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HERITABILITY OF PERSONALITY
A DEMONSTRATION [1]

IRVING I. GOTTESMAN [2]
Harvard University

Ss were 68 pairs of adolescent twins from the public schools of an urban area. They comprised 60% of the same-sexed twin population. Zygosity diagnosis was determined by blood grouping for 9 groups; half of the sample was identical (MZ) and half was fraternal (DZ). Personality was assessed by the MMPI and Cattell's HSPQ. 24 standard scales were analyzed by intraclass correlations (R) and heritability indexes (H). Holistic analyses of MMPI profile similarity were done clinically and statistically. 6 personality scales had significant genetic components as revealed by higher MZ Rs. 11 scales had appreciable hereditary variance. Pooled accuracy of profile similarity judgments matching zygosity was 68% ($p = .005$). The general idea that psychopathology in man has a substantial genetic component, especially the psychoses, was supported. A dimension of introversion was the most heavily influenced by genetic factors.

MANKIND in general and life scientists in particular have long been curious about the basic nature of man. In recent years curiosity and speculation have given way to experimentation and controlled observation. One of the eventual outcomes of such research will be a knowledge of the sources of the individual differences in human behavior so that the variation may be explained, predicted, or controlled. The genetic source of variation in human personality is the focal concern of the present research. *Genetic* is used in the strict sense to refer to that science launched by Mendel's work with peas and not, as is common in psychology, as an abbreviation for *ontogenetic*. Although it is axiomatic that the phenotypic expression of a trait is dependent upon the resultant of interaction between genotype and environment, much heat and little light has been generated by attempts to answer the question, "How much of Trait X is due to heredity and how much to environment?" Since neither agent alone can produce the observed behavior, the question as stated is meaningless. The question has precise meaning only when framed in terms of the variation between individuals. Two answerable questions should be posed in the nature-nurture issue: (*a*) How much of the *variability* observed within a group of individuals in a specified environment on a specific measure of a specific trait is attributable to genetic factors? (*b*) How modifiable by systematic environ-

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[2] Formerly at the University of Minnesota.

mental manipulation is the phenotypic expression of each genotype? The answers to these questions will vary according to age, sex, culture, trait, and method of assessment. The importance of genetic factors will range from almost none to overwhelming for those individuals who have been found to have either more or less than 46 chromosomes (Lejeune & Turpin, 1961).

The genes exert their influence on behavior through their effects at the molecular level of organization. Enzymes, hormones, and neurons may be considered as the sequence of complex path markers between the genes and the aspects of behavior termed personality. The inability of behavioral genetics to demonstrate this type of reduction at the present time need be no more embarrassing than the lack of information concerning the biochemical changes associated with habit formation is to the psychology of learning. It may be that measures of behavior qua behavior are the only reliable indicators of certain kinds of genetic differences (Fuller, 1957; Fuller & Thompson, 1960). For our purposes the best way to conceptualize the contribution of heredity to a personality trait is in terms of heredity's determining a norm of reaction (Dobzhansky, 1955) or of fixing a reaction range (Gottesman, 1963). Within this framework a genotype determines an indefinite but circumscribed assortment of phenotypes, each of which corresponds to one of the possible environments to which the genotype may be exposed. Allen (1961) pointed out that the most probable phenotype of some genotypes may be such a deviant one that even the most favorable of currently known environments would not suffice to bring it within the normal range.

Within the broad context of evolution the demonstration of heritable components for personality traits involves more than an academic exercise. The one nonrandom genetic process which accounts for the adaptive orientation of evolution is differential success in reproduction. If there are heritable aspects to some personality traits and if there is assortative mating for these traits, the frequencies of the associated genes will increase in the gene pool of the population. Tryon (1957) has proposed a behavior genetics model of society which suggests that relative reproductive isolation between social strata plus social mobility could account for some of the class differences observed in achievement and personality.

In the brief history of contemporary psychology the search for genetic aspects of personality has been dominated by an understandable emphasis on mental illness and mental deficiency (Allen, 1958; Kallmann, 1959). Almost all of such research has occurred within a context of classical Mendelian major gene mechanisms. The inappropriateness of this model for the observed quantitative variation in normal personality traits has been one of the inhibitors to investigations by psychologists. Although the classical study by Newman, Freeman, and Holzinger (1937) focused on intelligence and achievement, a number of the personality tests then available were included in the battery administered to their large sample of twins. From their results the authors concluded,

> The only group of traits in which identical twins are not much more alike consists of those commonly classed under the head of personality [p. 352].

With very few exceptions (Cattell, Blewett, & Beloff, 1955; Vandenberg, 1962) this conclusion appears to have been accepted as a valid statement of the relationship of genetics to normal personality. Improvements in personality measurement (Cronbach, 1960) and a new era of sophistication about the construction and application of psychometric devices (Cronbach & Meehl, 1955; Loevinger, 1957) make it possible for us to re-examine the relationship in question. This study is an effort in this direction.

The present research attempted to improve upon the methodology of previous twin studies by incorporating a number of refinements. The sample was selected after the entire population of same-sex twins had been enumerated in a large area; the representativeness of the sample to the population was then ascertained. Accuracy and objectivity of zygosity diagnosis were ensured by means of serological tests for 46 different phenotypes in nine different blood group systems and by the use of fingerprints, height, and photographs. Two types of objectively scored

personality inventories were used, each purporting to be comprehensive but parsimonious in its characterization of the personality domain. Unlike the tests which historically have been used in an effort to elucidate the "nature and nurture" of personality, both types of tests in the present research have a recognized claim on construct validity (Cronbach, 1960, p. 122). One test depends upon the process of factor analysis for the derivation of "pure" trait measures while the other stems from item analyses which separate criterion groups on various empirical dimensions.

A primary goal of the present research is to answer the first question posed above about *how much* of the variability on various traits for a specified sample reared in a particular environment is attributable to genetic factors and how much to environmental. Earlier criticisms of this strategy (Anastasi, 1958; Loevinger, 1943) are well taken but do not render it obsolete. Fuller (1960) has noted that, while the question has no significance for an individual, the contribution of heredity to total variance in a population

> is still a useful object of inquiry, though with increased sophistication we have come to see that the answer to "How much?" is not a universal constant [p. 43].

PROCEDURE

This section gives the details of twin selection as well as a description of the first application in psychological research of the Smith and Penrose (1955) method for the determination of zygosity by extended blood grouping. The efficiency of this method is compared with the methods of the past. Only questionnaire measures of personality were used so as to facilitate the handling of scale scores within the context of quantitative genetics; the tests and their validity and reliability are described. A brief rationale of the twin method is presented followed by a description of the scheme of data analysis.

Selection of the Twin Sample

In sound twin methodology, it is essential that the sample be a miniature of the population of twins. This ensures proportional representation of the two kinds of twins (identical or MZ and fraternal or DZ) and allows accurate genetic analysis with the computed heritability indexes or concordance rates. It is also essential that the two groups of twins in the sample be matched on as many variables as possible so that differences in variance cannot be attributed to differences in age, sex, intelligence, socioeconomic status, or other factors which may influence personality other than the independent variable, genotype.

All class cards for the over 31,000 children in public school Grades 9 through 12 in the cities of Minneapolis, Saint Paul, and Robbinsdale, Minnesota, were examined. All pairs of children with the same last name, same sex, same address, and same birthdate were recognized as the twin population available. Opposite-sexed fraternal twins were not included in the study in order to eliminate the questionable procedure of comparing a boy with a girl on the same personality traits.

The best data available to date about the incidence of twin births in the United States "white" population are those of Strandskov and Edelen (1946) who reported that 1.129% of all births are twin births. Of these, one third are opposite-sexed fraternals, one third are same-sexed fraternals, and one third are identicals. The best known twin studies (Kallmann, 1946; Newman et al., 1937) assumed that only one fourth of all twins are identical.

A total of 163 pairs of same-sex twins were located in the schools' files of 31,307 children. Based on the incidence of twin *births*, 1.129%, the expected incidence of same-sex twins would have been 237 pairs. After calculating neonatal mortality, however, Allen (1955) found that the incidence of twins at 1 month of age had already been lowered to .87 pairs per 100 children (.87%). Based upon this incidence, the expected number of same-sex twin pairs in the entire population would have been 182. After 1 month of age, the mortality of twins is the same as that of single born survivors. By subtracting the known mortality rate in the general population for children reaching the age of 15 (5%), the final expected number of same-sex twin pairs was 173.[3] At the time the present study was conducted, there were no adolescent twins in either the correctional or mental institutions (not counting the two housing mental defective and brain damaged cases) of the state. It would appear that virtually the entire population of same-sex adolescent twins in the public high schools of the three communities was enumerated.

The parents of all pairs in Minneapolis and Robbinsdale and of those in the largest high school in Saint Paul were sent a letter describing the project and a return postcard on which was printed a medical release authorizing blood typing. After 10 days, telephone calls were made to those who had not returned the card indicating the voluntary participation of their children. After another 10 days, a second and last, hopefully persuasive, telephone call was made. These efforts secured the initial cooperation of 26 pairs of boys and 48 pairs of girls. By the end of the study 6 pairs of twins had defaulted for various reasons: 1 pair was lost as a result of fear of the intravenous removal of the blood specimen, one member of another pair had cerebral palsy and could not take the personality tests in the stand-

[3] Evaluation of the sampling adequacy was suggested by and facilitated by E. Anderson.

ard manner, and 4 pairs were unavailable at the times provided for the tests which were Saturday afternoons and mornings.

The final study sample, then, consisted of 23 pairs of boys and 45 pairs of girls. These 68 pairs, disregarding sex, represented 60.2% of the total possible 113 pairs in the schools sampled. The sample contained, respectively, 43.4% and 75.0% of the male and female twin pairs. The sample of the present study compares favorably in size with the majority of twin studies reported in the psychological literature. In representativeness, it is superior to the majority. The simplest explanation for the preponderance of girls over boys is the reluctance of adolescent boys to volunteer their spare time for taking paper-and-pencil tests, especially on Saturdays. The children came from 13 different high schools (all that were sampled), some of which included a ninth grade, and 5 different junior high schools. Participation ranged from 8 out of 8 pairs to 3 out of 8 in the high schools. There was a tendency toward better participation as the economic level of the neighborhood increased.

After the parents of a twin pair had returned the signed authorization for participation and blood typing, an appointment was made to drive the pair to the Minneapolis War Memorial Blood Bank. An appointment was then made for the personality tests. The children were tested in small groups ranging up to 12 pairs. At the time of testing, the children filled out a personal history data sheet, the Minnesota Multiphasic Personality Inventory (MMPI), and the High School Personality Questionnaire (HSPQ; Cattell, Beloff, & Coan, 1958); they were weighed, measured for height, fingerprinted, and photographed. The entire procedure usually took between 3 and 4 hours for each group.

John D. Douthit, Identification Officer with the Minnesota Bureau of Criminal Apprehension, fingerprinted about half of the twins and, after being tutored in the technique, the author fingerprinted the rest. The Faurot inkless method was used with acceptable results and a considerable saving of time. It makes use of a colorless fluid and chemically sensitive paper. An ordinary bathroom scale was used for weighing. Height measurement is estimated to be correct within 5 millimeters. Photography was done by the author with a 35 mm. camera; both a front view and a profile were shot of the head and shoulders.

Some descriptive characteristics of the sample are presented in Table 1. By a serological procedure described in the next section, the 68 pairs of twins were classified into 34 pairs of MZ and 34 pairs of DZ. That this split corresponds to genetic theory is a stroke of luck and an illustration of the representativeness of the sample. About 90% of the twins reported they were of Scandinavian or Western European extraction. In addition to obtaining Otis IQs on the sample, the same data were obtained for 30 more pairs of twins who had not volunteered in Minneapolis and Robbinsdale so that any selection for intelligence might be revealed. It should be noted that the total of 98 pairs accounts for information about the IQs of 86.7% of the *population* of same-sex twins in the schools used. A sampling bias was revealed by the fact that the mean IQ of the nonsample twins was 97, while those of the MZ and DZ samples were 105 and 108, respectively. A t test for the significance of these differences showed that both study samples were significantly different from the nonvolunteers ($t=2.66$, $p < .01$; $t=3.66$, $p < .001$).

Criteria for the Diagnosis of Zygosity and an Evaluation of their Relative Efficiencies

One of the most serious criticisms of much twin research is the inaccuracy of zygosity diagnosis. In reaching a judgment in the past, reliance has been placed on an evaluation of the type of birth membrane or the degree of physical resemblance between the twins. Diagnoses based upon the birth membranes are unreliable because while MZ twins are always monochorionic (i.e., a single membrane surrounding both fetuses), the presence of two chorions is known to occur with both MZ and DZ twins (Stern, 1960, p. 536). In addition, when studying adult or adolescent twins, it is difficult to obtain accurate information about the birth membrane. Diagnosis by means of the placenta is even more unreliable. In evaluating the extent of physical resemblance, geneticists have used such traits as sex, height, weight,

TABLE 1

DESCRIPTIVE CHARACTERISTICS OF THE SAMPLE

Character	MZ	DZ	Combined
Pairs of boys	12	11	23
Pairs of girls	22	23	45
Age			
14	0	2	2
15	15	4	19
16	9	13	22
17	7	10	17
18	3	5	8
Grade			
9	7	5	12
10	15	11	26
11	7	11	18
12	5	7	12
Level of paternal occupation [a]			
I and II	15	9	24
III	7	13	20
V and VI	12	12	24
M Otis IQ	105	108	107
IQ *SD*	12	12	12

[a] The Minnesota Scale for Paternal Occupations, Institute of Child Welfare, University of Minnesota.

eye color, hair color and form, familial appearance, and various types of fingerprint or palmprint analyses. Although there is an unavoidable subjective element in evaluating many of these characteristics, one expert has estimated the error to be no greater that 1 in 10 (Newman, 1940). That this estimate may be in error is demonstrated below.

If twins differ in sex or any other known inherited characteristic, they cannot be MZ twins. However, if the characteristics are alike, the possibility still remains that the twins are DZ. Given a number of simply inherited and widely distributed traits, it is possible to state the probability of monozygosity or dizygosity for a given pair of twins. It is to be noted, however, that all such diagnoses of monozygosity, no matter how many characteristics are identical, will always be statements of probability; that is, the probability of sharing the given number of traits in common.

Numerous criteria were examined in this study with the hope that the various suggestions in the literature for the diagnosis of zygosity might be objectively evaluated against the recognized best method of extensive blood typing recently quantified by Smith and Penrose (1955). Thus blood type alone was compared with blood type combined first with height, second with a difference in total fingerprint ridge count, and then with both height and ridge count. The accuracy of fingerprints alone and height alone was ascertained. In addition, three groups of judges, geneticists, psychologists, and artists, looked at photographs of the twins and made another form of judgment.

All blood specimens were drawn and typed by the Minneapolis War Memorial Blood Bank, Incorporated. The following blood group systems (Race & Sanger, 1958) were used: ABO, MNSs, Rh, P, Lutheran (Lu), Kell (K), Duffy (Fy), Kidd (Jk), and Lewis (Le).

Smith and Penrose (1955) tabulated the probabilities used for an objective determination of the likelihood of dizygosity based on the incidence of phenotypic sib-sib concordance for the above blood groups. A specific example will illustrate the basic principle underlying the origin of the tabulated probabilities. Blood typing of a large Caucasian population in Great Britain shows that the frequency of Type B blood is .084509 and the frequency of two sibs being B is .040062. The probability that if one of two sibs is B the other is also becomes .040062/.084509 or .4741. Since DZ same-sex twins are genetically as similar as ordinary sibs, the probability of DZ twins both being Type B is equally .4741. Probabilities derived in this manner are listed in the upper part of Table 2 together with the initial probability that Caucasian, United States twins are DZ and that of a DZ pair being the same sex. Multiplication of all these independent probabilities results in the probability of finding twins who are DZ and alike in all the gene loci involved. A more extensive discussion of the Smith and Penrose method together with the rationale for the derivation of probabilities for the morphological traits used can be found elsewhere (Gottesman, 1960).

TABLE 2

EXAMPLE OF THE SMITH AND PENROSE METHOD FOR ZYGOSITY DETERMINATION

Character	Independent relative chance
Initial odds	1.9246
Likeness in sex	.5000
Likeness in ABO	.6891
Likeness in MNSs	.4556
Likeness in Rh	.5021
Likeness in Le	.8681
Likeness in K	.9485
Likeness in Fy	.8036
Likeness in Jk	.8531
Likeness in Lu	.9614
Likeness in P	.5699
Total relative chance p_{DZ} (blood)	.0470
Total chance $p_{DZ}/(1+p_{DZ})$	.0448
Difference in ridge count	.2288
Total relative chance (blood + ridges)	.0107
Total chance	.0106
Difference in stature	.4671
Total relative chance (blood + stature)	.0219
Total chance	.0214
Total relative chance (all of above)	.0050
Total chance	.0050

As a result of the blood typing, 34 pairs of twins were diagnosed as definitely DZ, that is, they differed on at least one of the independently inherited blood groups. Using only blood, the remaining 34 pairs were diagnosed as MZ with the probability of accuracy no less than 95 times in 100. Table 3 summarizes the results of the accuracy for the various combinations of blood and physical characteristics. It seems paradoxical that while additional information increased the accuracy of some of the diagnoses, it was at the expense of serious errors, e.g., using all the characters resulted in calling 22 pairs MZ at the .01 level or better, but at the expense of 6 pairs failing to meet the criterion of the .05 level. The primary reasons for this are the lack of cross validation and the small samples upon which the fingerprint and height probabilities are calculated, 52 and 50 pairs of MZ, respectively. This resulted in a range of within-pair differences too narrow to allow for those found in the present sample of MZ twins. The probability figure given was too much in the DZ direction to be overcome by any amount of additional information. Eight pairs of MZ twins had differences of ridge count which were tabulated at probabilities greater than 1.0 in favor of the DZ contingency. Similarly, five pairs were "penalized" for differences in height larger than the tabulated ones for the 50 criterion pairs of MZ twins on which they were based. Differential growth rates during adolescence

may have been another attenuating factor in the use of the probabilities attached to differences in height.

Let us turn now to two different analyses of the fingerprints: one clinical and the other statistical. Given the 68 pairs of fingerprints and no information as to the base rates, i.e., incidence of DZ and MZ twins in the sample, how accurately can an expert diagnose the two kinds of twins? Douthit undertook this task and was able to correctly identify 30 MZ pairs and 23 DZ pairs. Most important in his clinical decisions were three components (Cummins & Midlo, 1943): differences in pattern slope for the same finger in a twin pair, similarities in slope but different patterns, and differences in the range of dermal ridges for paired fingers. His decisions were not purely clinical in the Meehl (1954) sense of the word in that he subjectively assigned different weights to these components, and used the scores a pair of prints obtained. The statistical method used was for the author to assign what appeared to be the optimum cutting score (Meehl & Rosen, 1955) to the distribution of differences between total ridge count. This cutting score was then cross validated by applying it to the original distribution (Smith & Penrose, 1955) from which the aforementioned probabilities were determined. A cutting score of 30 classified 33 of 34 MZ pairs and 20 DZ pairs correctly. This score correctly classified 51 of the original 52 MZ pairs at the expense of misclassifying 39 of 101 (38.6%) like-sex siblings. The clinical and statistical methods tied in their accuracy for diagnosing the entire present sample with both hitting 78%. Both Newman, Freeman, and Holzinger (1937) and Slater (1953) make use of some aspects of fingerprints in their diagnosis of zygosity.

Judgments of photographs constituted the final method of zygosity determination evaluated in this section. A summary of all the methods attempted is then presented. Three groups of judges were utilized; three geneticists, three child psychologists, and three artists.[4] Although the front and profile pictures of the head were black and white 35 mm. contact prints, expressions of dissatisfaction with their quality were minimal.

It is obvious that previous estimates (e.g., Newman, 1940) of a 10% error in the diagnosis of zygosity by general appearance are subject to doubt. Jackson's (1960) contention that he observed a "striking difference" between photographs of MZ and DZ twins in the literature needs to be re-evaluated. Even allowing for the quality of photographs and the absence of the cues from the twins' physical presence, the median accuracy of 72% for all nine judges was significantly less than an expected 90% ($\chi^2 = 24.33$, $p < .001$). Poor reliability of judgments may be inferred from the fact that for only 13 MZ pairs and 14 DZ pairs were there one or no inaccurate judgments. There was a total of 84 errors in judging the MZ twins and 70 errors in judging the DZ twins. Judging the MZ girls seemed to be the most difficult. To the extent that the data in Table 3 were stable, only the geneticists made sufficient allowance for the variability that existed between MZ twins.

[4] I am grateful for the assistance of Vivian Phillips, Elizabeth Reed, S. C. Reed, J. E. Anderson, Mildred C. Templin, R. D. Wirt, Carol Safer, L. Safer, and Ane Wolfe Graubard.

Summary

For the sake of clarity, the accuracy of zygosity determination for all the methods described thus far is presented in Table 3.

It should be noted that the three columns cannot be evaluated independently of one another. A judge of the photographs or fingerprints could maximize his accuracy in one category at the expense of the other. It is the final column which conveys the most meaning. The blanks in the table derive from the fact that the DZ twins were absolutely removed from further consideration by the blood typing methodology in the Smith and Penrose scheme.

Psychometric Devices

Both instruments used to measure personality in this study come under the category of objective as contrasted with projective tests. Within the former group there are two major types of questionnaires: one is derived empirically from its ability to discriminate among behavioral phenotypes and the scales may be said to have functional unity, and another type is derived by factor analysis and the scales may be said to have statistical unity. The MMPI was selected as an example of the first type and the HSPQ of the second.

Widespread usage of the MMPI precludes the necessity for a detailed description (Dahlstrom & Welsh, 1960). The test was constructed to provide,

TABLE 3

ACCURACY SUMMARY FOR METHODS OF ZYGOSITY DETERMINATION

Method	MZ %	DZ %	Total %
Blood ($p \leq .05$)	100	100	100
Blood + Height	85	—	—
Blood + Ridge count	88	—	—
Blood + Height + Ridge count	82	—	—
Height + Ridge count	0	—	—
Fingerprints			
Clinical	88	68	78
Statistical	97	59	78
Photos			
Best geneticist	97	74	85
Best psychologist	59	82	71
Best artist	79	91	85
Pooled judges (6/9 agreement)	68	88	78

in a single instrument, measures of all the more important phases of personality of interest to the psychiatrist. Items were selected from 26 subject-matter categories, e.g., general health, sensory disturbances, family problems, sexual and social attitudes, masculine and feminine interest patterns, and schizophrenic thinking disturbances. The 550 items were answered *true* or *false*. Use of the MMPI with normal adolescents may be questioned, but this practice is becoming more popular as experience accumulates with this age group (Hathaway & Monachesi, 1961; Wirt & Briggs, 1959). A basic assumption of the present research was that personality scales represent dimensions or continua of behavior, not categories. Such scales thus lend themselves to the assumptions of quantitative inheritance and permit the use of nonpsychiatric subjects. Numbers have been assigned to the MMPI scales instead of their Kraepelinian based names by the developers of the test so as to facilitate fresh associations to the meaning of the scales as personality constructs. There is no simple translation from MMPI data into descriptive terms for normal populations, but adjectives associated with the behavior of subjects with different scale patterns are easily obtained (e.g., Black, 1953).

The group form of the test was used and scored in the usual fashion for the four validity indicators and 10 clinical scales, 1 through 0 (or Hypochondriasis —*Hs*—through Social Introversion—*Si*). In addition, 6 experimental scales (Hathaway & Briggs, 1957), Ego Strength (*Es*), Anxiety (*A*), Repression (*R*), Dominance (*Do*), Dependency (*Dy*), and Social Status (*St*) were scored and analyzed. The 5 scales requiring a *K* correction were analyzed after the correction had been made.

Test-retest reliability coefficients on the 10 standard MMPI scales for a sample of 100 male and female college students after a 1-week interval (Dahlstrom & Welsh, 1960, p. 472) range from .56 to .90. These particular coefficients were chosen because they are most comparable to the circumstances under which the HSPQ reliabilities were computed.

The HSPQ is new to the literature on personality tests and requires more exposition than the MMPI. Cattell, Beloff, and Coan (1958) constructed this instrument by factor analysis especially for adolescents 12 through 17 years in the tradition of the Cattell (1946, 1950) laboratory. It is said to cover all the major dimensions involved in any comprehensive view of individual differences in personality (Cattell et al., 1958).

It consists of 280 forced-choice items, all of which are scores, which form 14 independent, equal length, scales. Although printed in two forms of 140 items each, the authors[5] recommend the use of both to obtain sufficient reliability. It is also suggested that raw scores rather than standard scores be used for research purposes and this suggestion was followed. The scale designations and their titles are given in Table 4. Test-retest correlations based on 112 children aged 13 through 15 tested 2 weeks apart with the full test range from .68 to .80.

In the opinion of the constructors, validity for the 14 scales is satisfactorily established. The main technique used to demonstrate this is the computation of a multiple correlation from factor–item correlations. This gives a median r of .81. Although no correction for Test-Taking Attitude is used, there are equal numbers of "yes" and "no" keyed answers on each scale.

It should be obvious that the reliabilities of the MMPI and the HSPQ are on much firmer ground than the validities. Unfortunately, the magnitude of the test-retest correlations has no direct bearing on the construct validity of a scale (Loevinger, 1957). An inherent difficulty in measuring personality traits is the observation that they change with the passage of time and with intervention. After the data of the present study are analyzed, there should be more evidence for the validity, or lack thereof, of the various scales. At the least one might expect significant correlations between MZ twin siblings. Another speculation would be the absence of negative correlations between either class of twins unless there were some parsimonious explanation of a within-pair interaction on a trait.

Twin Method

Bacteria, fruit flies, and mice have contributed greatly to the body of genetic knowledge, but the application of this knowledge to the causes of variation in human behavior raises difficulties. Moreover, relatively few direct methods are available to the

TABLE 4

HSPQ SYMBOLS AND TITLES[a] FOR TEST DIMENSIONS

Symbol	Low score	High score
A	Stiff, Aloof	Warm, Sociable
B	Mental Defect	General Intelligence
C	General Neuroticism	Ego Strength
D	Phlegmatic Temperament	Excitability
E	Submissiveness	Dominance
F	Sober, Serious	Enthusiastic
G	Casual, Undependable	Super Ego Strength
H	Shy, Sensitive	Adventurous, Thick-Skinned
I	Tough, Realistic	Esthetically Sensitive
J	Liking Group Action	Fastidiously Individualistic
O	Confident Adequacy	Guilt Proneness
Q_2	Group Dependency	Self-Sufficiency
Q_3	Uncontrolled, Lax	Controlled, Showing Will Power
Q_4	Relaxed Composure	Tense, Excitable

[a] A mixture of technical and popular terms was used here.

[5] R. B. Cattell, personal communication, February 1959.

researcher in human behavior genetics because of such problems as those introduced by uncontrolled mating, small numbers of offspring, heterogeneous environments, and the uniqueness of one individual's heredity. Of the available methods, the twin method approaches the ideal experimental design. Galton (1875) first called attention to the possible usefulness of twins for casting light on the nature-nurture problem. The underlying principle is simple and sound: since MZ twins have identical genotypes, any dissimilarity between pairs must be due to the action of agents in the environment, either postnatally or intrauterine; DZ twins, while differing genetically, have certain environmental similarities in common such as birth rank and maternal age, thereby providing a measure of environmental control not otherwise possible. When both types of twins are studied, a method of evaluating either the effect of different environments on the same genotype or the expression of different genotypes under the same environment is provided. This means, with respect to any given genetically determined trait, that there should be a greater similarity betwen MZ than between DZ twins. If both members of a twin pair develop the same phenotype in a given environment, they are called *concordant* for the trait under study; *discordant* is the designation for differing phenotypes. When dealing with a single gene difference, such as Huntington's chorea, MZ twins should always be concordant; DZ twins may be either concordant or discordant. The expected difference in concordance can then be used to give a measure of heritability (H) of the trait if the traits are amenable to discrete classification.

Inasmuch as few traits in the normal range of human personality are dichotomous, another approach is needed to estimate H when traits are continuous and the genetic component is of the polygenic variety. In the present research, H will be defined as the proportion of total trait variance associated with genetic factors. Holzinger (1929) suggested that the best comparison to make in evaluating the nature-nurture interaction for a quantitative characteristic is that between the intraclass correlation coefficients (R) for MZ and like-sexed DZ twins. Holzinger's H gives the proportion of variance produced by genetic differences *within families*. The method underestimates the effects of heredity in the general population by a factor of approximately 2 since the genetic variance is estimated from the genetic overlap between DZ twins which is .5. The index of heritability, h^2, computed in animal behavior genetics (e.g., Falconer, 1960; McClearn, 1961) is different from H in that it is an estimate of the proportion of trait variance in a population determined by genotypic variation in that population. Both between- and within-families variance components are used to compute h^2.

Holzinger gave two formulas for his estimate of heritability, one based on R and another, statistically equivalent, based on the within-pair variances.

$$H = \frac{R_{MZ} - R_{DZ}}{1 - R_{DZ}}$$

$$H = \frac{V_{DZ} - V_{MZ}}{V_{DZ}}$$

where,

R_{MZ} = intraclass correlation between MZ twins
R_{DZ} = intraclass correlation between DZ twins
V_{MZ} = within-MZ pairs variance estimate (mean square)
V_{DZ} = within-DZ pairs variance estimate (mean square)

Falconer has suggested that the difference between the MZ and DZ Rs could be taken as an estimate of half the heritability if there were no nonadditive genetic variance; since the latter assumption is probably not warranted, the difference can only be regarded as setting an upper limit to half the heritability.

Limitations and Criticisms of the Twin Method

After reviewing probable natal and prenatal influences on twin development, Price (1950) was willing to conclude,

> In all probability the net effect of most twin studies has been underestimation of the significance of heredity in the medical and behavior sciences [p. 293].

This appears to be the result of biases of two sorts. Inferences drawn from data on twins are subject to both statistical and biological biases. In the first category, it is basic to the kinds of analyses discussed above that the samples be proportional and therefore representative of the population of MZ and like-sexed DZ twins before *the* concordance or *the* variance used in the formulas can be assumed to be valid enough to support the inferences. This assumption is difficult to meet. Use of the twin method also assumes that the within-pair environmental variance is the same for the two types of twins. This is not necessarily true for the personality traits as measured by the tests, but one can proceed only on the assumption that such variance is not too different for the two types of twins. Loevinger (1943) mentioned some additional difficulties underlying the use of the variance method, chief among which were the assumption that influences combine additively and the assumption that estimates of the error variance are eliminated from the computation of H. Again the extent to which these conditions are met is hard to assess. Cattell (1953) concluded that approximations of a solution to the nature-nurture issue, with an awareness of methodological shortcomings, were better than postponing all research in the area. The author is inclined to agree.

Biological biases have been reviewed by Price (1950) who divided them into natal factors (e.g., position in utero), lateral inversions, and effects of mutual circulation. No attempt to evaluate these factors will be made since data are not available. Postnatal biological biases are often overlooked on the apparent assumption that the general environment for a pair of twins is the same. Once more the assumption is questionable. Should one of a pair, for

example, contract some form of encephalitis with its well-known sequelae, the results on personality measurement would be obvious.

The main limitations of twin studies were viewed in somewhat different terms by Kallmann and Baroff (1955) as the following:

> (*a*) twins cannot be separated before they are born, nor can they be provided with two mothers of different age, personality, or health status; (*b*) two-egg twins are no more dissimilar genotypically than brothers and sisters and like them, are rarely raised in different cultures; therefore, even fraternal twins are unlikely to fall into the extremes of theoretically possible genetic and cultural differences; and (*c*) the average difference between one-egg twin partners is no precise measure of environmentally produced variation, nor does an increase over the average difference between two-egg twins represent the exact contribution of genetic influences even in relatively comparable environments [p. 303].

Intraclass Correlation Analysis of Personality Traits

Following the diagnosis of zygosity and the collection of the personality test data, each scale of the two tests and the IQ from the school records were analyzed by means of the intraclass correlation coefficient, first for the two classes of twins and then for the two sexes within each class. A total of 186 coefficients was obtained from 186 simple one-way analyses of variance using *T* scores for the MMPI, raw scores for the HSPQ, and Otis IQs.

Haggard's (1958) book on the intraclass correlation gives a detailed exposition of the method used here. Although the *intraclass* correlation was formerly computed by calculating the *interclass* correlation after constructing a symmetrical table with double entries for a pair of scores and then dividing by 2, it now is recognized as a simple function of variances. Haggard (1958, p. 11) gives this formula for the computation:

$$R = \frac{BCMS - WMS}{BCMS + WMS}$$

where,

$BCMS$ = between-classes (twin pairs) mean square

WMS = within-classes (twin pairs) mean square

This means that the unbiased estimate of R may be obtained in terms of the mean squares (i.e., variance estimates) of the analysis of variance table. This formula is the specific one to use for pairs of scores. The relationship of F, the variance ratio, to R is given by:

$$F = \frac{1+R}{1-R}$$

The level of statistical significance of R is identical with that of the corresponding F (i.e., $BCMS/WMS$). In other words, the hypothesis that an observed R could have come from a population with a true correlation of zero can be tested by the F ratio computed from the same mean squares, with the appropriate degrees of freedom, as were used to obtain R.

In order to test the significance of the differences between two independently obtained Rs, they were converted into Fisher's z (Fisher & Yates, 1949) which has an approximately normal distribution with variance:

$$V = \frac{k}{2(c-2)(k-1)}$$

where,

k is the number of individuals within a class, i.e., 2 (MZ or DZ twins), and c is the number of classes, i.e., 34 (pairs).

The distribution of the difference between the corresponding z values is approximately normal with variance:

$$V_d = \frac{k_1}{2(c_1-2)(k_1-1)} + \frac{k_2}{2(c_2-2)(k_2-1)}$$

Dividing the difference between z's by the square root of the above gives a normal deviate, the p value of which is found in the usual manner. A one-tailed test of significance was appropriate and was used.

Recapitulating, the objectives of this intraclass correlation analysis of traits are (*a*) to demonstrate that the traits are significantly and positively correlated in MZ twins and may or may not be in DZ twins and (*b*) to demonstrate that for any genetically influenced trait the correlation within MZ pairs will be significantly greater than that within DZ pairs.

Subsequent to this analysis, the heritability indexes were computed as described in the previous section using the independently obtained WMS or within variances. It should be noted that the two procedures, intraclass correlation analysis and computation of heritability indexes, involve simple and complex assumptions, respectively. The correlation analysis is sufficient to show that heredity has something to do with individual differences. Estimates of the relative importance of nature and nurture as indicated by H must be considered as suggestive rather than definitive in human behavior genetics.

Configural (Holistic) Analyses of Personality Similarity

Following a scale-by-scale analysis, one of the two personality tests was selected for holistic profile analyses. The MMPI was chosen because MMPI configurations have been treated extensively in the literature. Recent emphasis on the study of profiles has resulted from the realization that interpretation of an individual's set of scores must frequently be based on the pattern of scores rather than examination of one scale at a time or the use of a linear sum of the scale deviations. General and specific methodological difficulties arise which weaken any confidence that may be attached to the quantification of profile similarity. Only a few of the difficulties

noted by students of the problem (Cronbach & Gleser, 1953; Osgood & Suci, 1952) will be discussed.

Similarity as a general quality of personality is nebulous but necessary for communication. Cronbach and Gleser (1953) say:

> *similarity is not a general quality. It is possible to discuss similarity only with respect to specified dimensions (or complex characteristics).* This means that the investigator who finds that people are similar in some set of scores cannot assume that they are similar in general. He could begin to discuss general similarity only if his original measurement covered all or a large proportion of the significant dimensions of personality [p. 457].

Other general methodological difficulties involve the loss of information by reducing the relationship between two configurations to a single index; lack of comparability between indexes of similarity; and violations of assumptions about ratio scales, uncorrelated measures, and equal reliability among subtests.

There are two aspects of profiles which matching may involve: the shape or configuration of scores and the general elevation from the mean of the norm group. It is logical to distinguish between matching for absolute agreement, in which both shape and elevation are considered, and relative agreement, in which only shape is considered. Three statistical and one clinical indexes of similarity were computed for the two classes of twins. In addition, the profile of each twin was coded according to the methods of both Hathaway and Welsh (Dahlstrom & Welsh, 1960) to facilitate further clinical assessment (Gottesman, 1960).

Statistical Indexes

Rank-Difference Correlation. This well-known measure, Spearman's rho, was the first index computed. It yielded a nonarbitrary number which reflected similarity of shape but disregarded elevation. One of its disadvantages was that a rho of 1.00 did not necessarily indicate perfect similarity and another was that two pairs of profiles with the same coefficient need not be equally similar. Rho's were calculated from the Welsh codes; ties were resolved by using the scales in numerical order.

D *Coefficient.* This index, sometimes known as the generalized distance function, was then computed. Cronbach and Gleser (1953) devote considerable attention to this index which is designed to reflect both shape and elevation. The D coefficient is based on the geometric principle that in a space of N mutually orthogonal dimensions, the distance between two points is equal to the square root of the sum of the squared differences between the coordinates of the points on each dimension. Since profiles may be considered as points in N space, where N equals the number of scales (i.e., 10), the distance between them serves as a measure of similarity. Note that orthogonality does not obtain for the MMPI. The D coefficient results in an arbitrary number whose value depends on the number of scales.

Concordance of Test Behavior (TT'). In the context of discovery it was decided to compute the absolute percentage of MMPI items answered in the same direction by a pair of twins, i.e., one twin's answer sheet was used to score the other's. Of course the MMPI was not designed to be used this way and in this instance serves primarily as an item pool. The percentage of agreement for the 566 items has been termed *TT'*, to signify the comparison of one twin with his sibling. No provision was made for the few items which are repeated, but any question omitted by either twin was subtracted from 566 before the percentage was calculated. This process was then repeated using only those items appearing on the 10 clinical scales (337 items).[6]

Clinical Index

Visual Judgment. The only quantifiable clinical index of similarity used was the accuracy of visual judgment in sorting the profiles into four categories: Very Similar, Similar, Dissimilar, and Very Dissimilar. By *accuracy* was meant the number of MZ pair profiles placed in the first two categories and the number of DZ in the last two. Three psychologists[7] skilled in the use of the MMPI were the judges. Another indication of similarity was provided by comparison of the accuracy of visual judgments in the extreme categories with the overall accuracy.

Recapitulating, the objective of each of the above four procedures was to search for a greater similarity of personality, as measured by the configural aspects of the MMPI, for the MZ twins than for the DZ twins.

RESULTS

The presentation of the findings is organized around the two instruments of assessment; first the MMPI with its 10 clinical scales, 6 experimental scales, and K (a validity scale thought to have personality referents); and second the HSPQ with its 14 factored scales. Indexes of H are presented separately after each correlational analysis. Results are displayed for the total sample of 34 pairs each of MZ and DZ twins, then for the female subsample (22 MZ and 23 DZ pairs) and then for the male subsample (12 MZ and 11 DZ pairs). The results by sex are provocative but any extensive discussion of

[6] Hathaway's linear statistic *CC'* was also calculated with no improvement over any of the statistical methods reported here. Data are available upon request.

[7] Thanks are due Jan Duker, H. Gilberstadt, and R. D. Wirt.

TABLE 5

MMPI INTRACLASS CORRELATIONS FOR MZ AND DZ TWINS FOR TOTAL GROUP, FEMALES, AND MALES

	Total Groups' *R*		Females' *R*		Males' *R*	
Scales	MZ	DZ	MZ	DZ	MZ	DZ
1 *Hs*	39**	21	14	19	44	25
2 *D*	47**	07	44*	25	48*	−19
3 *Hy*	47**	41**	36*	51**	65**	30
4 *Pd*	57***	18	45*	25	66**	−07
5 *Mf*	52***	32*	52**	35*	55*	28
6 *Pa*	44**	18	44*	31	43	−10
7 *Pt*	55***	20	62***	11	40	31
8 *Sc*	59***	19	50**	12	65**	19
9 *Ma*	24	−07	29	−28	11	42
0 *Si*	55***	.08	37*	18	73**	−04
K	32*	−02	30	03	40	−26
Es	25	47**	17	49**	48*	30
A	45**	04	46*	12	42	−35
R	29*	.22	20	15	50*	42
Do	46**	21	22	40*	72**	−44
Dy	52***	25	59**	47**	28	−37
St	47**	53***	28	63***	72**	24

* $p \leqq .05$.
** $p \leqq .01$.
*** $p \leqq .001$.

them is vitiated by the size of the samples. This section concludes with the results of the configural and holistic MMPI profile analyses. Thorough discussion of the results is deferred to the next section.

Minnesota Multiphasic Personality Inventory

The excellent matching of the two classes of twins and their representativeness of adolescents in general were observed on the mean scores and standard deviations of the 3 validity scales and the 10 clinical scales. Intraclass correlation coefficients for the twins are given in Table 5. Nine of the 10 standard MMPI scales were significantly different from zero at the .01 level for the MZ twins. Fifteen of the 17 MMPI MZ scale correlations were larger than the corresponding correlations for DZ twins. It should be noted that for 6 of the 8 total MZ scale correlations for which test-retest reliability data on adolescents were available, the magnitudes are about the same.

Rozeboom (1960) has reminded us that the

> primary aim of a scientific experiment is not to precipitate decisions, but to make an appropriate adjustment in the degree to which one accepts, or believes, the hypothesis or hypotheses being tested [p. 420].

Since the traditional null hypothesis tests in psychological research pay no attention to the utilities of various outcomes, he suggested that the basic statistical report should be in the form of a *confidence interval* whenever possible. It is obvious, in the case of correlation coefficients, for example, that the researcher is concerned with more than the fact that a particular coefficient is not zero—he hopes he is in a position to account for more than a trivial amount of variation. In sympathy with the Rozeboom position, a few of the 90% confidence limits for the data in Table 5 will be mentioned. For the largest nonzero R in the total sample of MZ twins, .59 for Schizophrenia (*Sc*), the limits are .35 and .74; for the smallest nonzero R, .39 for *Hs*, the limits are .13 and .61. For the corresponding Rs, in the sample of DZ twins, .19 for *Sc*, the limits are −.10 and .44; for *Hs*, .21, the limits are −.08 and .46.

The results of testing whether or not the correlation between MZ pairs is significantly greater than that between DZ are presented in Table 6. All Rs were first converted to

TABLE 6

ONE-TAILED TEST OF THE DIFFERENCE BETWEEN MZ AND DZ MMPI SCALE INTRACLASS CORRELATIONS FOR TOTAL GROUP, FEMALES, AND MALES

	Total group		Females		Males	
Scale	Normal deviate	*p*	Normal deviate	*p*	Normal deviate	*p*
1 *Hs*	.79	.21	−.16		.47	.32
2 *D*	1.76	.04	.69	.24	1.56	.06
3 *Hy*	.30	.38	−.59		1.01	.16
4 *Pd*	1.86	.03	.73	.23	1.88	.03
5 *Mf*	.98	.16	.68	.25	.72	.24
6 *Pa*	1.16	.12	.48	.31	1.22	.11
7 *Pt*	1.66	.05	1.97	.02	.22	.41
8 *Sc*	1.94	.03	1.37	.08	1.27	.10
9 *Ma*	1.26	.10	1.88	.03	−.73	
0 *Si*	2.15	.02	.66	.25	2.11	.02
K	1.40	.08	.89	.19	1.50	.07
Es	−1.02		−1.17		.46	.32
A	1.78	.04	1.20	.11	1.77	.04
R	.30	.38	.16	.43	.22	.41
Do	1.14	.13	−.64		3.00	.001
Dy	1.28	.10	.54	.30	1.47	.07
St	−.32		−1.45		1.44	.08

Fisher's z's. The MZ twins appeared to be significantly higher than DZ on 5 of the 10 standard MMPI scales (p less than or equal to the 5% level). The results from the correlational analyses then left 5 of the 10 standard scales, 2—Depression (D), 4—Psychopathic deviate (Pd), 7—Psychasthenia (Pt), 8—Schizophrenia, and 0—Social Introversion, which appeared to have significant genetic (i.e., gene determined) components for the combined group.

The heritability estimates for the MMPI scales, which only utilize within-pair variances, are presented in Table 7. While there is no method yet for the computation of confidence limits for H, the suggested way for testing its significance is a function of the significance of the F ratio formed by the within-DZ pair variance divided by the within-MZ pair variance. Even when the computation of H in the present study showed that 42% of the observed within-family variance for the total group could be accounted for by genetic factors, the associated F was not statistically significant at the .05 level. The infrequent reporting of the significance of H in the literature together with the paucity of positive results for even intellectual and psychomotor tasks (Vandenberg, 1962) suggests a need for mathematical clarification of H. Within the limits of the assumptions for this kind of analysis, this attempt at quantification of the proportion of scale variance accounted for by heredity gave positive results for the same five scales identified by the correlational analysis. Scales Pt and Sc showed appreciable variance accounted for by heredity but with environment predominating. Scales D and Pd showed about equal contributions of heredity and environment. Scale 0, Social Introversion, showed a predominance of variance (.71) accounted for by heredity. The value of H for the Si scale is of the same magnitude as that found in this study and others for intelligence as measured by standard IQ tests.

TABLE 7

MMPI SCALE HERITABILITY INDEXES FOR TOTAL GROUP, FEMALES, AND MALES

	Total group		Females		Males	
Scale	H	F[a]	H	F[a]	H	F[a]
1 *Hs*	.16	1.19	.25	1.33	.01	1.01
2 *D*	.45	1.81	.22	1.28	.65	2.83
3 *Hy*	.00	.86	.00	.56	.43	1.74
4 *Pd*	.50	2.01	.37	1.60	.77	4.35
5 *Mf*	.15	1.18	.00	.99	.45	1.83
6 *Pa*	.05	1.05	.00	.70	.52	2.09
7 *Pt*	.37	1.58	.47	1.89	.24	1.31
8 *Sc*	.42	1.71	.36	1.56	.50	2.00
9 *Ma*	.24	1.32	.33	1.50	.00	.81
0 *Si*	.71	3.42	.60	2.49	.84	6.14
K	.06	1.06	.00	.95	.26	1.35
Es	.00	.73	.00	.69	.00	.84
A	.21	1.26	.22	1.28	.18	1.22
R	.00	.82	.00	.79	.00	.86
Do	.00	.95	.00	.76	.33	1.50
Dy	.24	1.32	.03	1.03	.45	1.82
St	.34	1.52	.14	1.16	.63	2.69

[a] The three values of F required for significance at the .05 level are 1.78, 2.04, and 2.72.

Cattell's Factored Test

Once again the excellent matching of the two classes of twins and their representativeness of adolescents in general may be inferred from the comparison of mean scores on the 14 scales with the normative data. Intraclass correlation coefficients for the MZ and DZ twins are given in Table 8. Eight of the 14 scales had correlations between MZ twins greater than zero. Two scales, A and J, were not significantly different from zero for both MZ and DZ twins.

Six of the 14 factors resulted in correlation coefficients which were not significantly different from zero for the MZ twins. That DZ should obtain significant correlations on 4 of these 6 was paradoxical. It is difficult to reconcile claims of construct validity for these 6 scales with these results. Unless there were some logical a priori grounds for identical twins to be opposed on some trait, their identical heredity and/or their very similar environment would lead us to expect other than a zero correlation between them for a personality trait. The factor derivation of all the scales and their low intercorrelations permitted acceptance and interpretation of the remaining eight scales on their own merit. Factors B, F, G, H, I, O, Q_2 and Q_3 at this point in the analysis have the potential for showing a predominance of genetic variance.

For the largest nonzero R in the total sample of MZ twins (other than the intelligence

factor), .60 for Q_2, the 90% confidence limits are .38 and .75; for the smallest nonzero *R*, .30 for Q_3, the limits are .02 and .54. For the corresponding *R*s in the sample of DZ twins, .15 for Q_2, the limits are −.13 and .42; for Q_3, .12, the limits are −.16 and .39.

In Table 9 are presented the results of testing whether or not the correlation between MZ pairs is significantly greater than that between DZ. All *R*s were first converted to Fisher's *z*'s.

The MZ twins were significantly higher than DZ on only one HSPQ factor, Q_2. For 8 of the 14 factors the differences were in the predicted direction. The results from both the correlation analyses then left only 1 factor, Q_2—Group Dependency versus Self-Sufficiency, which appeared to have significant genetic (i.e., gene determined) components.

The heritability indexes for the HSPQ scales, computed only from the within-pair variances, are presented in Table 10. Within the limits of the assumptions for this analysis, this attempt at quantification of the proportion of scale variance accounted for by heredity gives positive results for 6 of the 14 factors. Factors E, Submissiveness versus Dominance; H, Shy, Sensitive versus Adventurous; and J, Liking Group Action versus Fastidiously Individualistic showed appreciable variance accounted for by heredity but with environment predominating. Factors F, Sober, Serious versus Happy-Go-Lucky; Q_2; and O, Confident Adequacy versus Guilt Proneness showed about equal contributions of hereditary and environmental variance (.56, .56, and .46).

TABLE 8

HSPQ INTRACLASS CORRELATIONS FOR MZ AND DZ TWINS FOR TOTAL GROUP, FEMALES, AND MALES

	Total groups' *R*		Females' *R*		Males' *R*	
Factor	MZ	DZ	MZ	DZ	MZ	DZ
A	19	27	26	40*	−10	05
B	60**	61***	65***	66***	56*	57*
C	28	38*	05	12	33	76**
D	21	47**	23	62***	19	23
E	16	41**	−06	53**	33	−18
F	47**	12	29	16	64**	04
G	49**	42**	23	33	76***	56*
H	38*	20	42*	34	34	−15
I	55***	47**	26	00	37	14
J	26	−04	29	−08	24	−01
O	45**	37*	50**	51**	20	−04
Q_2	60***	15	54**	−02	51*	42
Q_3	30*	12	56**	34	−01	−22
Q_4	27	32*	35*	16	12	73**

* $p \leq .05$.
** $p \leq .01$.
*** $p \leq .001$.

TABLE 9

ONE-TAILED TEST OF THE DIFFERENCE BETWEEN MZ AND DZ HSPQ SCALE INTRACLASS CORRELATIONS FOR TOTAL GROUP, FEMALES, AND MALES

	Total group		Females		Males	
Factor	Normal deviate	*p*	Normal deviate	*p*	Normal deviate	*p*
A	−.34		−.50		−.32	
B	−.03		−.05		−.02	
C	−.46		−.23		−1.45	
D	−1.21		−1.56		−.07	
E	−1.10		−2.07		1.13	.13
F	1.56	.06	.44	.33	1.56	.06
G	.36	.36	−.33		.77	.22
H	.78	.22	.33	.37	1.09	.14
I	.40	.34	.86	.19	.54	.29
J	1.20	.11	1.23	.11	.56	.29
O	.40	.34	−.04		.53	.30
Q_2	2.13	.02	2.00	.02	.24	.41
Q_3	.74	.23	.88	.19	.46	.32
Q_4	−.25		.63	.26	−1.78	

Results of the Otis IQ analysis

The results of the school administered intelligence test are given at this point because Factor B of the HSPQ is a brief 20-item measure of intelligence. Intraclass correlations for the MZ and DZ twins were .83 and .59, respectively, both significant at the .001 level with the first significantly greater than the second at the .02 level. The *H* value computed from the Otis within variances was .62. This means that 62% of the within-family intelligence variance measured by the Otis is accounted for by hereditary factors in this sample.

Configural and Holistic Analyses

Rank-Difference Correlations for the Coded MMPI Profiles

Table 11 shows the distribution of the Spearman rho's for the 68 pairs of profiles by twin type. It is obvious that the overlap is too great to permit other than chance discrimi-

TABLE 10

HSPQ FACTOR HERITABILITY INDEXES FOR TOTAL GROUP, FEMALES, AND MALES

	Total group		Females		Males	
Factor	*H*	*F*[a]	*H*	*F*[a]	*H*	*F*[a]
A	.10	1.11	.00	.97	.24	1.32
B	.05	1.05	.00	.96	.18	1.22
C	.03	1.03	.25	1.34	.00	.43
D	.00	.62	.00	.37	.42	1.72
E	.31	1.44	.00	.80	.74	3.84
F	.56	2.29	.45	1.81	.74	3.83
G	.00	.97	.01	1.01	.00	.79
H	.38	1.62	.42	1.73	.34	1.52
I	.06	1.07	.05	1.05	.10	1.11
J	.29	1.41	.27	1.37	.34	1.51
O	.46	1.85	.22	1.29	.69	3.18
Q_2	.56	2.28	.60	2.52	.47	1.89
Q_3	.12	1.13	.31	1.44	.00	.99
Q_4	.00	.53	.18	1.22	.00	.09

[a] The three values of *F* required for significance at the .05 level are 1.78, 2.04, and 2.72.

nation (χ^2=.47, $p > .25$) between the two kinds of twins on the basis of their MMPI profile rank-difference correlation coefficients. A cutting score for a rho of .40 and above would correctly classify 53% of all the twin pairs.

D *Coefficient*

Table 12 shows the distribution of the generalized distance function computed from the 68 pairs of profiles. This index abstracts information about the shape and elevation of the profile. There was a tendency for the identical twins to have a lower *D*, i.e., be less dissimilar; 19 of the MZ pairs were below the median of the combined group as contrasted with 15 of the DZ pairs (χ^2=.94, $p < .17$). Using the median *D* as a cutting score resulted in correct classification of 56% of the profiles.

TABLE 11

DISTRIBUTION OF MZ AND DZ MMPI PROFILE CODE RHO'S

Rho	MZ	DZ
.80–.89	2	1
.70–.79	2	1
.60–.69	3	3
.50–.59	6	6
.40–.49	4	4
.30–.39	3	2
.20–.29	3	2
.10–.19	3	5
0–.09	2	1
−.50 to −.01	6	9

TABLE 12

DISTRIBUTION OF MZ AND DZ MMPI PROFILE *D* COEFFICIENTS

D	MZ	DZ
15–19	1	0
20–24	4	3
25–29	10	8
30–34	8	5
35–39	5	4
40–44	3	4
45–49	1	2
50–54	1	3
55–59	0	3
60–64	1	0
65–69	0	1
70–74	0	1

Concordance of Test Behavior (TT')

The percentage of all MMPI test items (566) answered in the same direction for a pair of twins is given in Table 13. There was a tendency for the identical twins to have a greater overlap in their responses to all the items; 21 of the MZ pairs were above the median of the combined group as contrasted with 15 of the DZ pairs (χ^2=2.35, $p < .06$). Using the median *TT'* of 72% as a cutting score resulted in correct classification of 59% of the profiles. There was some improvement in the use of this index when only the items in the 10 clinical scales were used as the denominator (337); 21 of the MZ pairs ex-

TABLE 13

DISTRIBUTION OF MZ AND DZ TOTAL MMPI ITEM AGREEMENT PERCENTAGES (*TT'*)

TT'	MZ	DZ
85–89	1	1
80–84	6	4
75–79	4	3
70–74	13	11
65–69	7	10
60–64	2	2
55–59	0	2
50–54	1	1

ceeded the median compared to 14 DZ pairs ($\chi^2=2.94$, $p < .05$). The cutting score was the same and correctly classified 60% of the profiles.

Clinical Judgment of Profile Similarity

The extent to which the judges' clinical assessment of personality similarity agreed with the zygosity of the twin pairs is given in Table 14. Computing the combined p levels (Mosteller & Bush, 1954, p. 329) for the accuracy of the three judges on their sorting of all profiles resulted in a p equal to .003. The comparable figure for accuracy of judging the two extreme groups of Very Similar and Very Dissimilar was .004. By pooling the ratings for each pair (i.e., 2 of 3, or 3 of 3 votes) in an effort to correct for the various sources of attenuation in the "configural powers" of the clinician, the accuracy of the total sort increased to 67.6% ($z=2.90$, $p=.005$).

DISCUSSION

In the introduction the purpose of the present research was said to be to answer this question—How much of the variability observed within a group of individuals in a specified environment on a specific measure of a specific personality trait is attributable to genetic factors? Implicit in the posing of this question was the assumption, subsequently confirmed by the data, that there were measurable genetic influences for at least some of the aspects of human personality tapped by the selected personality tests. Since the quantification of genetic variability derived from the computation of heritabilities by the classical twin method, and since this method rests upon some unproved assumptions, the results are recognized as suggestive and heuristic rather than definitive. While the data language for this research consists of scores on scales of personality tests, the discussion which follows is in terms of the underlying biophysical traits which the scales (read constructs) reflect.

TABLE 14

AGREEMENT OF CLINICAL JUDGMENTS OF MMPI PROFILE SIMILARITY WITH TWIN ZYGOSITY

Judge	Total sort	z	p	Extreme pile sort	z	p
A	64.7%	2.43	.01	67.6%	2.06	.03
B	61.8%	1.95	.03	73.5%	2.74	.006
C	58.8%	1.45	.08	58.8%	1.03	.16
Combined p			.003			.004

The first section of the discussion deals with the specific traits and their configurations demonstrated to have been influenced by hereditary factors together with some of the implications of these data for personality theory and the etiology of mental illness. This is followed by an attempt to explain the apparent failure of some of the holistic analyses of personality to support strongly the findings of the trait analyses.

To what extent can the results of the present study be applied to human behavior in general? The representativeness of the twin sample to Minnesota adolescents in general suggests that this kind of extrapolation is fairly safe. There is the possibility that the twins, preponderantly of Scandinavian extraction, sample a unique gene pool. Whether the further extrapolation to adults can be safely made is dubious and difficult to assess. When *rate* of development enters the picture, biological influences on a trait might be emphasized compared to a final adult stage. The present results could be very different if derived from adult twins as suggested by studies of morphology (Osborne & DeGeorge, 1959). Another important question is the extent to which these data from normal nonhospitalized individuals can be applied to identifiable psychiatrically ill. A basic assumption throughout this project was that the measured aspects of personality varied continuously, and that any underlying genetic mechanisms were polygenic in nature. The possibility that the extremes of distributions for some personality characteristics constitute discrete series exists, but this phenomenon would be masked by the strategy used. The net effect would be the underestimation of the importance of heredity since concordances in MZ twins for low incidence Mendelian or polygenic characteristics would pass unnoticed in the analysis of quantitative variability.

Genetic Aspects of Personality

A total of 6 traits out of the standard 24 in the two tests met a criterion which classified them as significantly influenced by genetic factors; that is, correlations between the scores of indentical twins were significantly higher than those between the scores of fraternal twins. Beyond this, for 23 of the total 31 scales analyzed in the two personality tests, the differences were in the predicted direction. Trait Q_2, Self-Sufficiency, was the only survivor of the 14 HSPQ measures. Although Factor Q_2 is not thought to be clearly established, the item content suggests that a person who is resolute and accustomed to making his own decisions will obtain a high score, while low scorers would be described as followers and conformists. A synthesis of this trait and F, Surgency (significant at the .06 level), is provided by Cattell's large second-order factor, Extraversion versus Introversion, which is composed of four factors. Two of the four are F and Q_2. Tying in neatly with the MMPI findings which are discussed next is a study on the construct validity of the adult form of the HSPQ by Karson and Pool (1957). These authors found the highest MMPI scale correlate of Factor F to be Scale *Si*, Social Introversion, and the highest correlate of Q_2 to be *Si* also with correlations of $-.48$ and .32, respectively. Together such results appear to identify a general dimension closely related to introversion-extraversion as one which is heavily influenced by genetic factors. Such a conclusion has also been reached by Eysenck (1947, 1956) who isolated introversion-extraversion as one of the two (now three) dimensions of personality by a factor analysis of ratings and personal data on 700 neurotic soldiers. He considers his findings to represent a confirmation of the theoretical ideas of Jung (1933). Genetic factors are given a prominent place in Eysenck's typology; his twin study (Eysenck, 1956) using statistics similar to those in the present study, yielded a tentative value for *H* on a factored measure of introversion-extraversion of .62.

The trait of introversion as measured by the MMPI may also have implications for one of the genetic theories of schizophrenia. Patients with very high scores on Scale *Si* are clinically described as "schizoid" and Kallmann (1953) and others have suggested that the schizoid individual may represent the genetic "carrier state" of the recessive schizophrenic gene. In other words, the schizoid individual may represent the heterozygote and the schizophrenic may represent the homozygote. If the schizoid carrier can be identified, Kallmann's hypothesis about recessivity is no longer tenable. The mode of inheritance must then be that of incomplete *dominance* or polygenic, thus better accounting for the high familial incidence of schizophrenia (cf. Gregory, 1960). The magnitude of the heritability for Scale *Si* was the largest found in the present study. The belief in the genetic contribution to intelligence has come to have a fairly secure status in contemporary psychology (Gottesman, 1963); the results of this investigation indicate that a similar status is appropriate for the more pure personality trait of introversion.

The results concerning the four remaining MMPI scales, *D*, *Pd*, *Pt*, and *Sc*, lend support to the general idea that in human beings psychopathology, especially psychosis, has a substantial genetic component. The scoring keys for these scales were developed for the purpose of locating patients with respect to psychiatrically diagnosed states of depression, psychopathic personality, psychasthenia, and schizophrenia. Patients of each type were compared, item by item, with a normal group. Those items which statistically differentiated a diagnostic group from normals were then included in the appropriate scale. Taken *singly*, these MMPI scales are able to discriminate about 60% of the patients corresponding to their label at a cost of 5% false positives among the normals; however, the single scale approach has been largely supplanted by the interpretation of the entire profile with particular attention to the two or three highest scores. The use of the pattern types formed by the various combinations of high scores has led to their establishment as constructs which can be used in lieu of diagnostic classes. Many correlations have been observed between other variables and the personality construct patterns. For the *D-Sc* pattern, for example, a majority of the diagnoses among psychiatric patients obtaining

such a configuration were psychotic ones, either depression or schizophrenia.

> Heredity, defined here rather crudely simply as psychosis in siblings or parents, tended to be unfavorable in these individuals [Hathaway & Meehl, 1956, p. 143].

Recent research on the *D-Pt* type (Gilberstadt & Duker, 1960) showed that it could be analyzed into three subtypes. Among other important findings, the authors observed that the *D-Pt-Sc* type of MMPI profile was characterized by a diagnosis of chronic undifferentiated schizophrenia and that such patients had much in common with descriptions in the literature of pseudoneurotic schizophrenia (Peterson, 1954). Surveys of the significance of major configural patterns are available in Hathaway and Meehl (1951) as well as in Dahlstrom and Welsh (1960).

A discussion of the results of the attempted quantification of hereditary influence adds some new information but it is not on the same firm footing as the correlational results. Eleven of the 24 traits measured by the two tests showed at least an appreciable genetic component. By *appreciable* is meant one third or more of the trait variance accounted for relative to the contribution of environmental factors (this required an H of .25 or more so that H divided by one minus H equalled one third). HSPQ factors, F, Q_2, and O showed about equal roles for heredity and environment. Factor O in the Karson and Pool (1957) study correlated most highly, .77, with MMPI Scale 7 (Psychasthenia) and .54 with Scale 0 (Social Introversion). Scale 7 was also found to have an appreciable genetic component in the present study. Three more HSPQ factors survived the criterion, E, H, and J. H along with F and Q_2 formed three of the four factors in Cattell's second-order factor Extraversion versus Introversion. In a study using an early form of the HSPQ (Cattell et al., 1955) both E and J were found to have appreciable genetic components. All five of the MMPI scales surviving the correlation criterion appeared in the quantitative analysis as having an appreciable genetic component. Only Scale *Si*, as noted above, was predominantly genetically determined.

Heritability values given in Tables 7 and 10 as well as those in other twin studies give the proportion of variance produced by genetic differences ***within*** families and underestimate the effects of heredity in the general population. *If* we could assume random mating for the traits measured, the values in Tables 7 and 10 would have to be multiplied by a factor of approximately two to indicate the true degree of genetic determination. The values thus obtained are remarkable even when compared with the results from animal behavior genetics. McClearn (1961) reported a value of .69 for activity in strains of mice. Fuller and Thompson (1960) reported a heritability of .59 for exploratory behavior in two strains of mice. In animal breeding intense selection pressure permits the value of heritability to become large for such characters as egg weight and wool length (Falconer, 1960). An overview of the relative contributions of heredity and environment to within-family variance on the personality traits measured leads to the observation that environment is the preponderant influence in a majority of the traits. Cattell, Stice, and Kristy (1957) reached a similar conclusion for both within- and between-family variances.

Sex Differences

It is difficult to evaluate the meaning to be attached to the observed sex differences in heritability of the various traits since the sample sizes are reduced. It is tempting to speculate about the possible evolutionary origin of sex differences. Confidence in, and extension of, the interpretations which follow must await the completion of an ongoing study using 180 pairs of twins. To suggest that variation in a personality trait is more under genetic control in one sex than the other, it is only necessary to be reminded of the range of secondary sex differences already observed in physical and behavioral characters in both man and animal. The differentiation of such traits is brought about by hormones; the latter are one of the links in the gene to behavior pathway.

Changing from an expressive environment to a suppressive one will lower the heritability of a trait. Suppose, for example, that early experience in fighting is essential for inducing aggressive behavior. Genetic differences in

variability on the *Pd* scale will not be detected in boys reared without this experience. The process of sex typing in our culture restricts certain types of behavior in the two sexes. Fighting is not tolerated and is suppressed in little girls so that we might expect the value of *H* for females on the *Pd* scale to be less than that for males. The results for Factor E, Submissiveness versus Dominance, and for Surgency reveal the same pattern of greater heritability for males than females. This attempt at an environmental explanation for the sex difference observed in trait heritability should not be thought of as appropriate for all the patterns observed.

Factorially Derived Scales versus Empirically Derived Scales

The positive correlational results for the 1 of 14 HSPQ factors could have been attributed to chance. In comparison with the positive results for 5 of the 10 MMPI scales, the harvest from the factorially derived personality test looks poor. The validity of 6 of the 14 HSPQ scales was cast into doubt by finding a zero correlation between identical twins. Many psychologists (e.g., Hall & Lindzey, 1957) have noted that factors derived by factor analysis are often not psychologically meaningful and do not agree with reality. Perhaps the empirical derivation of the MMPI scales was such as to allow Nature to be carved, albeit imperfectly, at the joints. The ease with which MMPI scales can be factored into subscales may mean that the original scales and those derived in similar fashion are equivalent to the large second-order factors of the factor analysts. The *Si* scale, for example, correlates with 10 of Cattell's factors (Karson, 1958). Demonstration of behavioral correlates for factors, such as Eysenck's (1950) criterion analysis, could result in a formidable merger of the ideas of Cattell, Eysenck, Hathaway, and Meehl.

Fate of Attempts at a Holistic View of Personality

Although all three statistical measures of MMPI profile similarity, rho, *D*, and *TT'*, tended to support the hypothesis of greater personality similarity between isogenic individuals, only the clinical judgments of similarity gave substantial support. Inasmuch as the statistical method usually surpasses the clinical in psychology (Meehl, 1954), these findings require close attention. Factors favoring successful clinical prediction in a profile sorting task have been suggested by Meehl (1959). Perhaps the most directly relevant factor he mentioned was the clinician's ability to analyze a configural relationship existing between predictor variables and a criterion, when the function is not derivable on rational grounds.

Even casual inspection of the results of the clinical judgments of personality similarity are conducive to accepting the general hypothesis of this research—the greater the gene similarity, the greater the overall personality similarity. The judging task required a discrimination between sisters, for example, of the same age, with the same parents, sharing more or less the same environment for their entire lives, but who differed in the amount of genetic overlap by a factor of only two. We might speculate that the task would have been easier had the pairs consisted of unrelated individuals or first cousins of the same age, sex, and social class background contrasted with identical twins. Misjudgments from the pooled ratings of the judges afford some insight to the range of heredity-environment interactions. The amount of variability available to the same genotypes is shown by the fact that 10 of the 34 pairs of identical twins' profiles were classified as dissimilar. Conversely, the lack of variability in personality available to genotypes with only half their genes in common is shown by the fact that 12 of the 34 fraternal twins' profiles were classified as similar.

Summary and Conclusions

The present study was carried out in the context of behavior genetics, the interdisciplinary science combining the knowledge and procedures of modern genetics with those of psychology. By means of the classical twin method, as it has been recently improved, and objective personality tests, the purpose of the research was to answer the question, how much of the variability observed within a group

of individuals in a specified environment on specific measures of specific personality traits is attributable to genetic factors? It was recognized that the genetic variance, heritability (H), could vary according to such things as age, sex, culture, trait, and method of trait assessment.

Among the key constructs from genetics, *reaction range* and *polygenic inheritance* are central to the methodology used and interpretation of results. Heredity fixes a reaction range; within this framework a genotype determines an indefinite but circumscribed assortment of phenotypes, each of which corresponds to one of the possible environments to which the genotype may be exposed. The classical Mendelian model of dominant and recessive gene inheritance will not handle the data on continuous variation, the kind observed with human behavior. Polygenic systems are posited to account for quantitative inheritance, the phenotypic effects being simply a function of the number of genes present. Both the twin method and its limitations were discussed.

Thirty-four pairs each of identical (MZ) and fraternal (DZ) same-sex adolescent twins from the public high schools of Minneapolis, St. Paul, and Robbinsdale, Minnesota, served as the sample. The entire population of same-sex twins among the 31,000 children in the schools was first enumerated. Forty-five pairs of girls and 23 pairs of boys volunteered which represented 75% and 43%, respectively, of the total possible twin pairs available in the selected sample of schools. Disregarding sex, the twins comprised 60% of the possible 113 pairs.

At the time of testing, the twins filled out a personal history data sheet, the Minnesota Multiphasic Personality Inventory (MMPI), and Cattell's High School Personality Questionnaire (HSPQ); they were weighed, measured for height, fingerprinted, and photographed. The diagnosis of zygosity was based upon extensive blood grouping with respect to nine blood groups. This resulted in 100% accuracy in the diagnosis of DZ twins and at least 95% for MZ twins. A methodological contribution to twin diagnosis was made by the comparison of the accuracies of various methods and their combinations. Blood typing is necessary and sufficient for the accuracy required in human behavior genetics research.

Each scale of the two personality tests and the school recorded Otis IQ were first analyzed by means of the intraclass correlation coefficient for the two classes of twins and for sex differences. Subsequent to this analysis, the heritability indexes were computed; H is defined as the proportion of personality scale variance attributable to genetic factors. The correlation analysis of the 14 HSPQ scales suggested that two factors (F, Sober, Serious versus Enthusiastic, Happy-Go-Lucky, and Q_2, Group Dependency versus Self-Sufficiency) had significant genetic (i.e., gene determined) components. The correlation analysis of the 10 MMPI scales resulted in five, Scale 2 (Depression), Scale 4 (Psychopathic Deviate), Scale 7 (Psychasthenia), Scale 8 (Schizophrenia), and Scale 0 (Social Introversion), which appeared to have significant genetic components.

Within the limits of the assumptions, the attempt at quantification of the proportion of scale variance accounted for by heredity gave positive results for six of the HSPQ factors. Factors E, Submissiveness versus Dominance; H, Shy, Sensitive versus Adventurous; and J, Liking Group Action versus Fastidiously Individualistic showed appreciable variance accounted for by heredity but with environment predominating. Factors F, Q_2, and O, Confident Adequacy versus Guilt Proneness, showed about equal contributions of heredity and environment. The same kind of analysis of the MMPI gave positive results for 5 of the 10 scales. Scales 7 (Psychasthenia) and 8 (Schizophrenia) showed appreciable variance accounted for by heredity but with environment predominating. Scales 2 (Depression) and 4 (Psychopathic Deviate) showed about equal contributions of heredity and environment. Scale 0 (Social Introversion) showed a predominance of variance ($H = .71$) accounted for by heredity. The value of H for the Otis IQ in this study was .62.

Following the scale-by-scale analysis, three holistic statistical analyses and one clinical holistic analysis of the MMPI profiles were done. The rank-difference correlations (rho) for the coded MMPI profiles, the generalized

distance function (D), and a measure of test item verbal behavior concordance (TT) all showed a tendency for the MZ profile pairs to be more similar. The tendency was not strong enough to discriminate between the two classes of twins on the basis of any of the three measures. Clinical judgments of profile similarity by three experts supported the general hypothesis that the greater the gene similarity, the greater the personality similarity. The pooled accuracy of the agreement of clinical judgments of MMPI profile similarity with twin zygosity was 68% ($p = .005$).

Elaboration of the various biochemical or structural differences in the gene to behavior pathway which correspond to the results reported here might be intellectually satisfying, but progress in personality genetics need not await this step. A useful taxonomy of the aspects of behavior termed personality can be facilitated by the use of relatively invariant psychometric configurations to describe behavioral phenotypes. An important by-product of the study of twins and a concern with human behavior genetics is the emphasis given to the need for a multidisciplinary analysis of behavior ranging from biochemistry through evolution. Granting that the difficulties in accurately assessing the contribution of heredity to variation in socially important behavior are great, such efforts will not have been in vain if they contribute to a greater understanding of the sources of individual differences. The provision of an optimum environment for the optimum development of the various aspects of human behavior should follow such increased understanding.

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