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ABSTRACT

Heritability is defined as the proportion of a manifested trait's varience that is due to genetic variation. Sixty-five pairs of twins were employed to investigate the heritability of: (1) short term memory (Jensen's Level 1), operationalized using of modified "digit span" test; (2) the general intellective factor (Jensen's Level II), operationalized as the score on Raven's Progressive Matrices; and (3) Divergent Thinking, operationalized as scores on the Torrance Tests of Creative Thinking. Utilizing both identical twins, who have exactly the same genes, and fraternal twins, who share only about half of their genes, the authors concluded that (1) short term memory has a moderate index of heritability; (2) the general intellective factor has a somewhat high heritability index; and (3) there is no evidence of heredity variation in Divergent Thinking measures. Possible implications for compensatory education programs, as well as for training classroom teachers, are mentioned. (TL)

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THE HERITABILITY OF JENSEN'S LEVEL I AND II AND DIVERGENT THINKING

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ABSTRACT

A heritability study employing 65 pairs of twins was conducted investigating the heritability of Jensen's Level I (operationalized using a modified "digit span" test), Jensen's Level II, or 'g', the general intellective factor, (operationalized as the score on Raven's Progressive Matrices), and Divergent Thinking, (operationalized as scores on the Torrance Tests of Creative Thinking).

Null hypotheses concerning the heritability of Jensen's Level I and Level II were rejected (5%) while the Divergent Thinking hypotheses were not. The indices of heritability for Level I and II were .54 and .85 respectively, which indicate the proportion of concomitant variation between genotype and phenotype.

INTRODUCTION

Arthur Jensen's seminal article in the Harvard Educational Review (1969) has rekindled interest in the subject of heritability, that is, the proportion of a manifested trait's variance that is due to genetic variation. Summarizing the literature on the heritability of intelligence, more precisely the heritability of whatever common factor is measured by the conventional IQ tests, Jensen concludes that 80% of the variation in IQ is concomitant with variation in genetic composition. A good deal of the rekindled interest created by the article centers around the very nature of intelligence. Few scholars today still assert that intelligence is unitary in nature. Instead most researchers have asserted the presence of a number of seperate factors in intelligence, and several, e.g. Vandenberg (1956b, 1967), Block (1968), Strandskov (1955), have attempted to isolate those factors to assess separate heritabilities even before the publication of the Jensen article. This interest led to the investigation of several of these factors, namely Jensen's Level I of Learning Ability, short term memory; Jensen's Level II of Learning Ability, Spearman's 'g'; and Verbal and Figural Divergent Thinking.

BACKGROUND

A good deal of data is available on the heritability of the conventional global measure of cognitive ability, the IQ. In "How Much Can We Boost IQ and Scholastic Achievement?" Arthur Jensen (1969) bases much of his argument for the immutability of IQ differences on the high heritability of IQ. He argues that IQ variation is due in great measure to genetic variation.

His thesis, of course, is not without criticism, both philosophical (Cronbach, 1969), (Bereiter, 1969), (Hunt, 1969), and methodological (Kagan, 1969), (Light & Smith, 1969). Some of these criticisms regard the conception of the nature of intelligence. Jensen has focused his review of heritability on the underlying common factor in intelligence tests, Spearman's 'g', though factor analysis has shown intelligence is not a unitary trait. There may be therefore other factors of intelligence with heritabilities which differ from Jensen's conclusion concerning the heritability of 'g'.

Considerable evidence is available supporting the existence of separate, somewhat independent factors in intelligence. Guilford (1956) has postulated 120 such separate abilities. Burt (1966, p. 137) points out that "the concept of a motley assortment of cognitive faculties or primary abilities" is no longer an acceptable notion of the intellect as a result of the statistical studies using factorial techniques. He asserts that the evidence points to an "organized hierarchy comprising both a 'general cognitive factor' (the subject of Jensen's review) and a number of more specialized 'group factors' of varying extent or breadth" (op. cit., p. 137).

In his review of what has been labeled the "nature-nurture" controversy, Vandenberg (1968, pp. 508) asserts that evidence shows at least six independent intelligence abilities: size of vocabulary, verbal fluency, numerical ability, spatial ability, reasoning ability, and memory, which are coincident with Thurstone's "primary mental abilities."

Jensen himself hypothesizes two levels of learning ability (Jensen, 1969, pp. 110-111) to explain differences in performance on tests of intelligence, learning and scholastic achievement. The first, Level I, is associative learning, in which there is little transformation of the input, manifested by digit memory, (op. cit., p. 111). The second level, Level II, involves self-initiated elaboration and transformation of the input, before it becomes an output response. Level II is best measured by "intelligence tests with a low cultural loading and a high loading on 'g' such as Raven's Progressive Matrices" (op. cit., p. 111).

Divergent thinking has been shown to be relatively independent of variously operationalized measures of intelligence. Madaus (1967), (Getzels & Madaus, 1969) has explored and reviewed the relationship between intelligence and divergent thinking and concludes that there is negligible relation between the two. Madaus (1967, p. 232) factor analyzed an array of divergent thinking and intelligence measures and found the first unrotated factor was dominated by the divergent thinking measures with only low to moderate loadings for the intelligence measures.

Some evidence exists which supports the notion that memory, like divergent thinking, is relatively independent among factors in intelligence. Jensen suggested that short term memory, his Level I, is a necessary but not sufficient condition for high intelligence, which connotes some independence between short term memory and intelligence, (Jensen, 1970). In reviewing the controversy over the genetic components of cognitive processes, Vandenberg (1968, p. 7-8) points out that memory is an independent factor among six or more independent factors in intelligence.

Additional evidence supporting the independence of Level I ability comes from Morrison (1967, p. 275) who factor analyzed the eleven WAIS subtests and found that "Digit Span," a short term memory subtest, loaded only moderately on the first factor, 'g', and that the second factor was dominated by "Digit Span."

Research literature on the heritability of any of these factors has been sketchy and in some respects contradictory. Table 1 summarizes the studies of heritability of memory. The two studies using the <u>Primary Mental Abilities Tests</u> "Memory," showed no significant heritability. However, of the two studies using "Digit Span," one found a significant

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heritability component beyond the 5% level; the other did not. Two additional studies conducted in Sweden, using four different instruments, also yielded conflicting results.

Some of the differences in the studies appearing in Table 1 may be attributed in part to the fact that there may be real differences in heritability in the samples, for in many reports different nationalities and different age groups were sampled.

Some of the differences may be attributed in part to the different criterion instruments. A slight variation in the time lapse between presentation and recall or recognition, may mean that the tests are tapping slightly different traits. In particular reference to this possibility of confusing traits, Vandenberg (1968, p. 7) has said "Memory.....may not be unitary.....Recent work suggests that there are different mechanisms for short-term and long-term memory storage, as well as separate memory abilities for different types of materials."

In addition, there may be differences in the results of Table 1 that are attributable to the unreliability of the tests. None of the studies in Table 1 reported the reliabilities for their criterion instruments on their samples under study and Jensen (1970) has suggested that the usual test of "Digit Span" does not yield sufficiently high reliability for consistent results in heritability studies.

A review of the literature of heritability of divergent thinking produced only one study, summarized in Table 2. Only one of the nine subtests was found to be significantly heritable.

In the area of research on heritability of 'g' using Jensen's suggested Raven's Progressive Matrices only one study was found by Husen in 1953 conducted on Swedish children and reported in Vandenberg (1968), p. 37) which derived a significant heritability for that sample.

TABLE 2

F Ratios Between Fraternal and Identical Within-Pair Variances for Nine of Guilford's Tests of Divergent Thinking for 24 Pairs of Like-Sex DZ and 67 Pairs of MZ Twins

Name of Test	F
1. Pertinent Questions	1.85*
2. Different Uses	1.53
3. Social Institutions	1.39
4. Seeing Dificiencies	1.35
5. Making a Plan	1.11
6. Similar Words	1.10
7. Associations	1.08
8. Figure Production	1.03
9. Picture Arrangement	0.94

*p less than .05.

Table from Vandenberg (1968, p. 193).

Due to the almost total lack of heritability research in divergent thinking and 'g' and the wide range of variation in results on short term memory, these investigators sought to undertake an investigation of the following variables:

1) Jensen's Level I of Learning Ability or short term memory as measured by a modified version of the Digit Span subtest of Wechsler's Intelligence Scales;

2) Jensen's Level II of Learning Ability or 'g' as measured by Raven's Progressive Matrices;

and 3) Verbal and Figural Divergent Thinking as measured by the Torrance Tests of Creative Thinking scored for Fluency, Flexibility and Originality.

DESIGN

The method for assessing heritability in this study is the simultaneous comparison twin study. Vandenberg (1966, p. 329) recommends the twin study technique for reasons of economy as well as the fact that it overcomes the difficulties of comparing scores of individuals of vastly different ages, as would be encountered in family and inbreeding studies. The age range of twins does not interfere with the easy interpretation of the data, even though the variables have some amount of age-related variation. Since each twin is perfectly matched with his co-twin on age, and comparisons are made only within pairs, the age variation does not enter into the analysis for heritability. This is equivalent to "control" of age.

The twin study technique consists of administering criterion instruments to samples of identical and fraternal twins and calculating the within-pair variance in each set. Since identical twins have exactly the same genes, and fraternal twins share only half their genes on the average, any differences in measures on identical twins will be due to environment alone, while differences in fraternal twins will be due to environment <u>and</u> genetic differences. A substantial difference, then, in the within-pair variance is evidence of an hereditary component in the trait.

The present study employed an adaptation of the method of Clark (1956) as outlined by Vandenberg (1969a, pp. 128-129). This method overcomes the weaknesses of earlier statistical methods and represents the most efficient analysis appropriate to the model of heredity. Sometimes called the "analysis of variance method," the technique calls for one-way ANOVA table where the "group" is a pair of twins; naturally each of the N groups has $n = 2$ members. The partition of variance for this method and the degrees of freedom are illustrated in Table 3 below.

TABLE 3

Partition of Variance for Twin Studies

Sources of Variation	SS	df
Between p pairs	$\frac{1}{2}\Sigma(X_a + X_b)^2 - \frac{1}{2p}(\Sigma X)^2$	$p - 1$
Within p pairs	$\Sigma X^2 - \frac{1}{2}\Sigma(X_a + X_b)^2$	p
Total	$\Sigma X^2 - \frac{1}{2p}(\Sigma X)^2$	$2p - 1$

If the within-pair variance for fraternal and identical pairs are abbreviated $\sigma^2 W_{dz}$ and $\sigma^2 W_{mz}$ respectively, then the variances may be tested using Fisher's F test:

$$F = \frac{\sigma^2 W_{dz}}{\sigma^2 W_{mz}}$$

Since phenotypic variance is viewed as the sum of the genotypic variance, the environmental variance, and the interaction variance, and it is assumed that environmental influences have as much impact on fraternal twins as on identical twins, the environmental variance term in identical and fraternal twins within-pair variance should tend to equality.

Hence, if the trait we are interested in has an hereditary component, then the within variance for the dizygotic pairs will be greater than the within variance for the monozygotic pairs, since the added variance will be due to genetic variation. This difference due to an hereditary component reveals itself in the F test and can be converted to Holzinger's h^2 by the following formula:

$$h^2 = \frac{\sigma^2 W_{dz} - \sigma^2 W_{mz}}{\sigma^2 W_{dz}}$$

The h^2 index is generally thought of as the proportion of variance accounted for by genetic components of variance. A simpler interpretation is that the square root of the index, or simply 'h,' is the correlation between genotype and phenotype. It should be pointed out that the index has fallen out of vogue due to the careless interpretation of it as a proportion of the trait, rather than as a proportion of the variance of a trait under hereditary influence.

The F value has become more popular because it is probabilistic, i.e. it carries a confidence value and its degrees of freedom give an indication of the strength of the estimate of heritability. Recall that the degrees of freedom associated with the F test in a twin study are the number of fraternal twin pairs and identical twin pairs respectively, hence the larger the sample, the stronger the estimate.

RESULTS

The sample for this investigation was drawn from the Massachusetts Mothers of Twins Association membership lists. Mixed-sex fraternal twin pairs were deleted from the choices to eliminate within-pair variance due to sex. Pairs whose zygosity had not been objectively determined were likewise eliminated. The resulting sample tested consisted of 35 pairs of fraternal twins and 28 pairs of identical twins.

Within-pair variances for both identical twin pairs and fraternal twin pairs, and F ratios were calculated. In the two cases of a significant F ratio, an heritability index was calculated. The conversion of F to h^2 is facilitated by observing that since

$$h^2 = \frac{\sigma^2 W_{dz} - \sigma^2 W_{mz}}{\sigma^2 W_{dz}}$$

$$+ 1 \quad \frac{\sigma^2 W_{mz}}{\sigma^2 W_{dz}}$$

and

$$F = \frac{\sigma^2 W_{dz}}{\sigma^2 W_{mz}}$$

then

$$h^2 = 1 - \frac{1}{F}$$

The results of the analysis of variance, i.e. the within-pair variance, F-ratios, and the significant index of heritability, h^2, for short term memory, appear in Table 4.

Holzinger's Index of Heritability (Newman, Freeman, & Holzinger, 1937) calculated for Jensen's Level II is .85 and for Level I is .54. This can be interpreted as 85% concimitant variation between genotype and phenotype of Level II and 54% concomitant variation between phenotype and genotype in Level I.

One is cautioned not to oversimplify the interpretations of this index. The index is interpreted as a proportion of the variance of a trait under hereditary influence, not the proportion of the trait itself. It is also fitting to mention again, here, that differences in

TABLE 4

Within-Pair Variances, F-Ratios, and Heritabilities for the Raven's Progressive Matrices, Short Term Memory Test, Figural Flexibility, Figural Fluency, Figural Originality, Verbal Flexibility, Verbal Fluency, and Verbal Originality

	Within-Pair Variances		F-Ratio	Index of Heritability
	DZ	MZ		
Raven's Progressive Matrices	96.39	14.05	6.86**	.854
Short Term Memory	909.85	414.49	2.20*	.545
Figural Tests				
Flexibility	25.11	18.22	1.38	---
Fluency	53.82	36.03	1.49	---
Originality	215.43	152.62	1.41	---
Verbal Tests				
Flexibility	10.43	15.78	0.66	---
Fluency	41.68	49.70	0.84	---
Originality	19.61	38.84	0.50	---

*Significant at the .05 level. $F_{.05;28,37} = 1.78$

**Significant at the .01 level. $F_{.01;28,37} = 2.26$

heritabilities may be found from one sample to another as mentioned earlier, along this line heritability indices were calculated for other published studies and are summarized and compared to the current investigation in Table 5.

The differences in heritability estimates when other than "digit" memory was used may be explained by the difference in the criterion measures, as well as possible differences in heritability from one population to another.

TABLE 5

A Comparison of Holzinger's Index of Heritability Calculated for the Current Investigation and Past Investigations in Memory, Divergent Thinking, and Other Mental Traits

Investigation	Variable	Holzinger's Index of Heritability
Current Investigation	Short Term Memory	.54
	Raven's Progressive Matrices	.85
Jensen (1969)	"Measured Intelligence" - 'g'	.80 (averaged value)
Strandskov (1955)	Primary Mental Abilities Test "Memory"	.38
Vandenberg (1965b)	Primary Mental Abilities Test "Memory"	.21
Vandenberg (1967)	W.I.S.C. "Digit Span"	.27
Block (1968)	W.I.S.C. "Digit Span"	.35
Wictorin (1952)	Digit Recall	.19
	Digit Recognition	.14
Bruun et al. (1968)	Memory for Names	.52
	Memory II	.49
Vandenberg (1968)	Guilford's "Pertinent Questions"	.46

When the heritability index for short term memory is compared to other mental trait's heritability in Table 5, one finds that it is substantially lower than the estimates for the general intellective factor, 'g,' from Jensen, whose estimate for the heritability of 'g' comes from his review of the literature on the heritability of standard intelligence test scores rather than a pure measure of 'g' and represents an "average value."

Some emphasis in the origin of this research was placed on the relationship between the various 'factors' and the general intellective, 'g'. The correlation matrix below in Table 6 depicts some of those relationships in this study.

Several of the correlations are notable, particularly the correlation between Jensen's Level I and II. Jensen has said that they are somewhat independent in that Level I is a necessary but not sufficient condition for Level II. The correlation of .578, (.327 when age and sex are partialled out), seems consistent with a degree of independence. Also worthy of some attention is the uniform tendency for the divergent thinking measures to be only low correlates of Level II and Level I. Attempts were made to disattenuate the correlations, i.e. eliminate the effects of unreliability (a weakness of creativity tests in general) and even disattenuated these correlations remain low, though positive.

The relationships among the divergent thinking variables, however, are so confused as to make clear interpretation of the array difficult if not impossible. Disattenuation of the correlations resulted in some correlations greater than unity. This is most likely due to underestimations of the Torrance Tests reliabilties.

TABLE 6

Correlation Matrix for Raven's Progressive Matrices, Short Term Memory, and Verbal and Figural Divergent Thinking.

Reliabilities							
r>.90 Raven's Matrices	r>.90 Short Term Memory	.62* Figural Flexibility	.65* Figural Fluency	.70* Figural Originality	.67* Verbal Flexibility	.72* Verbal Fluency	.68* Verbal Originality
1.00	.578**	.261 (.331)	.208 (.258)	.062 (.074)	.334 (.408)	.256 (.301)	.258 (.313)
	1.00	.150 (.190)	.179 (.222)	.064 (.076)	.206 (.252)	.181 (.213)	.148 (.179)
		1.00	.875 (1.38)	.109 (.165)	.334 (.518)	.314 (.470)	.239 (.368)
			1.00	.074 (.110)	.309 (.468)	.350 (.512)	.208 (.313)
				1.00	.330 (.482)	.334 (.470)	.389 (.564)
					1.00	.665 (.957)	.832 (1.23)
						1.00	.668 (.955)
							1.00

†Original correlations are in position above disattenuated correlations in parentheses.

*Reliabilities for the Torrance tests are medians of the values reported by Mackler and Yamamoto in Torrance (1966).

**When age and sex are partialled out, the resulting correlation becomes .327.

IMPLICATIONS OF THE FINDINGS

As was pointed out earlier, Jensen (1969) feels that high heritability is sufficient to preclude facilitation of intelligence in compensatory education programs. By facilitation is meant the "nurture," "stimulation," or "liberation" of certain traits or attributes. If this assertion of Jensen's is indeed correct, then such compensatory education programs as Head Start are doomed to failure if they attempt to manipulate the environment and experiences of their subjects in order to produce gains in IQ. Yet most heritability data has been generated in the general factor of intelligence, and not for specific factors that have been identified as independent or relatively independent. Thus the pool of mental capacities to be considered for facilitation efforts has not been exhausted.

This research has demonstrated that first, short term memory (Jensen's Level I) has only a moderate index of heritability, .54; second, that the general intellective factor, 'g' (Jensen's Level II) has somewhat high heritability with an index of .85, which agrees quite closely with Jensen's projected value of .80; and third that no evidence of heredity variation appeared in the Figural and Verbal Divergent Thinking measures.

These mental capacities that have only low or moderate heritability are identified as candidates for facilitation efforts. If further research supports the notion that many intellectual factors have little or no hereditary components, then these factors are more likely candidates for facilitation than the conventional IQ.

A cautionary note is necessary here. To say that a mental trait is not heritable or has low heritability is <u>not</u> to say that it <u>can</u> be facilitated, but merely that it may be facilitated. For example, much controversy centers around the facilitation of divergent thinking (Dacy et al., 1968), with little concensus as to how or when divergent thinking may be facilitated.

A further implication of the findings of a lower heritability for Level I is in the area of training the classroom teacher, since most of the learning in school today is conducted through Level II - 'g.' As Jensen states (1969, p. 116),

> Too often, if a child does not learn the school subject matter when taught in a way that depends largely on being average or above average on 'g,' he does not learn at all, so that we find high school students who have failed to learn basic skills which they could easily have learned many years earlier by means that do not depend much on 'g.' It may well be true that many children today are confronted in our schools with an educational philosophy and methodology which are mainly shaped in the past, entirely without roots in these children's genetic and cultural heritage.

If teachers are made aware of the narrowness of the range through which learning is conducted, and that other learning capacities not only exist but are much less "fixed" than the conventional 'g,' they may be more open to alternative methods of teaching. In this way the schools may learn to utilize the relatively unused strengths of children whose major strength is not of the verbal-cognitive-abstract type. Jensen also points out (1969, p. 117) that Level I may be the basic avenue to learning among the disadvantaged. If this is the case, then it seems mandatory that teachers be made aware of a diversity of approaches to make learning rewarding to children of diverse ability patterns.

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