The Hereditary Components of the Project TALENT Two-Day Test Battery

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A continuing research program undertaking analysis of the Project TALENT test data obtained from twins was initiated in 1966. The general goal of this program is to explore the influence of variation attributable to heredity, environment, and the interaction of the two on human development. The purpose of this paper is to present the initial results concerning the extent to which variation in performance on the Project TALENT battery is influenced by heredity.

The Sample

In 1960 a probability sample was drawn of approximately 5 per cent of the public, private, and parochial high schools in this country. The 400,000 students in grades 9 through 12 attending the 1,225 randomly selected schools were administered specially constructed tests and inventories for two days.

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The Test Battery

The tests comprising the two-day battery administered in 1960 can be roughly grouped into measures of maximum performance and measures of typical behavior. The 60 distinct maximum performance scores include:

1. information knowledge acquired in and out of school (38 scores);
2. language and mathematics aptitude and ability tests (13 scores);
3. tests of specific aptitudes, including creativity, mechanical and abstract reasoning, and visualization (15 scores); and
4. tests of specific clerical, computational, and perceptual abilities (4 scores).

The typical behavior measures were derived from student responses to three questionnaires; The Student Information Blank (394 items), Interest Inventory (17 scales), and Student Activities Inventory (10 temperament scales) which collected data about the students' future plans, family background, temperament, and interests.

PROCEDURE

Determination of Physical Similarity

The initial identification of twins who participated in Project TALENT attempted to match individuals who responded "yes" to Student Information Blank item 200, "Are you a twin, triplet, or quadruplet?" Approximately 1,900 student pairs, 1,511 of the same sex, were matched.

Information concerning the physical similarity of the individuals representing same sex pairs was obtained by means of a mailed questionnaire. The questionnaire was patterned after the very successful instrument designed by Nichols (1965) of the National Merit Scholarship Corporation. The responses of each individual were coded separately, preserving information concerning over 50 characteristics of the individual and his perception of differences between his physical features and those of his twin. A computer program was developed to read the relevant cognitions concerning each physical feature and quantify the similarity of the twin pair (Schoenfeldt, 1966).

Estimation of Zygosity

Since the zygosity of the TALENT twins was unknown, the classification of these pairs was based on the discriminant analysis results of twins for whom zygosity was known, the 123 pairs from whom Nichols* (1966) obtained both physical similarity and blood-diagnosed criterion data. The result of the two-group discriminant analysis was a vector of weights which maximally differentiated the two blood-diagnosed groups.

The discriminant weights were applied to the physical similarity variables obtained from 524 pairs who responded to the questionnaire mailing. Thus each pair received a discriminant score, and was classified as monozygotic (mz) or dizygotic (dz) based on the mix of the known groups at that point along the discriminant function. Preliminary experimentation with a cross-validation sample of blood-diagnosed NMSC twins resulted in 88 per cent correct classifications (Schoenfeldt, 1966).

Factor Scores

It should be noted that well over 100 scores plus hundreds of unscaled item responses comprise the basic data file for each participant. In order to organize this vast array of data, Paul Lohnes of Project TALENT conducted a factor analytic study of the 1960 battery which has proved to be extremely illuminating and useful in subsequent criterion studies.

Lohnes' research involved not one, but two, factor analyses. The first began with the intercorrelations among 60 ability tests and resulted in 11 orthogonal factors. The second concerned

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* I am indebted to Robert C. Nichols for supplying these data.

measures of typical behavior, and began with the intercorrelations among 38 scales, 11 of which were created from Student Information Blank items specifically for this research. An additional 11 orthogonal factors emerged from the second analysis.

The factor analyses and rotations were done to guarantee that each set of factors would be orthogonal. In addition, scores computed for subjects on the factors are standardized with respect to the total population. Thus sex and grade differences inherent in the tests were preserved in the factor score distributions. Those desiring additional details regarding this factor analytic research are referred to *Measuring Adolescent Personality* by Lohnes (1966).

The opportunity to report the extent to which variation on the two sets of orthogonal factors can be attributed to heredity is indeed fortunate. It makes unnecessary the analysis, in turn, of numerous tests and scales known to contain overlapping variance. For this reason the analyses reported herein are based on the scores computed for each individual on the 22 factors.

Heritability

The utility of comparing mz and dz twins derives from the fact that, since mz twins have identical heredity, all differences between the two twins of an mz pair have an environmental origin. On the other hand, differences between twins of a dz pair can arise from both environmental and hereditary sources since their genetic structures are only similar, not identical. Thus, assuming mz and dz pairs are treated enough alike so that environmental differences between co-twins are essentially uniform for both types, the excess of dz within-pair variation is a function of heredity.† In 1929, Holzinger proposed h^2,

$$h^2 = \frac{\sigma^2_{w_{dz}} - \sigma^2_{w_{mz}}}{\sigma^2_{w_{dz}}} = \frac{r_{mz} - r_{dz}}{1 - r_{dz}}$$

where σ^2_w is the within twin pair variance and r is the intraclass correlation for expressing the degree to which observed variation on a test or a factor is genetically determined. (It should be pointed out that these two formulas produce equal results *only* when the mz and dz scores are standardized with respect to the total mean.) Although still widely used, it is generally recognized that Holzinger's index is not a satisfactory estimate of the extent to which variation is heritable (Jensen, 1967; Vandenberg, 1966).

A number of alternate procedures for calculating heritability have been proposed since Holzinger first introduced h^2. Preliminary results of an empirical study underway at Project TALENT to compare many of these procedures indicate one of the more

† There continues to be much discussion concerning the validity of this assumption (Dobzhansky, 1967; Vandenberg, 1966). One of the goals of the Project TALENT twin research is to use twins reporting to be mz but diagnosed as dz, and vice versa, in a study of environmental similarity.

promising to be what is identified, for the purpose of this report, as γ (gamma). This index,

$$\gamma = \frac{2\ (r_{mz} - r_{dz})}{\sigma^2_t} = 2\ (r'_{mz} - r'_{dz})$$

where r is the intraclass correlation, r′ is the intraclass correlation corrected for attenuation, and σ^2_t is the true score variance, is simply the proportion of true score variance that is genetically induced.

In applying either formula, it is important to recognize that if the r'_{mz} is not statistically different from r'_{dz} the true value of h^2 or γ is essentially zero. Separate factor reliability estimates were calculated for the male and female twins. When the reliability estimates are .50 or less the intraclass correlations corrected for attenuation become too unstable to permit reasonable interpretation.

RESULTS

Ability Factors

Results of comparing mz and dz twins on 11 factors of ability are presented in Table 1. The tests with the highest loadings on each factor are listed below the factor name. As Lohnes (1966) has indicated in his monograph, the factors fall logically into the four groups indicated in the table.

It will be recalled that the 11 factors are orthogonal. Since the first factor, Verbal Knowledges, is clearly a *g* factor tapping the general component of the battery, the constructs represented by the remaining 10 factors are independent of this general factor. In this respect it is unlikely that it would be possible to design tests reproducing the variance measured by these 10 independent constructs. However, in terms of the present research, these factors represent a unique and extremely valuable opportunity to examine the degree to which genetic sources account for variation observed on dimensions of adolescent personality—dimensions known to be representative of the adolescent population and independent of highly heritable, general intellectual competence.

Verbal Knowledges

To quote Lohnes (1966, p. 3-19), "Verbal Knowledges (VKN) is our closest approximation to [the construct of] general intelligence, or IQ. Technically, VKN is a *g* factor, since every single one of the 60 ability tests has a positive nonzero correlation with this factor."

Approximately three-fourths of the observed variance on this factor can be attributed to genetic sources. This result was consistent with the findings of other investigators (Vandenberg, 1966).

Differential Aptitudes

The three factors comprising this group, as described by Lohnes (1966), represent a sub-set of constructs generally accepted as a "unique class of relatively simple tasks."

As is shown in Table 1, substantial proportions of both male and female

TABLE 1

Intraclass Correlations and Heritability Ratios for 11 Project TALENT Ability Factors.

Factor Name and Tests with Highest Loadings[a]	Males: Intraclass Correlation MZ N=150	Males: Intraclass Correlation DZ N=53	Males: t^b	Males: γ^c	Males: $h^{2\,d}$	Females: Intraclass Correlation MZ N=187	Females: Intraclass Correlation DZ N=103	Females: t^b	Females: γ^c	Females: $h^{2\,d}$
General Intelligence										
VERBAL KNOWLEDGES	.783	.391	5.30**	.88	.77	.813	.520	9.10**	.69	.87
A *g* factor representing the General Intell. component of the battery										
Differential Aptitudes										
VISUAL REASONING	.683	.527	2.25*	.37	.47	.655	.345	6.37**	.81	.74
R-282 Visualization in 3 Dimen.										
R-281 Visualization in 2 Dimen.										
PERCEPTUAL SPEED AND ACCURACY	.637	.618	.25			.702	.450	4.53**	.59	.61
R-430 Clerical Checking										
R-420 Table Reading										
MEMORY	.484	.115	3.62**	.96	.57	.385	.225	2.03*	.42	.30
R-211 Memory for Sentences										
R-212 Memory for Words										
Educational Achievements										
ENGLISH LANGUAGE	.655	.379	3.55**	.67	.62	.607	.454	3.36**	.41	.51
R-232 Capitalization										
R-233 Punctuation										

TABLE 1 (cont.)

MATHEMATICS	.616	.629	—.20	.626	.467	5.01**	.45	.67
R-333 Advanced Mathematics								
R-106 Mathematics Information								
Special Knowledges								
SCREENING	.422	.326	1.14	e				
R-101 Screening (simple info test)								
R-113 Farming Information								
HUNTING-FISHING	.413	.439	—.53	e				
R-146 Fishing Information								
R-151 Hunting Information								
COLOR, FOOD	e			e				
R-143 Colors Information								
R-151 Foods Information								
ETIQUETTE	e			e				
R-144 Etiquette Information								
GAMES	e			e				
R-149 Games (sedentary) Information								

[a] Groups are listed in decreasing order of variance extracted; and within each group, factors are listed in decreasing order of variance extracted.

[b] t-test of significance of difference between r'_{mz} and r'_{dz}, where r' = intraclass correlation corrected for attenuation.

[c] $\gamma = 2 \frac{(r_{mz} - r_{dz})}{\sigma^2_t}$ where r = intraclass correlation and σ^2_t = standardizedd true score variance.

[d] $h^2 = \frac{r'_{mz} - r'_{dz}}{1 - r'_{dz}}$ where r' = intraclass correlation corrected for attenuation.

[e] Results on this variable are not reported—error variance for this group was equal to or greater than true score variance.

* $p < .05$

** $p < .01$

variation on the factors comprising this group were attributable to genetic sources, with the exception of males on the Perceptual Speed and Accuracy factor. The proportions for females on the Visual Reasoning factor and for males on the Memory factor exceeded those observed for each group on the Verbal Knowledges factor.

Educational Achievements

The two factors forming this group appear to be measuring acquired knowledge that is independent of the general factor. For both males and females, significant proportions of the English Language variation arose from genetic sources. A substantial segment of the female variation on the Mathematics factor was heritable.

As is shown, the male r's on the Mathematics factor were not significantly different, thus the heritability was assumed to be zero. Further research is planned to determine to what extent scores on this factor are influenced by number of mathematics courses taken. The hypothesis is that such is the case. Even so, it is hard to imagine why some portion of the propensity to acquire mathematics training would not be heritable.

Special Knowledges

Five minor knowledge factors comprise the fourth and final group. Four tests had loadings above .35 on the Screening factor, two on the Hunting-Fishing and Color-Food, and one each on the Etiquette and Games factors. In all but two instances the factors were not reliable enough to warrant calculation of intraclass correlations. On the two factors with reliabilities over .50 the corrected mz and dz intraclass correlations did not differ.

Summary

The results on the 11 abilities domain factors were essentially the same for males and females. Six of the 11 factors for the females and four for the males had a significant component of heritable variance. The Mathematics and Perceptual Speed and Accuracy factors were the exceptions with results for the females being significant and those for the males nonsignificant. The low reliabilities of the five minor special knowledge factors precluded analysis of their heritabilities.

Non-Cognitive Factors

The second factor analysis began with the intercorrelations among 38 typical behavior scales derived from the TALENT battery. As with the previous set, the resulting 11 factors are orthogonal, and can be logically divided into two groups: a set of seven factors measuring motives and a second group measuring interests.

Table 2 presents the results of contrasting the mz and dz twins on the 11 typical behavior factors. The most striking feature was the lack of agreement between the two sexes. A component of the true score variance on seven of the factors was heritable for the females. Only three of the factors had genetically related variance components for the males: Business Interests, Cultural Interests, and Outdoors-Shop Interests. Cultural Interests, was among the significant seven for the females.

In general, needs or motives have genetically related components of variance for females but not for males, whereas interests have genetically related components for males but not for females. Exceptions include two factors, Introspection and Science Interests, which have no heritable component for either sex, and Cultural Interests, which has a significant genetically related component for females as well as males.

DISCUSSION

It is obvious, but nevertheless worth recalling, that behavior is a product of both heredity and environment. Without both, there can be no behavior. This is not to deny the legitimacy of attempting to quantify the components of observed behavior. Knowing the degree each contributes or the extent to which they interact, can be of great value in understanding the outcome, i.e., behavior.

With this in mind, it is in many respects unfortunate that e^2, or the component variance attributable to environment, lacks the rich tradition h^2 has accrued. Although e^2 is simply $1 - h^2$, it represents the portion of the total, i.e., behavior, most responsive to influence.

This leads to a second point, the stability of h^2 as a variance component. Obviously h^2 will equal 1.0 if environmental influences are constant within a given population or sub-population. In this respect, h^2 is not invariant, but is instead influenced by environmental variation. As the e^2 increases as a source, the h^2 will decrease.

This may be the explanation for the seeming differences in heritability for males and females on the 11 motives domain factors. If one can accept the hypothesis of less environmental variance for females than for males, that is, more environmental pressure for behavioral conformity in the typical behaviors domain, this would explain the larger female heritability estimates. This certainly seems plausible with regard to occupationally related interests, where the range of opportunities is typically more restricted for women. In the area of non-occupational interests and needs, I would suggest that, while the same basic developmental opportunities exist, females are less likely to deviate from the perceived norm. The results on the first factor, Conformity Needs, showed that a substantial component of the female variation was heritable. This result can be considered as support for the hypothesis.

Accuracy of Zygosity Estimates

As mentioned, preliminary experimentation using the discriminant weights for classification of a small cross-validation sample of NMSC twins ($N = 24$) resulted in 88 per cent accuracy. The three errors were dz twins misclassified as mz twins. For this reason it is assumed the principal source of error in estimating zygosity for the TALENT subjects was in the same direction. This type of error, inclusion of some dz twins with the mz pairs, would be conservative and

TABLE 2

Intraclass Correlations and Heritability Ratios for 11 Project TALENT Non-Cognitive Factors

Factor Name and Tests with Highest Loadings[a]	Males: Intraclass Correlation MZ N=150	Males: Intraclass Correlation DZ N=53	Males: t^b	Males: γ^c	Males: $h^{2\,d}$	Females: Intraclass Correlation MZ N=187	Females: Intraclass Correlation DZ N=103	Females: t^b	Females: γ^c	Females: $h^{2\,d}$
Needs										
CONFORMITY NEEDS	.387	.280	.79			.433	.123	3.00**	.67	.39
A g factor representing the response conformity bias of the SAI scales										
SCHOLASTICISM	.523	.391	1.21			.552	.363	2.82**	.47	.42
Grades scale from SIB items										
Studying scale from SIB items										
ACTIVITY LEVEL	.444	.357	.78			.490	.328	2.60**	.44	.40
Work scale from SIB items										
Hobbies scale from SIB items										
LEADERSHIP	.304	.447	−1.60			.495	.406	3.10**	.30	.50
Leadership scale from SIB items										
R-608 Leadership (SAI scale)										
IMPULSION	.237	.211	.26			.319	.111	3.94**	.79	.50
R-603 Impulsiveness (SAI scale)										
SOCIABILITY	.555	.430	1.66			.601	.349	5.11**	.69	.65
Social scale from SIB items										
INTROSPECTION	.402	.333	.66			.346	.220	1.52		
R-609 Self-confidence (SAI scale)										
Reading scale from SIB items										

TABLE 2 (cont.)

Interests										
BUSINESS INTERESTS	.380	—.049	2.63**[e]	.81[e]	.41[e]	.397	.348	.52		
P-712 Computation Interest										
P-710 Sales Interest										
OUTDOORS, SHOP INTERESTS	.583	.353	2.02*	.49	.39	.384	.361	.25		
P-716 Farming Interest										
P-715 Skilled Trades Interest										
CULTURAL INTERESTS	.455	.189	2.20*	.61	.39	.548	.231	3.73**	.72	.49
P-707 Musical Interest										
P-706 Artistic Interest										
SCIENCE INTERESTS	.531	.315	1.85			.362	.265	1.07		
P-702 Biological Science, Medicine										
P-701 Physical Sci., Eng., Math.										

[a] Groups are listed in decreasing order of variance extracted; and within each group, factors are listed in decreasing order of variance extracted.

[b] t-test of significance of difference between r'_{mz} and r'_{dz}, where r' = intraclass correlation corrected for attenuation.

[c] $\gamma = 2\frac{(r_{mz} - r_{dz})}{\sigma^2_t}$ where r = intraclass correlation and σ^2_t = standardized true score variance.

[d] $h^2 = \frac{r'_{mz} - r'_{dz}}{1 - r'_{dz}}$ where r' = intraclass correlation corrected for attenuation.

[e] Results assume true value of $r_{dz} = 0.0$

* $p < .05$

** $p < .01$

would lead to an understatement of the genetic component.

SUMMARY AND CONCLUSION

The purpose of this initial study of what is planned as a series of research explorations using the twins who participated in Project TALENT has been to examine the variance attributable to genetic sources within the TALENT two-day battery. Specifically, scores of mz and dz co-twins were contrasted on 11 orthogonal abilities factors and another orthogonal set of 11 non-cognitive factors.

The 11 ability factors logically fell into four groups: a *g* factor, a set of three differential aptitude factors, two educational achievement factors, and five special knowledges. Factors in the first three groups contained significant components of genetically related variance. None of the five factors in the special knowledges group had a significant heritable component. The factor with the largest proportion of heritable variance was Memory for the males and Visual Reasoning for the females. The factor with the second largest proportion of heritable variance for both males and females was Verbal Knowledges, the factor equivalent to the measures of general intelligence reported by others.

The 11 factors of typical behavior were divided into a group of seven needs factors and four interest factors. The highlight of analyzing the variance on these factors was the differential results for males and females. Significant heritable components were identified on seven factors for females and three for males. Results on only one factor, Cultural Interests, were significant for both sexes. The Interest factors tended to be significant for the males, and the needs factors significant for the females.

Important genetically related variance components were identified in most factors of the TALENT battery. It was concluded that genetic sources of variance are important factors in explaining differences among individuals in ability and non-cognitive behavior.

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