Behavior Genetics, Vol. 6, No. 1, 1976

Heritability of Personality Traits in Adult Male Twins

Joseph M. Horn,[1] Robert Plomin,[1,2] and Ray Rosenman[3]

Received 1 July 1974 Final 28 Jan. 1975

Personality test data from the California Psychological Inventory were collected on 99 pairs of identical and 99 pairs of fraternal adult male twins. Heritabilities were computed for all 18 scales and compared to the heritabilities for "pure" scales with overlapping items omitted. Two of the pure scales, Responsibility and Femininity, had zero heritabilities, whereas all of the full scales had moderate to high heritabilities. It was concluded that item overlap has contributed significantly to previous failures to find evidence for the differential heritability of personality traits as measured by the CPI. CPI items were classified into genetic or environmental categories and separate factor analyses of items in these categories revealed more differences than similarities in factor structure. The genetic personality factors included Conversational Poise, Compulsiveness, and Social Ease. Environmental factors included Confidence in Leadership, Impulse Control, Philosophical Attitudes, Intellectual Interest, and Exhibitionism. Compared to the genetic factors, each of the environmental factors accounted for only a very small percentage of the variance.

KEY WORDS: CPI; twins; heritability; genetic factors.

INTRODUCTION

The twin method has been used extensively in efforts to assess the importance of genetic factors in determining the variability of scores on the scales of objective personality inventories. It is extremely hard to compare

This research was supported under NSF Grant GU-1598. The twins in the present study are part of the Twin Registry maintained by the NAS-NRC Medical Follow-Up Agency.

[1] University of Texas at Austin, Austin, Texas.
[2] Present address: University of Colorado, Boulder, Colorado.
[3] Mount Zion Hospital and Medical Center, San Francisco, California.

the results of such studies. Only a few investigations (Bruun *et al.*, 1966; Nichols, 1966; Schoenfeldt, 1968) have utilized samples of sufficient size for there to be much possibility of replicating a previous finding (Klein *et al.*, 1973) and unfortunately all of these larger studies employed personality scales that were widely different in terms of the origins of the personality items and the number and types of traits measured.

When Nichols (1966) compared the results of his twin study of the personality traits measured by the California Personality Inventory with the results of a similar study, also employing the CPI, by Gottesman (1966), he concluded that (1) there was no agreement between the two studies as to which scales were heritable and which were not, (2) within each study there was no agreement between the sexes on which scales were significantly heritable, and (3) overall, the differences in similarity between MZ and DZ twins were too large to fit a genetic hypothesis. Because of these conclusions, Nichols saw the major value of his findings in terms of their implications for the methodology of twin studies of personality. Specifically, Nichols speculated that the twin method may be inapplicable to personality inventories based on self-report since the random error in inventory items may be random between sets of twins while at the same time a large source of covariance between twins of a set and more so for MZ than for DZ twins. While not denying the plausibility of such an explanation, the present authors feel that Nichols' pessimistic view of the future of twin research in personality is premature. Three considerations prompted this conclusion. First, Nichols' conclusions were based on the supposed lack of replication in the results from two studies of adolescent twins. Gottesman's study had small sample sizes and this may have played a significant role in the failure to replicate, but even if Nichols' conclusions prove to be correct for high school twins living at home, caution should be exercised in generalizing the conclusion to all twins, including adults living apart, who, according to Nichols' hypothesis, should have fewer environmental influences in common than high school twins living together. Second, Nichols' failure to find any similarities between his and Gottesman's study was due to the fact that all of the CPI scales in Nichols' study were equally heritable. This lack of differential heritability for the CPI may be an artifact of the sizable amount of item overlap in the CPI scales. Finally, as with most personality scales, the CPI was constructed without any consideration given to the within-scale item heritabilities and consequently the lack of differential heritability for CPI scales may be due to the fact that genetic and environmental items are mixed in approximately equal proportions in all the scales.

The present investigation had three main goals. Each goal was related to gathering information concerning the validity of the three aforementioned reasons for questioning Nichols' conclusions. Our first goal was to compare a twin study of the CPI utilizing a sample of adult twins with Nichols' previous CPI study on adolescent twins. The second goal was to investigate the contribution of item overlap to any obtained similarity in heritability indices for the scales of the CPI. For this analysis, the 182 CPI items that are scored on more than one scale were eliminated and new intraclass correlations were computed for the resulting "pure" scales of the CPI. The third goal was related to the idea that genetic and environmental items are mixed in the same scale and that a clearer picture of the inherited components of personality would come from a demonstration that substantial clusters of items, forming recognizable personality traits, could be identified in a factor analysis of all heritable CPI items. Thus our final goal was to separately factor-analyze groups of genetic and environmental items and identify the genetic and environmental factors in the California Personality Inventory. Loehlin (1965) had the same purpose in mind when he divided clusters of items from the Cattell Junior Personality Questionnaire and the Thurstone Temperament Survey into high- and low-heritability clusters as determined by another investigator's twin study (Vandenberg, 1962). He then factor-analyzed the high- and low-heritability clusters separately. Contrary to expectations, the factors derived from the high-heritability clusters were not radically different from the factors from the low-heritability clusters. There are three possible reasons for the failure to obtain different factor structures for the high- and low-heritability clusters. First, Loehlin obtained the clusters of items and performed the factor analysis of the high- and low-heritability clusters on data for high school boys in Nebraska while the heritability estimates were obtained from data for boys and girls in Michigan. This point is especially important in light of the sample specificity of the heritability statistic (Gottesman, 1965). In the present study, the same sample was used to obtain the item heritabilities and the factors. Moreover, Loehlin's twin sample was small (45 MZ and 35 DZ pairs) and combined the data from boys and girls. The present study used a larger sample (99 MZ and 99 DZ pairs) of adult male twins.

Second, in Loehlin's study, items were first grouped into clusters and then divided into high- and low-heritability clusters. Such a procedure allows environmental and genetic items to be clustered together on the basis of low-order correlations (Loehlin used 0.3). In the present study, the analysis was carried out on the item level, thereby eliminating the possibility of genetic and environmental items being clustered together prior to the factor analysis. Third, in Loehlin's study, 35 clusters of items were obtained and the 15 most heritable clusters were factor-analyzed as the high-heritable clusters and the 14 least heritable clusters were factor-analyzed as the low-heritable clusters. The present study used more stringent criteria for inclusion of items in the genetic and environmental categories. These criteria excluded a much larger proportion of items in the middle range of heritability.

METHOD

Subjects

The CPI questionnaire (Gough, 1969) responses for this study were obtained from a large battery of tests administered by Rosenman (project in progress) to 198 pairs of twins living in California. These twins are part of the Twin Registry maintained by the Medical Follow-Up Agency of the National Research Council (Jablon *et al.*, 1967) and were included in a study investigating personality factors as predictors of coronary problems. There were 99 pairs of MZ and 99 pairs of DZ twins, where zygosity was determined by analysis of blood groups.

Procedure

The first part of the study was a straightforward twin study of this adult population. The "full" scale scores for each subject for all items on each of the 18 CPI scales were computed and used in the computation of separate intraclass correlation coefficients for the 99 MZ and 99 DZ twins. For the analysis of the "pure" CPI scales, the 193 CPI items that are scored on more than one scale were eliminated from the scoring and separate intraclass correlations were then computed using only individual scale scores derived from the reduced number of items. The item overlap on five full scales was so great that the reduced pure scales contained fewer than ten items. The intraclass correlations are not reported for these pure scales since, with such a small number of items, the scale reliability is questionable.

The procedure for identifying genetic and environmental items was as follows: First, unreliable items were eliminated from consideration as genetic or environmental items by retaining for analysis only those items with a below-average Ambdex statistic as computed by Goldberg and Rorer (1964). Goldberg's study involved administering the CPI twice at a 3-week interval to 230 male college undergraduates. Goldberg's Ambdex statistic is essentially a stability coefficient where the proportion of subjects with consistent responses across the 3-week period is corrected for the item's endorsement frequency. Only items with lower than average ambiguity (higher than average stability) were retained for consideration as genetic or environmental items. The sample of 99 MZ twins was then randomly divided into two groups of MZ twins, one group of 50 pairs and one group of 49 pairs. The 99 DZ twins were also randomly divided into two groups of 50 and 49, respectively. For each of these four groups of twins, separate ϕ coefficients were computed on all the low-ambiguity items. An item was classified in the *genetic* category only if each MZ correlation exceeded each DZ correlation by 0.10 or greater. This is essentially a cross-validation criterion. Each MZ sample had to exceed both DZ samples by the specified amount. Thus four separate hurdles had to be overcome before an item was classified as genetic. In order to exclude items with low MZ and negative DZ correlations from the genetic category, an additional restriction was imposed on the average DZ correlation. If the average DZ correlation was negative and exceeded −0.10, the item was dropped from the genetic category. An item was classified as an *environmental* item if the average MZ correlation did not exceed the average DZ correlation by more than 0.10 and each average correlation was positive and greater than 0.10.

Both groups of items were then factor-analyzed using SPSS programs (Nie *et al.*, 1970). Standard options were used, including principal factoring with iteration and Varimax rotation of factors with eigenvalues greater than 1.0. Guttman's image factoring was also used in place of principal factoring and both the principal factor and image factoring solutions were rotated by orthogonal (Varimax) and oblique (Oblimin with δ value of zero) programs. Because the factor structures resulting from all of these methods were very similar, only the Varimax rotation of the principal factor solution will be reported.

RESULTS

Table I presents the twin results for the adult males and compares them to Nichols' data for high school boys. Considering the differences in the samples, the full-scale twin correlations of the present study were surprisingly similar to Nichols'. The average MZ correlation in Nichols' data was 0.51 and the average DZ correlation was 0.25. The corresponding correlations for the present sample were 0.44 and 0.19. Thus the adult males in the present sample were nearly as similar to their twins as the high school boys in Nichols' sample despite the fact that the adult twins were between 45 and 55 years of age and had been living apart for about 25 years.

The present results and those of Nichols were also similar in that, for a number of scales, the DZ correlation was significantly *less* than half the MZ correlation. A simple genetic model, where the effects of assortative mating, dominance, and epistasis are ignored, expects the DZ correlation

Table I. Intraclass Correlations for the 18 Scales of the CPI—Adult Males of the Present Study and Nichols' High School Boys Compared

Full scale[c]	Pure scale[c]	CPI scale	Nichols' high school boys[a]			NRC males[b] full scale			NRC males[b] pure scale		
			MZ	DZ	H[d]	MZ	DZ	H[d]	MZ	DZ	H[d]
46	25	Dominance	0.58	0.13	(0.90)	0.53	0.28	0.50	0.44	0.25	0.38
32	15	Capacity for Status	0.57	0.36	0.42	0.54	0.25	0.58	0.45	0.18	0.54
36	9	Sociability	0.53	0.25	0.56	0.51	0.18	(0.66)			
56	6	Social Presence	0.51	0.15	(0.72)	0.54	0.21	(0.66)			
34	3	Self-acceptance	0.43	0.16	(0.54)	0.47	0.23	0.48			
45	30	Sense of Well-being	0.54	0.33	0.42	0.43	0.13	(0.60)	0.38	0.13	0.30
42	16	Responsibility	0.57	0.29	0.56	0.44	0.33	0.22	0.20	0.28	0.00
56	28	Socialization	0.53	0.15	(0.76)	0.43	0.25	0.36	0.44	0.21	0.46
50	2	Self-control	0.56	0.27	0.58	0.45	0.12	(0.66)			
32	9	Tolerance	0.59	0.30	0.58	0.47	0.17	(0.60)			
40	18	Good Impression	0.48	0.32	0.32	0.42	0.13	(0.58)	0.37	0.11	(0.52)
28	28	Communality	0.32	0.24	0.16	0.22	0.06	0.32	0.22	0.06	0.32
38	18	Ach via Conformance	0.49	0.06	(0.86)	0.41	0.01	(0.80)	0.36	−0.05	(0.82)
32	11	Ach via Independence	0.58	0.36	0.44	0.49	0.25	0.48	0.39	0.05	(0.68)
52	23	Intellectual Efficiency	0.59	0.27	0.64	0.49	0.30	0.38	0.34	0.21	0.26
22	11	Psychological Mindedness	0.47	0.28	0.38	0.36	0.18	0.36	0.39	0.20	0.38
22	22	Flexibility	0.43	0.25	0.36	0.49	0.10	(0.78)	0.49	0.10	(0.78)
38	24	Femininity	0.42	0.27	0.32	0.27	0.15	0.24	0.15	0.17	0.00
		Average	0.51	0.25	0.52	0.44	0.19	0.50	0.35	0.15	0.40

[a] Nichols' high school boys: 207 pairs of MZ and 126 pairs of DZ twins.
[b] NRC adult males: 99 pairs of MZ and 99 pairs of DZ twins.
[c] "Full scale" includes all items typically scored on each CPI scale; "pure scale" eliminates items scored on more than one scale.
[d] Falconer's (1960) formula was used to compute heritabilities. Heritabilities are enclosed in parentheses if the DZ correlation was less than half the MZ correlation by a standard error or greater.

to be half the MZ correlation. If common environmental factors are in part responsible for the similarity of twins, the DZ correlation may be *greater* than half the MZ correlation. However, DZ correlations that are less than half the MZ correlations cannot be explained unless epistasis or contrast effects exist (Plomin *et al.*, 1976). Heritabilities based on such patterns of correlations are thus overestimates. The heritabilities in Table I are enclosed in parentheses if the DZ correlation was less than half the MZ correlation by an amount greater than the standard error of the DZ correlation. In all three sets of data in Table I, Achievement via Conformance yielded MZ correlations of about 0.4, DZ correlations that were nearly zero, and heritabilities of 0.8. Based on an MZ correlation of 0.4, the expected DZ correlation was 0.2. The Dominance scale for Nichols' high school boys and the Flexibility scale for the adult male sample also showed a similar pattern of correlation.

It is possible that either the MZ twins rated themselves too similarly or the DZ twins rated themselves too dissimilarly on these scales. Nichols speculated that the inflated differences between the MZ and DZ correlations were caused by inflated MZ correlations. Specifically, he suggested that the random variance between pairs of twins may be a source of covariance within pairs of twins and that the size of the covariance component is larger for MZ than DZ twins. This two-step assumption does not seem to be borne out by the present data. If MZ twins share the environmental events that are random between sets of twins more than DZ twins, a straightforward prediction follows: twins living together ought to share more of these experiences than twins living apart and the effect of living apart on twin correlations should be greater for MZ than for DZ twins. Thus Nichols' hypothesis would have to predict that for the present sample of adult male twins living apart for about 25 years the MZ correlations (and not the DZ correlations) would be substantially lower than the MZ correlations in his sample. The data in Table I do not support this prediction. The average MZ correlation for the adult males was only slightly (0.07) lower than the average MZ correlation for the high school boys; moreover, the average DZ correlation for the adult males was lower by the same amount (0.06). Thus it is unlikely that the inflated differences between the MZ and DZ correlations for some CPI scales are caused by the MZ twins experiencing in common the environmental events that are random between sets of twins more than the DZ twins.

The second goal of the study was to investigate some possible explanations for the limited range of the heritabilities and the absence of zero heritabilities in Nichols' results. The first two columns of Table I deal with the issue of item overlap in the CPI. The first column lists the number of items scored on the 18 CPI scales. The second column indicates the number of items that are scored on only *one* of the 18 scales. The first column totals 701 items, the second column totals 298 items; 108 of the 480 CPI items are scored on more than one scale, which suggests that CPI full-scale scores should not be used where the differential heritability of traits is an issue.

The item overlap may, in part, account for Nichols' (1966) finding that all the CPI scales yielded low to moderate heritabilities. The inclusion of overlapping items in the full scales of the CPI may add heritable items to generally nonheritable scales and nonheritable items to generally heritable scales, reducing the range of the heritabilities and preventing the occurrence of zero heritabilities. However, Nichols' use of Holzinger's formula for the estimation of heritability also contributed to the narrow range of heritability estimates. Since Holzinger's formula tends to truncate the range of heritabilities, a more appropriate formula would be Falconer's (1960), which simply doubles the difference between the MZ and DZ correlations. The heritabilities listed in Table I for both Nichols' data and those of the present study are derived from Falconer's formula. For Nichols' data, the range of these heritabilities is greater than the range of Holzinger heritabilities that Nichols reported earlier.

The absence of zero heritabilities in the full-scale data of both studies may reflect the considerable item overlap in the CPI scales. It is possible to compute MZ and DZ correlations using only those 298 items that are scored on only one scale. The correlations and heritabilities for these "pure" scales are reported in the last column of data in Table I. Correlations and heritabilities are listed only for scales with ten or more "pure" items. As expected, these pure-scale heritabilities had a greater range of values, primarily because two scales (Responsibility and Femininity) showed higher DZ than MZ correlations, which resulted in zero heritabilities.

Although part of the reason for previous failures to demonstrate differential heritability among the CPI scales is the item overlap, even the "pure" scales are likely to contain some items that are genetic and others that are environmental. A third goal of this study was to use items rather than scales as the unit of genetic analysis. The criteria discussed in the Method section were used to identify 82 genetic items. These 82 items constituted 17% of the 480 total CPI items. Table II lists the distribution of these genetic items across the scales of the CPI. The genetic items were evenly distributed across the 18 scales. On the average, 18% of the items of each scale were genetic items. Thus it is not suprising that twin studies using the full-scale scores of the CPI show consistently low to moderate heritabilities and are unable to differentiate scales on the basis of heritability.

Table II. Proportion of Items Meeting a Genetic Criterion Across the Scales of the CPI

Do	Dominance	8/46 = 0.17
Cs	Capacity for Status	4/32 = 0.13
Sy	Sociability	6/36 = 0.17
Sp	Social Presence	10/56 = 0.18
Sa	Self-acceptance	8/34 = 0.24
Wb	Sense of Well-being	5/45 = 0.11
Re	Responsibility	6/42 = 0.14
So	Socialization	8/56 = 0.14
Sc	Self-control	5/50 = 0.10
To	Tolerance	6/32 = 0.19
Gi	Good Impression	10/40 = 0.25
Cm	Communality	3/28 = 0.11
Ac	Ach via Conformance	7/38 = 0.18
Ai	Ach via Independence	8/32 = 0.25
Ie	Intellectual Efficiency	6/52 = 0.12
Py	Psychological Mindedness	5/22 = 0.23
Fx	Flexibility	6/22 = 0.27
Fe	Femininity	7/38 = 0.18
82 genetic items/480 total items		= 0.17
Scale average		= 0.18

Of the 82 items that met the genetic criteria, 41 also had below-average Ambdex ratings. The results of a factor analysis of these 41 reliable (unambiguous) genetic items are presented in Table III. Only the items that loaded greater than 0.30 on one of the factors are listed.[4] The loadings listed in Table III are the factor loadings obtained from Kaiser's Varimax rotation of a principal factoring solution with iteration. Oblique rotation (Oblimin) and Guttman's image factoring yielded very similar factors. Factors with eigenvalues of 1.0 or greater were rotated, but the Scree test and interpretability of the factors suggested a cutoff of five factors. The third factor is not presented in Table III because it was a doublet consisting of items 84 and 297.

The factors of the genetic items have been tentatively labeled, but the items and factor loadings are presented for the reader to judge the adequacy of the factor names. Two of the factors are related to sociability. The first factor, Conversational Poise, accounts for a considerable percentage of variance and is very specifically related to talking to strangers. The fifth factor, Social Ease, is more general. The other two genetic factors are Compulsiveness and Openness to Common Human Faults.

[4] The other reliable CPI items in the genetic category were items No. 8, 62, 84, 101, 113, 118, 129, 136, 139, 196, 249, 250, 266, 295, 297, 323, 411, 431, 461, 468.

Table III. Factor Analysis of Genetic Items (41 Reliable Items)

Factor I. Conversational Poise (27.5% of variance)

227. It is hard for me to find anything to talk about when I meet a new person. (0.77)
38. It is hard for me to start a conversation with strangers. (0.67)
111. When in a group of people I have trouble thinking of the right things to talk about. (0.56)
242. I am a good mixer. (−0.48)
429. Even the idea of giving a talk in public makes me afraid. (0.34)
334. I get nervous when I have to ask someone for a job. (0.34)
346. I must admit I am a pretty fair talker. (−0.32)

Factor II. Compulsiveness (11.3% of variance)

246. I like to plan out my activities in advance. (0.53)
400. I think I am stricter about right and wrong than most people. (0.45)
24. I always like to keep my things neat and tidy and in good order. (0.41)
397. Once I have my mind made up I seldom change it. (0.32)

Factor IV. Openness to Common Human Faults (6.6% of variance)

426. There have been times when I have been very angry. (0.50)
254. I have never deliberately told a lie. (−0.45)
355. I have strong political opinions. (0.44)
262. There have been a few times when I have been very mean to another person. (0.32)

Factor V. Social Ease (5.3% of variance)

403. I have a natural talent for influencing people. (0.64)
319. In a group, I usually take the responsibility for getting people introduced. (0.60)
346. I must admit I am a pretty fair talker. (0.59)
239. Ilike to talk before groups of people. (0.52)
320. I would be willing to describe myself as a pretty "strong" personality. (0.52)
429. Even the idea of giving a talk in public makes me afraid. (−0.39)
242. I am a good mixer. (0.38)

The factor-analytic results for the 74 environmental items that met the environmental criteria are reported in Table IV.[5] None of the environmental factors accounted for a large portion of variance. This suggests that there are no broad systematic environmental influences operating to make the children within a family similar in personality. However, the environmental factors that did emerge from this analysis can be reasonably interpreted within the framework of the environmental influences shared by twins in a family. The factors are Confidence in Leadership, Impulse Con-

[5] Environmental items that did not load above 0.30 on any of the factors were items No. 5, 35, 45, 67, 70, 71, 72, 99, 103, 105, 114, 122, 127, 131, 144, 166, 167, 180, 181, 192, 205, 213, 218, 244, 252, 277, 278, 286, 299, 300, 307, 308, 321, 340, 371, 373, 385, 394, 395, 439, 467, 475, 480.

Table IV. Factor Analysis of Environmental Items (74 Reliable Items)

Factor I. Confidence in Leadership (4% of variance)

359. I think I am usually a leader in my group. (0.73)
412. I like to give orders and get things moving. (0.72)
31. I doubt whether I would make a good leader. (−0.71)
202. If given the chance I would make a good leader of people. (0.70)
102. I like to be the center of attention. (0.36)

Factor II. Impulse Control (2.9% of variance)

268. At times I have been very anxious to get away from my family. (0.62)
336. Sometimes I used to feel that I would like to leave home. (0.69)
66. Sometimes I feel like swearing. (0.39)
248. I must admit that I have a bad temper, once I get angry. (0.31)
285. I refuse to play some games because I am not good at them. (0.31)

Factor III. Philosophical Attitudes (2.6% of variance)

23. In most ways the poor man is better off than the rich man. (0.61)
263. Lawbreakers are almost always caught and punished. (0.51)
462. Even though I am sure I am in the right, I usually give in because it is foolish to cause trouble. (0.41)
237. The future is too uncertain for a person to make serious plans. (0.38)
261. We ought to let Europe get out of its own mess; it makes its bed, let it lie in it. (0.34)
393. I have used alcohol excessively. (−0.31)

Factor IV. Intellectual Interest (2.8% of variance)

283. I like to read about science. (0.72)
95. The idea of doing research appeals to me. (0.47)
87. I like adventure stories better than romantic stories. (0.43)
55. Some of my family have quick tempers. (−0.40)
215. I would like to write a technical book. (0.39)
103. I like to listen to a symphony orchestra concert on the radio. (0.34)
140. I enjoy hearing lectures on world affairs. (0.31)

Factor V. School Problems (2.7% of variance)

214. In school I was sometimes sent to the principal for cutting up. (0.73)
288. As a youngster I was suspended from school one or more times for cutting up. (0.69)
420. I used to steal sometimes when I was a youngster. (0.35)
3. I looked up to my father as an ideal man. (0.32)
61. I liked school. (−0.32)

Factor VI. Exhibitionism (2.9% of variance)

134. It makes me uncomfortable to put on a stunt at a party even when others are doing the same sort of thing. (0.70)
52. I usually take an active part in the entertainment at parties. (−0.67)
231. I am apt to show off in some way if I get the chance. (−0.49)
102. I like to be the center of attention. (−0.47)
159. I feel nervous if I have to meet a lot of people. (0.33)

trol, Philosophical Attitudes, Intellectual Interest, School Problems, and Exhibitionism.

DISCUSSION

The factor analyses of genetic and environmental CPI items yielded different factor structures. This suggests that the strategy of factor-analyzing heritable and nonheritable items may prove more useful than additional twin studies of existing personality inventories which were largely constructed without regard to the problems of untangling genetic and environmental influences. The results indicate that, at least in one study, the genetic CPI items are distributed evenly across the 18 scales of the CPI. This may explain why Nichols (1966) found moderate heritability for all the CPI scales, although overlapping items on the CPI and the use of Holzinger's heritability formula contributed to that result.

The data also suggest that differences between MZ and DZ correlations that are too large to be explained by simple genetic models are not found only among adolescent twins. The present study suggests that Nichols' speculation about the cause of these deviations was wrong. Alternative explanations could involve a contrast effect among DZ twins, or perhaps more attention should be paid in the future to considerations of the effect of epistasis.

The emergence of sociability-related factors from the genetic items is consistent with other data. For example, Scarr (1969) summarized several twin studies of sociability questionnaires and ratings and found impressive consistency in the evidence for significant heritability. The present study provides a clue for the genetic underpinning of the trait of sociability. Although most definitions of sociability connote gregariousness or the need to be with people, the first factor derived from the genetic items was much more specific. It was limited to talking with strangers. Because this factor accounted for 28% of the variance of the genetic items, it ought to be carefully considered in future studies as the possible genetic foundation for the development of the trait of sociability. Although the second sociability factor was more general than the Conversational Poise factor, it also did not involve elements of the need or desire to be with people that is part of gregariousness.

The absence of any pervasive environmental factors is also illuminating. It suggests that whatever environmental influences make twins from the same family similar in personality are limited in their effect. The factors derived from the environmental items were specific factors that accounted for little of the variance. However, the limited factors that were identified seemed to be reasonable candidates for personality traits influenced primarily through common environmental experiences.

The distinct factor structures for genetic and environmental items do not agree with the original work by Loehlin (1965). The essential difference between the present results and those of Loehlin is that Loehlin found more similarity than differences in the factor structures he examined, whereas we find more differences than similarities. In the present study, however, some of the items in the genetic Social Ease factor resemble the environmental Leadership items. The environmental Exhibitionism factor bears some resemblance to items of the genetic Conversational Poise factor. Thus, as Loehlin suggested, the differences between some genetic and environmental items or factors may be subtle. The subtleties (in phrasing, for example) may obscure the distinction between environmental and genetic components of personality unless, as in the present study, some effort is made to bring differences into focus. The efforts at sharpening the distinctions in the present study included eliminating item overlap, restricting the factor analyses to relatively unambiguous and reliable items, and eliminating items that did not meet relatively strict criteria for inclusion in the genetic category. Perhaps the road to replicable results in twin studies of personality will be found only after the tests (and items) employed in such investigations have undergone considerably more scrutiny.

The present study does not imply that the factors in Tables II and III exhaust the genetic and environmental traits in personality. Although the CPI contains 480 items in 18 scales, it may be limited in its sampling of the domain of personality. Nichols and Schnell (1963), for example, found two second-order factors called Person Orientation and Value Orientation that accounted for a large part of the variance of the CPI. Moreover, the environmental criteria of the present study considered only environmental factors common to both twins of a set for example, learning within the family that makes twins in that family similar to each other and different from twins in other families. Environmental factors that decrease twin correlations by providing differential experience to twins within a family were not considered.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Eldon Sutton and John Loehlin for their assistance, encouragement, and advice.

REFERENCES

Bruun, K. T., Markanen, T., and Partanen, J. (1966). *Inheritance of Drinking Behavior: A Study of Adult Twins*. Finnish Foundation for Alcohol Research, Helsinki.

Falconer, D. S. (1960). *Introduction to Quantitative Genetics*. Oliver and Boyd, London.

Goldberg, L. R., and Rorer, L. G. (1964). *Test Retest Item Statistics for the California Psychological Inventory*. Oregon Research Institute Monograph, Vol. 4, No. 1.

Gottesman, I. I. (1965). Personality and natural selection. In Vandenberg, S. (ed.), *Methods and Goals in Human Behavior Genetics*, Academic Press, New York.

Gottesman, I. I. (1966). Genetic variance in adaptive personality traits. *J. Child Psychol. Psychiat.* 7:199 208.

Gough, H. (1969). *Manual for the California Psychological Inventory*, rev. ed., Consulting Psychologists Press, Palo Alto, Calif.

Jablon, S., Neel, J. V., Gershowitz, H., and Atkinson, G. F. (1967). The NRS-NRC twin-panel: The panel, zygosity diagnosis, and proposed use. *Am. J. Hum. Genet.* **19**:145 160.

Klein, T. W., DeFries, J. C., and Finkbeiner, C. T. (1973). Heritability and genetic correlation: Standard errors of estimates and sample size. *Behav. Genet.* **3**:355 364.

Loehlin, J. (1965). A heredity environment analysis of personality inventory data. In Vandenberg, S. (ed.), *Methods and Goals in Human Behavior Genetics*, Academic Press, New York.

Nichols, R. C. (1966). The resemblance of twins in personality and interests. *National Merit Scholarship Corp. Res. Rep.* **2**:1 23.

Nichols, R. C., and Schnell, R. R. (1963). Factor scales for the California Psychological Inventory. *J. Consult. Psychol.* **27**:228 235.

Nie, N. H., Bent, D. H., and Huss, C. H. (1970). *Statistical Package for the Social Sciences*, McGraw-Hill, New York.

Plomin, R., Willerman, L., and Loehlin, J. C. (1976). Resemblance in appearance and the equal environments assumption in twin studies of personality traits. *Behav. Genet.* **6**:43–52.

Scarr, S. (1969). Social introversion extraversion as a heritable response. *Child Develop.* **40**:823 832.

Schoenfeldt, L. F. (1968). Hereditary environmental components of the Project Talent two-day battery. Paper read at XVIth Congress of Applied Psychology, Amsterdam, August 22.

Vandenberg, S. G. (1962). The hereditary abilities study: Hereditary components in a psychological test battery. *Am. J. Hum. Genet.* **19**:220 237.