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A Test of a Primary Bias in Twin Studies with Respect to Measured Ability

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It has been suggested that the twin method for investigating hereditary and environmental sources of variation in measured traits is biased by the unique prenatal environments of identical twins. MZ twins derived from eggs which split into two individuals early in their prenatal development, indicated by concordant handedness within sets, most likely developed with separate placentas, chorions, and amnions. Later-splitting eggs, indicated by discordant handedness within MZ pairs, more likely produced twins who shared the same placenta, chorion, and amnion, and experienced more severe prenatal competition. Greater prenatal competition was hypothesized to produce greater twin differences in measured ability. A group of 482 sets of MZ twins who took the National Merit Scholarship Qualifying Test in 1962 were used to test this hypothesis. No difference between handedness groups on the set of NMSQT scales was found, indicating that the unique prenatal environment of MZ twins does not appreciably bias heritability estimates of ability.

KEY WORDS: twins; prenatal development; ability; handedness; concordance; heritability.

INTRODUCTION

Perhaps the most popular research design employed in studies of the effects of heredity and environment on human trait variation has been the study of twins raised together. The reasoning behind the twin design is a simple one. Identical (MZ) twins are exact genetic copies of one another, and all dif-

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ferences between twins of a set are due to environmental influences. Identical twins are compared to fraternal twins (DZ), who are genetically no more alike than ordinary siblings but are of the same age. Any greater similarity between sets of identical twins over fraternal twins is assumed to be due to genetic influences.

One possible source of inaccuracy in the twin method has been discussed rarely by those who conduct psychological studies of twin populations. Price (1950) has named these "primary biases," and they involve the effects of the unique prenatal environment of MZ twins. While identical twins share the same prenatal environment in the sense that they share the same mother at the same time, Price proposed that the prenatal effects of being an MZ twin may actually produce more differences than similarities within MZ sets. If these prenatal differences make MZ twins less alike than DZ twins, heritability estimates based on the comparison of the two types of twins may be spuriously low.

Identical twins are formed by the splitting of one fertilized egg into two individuals early in the development of the twins. The time of this splitting is crucial, as it determines the nature of the prenatal environment in which the two individuals will develop. If the egg splits in two very early in the development of the twins, before the egg is implanted in the uterine lining, the twins will most likely develop with separate placentas, separate chorions (outer bags), and separate amnions (inner bags). Most fraternal twins develop with all three of these structures separate. Later-splitting MZ twins may share the same placenta, and may or may not share the same chorion, but will have separate amnions. Identical twins who split very late in their development, the extreme case being cojoined twins, will share the same placenta, chorion, and amnion (Scheinfeld, 1967; Strong and Corney, 1967; Stern, 1960; Rausen *et al.*, 1965).

Mutual circulation, resulting from the sharing of one placenta, may have an extreme effect on the later development of the twins. Price (1950) notes: "An even balance in the circulation between the twins is rarely maintained, imbalance is apparently the typical condition. . . . As a result, the development of either or both fetuses may be modified at any stage of gestation after the first or second month, and although the surviving twins in fact recover from the condition to a large extent, it seems very probable that some of these effects are lasting" (p. 305). He further suggests that the effect of mutual circulation may result in differences between the twins in size, susceptibility to disease, physical deformity, heart defects, and pre- and postnatal mortality. Price (1950) also suggests that some twin differences in achievement may be caused by this condition. Evidence of extreme physical differences due to mutual circulation between twins has been clearly demonstrated in the literature (Falker *et al.*, 1962; Corney and Aherne, 1965; Rausen *et al.*, 1965).

Some psychological studies support Price's hypothesis. Churchill (1965) studied twins who were referred to a psychological clinic for poor school performance. Of the 22 sets of identical twins tested, hospital records indicated that 13 sets were monochorionic. Comparison of birth weights of twins within each set showed that the heavier twin had a significantly higher full-scale IQ than did the twin who was lighter at birth. In this highly select group, it seems as if severe prenatal competition may have contributed to the intellectual deficiency of one twin later in life. Willerman and Churchill (1967) later expanded this sample to include 14 twin sets obtained from a twin mothers' club. Combining this group with the 13 sets previously sampled, the relationship between birth weight and intelligence again held, the heavier twin scoring higher on the intelligence test.

Babson *et al.* (1964) also investigated the relationship between birth weight and intelligence in twins. They collected a sample of nine sets of MZ twins where one twin was at least 25% smaller than his cotwin. Again the heavier twin had a statistically significant advantage on a series of ability measures.

The unselected population studied by Record *et al.* (1970), however, consisted of all live births in Birmingham, England, between 1950 and 1954. In this sample of 1242 twin sets, they found that twins with small or moderate birth weight differences did not differ greatly in their verbal reasoning score. Only those cases with extreme weight differences (2–3 kg) at birth showed an appreciable difference in scores. While these investigators did not have zygosity diagnosis of the twins, they compared like-sex to unlike-sex twins and found that birth weight differences between these two groups were trivial.

Scarr (1966) studied a volunteer sample of 24 sets of identical twin girls whom she found to be representative of twins in the Boston area. She found that birth weight did not correlate above 0.20 with any other variable in her study, which included measures of activity and motivation.

It appears that studies of twins selected for extreme differences in birth weight or intellectual capacity are more likely to have suffered severe prenatal competition. The fact that over 50% of Churchill's (1965) twins were known to be monochorionic further supports the hypothesis that prenatal competition due to common chorions affects intellectual performance later in life. However, in the unselected sample of Record *et al.* (1970) or in the reportedly representative sample of Scarr (1966) the effects of prenatal competition reflected by differences in birth weight do not show significant relationships to later development in the majority of cases.

Therefore, in larger twin studies where twins are not selected for extreme differences in birth weight or intelligence, the bias suggested by Price (1950) does not seem to be generally supported.

Determination of the actual time of the splitting and the resulting nature of the prenatal environment is difficult, even if the placentas or chorions can be observed and counted at the time of birth. However, an indication of the time of splitting can perhaps be observed any time after birth. If the splitting took place late in the developmental sequence, after the time lateral dominance is established, the twins will be mirror images of one another, having birthmarks on opposite sides of their bodies, for instance, and mirror images of crooked teeth. These twins will show opposite direction of hair swirl and will be discordant for handedness. Cojoined twins are always mirror images of one another (Newman, 1940). If the splitting is early, before laterality is established, the twins will not be mirror images of one another and will be concordant for handedness. Corner (1955) presents an embryological explanation for this phenomenon: "The degree of resemblance between one-egg twins may depend, in part at least, upon the amount of cellular differentiation that has taken place before twinning begins. By the time when the primitive streak forms, the right- and left-sidedness of the germ disc is fixed, and one embryo of a twin pair arising at this stage may get more, the other less of the right-sided material." (Corner, 1955, p. 946).

THE PRESENT STUDY

The subjects for the present study are selected from a larger sample of high school junior twins surveyed in 1962 by Robert C. Nichols in collaboration with the National Merit Scholarship Corporation. The zygosity of the twins was determined by a zygosity questionnaire validated by Nichols and Bilbro (1965). A large amount of questionnaire information was collected from this twin sample; only the NMSQT scores and the twins' indication of their handedness have been chosen for this analysis. The present study is based on 365 sets of identical twins concordant for handedness and 117 sets discordant for handedness.

While handedness is a crude indication of the time of the splitting of one egg into two separate twins, it is the only indicator easily available from data collected after birth by means of a questionnaire. Twins concordant for handedness are more likely to have developed with separate placentas, chorions, and amnions. Twins discordant for handedness, an indication of later splitting, have a higher probability of sharing the same placenta, and perhaps the same chorion and amnion. To the degree that mutual circulation adversely affected one twin, and to the degree that such

Table I. Means and Standard Deviations of Average Twin Pair Subtest Scores by Handedness Group

Test	Concordant (N = 365)		Discordant (N = 117)	
	Mean	S.D.	Mean	S.D.
English usage	19.44	4.54	19.66	4.04
Math usage	21.07	5.92	20.69	5.61
Social studies reading	20.66	4.77	20.56	4.07
Natural science reading	19.94	5.37	19.35	5.20
Word usage	20.93	4.90	21.07	4.37
Selection score	102.04	22.25	101.35	19.35

prenatal effects influence the later development of general and specific ability, we would expect discordant twins to show larger differences in measured ability than do twins concordant for handedness.

The National Merit Scholarship Qualifying Test yields scores on five subtests, and the sum of these scores constitutes a selection score. On the average, National Merit participants' scores on each of the five subtests (English Usage, Math Usage, Social Studies Reading, Natural Science Reading, and Word Usage) would have a mean of 20 and a standard deviation of 5. These parameters vary slightly from year to year, however. Means and standard deviations of average twin set scores within concordant and discordant handedness groups are presented in Table I. While each of these tests was constructed to measure a different aspect of school abilities, the within-group correlations of the average twin set scores yield correlations between 0.60 and 0.81. This indicates that these five measures have a strong common core and that they form a meaningful set for

Table II. Correlations Among Average Twin Pair Subtest Scores (N = 482)

	English usage	Math usage	Social studies	Natural science	Word usage	Selection score
English usage	1.00					
Math usage	0.59	1.00				
Social studies	0.70	0.69	1.00			
Natural science	0.65	0.74	0.75	1.00		
Word usage	0.71	0.59	0.82	0.62	1.00	
Selection score	0.83	0.85	0.91	0.88	0.85	1.00

Table III. Means and Standard Deviations of Within Twin Pair Difference Scores by Handedness

Test	Concordant (N = 365)		Discordant (N = 117)	
	Mean	S.D.	Mean	S.D.
English usage	2.64	2.18	2.38	1.84
Math usage	3.43	2.85	3.34	2.99
Social studies reading	2.69	2.16	2.49	1.89
Natural science reading	3.24	2.80	4.08	3.62
Word usage	2.03	1.76	1.88	1.50
Selection score	8.62	6.17	8.79	6.51

multivariate analysis. The correlation of average twin set scores is presented in Table II.

EXPLAINING MZ TWIN DIFFERENCES

It has been hypothesized that twins who are discordant for handedness, representing later-splitting sets, will show larger within-set differences on the group of ability measures than twins concordant for handedness, the group assumed to be earlier-splitting sets. A one-way, two-group multivariate analysis of variance was employed to test this hypothesis. The five dependent variables used in this analysis are the absolute values of the within-set difference scores on the five NMSQT scales. The means and standard deviations for each group on these five dependent variables are shown in Table III.

The multivariate test of equality of mean vectors yielded an F ratio of 1.908, evaluated with 5 and 476 degrees of freedom. This was not significant at the 0.01 level. Inspection of the univariate F statistics indicated that there were no significant differences on the within-set difference scores on English Usage, Math Usage, Social Studies Reading, or Word Usage. However, the univariate F statistic for the difference between handedness groups on the within-set difference score on Natural Science Reading yielded an F of 6.849, evaluated with 1 and 480 degrees of freedom, which is significant at the 0.01 level.

Inspection of the means on the Science difference score indicated that twins discordant for handedness were 0.84 point higher than twins concordant for handedness. The standard deviation of the discordant group was 0.82 point greater. To obtain a better understanding of this group mean difference, the difference scores on Natural Science Reading were plotted separately for the two handedness groups, and are shown in Fig. 1.

Those subjects at the higher end of these distributions are of particular interest, since these scores represent twin sets with the greatest within-pair difference. The profiles of all NMSQT scores for each twin within a set showing 10 or more points difference on the Natural Science Reading score were inspected to see whether the brighter student had a general advantage in other abilities.

In the concordant group, 14 subjects (3.8%) had difference scores of 10 or greater, a difference which represents a separation of about 2 standard deviations on the original score. Eleven (9.4%) pairs had large differences within the discordant group. Inspection of these profiles within each set did not indicate any persistent pattern of general superiority of one twin over his cotwin. The higher-scoring twin in all cases had a higher selection score, but did not necessarily excel over his cotwin on all subscales.

The hypothesis that twins who are discordant for handedness are no different in all overall ability than those concordant for handedness was not rejected. While there were significant group differences on the Natural Science Reading difference score, the lack of a consistent general advantage of the high-scoring twin over his cotwin indicated that some explanation other than possible prenatal competition accounts for this difference.

Three alternative explanations might be proposed to account for the

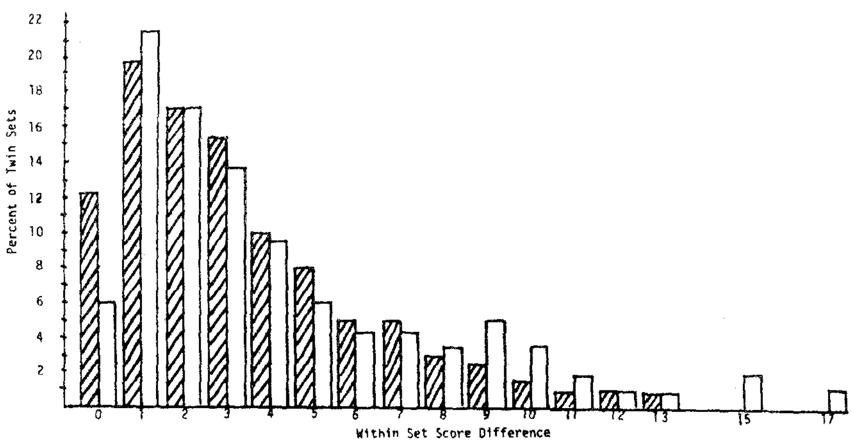

Fig. 1. Within twin set score differences on Natural Science Reading. Shaded bars represent percent of sets concordant for handedness (N = 365). Unshaded bars represent percent of sets discordant for handedness (N = 117).

lack of group differences on ability. First, handedness may not be an accurate enough indicator of the time of splitting of the one zygote into two individuals. An alternative explanation, however, is that imbalance and competition within the uterus of the mother pregnant with twins do not significantly alter the later development of general ability in the twins. The third explanation, which seems most likely, is that twin sets in the population who have severe differences due to prenatal competition may not be included in this sample. Many circumstances may have caused their exclusion. Twin sets with the greatest prenatal imbalance may not be able to be studied since the severely disadvantaged twin may have died before birth or shortly thereafter. Surviving twin sets with the greatest differences, such that only one twin might be attending a special school, might be in a different grade than his cotwin, or might not plan to go to college and therefore would not have taken the NMSQT, are not included in this sample due to the sampling procedure.

CONCLUSIONS

While discordance or concordance for handedness is a crude estimator of the time of splitting of one fertilized egg into two identical twins, it is one of the few indicators readily observable after birth. Since there were no significant differences between MZ sets concordant for handedness as compared to MZ twins discordant for handedness, it can be concluded that heritability estimates of ability based on the comparison of MZ to DZ twin sets selected from school populations are not appreciably biased by the differential prenatal environments of the identical twin sets.

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