternals, "this fact must be attributed ultimately to the influence of their heredity which led, or forced them to 'select' more similar environments." While it is impossible to be dogmatic on this point, it does appear that the argument against similarity of environment for the two types of twins is speculative and hypothetical; there is no evidence to suggest that such differences as may exist are not themselves due to hereditarily determined selection of environments, or that the small differences observed could account for the large differences in test results. Until more empirical evidence is produced by the critics we cannot concede that their arguments do much damage to twin research methodology.

(2) This criticism of twin work has not, to our knowledge, been made previously, although a solution to the problem posed by it has been published

elsewhere (Eysenck, 1950). It is relevant not only to studies of temperamental traits, but equally so to work on intelligence, and would seem to undermine the elaborate structure of argument built up on twin research. Essentially, this criticism concerns a conceptual jump which takes place when an argument is presented regarding the inheritance of *intelligence* from the intercorrelations of identical and fraternal twins on a *particular test*, say the Binet. We may generalize and say that *a demonstration that individual differences in performance on a given test are due to heredity cannot be used as proof that a hypothetical trait or ability imperfectly measured by that test is inherited.* The argument can best be presented by using an algebraic model.

We may write the factorial equation of the Binet test in the following form:

$$\sigma^2_{BINET} = \sigma^2_g + \sigma^2_V + \sigma^2_N + \sigma^2_{SP} + \sigma_M + \sigma^2_C + \ldots + \sigma^2_X + \sigma^2_S + \sigma^2_E$$

where σ^2_{BINET} denotes the total variance of the Binet test, σ^2_g the contribution to that total variance made by "*g*" or intelligence, while σ^2_V, σ^2_N, σ^2_{SP}, σ^2_M, $\sigma^2_C \ldots \sigma^2_X$ denote contributions to the variance by verbal, numerical, spatial, memory, comprehension and other group factors, and σ^2_S and σ^2_E stand for the contribution to the variance of specific and error factors. Using estimates derived from Burt and John's (1942) analysis of the Binet, the total variance contributed by "*g*" or intelligence is only about 30 to 40 per cent., or less than half the non-error variance. McNemar's (1942) series of analyses attributed on the average 40 per cent. of the total variance to "*g*", the proportion ranging from 35 to 50 per cent. If we neglect the error variance, which amounts only to about 5 per cent. and, of course, cannot be said to be caused either by heredity or environment, but which is merely an error of measurement uncorrelated with the abilities or traits the test is measuring, we can conclude by and large that one-half of the variance at most is due to "*g*" while at least one half is due to various other common factors or specifics.

It will be clear now how unjustified is the jump from the statement "Individual differences in Binet scores are accountable for in terms of heredity to the extent of 80 per cent.," which, granted certain assumptions, is a statement of fact, to the much more usual statement that "Individual differences in intelligence are accountable for in terms of heredity to the extent of 80 per cent.," which is a completely unwarranted generalization, which could be made only if all the non-error variance were attributable to "*g*." It could be that all the group and specific factors hypothesized were completely determined by heredity in which case heredity would play only a very minor part in the determination of "*g*"; it could be that the group and specific factors were largely caused by environmental differences, in which case "*g*" might be 100 per cent. inherited. *Unless we can analyse the total variance of a test into its constituent parts, and measure these parts separately, no scientifically tenable conclusion can be drawn from the data.* If this criticism be justified, it follows that the whole literature on the inheritance of intelligence, perserveration, social maturity, motor skill, conditionability, personality type, or any other ability or trait, in so far as it is based on twin studies, must be considered invalid. This conclusion may appear harsh in the extreme, but it is difficult to see how it can be avoided on the evidence to hand.

(3) The Experimental Variable: Neuroticism.

It follows from what has been said above that if we want to measure the degree to which a particular trait or ability is inherited in a given sample, then we must study, not the individual test results, but rather the hypothetical underlying factors which generate the test variance. In studying intelligence this would mean administering a battery of tests to the experimental population, intercorrelating these tests, factor-analysing the resulting factor matrix, and obtaining factor scores for each experimental subject on each factor isolated. We could then submit these factor scores to the mathematical treatment appropriate to our problem, and obtain data relevant not to one test only, but to intelligence, or verbal ability, or memory, or whatever our factors might turn out to be.

In the field of cognition, the main factors underlying test performance have been isolated by Spearman, Thurstone, Holzinger and other experimenters using the method of factorial analysis. We know now what to measure, and we know how to measure it. In the fields of conation and affection, however, the position is less clear. There are numerous theories, but few facts; much is hypothesized, but little known. The problem thus arises as to the correct choice of the experimental variable.

Our choice has been determined largely by two considerations: (1) The social importance of the trait investigated and (2) the existence of a sufficient body of knowledge regarding it. On both counts, we had little difficulty in arriving at our decision to study the inheritance of the trait variously named neuroticism, emotional instability, or lack of integration. This trait is conceived of as a personality variable ranging from the extremely stable nature, well integrated and through the average sort of personality to the extremely unstable, poorly integrated, neurotic type of individual. The population is conceived of as lying along this continuum, so that everyone can be assigned a "neuroticism score" which would specify his exact position. The distribution of people on this continuum is believed to be unlikely to deviate far from the normal type of curve which characterizes the distribution of scores on intelligence tests.* On this hypothesis a neurotic group would contain in the main people with very high neuroticism scores, while an unselected group would contain people with both high and low scores, but predominantly those with medium scores.

The hypothesis outlined above was originally advanced as the result of a factorial study of personality ratings made by a group of psychiatrists on 700 neurotics (Eysenck, 1944). Much evidence has been published since to show that this hypothesis leads on to various deductions which can be confirmed experimentally, thus strengthening the belief in its usefulness (Eysenck, 1947). In particular a new method of analysis, called "criterion analysis," has been elaborated to deal with hypotheses of continuity of normal and abnormal groups (Eysenck, 1950), and its application has added further proof for the essential correctness of the original hypothesis. These methods have been applied to data gathered through the use of objective psychological tests

* The actual form of distribution is irrelevant to the argument.

(Eysenck, 1951*c*), and batteries of tests have been constructed and used for the more detailed investigation of this trait of " neuroticism " (Himmelweit and Petrie, 1951).

Other traits investigated in a similar manner include Jung's conception of extraversion-introversion as a dimension of personality (Eysenck, 1947) and Kretschmer's hypothesized traits of schizothymia and cyclothymia (Eysenck, 1951). While these traits were considered at an early stage of the experiment, it was decided that too little experimental material was to hand to justify us in constructing a test battery for them, and it was also felt that from the point of view of social relevance neuroticism probably had a higher claim.

We may now state the hypothesis investigated in this paper in a formal manner: The trait of neuroticism, as operationally defined in terms of the pattern of intercorrelations between a specified set of objective personality tests, is in large part determined by heredity, and such individual differences with respect to it as appear in the experiment cannot be accounted for in terms of environmental influences.

The relevance of the experiment to the psychological and psychiatric fields needs little stressing; it may be worth while, however, to point out the importance attaching to the result from the point of view of the logic of factorial analysis. It will have been noted that our definition of neuroticism is essentially in terms of factorial analysis, i.e. in terms of the condensation of a set of observed correlations into a similar number of hypothetical underlying variables or factors. This method has frequently been criticized on various grounds, and while some of these criticisms have not always been based on thorough knowledge of precisely what is implied in the method, it cannot be gainsaid that some doubts could not be allayed in terms of statistical arguments alone. In particular, the fact that the resolution of a given matrix of intercorrelations into factors can be carried out in an infinite number of ways has perplexed many critics otherwise not hostile to this approach. Thurstone's method of overcoming this difficulty (a difficulty which is not faced at all by some writers, *e.g.* Burt and Stephenson) is well known; it consists essentially in overdetermining the solution. This method, while of the utmost importance in work on abilities, appears less well suited to the requirements of non-cognitive experimentation, and the method of " criterion analysis " has been suggested as a plausible alternative (Eysenck, 1950).

However, proof has been lacking hitherto that factors thus determined have any " real " existence, and are something other than mere " statistical artefacts." In part the argument about " real " existence is, of course, a philosophical and semantic one; in a very definite sense any scientific concept is an " artefact " lacking " real " existence. A concept, whether it be that of an electron, an instinct, a quantum of energy, a complex, or a sound wave, is an abstraction, and thus not " real "; scientific concepts are " artefacts " almost by definition. However, what critics usually mean by this objection is something quite different. They denote a factor an " artefact " if it does no more than merely to summarize existing knowledge, if it does not go beyond the circle of its own derivation.

Here the present experiment should be of crucial importance. Having

defined our factor of neuroticism in terms of the intercorrelations of a set of tests, we proceed to examine the biological unity of this factor by analysing the degree to which the factor *as a whole* is inherited. The crucial question, therefore, is this: Is the degree of hereditary determination of this factor greater than that of any single test contributing to the total factor variance, or is nothing gained by substituting the " factor score " for the score on any of the tests which jointly define the factor? If the result shows that the factor is inherited to a more marked extent than any single test, it follows that we have succeeded in proving that the factor is no mere artefact, but has a certain degree of biological reality. As will be shown later, the considerable difference actually observed in hereditary determination between factor and best test encourages us to believe that we have succeeded in its demonstration.

(4) Experimental Study.

(a) *Selecting the Sample of Twins.*

In any study involving a comparison of identical and fraternal twins, care must be taken to avoid errors that might arise from unrepresentative samples. Many previous studies have been open to criticism because of their methods of sampling. If the selection of twins is carried out as in the study of Newman, Freeman and Holzinger (1937), by inquiry into local schools, there exists the possibility of overlooking those fraternal twins who are quite dissimilar, thus yielding an underestimate of the average difference between fraternal twins. This is because twins who are much alike attract attention and are brought to the investigator's notice, while those differing considerably in appearance and behaviour may be overlooked. The questionnaire method of sampling is even more likely to yield a sample overloaded with fraternal twins who are very much alike. Probably the most adequate method of securing an unbiased sample is to use the birth record method (von Verschuer, 1940). This was the method used in the present study.

The birth records for five boroughs in South London were searched for all twins of the same sex, born during the period 1935–1937. The reason for selecting only like-sex twins was that identical twins of necessity belong to the same sex. If, then, fraternal twins of the opposite sexes had been included, they would have introduced a possible complication due to sex differences. Concerning the age limits, the lower limit was set because children younger than 11 could not have taken all of the tests; the upper limit was set because a wide age-range necessitates statistical corrections for age which complicate the picture.

The survey of the birth records yielded the names of 130 pairs of like-sex twins. From these it was possible to locate 68 pairs who were living in the London area, close enough to be able to attend the Psychological Laboratory of the Institute of Psychiatry. The remainder were either living too far away, had died, or could not be located. In no case was parental permission to test refused. The twins were examined as they were located. After examination they were classified as identical or fraternal according to a procedure to be described in the following section.

Methods of Diagnosing Monozygotic and Dyzygotic Twins.

Although there is no longer any doubt of the existence of two types of twins efficient criteria are needed in order to effect a valid separation in all cases. Two methods of diagnosis have been used to group identical and fraternal twins—the foetal membrane method and the similarity method. In view of the many criticisms made of the former, the latter was employed.

The similarity method involves the comparison of the members of a pair of twins in respect of numerous physical characteristics which are determined by heredity. As the number of characteristics is increased arithmetically, the chances of any two siblings not being alike on all the characteristics is increased geometrically. Therefore, if the chances of two children in the same family being alike in one such characteristic is one in two, the chances of their being alike in ten is one in one thousand.

In the present investigation the set of criteria upon which the diagnosis of zygoticity was made is as follows :

(1) Close resemblance of ears, teeth and facial features.
(2) Iris pigmentation.
(3) Standing height.
(4) Presence or absence of mid-digital hair.
(5) Ability to taste phenyl-thio-carbamide.
(6) Scapular shape.
(7) To (14) blood groups A_1A_2BO, Rh, MNS, P, Lewis, Kell and Lutheran.

(1) Close resemblance of ears, teeth and facial features was rated on a three-point scale : No resemblance, different (D) ; pronounced resemblance, but slight differences (SD) ; and very pronounced resemblance rendering it almost impossible to distinguish the twins, same (S).

(2) The *resemblance of the iris pigmentation* was rated on a three-point scale : No resemblance, different (D) ; pronounced resemblance, but slight differences in one zone (SD)* ; and very pronounced resemblance, rendering it almost impossible to distinguish the twins, same (S).

(3) The *standing height* of each twin was measured to the nearest quarter of an inch.

(4) *Presence or absence of hair* on the dorsum of the mid-digital region of the fingers was determined by placing the subject's hand, half clenched and bent slightly backwards, between the investigator and a source of light. This was provided by a 100-watt electric light placed 7 ft. behind the subject's hand. Presence of any hair on one or more fingers was scored as : *hair* +.

(5) *Ability to taste phenyl-thio-carbamide* was ascertained by having the subject drink one-quarter teaspoonful of a 1/20,000 solution of PTC. The subject was asked what the substance tasted like. Any answer other than water was scored as : *taste* +.

(6) The *scapular shape* was found by running the hand over the inside edge of both scapulae. The twins were classified as either concave (CC),

* In the majority of individuals, the iris is composed of two zones, an inner and an outer of different pigmentation. In fifty pairs of siblings studied by Rife (1943), no two pairs were found to have the same iris pigmentation in regard to both zones, although in ten pairs the outside zones were the same, and in four pairs the inside zones were the same.

straight (S) convex (CV), or mixed (M). The mixed type included any combination of the other three: (CC-CV), CV-S), etc.

Grouping the Twins into MZ and DZ.

Using the data on the 14 criteria the twins were first classified into one of three groups: definite MZ, definite DZ and doubtful. The application of criteria for the initial grouping of the twins is shown in Table I.

TABLE I.—*Application of Criteria for Initial Grouping of Identical and Fraternal Twins.**

Criterion number.	Definite MZ.	Doubtful.	Definite DZ.
(1) and (2)	(S) and (S)	(SD) and (SD) or (S) and (SD) or (SD) and (S)	(D) and (D)
	and	and	or
(3)	Difference 1·5 in.	Difference 3·5 in.	Difference 3·5 in.
	and	and	or
(4) to (14)	All exactly alike	All exactly alike	Different on any one

* See Text for Explanation of the Table.
(S) Same; (SD) slight difference; (D) different.

A pair of twins was considered definite MZ if they had (S)'s in criteria (1) and (2); differed less than 1·5 in. in height on criteria (3)*; and if the children agreed exactly on criteria (4) to (14) inclusive. Twins were considered as definite DZ if they were rated (D) on both criteria (1) and (2); *or* if their height differed by more than 3·5 in., criterion (3); *or* if they differed on any one of criteria (4) to (14) inclusive. Twins were considered doubtful if they had ratings of (SD) on both criteria (1) and (2), or a rating of (SD) on either (1) or (2) and a rating of (S) on the other; if they differed 3·5 in. or less on criteria (3); and if they agreed exactly on criteria (4) to (14) inclusive.

On the basis of the above procedure, 20 pairs of twins were classified as definite MZ, 24 pairs as definite DZ, and 6 pairs as doubtful.

When a pair of twins had been rated as doubtful, the blood groups of both parents were ascertained in order to effect a final classification.† The blood

* Newman, Freeman and Holzinger (1937) found that 94 per cent. of their 50 sets of MZ twins had pair differences in standing height of less than 1·5 in.; 53·8 per cent. of their 50 pairs of DZ twins had pair differences of less than 1·5 in. None of their MZ twins had a pair difference of over 3·1 in.; whereas 19·1 per cent of their DZ twins had a pair difference of over 3·1 in.

† Blood group tests were not made for the parents of all 50 pairs of twins, as it was feared that an attempt to persuade the parents to submit to a "blood-test" might have resulted in a loss of the co-operation already secured.

groups of the twins and their parents were then compared to determine the chances of the blood groups of two siblings from a known mating being alike on all of the blood groups. In five of the doubtful pairs, the chances of the two children being alike on all of the blood groups, taking into account the blood groups of their parents' blood, were : 1 : 256, 1 : 256, 1 : 1,000, 1 : 1,000 and 1 : 2,000. Accordingly, these pairs of twins were classified MZ. In the other doubtful pair the chances were : 1 : 16, therefore this set was classified DZ.

(b) *Selecting the Sample of Neurotics.*

The research design calls for a criterion group of neurotic children against which the factor extracted from the normal twins could be validated. Twenty-one children born between 1935–1937 were selected from out-patients at the Maudsley Child Guidance Clinic. Great care was taken to exclude children with organic complications, or with possible psychotic traits, or who were not definitely considered " unstable " by the examining psychiatrist. The resulting sample of 21 children approaches as closely as is possible at the present stage of psychiatric knowledge a " pure " neurotic group, with relatively little mixture of other mental or physical disorders.

(c) *Tests Used.**

1. *Intelligence.*

The Similarities and the Digit-Symbol Sub-Test of the Wechsler Bellevue Intelligence Scale were given and scored according to the author's instructions.

(2) *Tapping Area.*

The subject is given a sheet of 10 in. × 8 in. blank white paper, which is held down to the table by a frame ; he is then told " This is a tapping game. When I say ' Go,' tap this paper with the point of your pencil as fast as you can. Keep tapping on the paper until I say ' Stop.' Ready. Go." Two 10-second trials are given, one immediately after the other, the paper being turned over to the clean side for the second trial.

Scoring is in terms of the perimeter (in inches) of the area generated by the dots on the test paper, only convex lines being allowed in drawing the perimeter.

(3) *Speed of Tapping.*

An automatic counter is fastened to a table in such a way that the subject standing in front of the counter cannot see the window where the number of taps is recorded. The subject is instructed to tap on the counter as quickly as possible and the experimenter records the number of taps per 10-second period.

(4) *Level of Aspiration.*

A level of aspiration procedure is incorporated with the previous test in such a way that the subject, once he is familiar with this, states his aspiration for future trials and his judgment of past trials. Final score on the test is the affective discrepancy score as described in detail elsewhere (Eysenck, 1947).

* This investigation was planned in 1947, and consequently our choice of tests was made on the basis of our very incomplete knowledge then. To-day this choice could be much improved.

(5) *Motor Speed Test.*

The subject is required to trace an irregular path marked out between rows of holes with a metal stylus on the track tracer. Every time he touches a hole a buzzer rings. Instructions are to trace this path as accurately and quickly as possible ; score is the time in seconds taken to trace the path to the centre.

(6) *Speed of Decision.*

A pack of 52 playing cards was used in this. The experimenter places two cards face downwards before the subject and gives the following instructions : " Now we will play a game of chance. I want you to guess which of these is the higher. You don't know and I don't know—it is just a guessing game. As soon as you have decided, put your finger on the card you think is the higher and as you put your finger on the card I want you to say either ' certain ' or ' uncertain.' If you are certain and you are right, you win two points, but if you are wrong you lose two points. If you are uncertain you can only win or lose one point." A practice trial is given and when instructions are fully understood, 10 trials are given which constitute the test. The time to the nearest half second is recorded from when the second card is placed down to when the subject's finger touches the card. The average of these reaction times on the 10 experimental trials constitutes the score.

(7) *Static Ataxia.*

This is a test of the amount of body sway present during 30 seconds while the subject is standing upright with his eyes closed and his heels together. The score is the amount of sway.

(8) *Body-sway Suggestibility.*

In this test the score is the amount of body sway induced by means of a record which repeats for 2½ minutes " You are falling, you are falling forward, you are falling forward now," etc.

These two tests are described in detail elsewhere (Eysenck, 1947).

(9) *Strength of Grip.*

A hand dynamometer was used in order to measure the strength of grip of the subject.

(10) *Word Dislikes.*

A list of 30 words, given below, is shown to the subject, who is asked to read them out aloud to the experimenter. The subject is asked to put an L after each word liked and a D after each word disliked. The test score is the number of words disliked by the subject.

Lift	—	Crowd	—	Night	—	Dreams	— Bed
Train	—	Water	—	Thunder	—	Moon	— Dark
Boy	—	Stranger	—	Girl	—	Man	— Woman
School	—	Teacher	—	Lesson	—	Book	— Number
Father	—	Mother	—	Sister	—	Baby	— Brother
Dog	—	Cat	—	Spider	—	Mouse	— Rat

(11) *Personality Inventory.*

This is a revision of the Brown Personality Inventory for children given in the form of 32 cards, each with a statement printed on it. These have to be put in a box divided into two sections marked " True " and " False " respectively. The score is the number of symptoms to which the subject answers " Yes."

(12) *Lie Scale.*

In addition to the 32 cards of the above test, four cards were added containing items from the M.M.P.I. Lie Scale, which give another score purporting to show the tendency of the subject to give truthful answers.

(13) *Autokinetic Movement* and (14) *Autokinetic Suggestibility.*

In a completely dark room the subject is shown a very small source of light (stationary). He is asked by the experimenter : " Look in front of you and above the level of your eyes. What do you see ? " After the subject states that he sees a little light, say, " Tell me all about it." If the subject reports movement before three minutes, the light is turned off and (*a*), (*b*) and (*c*) are proceeded with immediately. If there is no report of movement at the end of three minutes, the light is turned off and (*a*) and (*c*) are proceeded with, omitting (*b*). If, during the three minute period, the subject stops describing the light the experimenter may say, " Tell me more about it," or " What else can you tell me about it."

(*a*) The flashlight is turned on. " Here is a drawing board and a pencil. In the centre of the board is a drawing pin. I want you to start with your pencil point against the pin and trace the path of the directions in which the light moves."

(*b*) " Thus, if the light appears to move upwards, move your pencil up on the drawing board, or if the light moves to the right, move your pencil to the right. In this way you will be able to record the movements of the small light. If you find that you have reached the edge of the drawing board, return to the centre and continue as before. Otherwise keep your pencil point on the board the whole time. Thus, start from the centre pin and record the movement of the small light. Only remove your pencil from the board if you reach the edge ; in this case start again from the centre." The flashlight is turned out and the little light turned on again. " There is the light. Start now." At the end of three minutes the small light is turned off and the subject is handed the red pencil, with the words " Here is another pencil."

(*c*) " The light is going to move down, and I want you to draw it exactly as you see it." If after (*b*) the small light is turned on and the experimenter says, " Start now." If (*b*) has been skipped, the flashlight is turned off, the small light is turned on, and the experimenter says " Start now." The small light is turned off after 30 seconds.

Scoring.—(*b*) Test 13—the length of the line in inches. In case of no movement reported the score is 0.

(*c*) Test 14—if the line is more than ½ in. long *and* the length of the down-

TABLE II.

	V1. Zygoticity.	V2. Sex.	V3. Age.	1. Intelligence.	2. Tapping area.	3. Tapping speed	4. Level of aspiration.	5. Motor speed test.	6. Speed of decision.	7. Static ataxia.	8. Body sway suggestibility.	9. Grip.	10. Word dislikes.	11. Personality inventory.	12. Lie scale	13. Critical flicker fusion.	14. Autokinetic movement.	15. Autokinetic suggestibility.	16. Backward sway.	17 Fluency.
V1		−·121	·002	−·147	·013	−·007	−·068	−·012	−·005	−·107	·068	−·021	·133	·225	−·292	−·084	·067	·020	−·055	·016
V2	·121		−·394	·152	−·053	−·006	−·033	−·080	·014	·046	·025	−·278	·177	−·031	·051	−·163	−·058	·023	·214	·065
V3	·002	−·394		·188	·073	·305	·008	−·337	−·025	·077	·025	·466	−·101	−·063	−·156	·131	−·032	−·034	·248	−·073
1	−·147	·152	·188		−·058	·130	−·078	−·010	−·151	−·094	−·015	·075	−·065	−·144	−·277	·132	−·203	−·133	·354	·181
2	·013	−·053	·073	−·058		·027	·123	−·115	−·107	·043	·018	·022	·081	·103	−·072	·010	·029	·095	−·014	·078
3	−·007	−·006	·305	·130	·027		−·033	−·075	·007	·022	·004	·290	−·234	−·127	−·029	·070	·007	−·395	·331	·136
4	−·068	−·033	·008	−·078	·123	−·033		·017	−·071	·033	−·015	·188	·040	−·088	−·072	−·050	·088	·177	−·126	−·143
5	−·012	−·080	−·337	−·010	−·115	−·075	·017		·072	−·015	·091	−·167	−·075	·189	−·006	·035	−·081	−·012	−·176	·045
6	−·005	·014	−·025	−·151	−·107	·007	−·071	·072		·135	·035	−·076	·084	·069	−·034	−·113	−·080	·100	−·109	−·038
7	−·107	·046	·077	−·094	·043	·022	·033	−·015	·135		·621	−·028	·083	−·043	·104	−·190	·382	·047	·092	−·142
8	·068	·025	·025	−·015	·018	·004	−·015	·091	·035	·621		−·049	·054	−·010	·012	−·146	·130	·155	·035	−·067
9	−·021	−·278	·466	·075	·022	·290	·188	−·167	−·076	−·028	−·049		−·220	−·174	−·106	−·016	−·160	·048	·200	·032
10	·133	·177	−·101	−·065	·081	−·234	·040	−·075	·084	·083	·054	−·220		·102	−·029	·023	·225	·089	−·081	·174
11	·225	−·031	−·063	−·144	·103	−·127	−·088	·189	·069	−·043	−·010	−·174	·102		−·296	−·020	·027	·048	−·156	·091
12	−·292	·051	−·156	−·277	−·072	−·029	−·072	−·006	−·034	·104	·012	−·106	−·029	−·296		−·092	·102	·030	−·014	−·192
13	−·084	−·163	·131	·132	·010	·070	−·050	·035	−·113	−·190	−·146	−·016	·023	−·020	−·092		·070	−·131	·002	·242
14	·067	−·058	−·032	−·203	·029	·007	·088	−·081	−·080	·382	·130	−·160	·225	·027	·102	·070		·045	·062	·047
15	·020	·023	−·034	−·133	·095	−·395	·177	−·012	·100	·047	·155	·048	·089	·048	·030	−·131	·045		−·042	−·149
16	−·055	·214	·248	·354	−·014	·331	−·126	−·176	−·109	·092	·035	·200	−·081	−·156	−·014	·002	·062	−·042		·110
17	·016	·065	−·073	·181	·078	·136	−·143	·045	−·038	−·142	−·067	·032	·174	·091	−·192	·242	·047	−·149	·110	

TABLE III.

Test.	Centroid factor saturations. I.	II.	III.	Correlation with criterion.	Score multiplier for rotation.	Rotated factor saturations. I.	II.	III.
1. Intelligence	·520	·203	·149	—·053	— 1	—·010	·577	·028
2. Tapping area	—·038	·210	—·107	—·244	— 1	·156	·006	·181
3. ,, speed	·432	·129	·099	·088	1	·049	—·458	—·028
4. Level of aspiration	—·130	·190	—·360	—·056	— 1	·095	—·159	·385
5. Motor speed test	—·123	—·249	·245	·215	1	·071	·121	·343
6. Speed of decision	—·158	—·120	·111	—·172	— 1	·007	—·148	—·173
7. Static ataxia	—·467	·437	·258	—·304	— 1	·656	—·184	—·106
8. Body sway suggestibility	—·358	·355	·225	—·183	— 1	·529	—·126	—·097
9. Strength of grip	·326	·246	—·339	—·052	— 1	—·052	·271	·454
10. Word dislikes	—·250	·115	·131	—·237	— 1	·250	—·142	—·102
11. Personality inventory	—·157	—·094	·209	—·064	— 1	·061	—·108	—·249
12. Lie scale	—·121	—·091	—·160	—·008	— 1	—·076	—·188	·086
13. Flicker fusion	·245	·031	·113	..	..	..	..	..
14. Autokinetic movement	—·271	·346	·138	—·167	— 1	·454	—·079	—·011
15. Autokinetic suggestibility	—·394	·061	—·283	·045	1	—·129	·415	—·223
16. Backward "S"	·391	·393	·063	·065	1	—·176	—·502	—·168
17. Fluency	·250	·161	·334	·027	1	—·136	—·379	·191

ward movement exceeds the upward, then the score is down, score 2. If the line is less than ½ in. *or* the upward movement exceeds the downward, the score is up, score 1.

(15) *Backward "S."*

The subject is required to draw S's in the ordinary position for 15 seconds, then backward S's for 15 seconds. The test score is the total number of backwards S's the subject is able to complete correctly.

(16) *Fluency.*

The subject is told to name as many round things as he can think of in one minute; the test score consists of the number of round things named by the subject.

(5) Results.

The intercorrelations between the 17 tests are reported in Table II for the 100 twins, as well as correlations with zygoticity, sex, and age. Table III records saturations of the tests for three significant factors, which leave only insignificant residuals. Also given in Table III are the correlations of each test with the criterion (these are bi-serial correlations; all others are product moment correlations). Item 13 has been omitted from further calculations, as it was impossible to give this test to the neurotic group. In order to rotate the factors so as to obtain maximum correlations with the criterion, those tests which showed negative correlations with the criterion were multiplied by − 1, as indicated in Table III; this is merely a device which reverses the direction of scoring of the tests affected, and leaves the data unchanged in any material way. The last columns of Table III give the rotated factors. The new Factor I correlates ·758 with the criterion column, having been rotated into maximum agreement with it. Factor II was then rotated in such a manner as to preserve othogonality with Factor I, and to take up all the remaining variance on the intelligence test. Factor III is irrelevant to our purpose, and no interpretation of it will be attempted. Interpretations of Factors I and II are straightforward and dictated by the results: Factor I is a factor of neuroticism, Factor II one of intelligence.

Table IV gives the means and variances for the neurotic children, the identical twins, and the fraternal twins, on all 17 tests and also on the factor score for the "neuroticism" factor. The first three columns give the means for the three groups; only two of the differences between identical and fraternal twins are significant at the 5 per cent. and the 1 per cent. levels respectively, viz. the neurotic inventory and the lie scale. It is difficult to interpret these results, particularly in view of the fact that the inventory did not discriminate at all between normal and neurotic children. Why identical twins should be more given to lying than fraternal twins we cannot explain. The next three columns give the variances for all the children as individuals; the only difference, at the 2 per cent. level of significance, is on the Static Ataxia test, where identical twins are more variable than fraternal twins. (Only differences between the two types of twins are reported, as no particular interest attaches

TABLE IV.

Description of test.	Means.			Variances: Individuals.			Pairs.	
	Neurotics.	Identicals.	Fraternals.	Neurotics.	Identicals.	Fraternals.	Identicals.	Fraternals.
1. Intelligence	14·86	14·82	13·52	14·02	24·48	14·46	47·50	24·48
2. Tapping area	19·05	12·42	12·66	181·80	95·06	67·54	113·86	57·36
3. ,, speed	43·33	45·34	45·22	71·62	65·33	71·56	102·90	91·13
4. Level of aspiration	32·86	31·74	29·84	151·38	144·64	255·69	192·26	277·70
5. Motor speed test	49·05	59·95	59·50	223·06	402·08	338·42	693·62	441·12
6. Speed of decision	3·94	3·02	3·00	7·54	2·54	4·33	3·43	3·80
7. Static ataxia	3·07	2·10	1·81	1·36	2·61	1·12	4·94	1·74
8. Body sway suggestibility	4·74	3·10	3·50	8·55	7·30	10·26	12·86	11·59
9. Strength of grip	68·57	68·74	68·32	85·46	98·40	107·49	185·26	159·33
10. Word dislikes	10·81	8·36	9·12	21·11	9·09	7·33	13·90	10·30
11. Personality inventory	12·86	10·70	13·14	35·10	34·38	22·74	47·42	29·10
12. Lie scale	1·33	1·66	0·96	1·43	1·58	1·10	2·36	1·29
13. Flicker fusion	*	2657·64	2613·64	*	71769·81	62204·32	124436·59	76820·54
14. Autokinetic movement	21·74	15·95	17·50	101·29	131·27	136·92	231·06	169·88
15. ,, suggestibility	1·43	1·48	1·50	0·26	0·26	0·26	0·40	0·29
16. Backward "S"	9·90	11·24	10·58	26·23	35·66	37·02	61·92	55·78
17. Fluency	10·05	10·28	10·40	16·69	18·66	11·63	25·50	13·04
18. Factor score (neuroticism)	*	23·20	22·96	*	91·55	41·47	172·67	50·83

* Test 13 could not be applied to the neurotic children. Factor scores were not calculated for neurotic children.

to differences between normals and neurotics, apart from the correlation of each test with this dichotomy, which is given in Table III).

The last two columns give variances for identical and fraternal twins taken as pairs. In 16 out of 18 cases the identical twin variance is larger; two of these differences are significant at the 2 per cent level (static ataxia and neuroticism factor Score). There seems to be little doubt that in our sample identical twins and fraternal twins have almost identical means with respect to neuroticism (23·20 and 22·96 respectively), but that the identical group contains pairs of twins tending to be more extremely unstable, and more extremely stable, than the fraternal twin group. We cannot explain this finding and must wait for a replication of the experiment before trying to generalize this tendency to all twins.

TABLE V.—*Raw Intraclass Correlations Between Twins, Correlations of Traits with Age, and Resulting Partial Correlations.*

Trait.	Identical twins.			Fraternal twins.			Hereditary determination h^2.
	Between twins.	With age.	Partial.	Between twins.	With age.	Partial.	
1. Intelligence	·905	·208	·890	·670	·168	·660	·676
2. Tapping area	·193	·187	·164	−·148	−·068	−·144	·269
3. ,, speed	·557	·105	·552	·266	·508	·011	·547
4. Level of aspiration	·320	−·256	·272	·084	·218	·038	·243
5. Motor speed test	·700	−·399	·643	·296	−·265	·243	·528
6. Speed of decision	·340	−·046	·339	−·122	−·009	−·122	·193
7. Static ataxia	·857	−·066	·856	·537	·101	·532	·692
8. Body sway suggestibility	·737	·104	·734	·128	−·045	·110	·701
9. Strength of grip	·850	·580	·774	·468	·354	·392	·628
10. Word dislikes	·512	−·060	·510	·394	−·152	·380	·210
11. Personality inventory	·369	−·081	·365	·273	−·046	·257	·145
12. Lie scale	·485	−·090	·481	·167	−·254	·109	·418
13. Flicker fusion	·709	·110	·705	·229	·157	·209	·627
14. Autokinetic movement	·734	−·210	·722	·228	·151	·210	·648
15. ,, suggestibility	·534	·011	·534	·141	−·081	·135	·461
16. Backward "S"	·711	·333	·708	·491	·161	·477	·423
17. Fluency	·357	−·077	·353	·118	−·068	·114	·270
Neuroticism" factor	·851			·217			·810

Table V shows the raw intraclass correlations between twins of both types, correlations with age, and the partial correlations resulting from eliminating age differences. It will be seen that age plays little part in determining scores, and that correction leaves the correlations very much as they were before. The last column of Table V gives Holzinger's h^2 values, i.e. the extent to which each test variance is determined by heredity. It will be seen that the test of intelligence has an h^2 (·676) which is almost identical with the h^2 values given by the best neuroticism tests: Static ataxia (·692), autokinetic movement (·648) and suggestibility (·701).

As the last step in this procedure, factor scores on the neuroticism factor were calculated for each twin and h^2 values calculated for these "neuroticism scores."

$$h^2 = \frac{i^r - f^r}{1 - f^r} = \frac{(l - f^r) - (l - i^r)}{(1 - f^r)}$$

where $_{i}r$ = intraclass correlation for identical twins and $_{f}r$ = intraclass correlation for fraternal twins, it follows that

$(1 - {}_{i}r) = \frac{\text{"within"}_{i}\text{ variance}}{\text{"total"}_{i}\text{ variance}} = \frac{13{\cdot}680}{91{\cdot}551} = 0{\cdot}149$, from which $_{i}r = {\cdot}851$.

Similarly, $(1 - {}_{f}r) = \frac{\text{"within"}_{f}\text{ variance}}{\text{"total"}_{f}\text{ variance}} = \frac{32{\cdot}480}{41{\cdot}468} = 0{\cdot}783$, from which $_{f}r = {\cdot}217$. It follows that $h^2 = 0{\cdot}810$. This value is considerably higher than that given by any single test, and indicates that the factor constitutes a biological unit which is inherited as a whole.

The h^2 technique used in this paper gives the per cent. of twin difference variance attributable to nature providing that certain assumptions are met. Two of these assumptions are that nurture influences are the same for both types of twins, and that differences due to nature are uncorrelated with differences due to nurture. It is probable that these assumptions are not completely met, and that consequently our estimate is too high. On the other hand, another assumption, viz, that the variance due to errors of measurement is negligible, is quite certainly not fulfilled, and in view of the known unreliability of personality tests we must assume that errors of measurement may play a considerable part. This would lead one to believe that the found h^2 would be an underestimate of the true value, and it seems not impossible that this factor may cancel out the two previously mentioned. It is possible, therefore, to argue that the h^2 found is a rough and ready estimate of the contribution which heredity makes to individual differences in neuroticism.*

Our conclusion regarding the rise of this contribution is not in agreement with that arrived at by Newman, Freeman and Holzinger (1937). They find that "the only group of traits in which identical twins are not much more alike consists of those commonly classed under the heading of personality . . . ," we have shown that identical twins show a correlation on neuroticism of ·851, while fraternal twins show a correlation of only ·217. From this it was concluded that individual differences with respect to neuroticism, stability, integration, or whatever we may wish to call this trait or factor, are determined to a very marked extent by heredity, and very much less markedly by environment. This conclusion, of course, applies only in the general type of environment from which all our twins came, and might not be applicable under conditions of more extreme environmental variation, such as may obtain in other cultures.

(6) Summary and Conclusion.

Twenty-five pairs of identical and 25 pairs of fraternal twins were tested with a battery of objective personality tests. A group of 21 neurotic children equal in age to the twins, were also tested and constitute a criterion group. The tests used were intercorrelated for the total twin population tested, and a

* We have used Holzinger's h^2 statistic in our estimates because no better estimate of the contribution of heredity to the total variance is available. In view of the various assumptions involved in this statistic we do not feel too much confidence in the accuracy, and would lay more stress on the directly observed intraclass correlations for identical and fraternal twins. A note by Joan May, from the Statistical Section of the Psychology Department, is appended to show more precisely the assumptions involved in Holzinger's argument.

factorial analysis carried out, using the method of " criterion analysis." In addition to other factors, a " neuroticism " factor was extracted. Factor scores were calculated for this factor, and intraclass correlations derived for the identical and fraternal twins. These correlations have the values of ·851 and ·217 respectively, giving rise to an h^2 value of ·810. If we can interpret this value, as Holzinger does, as measuring the contribution of heredity to the total variance, it would follow that some 80 per cent. of individual differences in the neuroticism factor were due to heredity and only about 20 per cent. to environment. In view of the many assumptions underlying the derivation of h^2 this interpretation is put forward with great hesitation. Regardless of the particular interpretation made of h^2, however, it has been shown that the factor of neuroticism is not a statistical artefact, but constitutes a biological unit which is inherited as a whole. From the methodological point of view this latter conclusion is perhaps as important as a demonstration that neurotic predisposition is to a large extent hereditarily determined.

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