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ABSTRACT

The results of a study investigating heredity components of mathematical ability as well as sexual differences related to this ability are reported. A test containing 26 arithmetic problems was administered to 300 pairs of twins. Analysis of the data included within and between pair variance, and intraclass correlations for each sex and zygosity group. In addition, the data were also analyzed by a new technique called "dichotomic analysis" to test for evidence of an underlying biomodality in the distribution of scores. The author concludes that there is an underlying heredity component for proficiency in quantitative reasoning, and that this component fits a sex-linked recessive model fairly well. The paper also includes summaries of previous studies of heredity and environmental components of mathematical abilities, and a bibliography of related research. [Not available in hardcopy due to marginal legibility of original document.] (CT)

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HEREDITARY AND ENVIRONMENTAL COMPONENTS OF QUANTITATIVE REASONING

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A multitude of investigators have tackled the problem of individual differences in mathematical ability. Two of their primary concerns have been to answer the basic questions: "Is mathematical ability largely innate or learned?" and "Why do boys do better in math than girls?" First, some of these studies will be summarized and then new evidence will be presented about the origin of mathematical ability and the cause of the sex differences.

Definition

There have been many attempts to define "mathematical ability" and different researchers have meant different things by the phrase. However, factor analytic studies have shown there are probably three components to mathematics. (Very, 1967, Coleman, 1956). The first is "arithmetic knowledge" which is basically the degree of achievement or sophistication in mathematics. The second is "numerical ability" which is basically computational operations and the third is "quantitative reasoning" a verbal problem solving ability. The latter two components are defined as Factor N: Number Facility (Cattell's U.I. T10; Guilford's NSI) and Factor R: General Reasoning (Cattell's U.I. T34; Guilford's CMS) by French, Ekstrom & Price (1963).

There may be some overlapping of these components at certain ages but an attempt will be made to identify them as the various studies are discussed. First of all, let us examine some of the evidence for environmental influences upon quantitative reasoning.

EVIDENCE FOR ENVIRONMENTAL COMPONENTS

Attitudes towards Mathematics

It has been demonstrated that a student's achievement in math is related to a degree by the length of time his teacher has taught and the quality of the college at which his teacher took his training (Shunert, 1951). Also considered to be important is his attitude towards mathematics. Early successes in mathematics courses brings about positive attitudes towards the subject (Gebhard, 1948). In addition, it appears that parental attitudes towards mathematics are equally important in setting the right climate. (Poffenberger & Norton, 1959). Hill (1967) found mother-son similarity in attitudes towards mathematics significantly correlated ($r = .39$) but father-son similarity was not.

Four studies undertaken by Sweeney (1953) revealed that there are sex differences in problem solving ability related to mathematics, and that these sex differences are not related to intelligence, special abilities or knowledge. However, the sex differences that remained appeared to involve a restructuring of the problems presented or involved a general reasoning factor. In a follow-up study Carey (1958) found that sex differences in problem solving were attributable to attitudes. Although her men originally scored higher on the attitude scale and did relatively better on solving problems, her women improved their scores on solving problems after a group discussion concerned with individual attitudes towards problem solving. Attitudes towards problem solving were also found to be more favorable for men and these attitudes were clearly correlated with problem solving ability (Berry, 1958).

Sex Role Identification

It was found that a significant positive correlation existed between masculine sex-role identification as determined by masculinity-femininity scales and the ability to solve problems which had previously exhibited sex differences (Milton, 1957). By changing the characteristics of the problems so as to make them less appropriate to the masculine sex role, Milton, (1959) later found that sex differences could be reduced although not completely eliminated. In trying to establish a relationship between non-intellectual variables and problem solving ability, Berry (1958) observed that women's scores on the Terman-Miles M-F Scale were significantly correlated with their problem solving ability. However, there has been a serious objection raised about the correlating masculinity-femininity scales with problem solving ability (Yonge, 1961). Such correlations may be artifacts of the manner in which M-F scales are constructed, that is, they may simply be confounded by the use of males and females (which are different in their problem solving ability) to supply the M-F item differences which make the scale.

Father Absence

Since several of the above studies imply that the masculine sex role is involved in mathematical problem solving ability, it may not be surprising to find that father absence or presence in the home can affect children's mathematical ability. Carlsmith (1964) sutdied male college freshman's scores on the Scholastic Aptitude Test and found that although scores on the math section normally exceeded those on the Verbal section for male students, those who had experienced a father absence in the home due to war, had higher Verbal than Math scores. In general, the longer the father was absent the greater the difference between V and M, especially if the absence ocurred when the son was very young. This study was replicated by her on a high school sample with the same results. A similar finding was reported for female college students enrolled in a psychology course (Landy, Rosenberg, Sutton-Smith, 1969). Here not only was the effect of complete father absence apparent as a depressant upon the Q scores of the ACE, but the effects of partial father absence such as night shift work was also detrimental to the girl's Q scores (see Table 1).

.... place Table 1 about here ....

In keeping with Calsmith's previous findings the authors concluded that the absence of the father was especially crucial when the daughter was very young but became less so as she grew older.

Ordinal Position

First borns have long been thought to exceed other children, however, no evidence concerning their quantitative ability had been noted until a study by Rosenberg and Sutton-Smith (1964) showed that second born females tended to excell over first born females on the Q score of the ACE Psychological Examination. In addition, they noted that third born girls are more likely to have higher Q than L scores, although, in general, just the reverse is true for girls (Rosenberg & Sutton-Smith, 1966). Among first born girls, the presence of a male sibling does not appear to alter the number who have higher Q than L scores but for second and third born females, there is a significantly greater number who score higher on the Q subtest than on the L when there is a male sibling in the family. However, the reverse is not true for boys.

Ordinal position also interacts with father absence so that while father absence acts as a depressant upon ACE scores in general. For Q scores, there is less effect upon sons with brothers than upon sons without; on the other hand, Q scores of daughters with a younger brother appear to be more affected than other daughters (Sutton-Smith, Rosenberg, and Landy, 1968).

Personality Correlates

Using selected items from the MMPI, Altus (1952) found that women who made higher Q than L scores on the ACE Psychological test were somewhat more immature and conventional than women in general (who make higher L than Q scores). However, another study measuring conformity with an Asch type test found a negative correlation between tendency to conform and problem solving ability, when the intelligence factor was statistically partialed out (Nakamura, 1958).

It was found that students who scored higher on the quantitative rather than the verbal part of a scholastic aptitude test were also found to be rated higher on dependence on authority with less extensional reality orientation (Sanders, Heffered, & Brown, 1960). From the same study it was observed that other personality variables such as low dominance and low autonomy were associated with high quantitative ability while need for affiliation was above average for the same group.

Choosing the PMA Number as a variable, Ferguson (Neé Rau) and Maccoby (1966) determined that high ability was associated with a high degree of social interaction with peers. High scorers in Number were also rated by their peers as low in withdrawal, and high scoring girls were judged to also have significantly high scores on the Likeability Scale. In boys, low score was associated with peer ratings of less masculinity and lower agression. Self reports of dependency on adults when sick, alone, or afraid were associated with high number ability also.

Child Rearing Practices

Since there are several studies indicating that personality variables were correlated with mathematical ability (not all were cited above), it would seem logical to turn to child rearing practices to see if here were he common demoninator.

Male college freshman who scored higher on quantitative than on verbal, reported fathers exclusively punished them but that they talked personal problems over with their fathers (Nelsen & Maccoby, 1966). Males who scored higher verbal than quantitative were more often punished exclusively by the mother, often because of father absence. However, Baer and Ragosta (1966) found little relationship between mathematics and child rearing techniques reported by a questionnaire, although there was some relationship with verbal ability.

Other Environmental Influences

The seemingly everlasting appeal of and belief in astrology should tempt scientists to investigate this age old phenomena. If there's truth in astrological forecasting, it should be dealt with scientifically if there is not, it should be exposed and put to rest. Three hundred and thirty-three family members were tested for aptitudes and data concerning their height, weight and date of birth were also obtained (Stafford, 1963). Subjects were classified according to seasons of birth and also according to their zodiac sign. Figure 1 shows that the highest average score for Mental Arithmetic problems was in the sign of Aries although it was not significant (Stafford, 1970). However, Emley (1930) described the child born under Aries as "the reasoning type, thinkers, and philosophers----independent, reserved----natural students, good at intellectual pursuits -----music, art and science." No differences were found for seasons of birth although some investigators have reported such differences in intelligence.

EVIDENCE FOR HEREDITARY INFLUENCES

Linkage or Pleiotropic Effects

While correlations between quantitative reasoning and body types or functions might appear as an arguement for a genetic pre-disposition, they might also arise from other sources. Indeed, linkage of two traits normally would only show a correlation with close relatives, because the crossing over of chromosomes after a few generations would tend to make the variables independent of each other. On the other hand, pleiotropic effects due to many faceted functions of a single gene might be an explanation for such correlations.

There appears to be a small positive, but significant correlation between height and ability to solve mental arithmetic problems for fathers, but not for mothers (Stafford, 1963). Body type correlations are being investigated on this population. Eye color and ability to do mental arithmetic problems also appears to have a small but significant relationship since those with light blue eyes averaged higher than any other color (Stafford, 1970).

..........place Figure 2 about here..........

Arithmetic ability (WAIS subtest) was found to be significantly correlated to preception of the hand and accuracy in drawing it (Hershenson, 1967).

In a study of biochemical correlates of quantitative ability, it was found that students who excelled in Quantitative over Verbal had a higher rate of excretion of urea, norepinephrine, arginine and glutamine but had a lower rate of valine excretion than students scoring higher in V over Q. Another investigator attempted to increase quantitative thinking by administration of Vitamin B_{12} but the results were negative (Steinberg, 1969).

Age Differences

Jones and Conrad (1933) in a cross sectional study of the population of a village observed that problem solving ability as measured by subtests of the Army Alpha declined after age twenty while vocabulary continued to increase throughout life although at a de-accelerating rate. Thurstone (1955) has shown that each of the Primary Mental Abilities have different rates of maturing with Number reaching approximately 87% of its growth by age nineteen. It was observed in family study (Stafford, 1963) that even parents in their thirties showed average scores on Mental Arithmetic Problems below those of their teenage sons and daughters, while their English vocabulary scores exceeded that of their offspring. It would appear that aging operates on quantitative reasoning ability much in the same manner as it does on physiological processes.

Cross Cultural Studies

In analyzing a battery of tests administered to eighth grade school children in Israel from various ethnic groups (Iraq, Persia, Morocco, Yemen, N&S Europe, etc.) Guttman and Guttman (1963) found that intercorrelations between tests ordered according to magnitude revealed patterns forming a Simplex (Guttman, 1955) which was invariant across these ethnic groups, Arithmetic Problems being one of these tests. They cite this invariance as partial proof for a genetic basis to these traits.

Cross cultural studies have been reported by Vandenberg (1968) with Chinese and South American students in which he found a common numerical ability factor. He also cited Irvin's factor analysis of tests administered to students in several African countries, which consistently yielded a number factor.

Comparison of tests score patterns for middle and lower class families of four cultural groups, Chinese, Jewish, Negro, and Puerto Rican showed that Number Facility was relatively similar for both social classes but differed widely across cultural groups (Lesser, Fifer & Clark, 1965).

It would seem from the above studies that there is a definite component involved in mathematics which transcends, nationality, culture or ethnic background.

Family Correlations

One of the first studies reporting family resemblances in school abilities was that by Starch (1915). He correlated siblings' grades and found a Spearman Rho coefficient of .32 for Arithmetic. Another study trying to investigate possibility of hereditary components in family resemblances reported that the Courtis subtest for multiplication had the highest child-mid parent correlation, .55, with the lowest for subtraction, .01 (Cobb, 1917).

Among the tests administered by Willoughby (1927) to parents and their children was the Arithmetic Reasoning Test. The family correlation coefficients are shown in Table 1-A.

Another study undertaken to check for family resemblances in numerical ability was that by Carter (1932) who administered the Courtis Tests in Arithmetic to 108 family members, and correlated them. (see Table 1-A). He also checked correlations between the child and more-alike and less-alike parent, obtaining a correlation of +.64 for the former and -.28 for the latter. He interpreted these latter figures as evidence that only a single gene was involved.

Kostik (1954) hypothesized that sex differences in a study of transfer of learning were due to male superiority in reasoning and abstraction ability. However, this avoids the question of "why?" Earlier, explanations based on sex-role identity, cultural stereotypes and differential learning have been offered. There is still another possibility that might explain sex differences in quantitative reasoning and that is a genetic one.

Male superiority over female in a trait such as quantitative reasoning might lead one to suspect a gene on the X chromosome. If this were the genetic mode we would expect to find a unique ordering of family correlations according to the magnitude of the coefficients (Charles, 1933, Hogben, 1932, Stafford, 1961). From this model we would expect father-daughter and mother-son correlations to be the highest, with mother-daughter next and a zero correlation for father-son. The order of these correlations is shown in Table 1-A with the results of three studies involving arithmetic tests.

The fit to the model is fair for the average of all correlations except for the father-daughter correlation. Nevertheless, the crucial test is the low father-son correlation, because if the trait is on the X chromosome then the father passes it to his daughter and not his son. Garron (1970) has cited various studies showing spatial and numerical defects in Turner girls (those with only one X chromosome) as supporting the above hypothesis.

TABLE 1-A

Expected Family Correlational Patterns

Based on an Assumption of a Sex-Linked Recessive Trait

Compared with Results from Three Studies

Hypothesized Pattern	F-D	≧	M-S	>	M-D	>	F-S	≧	F-M	≧	0
Arithmetic Reasoning[1]	.41		.23		.34		.16		.34		
Courtis Test of Arithmetic[2]	.04		.12		.24		.10		-.04		
Mental Arithmetic Problems[3]	.18		.51		.21		.07		.06		
Average	.22		.30		.27		.11		.12		

[1]Willoughby (1927)

[2]Carter (1932)

[3]Stafford (1963)

Correlational patterns between traits have also been shown to have ordered magnitude patterns indicative of the Simplex (Guttman, 1955) as demonstrated by Guttman (1966) in re-working the correlation data of Stafford (1963). These patterns were invariant across various family members again suggesting some basic component.

Twin Studies

There have been numerous studies of twins specific abilities, most of which are reported in Vandenberg's extensive compilation (1968). Those involving numerical ability, arithmetic achievement, or quantitative reasoning have been summarized in Table 2.

..........place Table 2 about here..........

If we consider that these F ratios represent the ratio of the dizygous within pair variance (which involves differences between twin pairs in environment and error of measurement plus only one half of the possible difference in hereditary make-up to the monozygous within pair variance (which involves only environmental differences and measurement error) it is apparent that the significant tests are very conservative. That is to say, the hereditary aspect of the variance would have to be quite large in proportion to the environmental to become significant. Thirteen of the nineteen F ratio's are significant at least at the .05 level and ten at the .01 or less.

Another type of twin study which adds to our knowledge of the nature-nurture story is: Comparing twins raised together with twins raised apart (Burt, 1958). Identical (MZ) twins reared apart correlated .723 for arithmetic scores while unrelated children reared together correlated .476 (see Table 2-A).

Table 2-A

Correlations Between Various Sibling Combinations
On
Arithmetic Ability

Identical twins reared together	Identical twins reared apart	Non-Identical twins reared together	Siblings reared together	Siblings reared apart	Unrelated children reared together
.862	.723	.748	.769	.563	.476

(from Burt, 1958)

A word of caution about twin studies, it must be kept in mind that twins generally have lower scores than singletons including quantitative reasoning (Koch, 1966). However it would seem from these twin studies that a hereditary component is definitely present although it must be kept in mind that this conclusion does not eliminate environmental influences as evidenced by the correlation of .476 between unrelated children reared together.

The Present Study*

A revised test of quantitative reasoning, Mental Arithmetic Problems, Form AA, (Stafford, 1965) was administered to 300 pairs of twins, 50 male monozygous (MZ), 69 female monozygous (MZ), 25 male dizygous (DZ), 56 female dizygous (DZ), and 100 hetero-dizygous (HZ) (male-female) pairs, ages 12 to 18.

The test consists of 26 arithmetic problems such as "how many pencils can you buy for 60 cents if they are 2 for 5 cents?" Eight multiple choice answers are provided in addition to the option of not answering. The test has a time limit of 15 minutes, the total score being the number of correct answers with no correction for quessing.

Means and standard deviations of the raw scores were plotted by sex and by age (see Table 3). Since age differences were found the raw scores were transformed to standard scores with an arbitrary mean of 50 and a standard deviation of 15. However, no attempt was made to partial out the sex differences.

The analysis of the data included within and between pair variance from which the Intraclass R's were computed for each sex and zygosity group. Table 4 shows the N, Intraclass R, the within pair variance (S^2w).

In addition, the within family and population estimates of heritability and their significance were determined for each sex separately and are also shown in Table 4. Comparable F ratios (within family) to those in Table 2 are 1.31 (n.s.) for females and 2.79 ($p < .01$) for males. The estimate of the heritability of the trait in the population is obtained by formula (1).

(1) $$\frac{2\,V_{DZ} - 2\,V_{MZ}}{2\,V_{DZ} - V_{MZ}} = H_p \text{ (heritability in population)}$$

Where: V_{DZ} = within pair variance due to 1/2 the hereditary differences plus the environmental differences between twins.

V_{MZ} = within pair variance due to environmental differences between twins.

The corresponding F ratios of these population heritability estimates are given by formula (2)

(2) $$\frac{2\,V_{DZ} - V_{MZ}}{V_{MZ}}$$

*The data were collected as part of the Louisville Twin Study, Dr. Steven G. Vandenberg, Principal Investigator, NIH Grant 00843

Another word of caution. Estimates of heritability are particularly susceptable to mis-and over interpret. They are sensitive to the degree of homogamy or assortative mating, the phenotypic frequency of the trait, reliability of measurement (Stafford, 1969), and interaction effects with environment! (Stafford, 1970). Therefore, as an indicator of the relative degree to which a trait's variation results from a genetic component such an estimate is helpful but it should not be taken literally as "78% of the variability of the trait is due to heredity." This might be true for a given test used to measure given variables at a given time for a given population, but in light of the above confounding factors one should take a dim view of such facile interpretation.

Next, a new technique called "dichtomic analysis" was applied to the twin data, to determine if there was any evidence for an underlying biomodately in the continuous distribution of scores. If the trait were due to a pair of allelic genes, one might expect to find two distinct groups, those "having" the trait and those "lacking" the trait (Stafford, 1959, 1965,1967). The first step in dichotomic analysis is to plot each pair of monozygous twins scores and connect them with a line in a univariate distribution (see figure 3). Next, each line is counted in between scores and a histogram is drawn of these frequencies.

..........place Figure 3 about here..........

It would appear that there are two normal curves suggesting a possible biomodality with the antimode at about a score of 55 for the males but this bimodality is not as clear for females. Combining the male and female histograms also shows an antimode around 55. To check the position of the antimode another technique,"averaged monozygotic scores", (Stafford, 1966, 1967) was tried. The average score for each monozygous pair was plotted and again the distribution showed a bimodality for both males and females. This time it appeared to be at a score of 53. From the result of the first step of dichotomic analysis and the averaged monozygotic scores, it was decided to call a score of 54.5 as the dividing line between "having" a proficiency in quantitative reasoning and "lacking" a proficiency in it. Then all females (MZ,DZ, and HZ) were plotted in a univariate distribution and likewise all the males (MZ,DZ,HZ). The number of each that were above or below the antimode are shown in Table 5. Taking into consideration the sex difference and the family correlation model (Stafford, 1963), it was hypothesized that the having a proficiency in quantative reasoning was due to the presence of a sex-linked recessive gene. The frequency of this gene can be estimated directly from the observed frequency of the phenotype in males. Accordingly, the percentage of males above the antimode was calculated (107 out of a total of 250) giving a frequency of .43. For women the gene frequency is the square root of the frequency observed, which was found to be .58. This is a large difference in frequency estimates of the same gene and no explanation readily comes to mind.

It was decided that in spite of the discrepencies in gene frequency estimates to continue the dichotomic analysis. Using the estimate of the recessive gene frequency based on the males, (q = .43)* probabilities were calculated for DZ males, DZ females and HZ twins predicting the frequency that both twins would have the trait, both would lack it, and one would have it-one would lack it.

Then, bivariate distributions were made plotting one twin on the ordinate and the other on the abscissa for DZ male, DZ female and HZ male-female twins. These bivariate distributions were then quartered at the score of 54.5, the estimated antimode of the MZ distributions.

The resulting frequencies actually observed for the four cells of each of the three bivariate distributions were matched with the theoretically expected frequencies and tested by Chi Square for goodness-of-fit. The results are given in Table 6. The fit is fairly good for DZ males and not too bad for HZ twins, but somewhat off for DZ girls. This is probably due to the fact that we used the gene frequency estimates based on the male population rather than that of the females. Nevertheless, if you consider the ranked magnitudes of the expected and the observed frequencies one cannot help but be impressed by the similarity.

In conclusion, we would say that there is an underlying hereditary component for a proficiency in quantitative reasoning which fits the sex-linked recessive model fairly well. This "have" or "lack" quality results in two normal curves one below and one above 54.5. Whether an individual placed in the top curve or the bottom curve would depend upon his genetic composition but where he placed within a curve would depend upon the effect of the host of environmental components discussed earlier in this paper.

I wish to acknoledge the assistance of Margaret Gunderson in both the library research and the calculations.

*Working independently, Dr. Foster Brown (SUNY at Oneonta) fitted the actual data to various genetic models of sibling relationships and based an interative solution of simultaneous equations derived a gene frequency value of .447.

TABLE 1

Summary of Scores on ACE for length of Father Absence in years

	Father Present	1-5	6-10	11+	Father Absent
ACE Median Scores	78.00	62.00	58.00	51.00	43.00

NOTE: N=20 females per category

(After Landy, Rosenberg and Sutton-Smith, 1969)

TABLE 3

Means and Standard Deviations for Raw Scores on Mental

Arithmetic Problems for all Twins taken as Individuals

	Males			Females		
Age	N	M	SD	N	M	SD
12	29	5.62	3.46	40	5.45	3.02
13	56	6.51	3.[illegible]7	53	6.42	3.24
14	68	7.62	4.43	74	7.08	3.76
15	55	8.67	5.59	67	7.09	3.92
16	57	10.05	4.47	76	8.70	4.28
17	33	9.55	5.13	60	8.08	3.93
18	12	10.92	3.04	20	8.65	3.90

TABLE 4

Intraclass R's and Within Pair Variances of Mental Arithmetic

Problems Scores for MZ and DZ Twins with Significance of Heritability

	N	R	S^2_w	H_p*	F**
MZ Females	69	.66	70.05		
DZ Females	56	.51	91.79	.28	1.62
MZ Males	50	.81	58.85	.78	4.57
DZ Males	25	.52	164.02		

* H = an estimation of the heritability of the trait in a population as a whole and is calculated as the ratio of the variance attributed to heredity against the total variance (see text for explanation).

** F = ratio of the variance attributed to heredity and environment against variance attributed to environment alone (see text for explanation)

TABLE 5

Frequencies of Individuals Scoring Above and Below the Antimode in the Averaged Monozygous Score Distribution and the Dichotomic Analysis

	Below Antimode		Above Antimode	
	Female	Male	Female	Male
MZ	85	54	53	46
DZ	78	34	34	16
HZ	70	55	30	45
Total	233	143	117	107

Total Female = 350
Total Male = 250

TABLE 6

Theoretical Expected and Actual Observed Frequencies of DZ and HZ Pairs of Twins: Both Having (+,+), One Having-One Lacking (+,-), and Both Lacking (-,-), Quantitative Reasoning

DIZYGOUS TWINS

(Males)

males		-	+
	Exp.	3.1	7.7
	Obs.	2 (4)	4
	Exp.	11.2	3.1
	Obs.	13	6 (4)

N = 25 prs.
Chi Sq. = 2.85 (3df)
$p > .40$

(Females)

females	-	+
Exp.	3.0	7.4
Obs.	11 (9)	8
Exp.	42.7	3.0
Obs.	30	7 (9)

N = 56 prs.
Chi Sq. = 28.27 (3df)
$p < .001$

(Females)

males	-	+
Exp.	29.8	13.2
Obs.	23	22
Exp.	51.8	5.3
Obs.	47	8

N = 100 prs.
Chi Sq. = 9.24 (3df)
$p < .05$

TABLE 2

F Ratios of Dizygous/Monozygous Twins Within-Pair Variance

for Various Numerical and Quantitative Resoning Tests

	F Ratio
Number Series (Wictorin 1952)'	2.01**
Number Analysis (Wictorin 1952)'	1.63**
Numerical Classification (Wictorin 1952)'	1.57**
Verbal Arith. Problems (Wictorin 1952)'	2.18**
Number Series (Husen 1953)'	1.54*
Number (PMA)	
Blewett (1954)	1.07
Thurston (1955)	1.52
Vandenberg (1962)	2.58**
Vandenberg (1964)	2.26**
Numerical Ability (DAT)	
Vandenberg (1961)'	1.39
Vandenberg (1965)'	1.37
Arithmetic (WISC)	
Vandenberg & McGinty (1964)	1.71
Arithmetic (WAIS)	
Block, (1968)	2.78***
Number Ability (Pacific Multifactor)	
Vandenberg, Stafford, & Brown (1968)	1.99*
Find the Longest Number	
Bruun, et al (1966)'	1.92
Simple Arithmetic Total	
Osborne, Gregor, & Miele (1967)	3.05**
Mathematics Achievement	
Arithmetic (Husen 1953)'	3.13*
Arithmetic Test (Husen 1963)	3.58***
Mathematics Usage (NMSC, Nichols 1965)	2.22**

Significance * = .05, ** = .01, *** = .001

' See Vandenberg (1968)

Fig. 1. Mean scores on the Mental Arithmetic Problems of quantitative reasoning by eye color. ($F = 2.221$, $p < .05$)

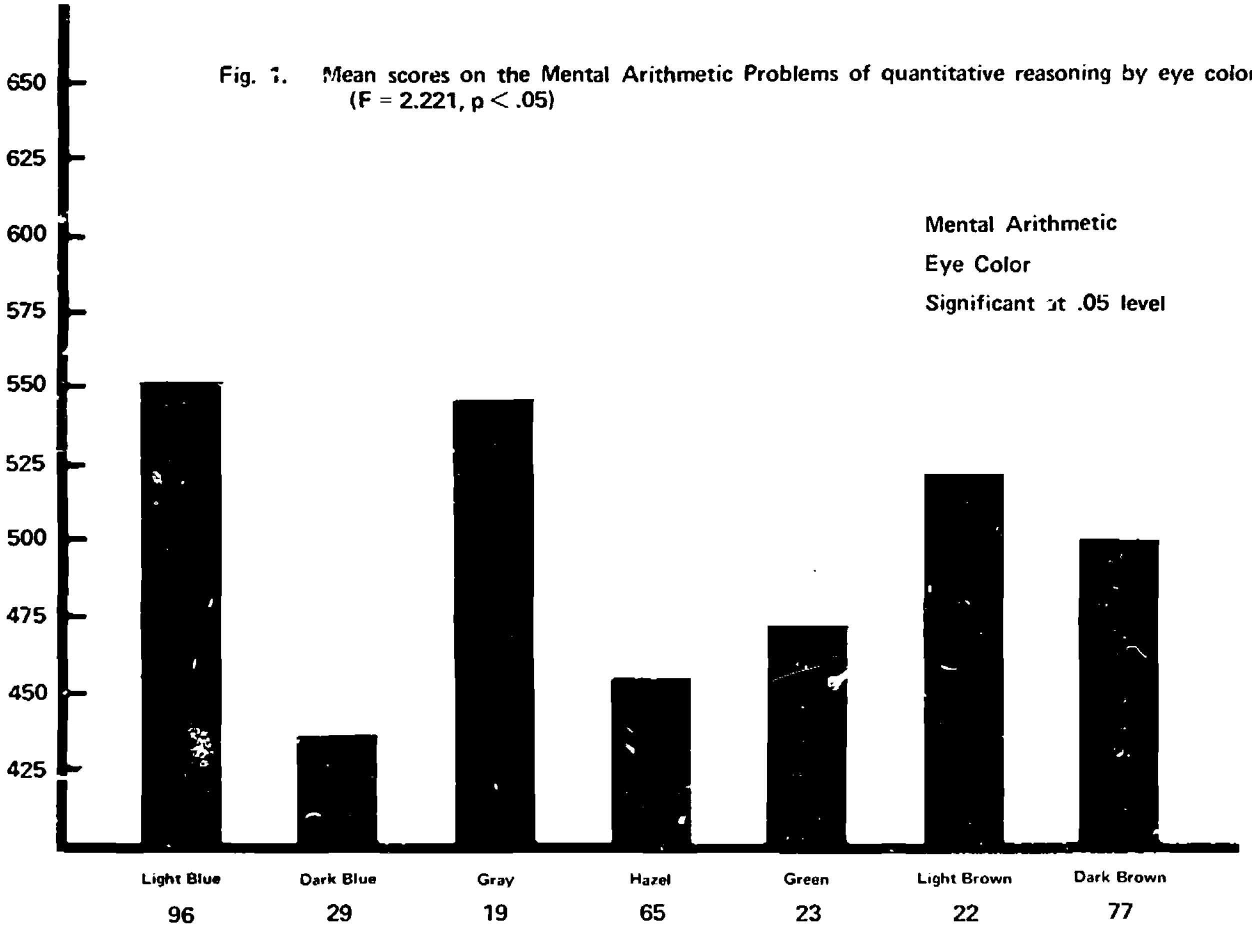


Fig. 2 Mean scores on the Mental Arithmetic of quantitative reasoning by zodiac sign.
(p = n.s.)

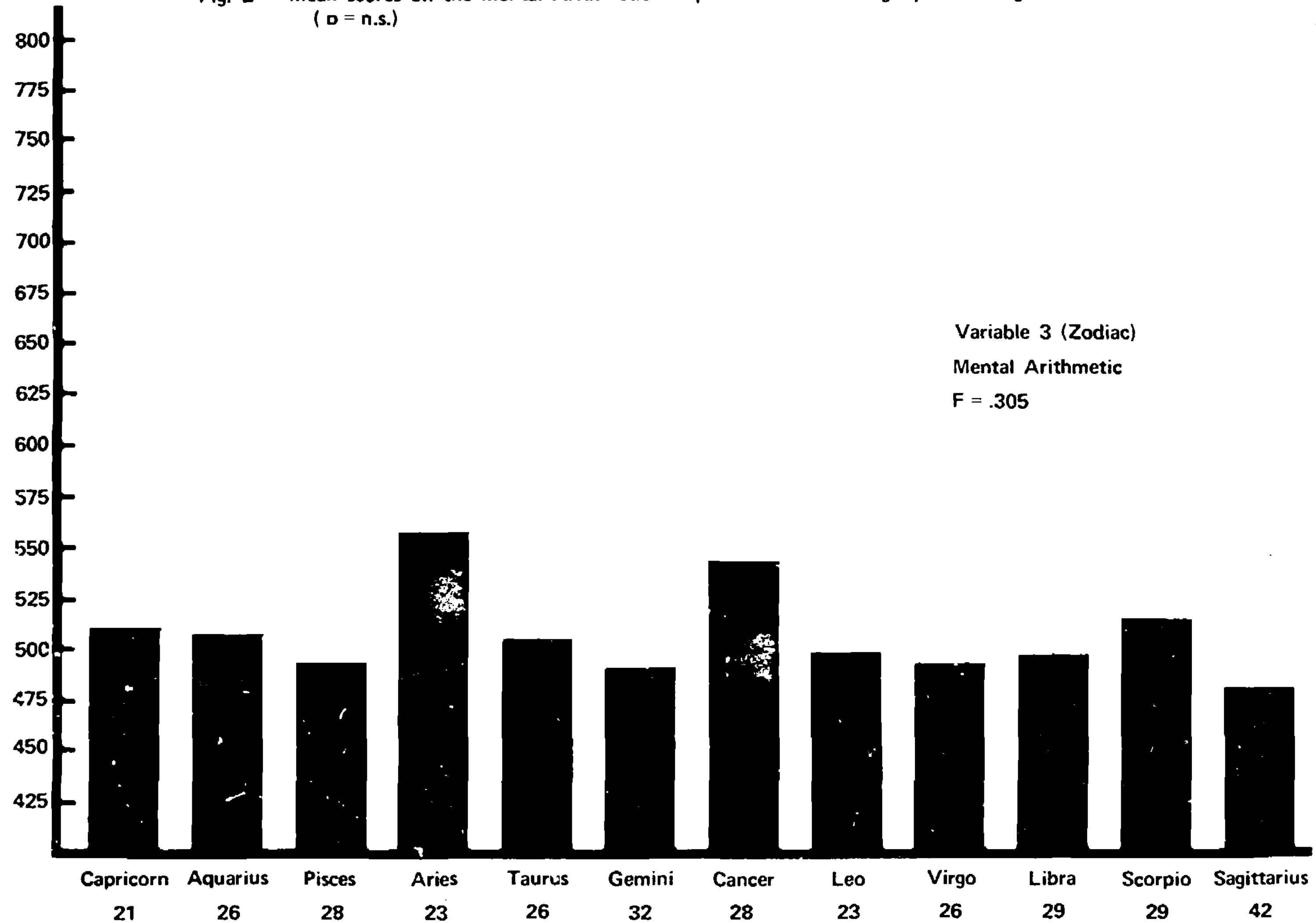


Fig. 3 Illustration of a bimodality revealed by the first step of dichotomic analysis on 50 pair of male monozygous twin scores on the *Mental Arithmetic Problems.*

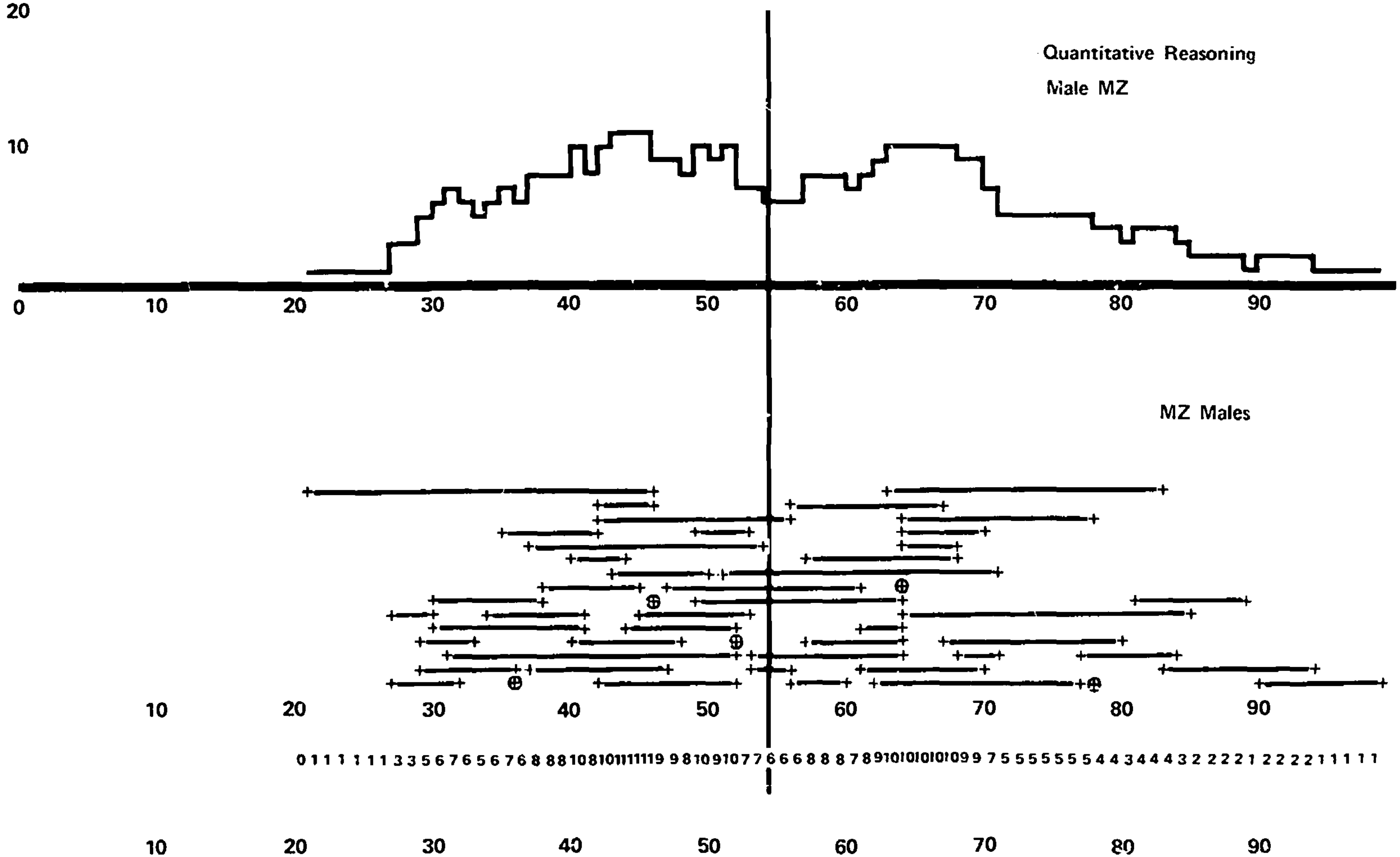
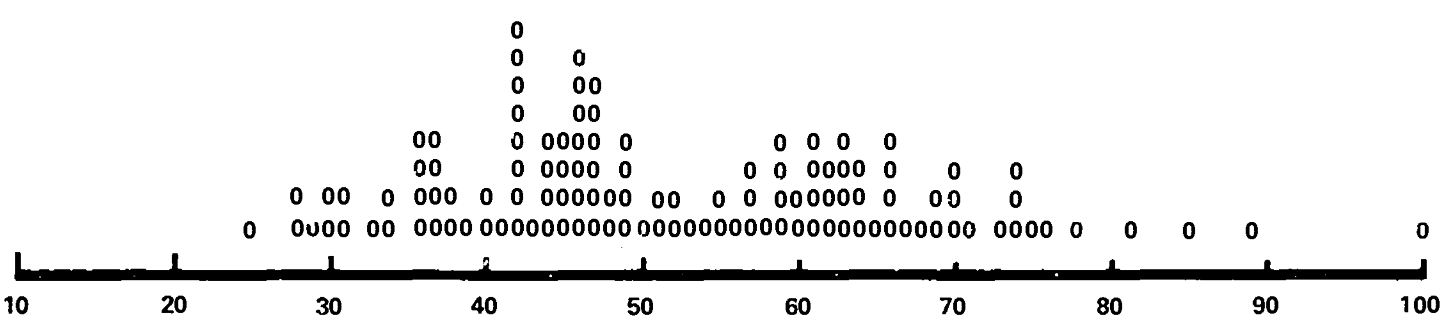


Fig. 4 Distribution of "Averaged Monozygotic Scores" on the Mental Arithmetic Problems for 50 pairs of male and 69 pairs of female monozygous twins.

Combined Male and Female

N = 119



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