THE JOURNAL OF
EDUCATIONAL PSYCHOLOGY

Volume XX April, 1929 Number 4

# THE RELATIVE EFFECT OF NATURE AND NURTURE INFLUENCES ON TWIN DIFFERENCES

KARL J. HOLZINGER

University of Chicago

## THE DATA

The data employed in this study consist of a portion of the material gathered for an extensive investigation of identical and fraternal twins. The measurements were made by Professor H. H. Newman (Department of Zoology), Professer F. N. Freeman, Mrs. Bryan Mitchell, and the writer, all of the University of Chicago. A number of articles and monographs based on these data are now in preparation.

Identical (monozygotic) twins are those resulting from the fertilization of one egg by a single sperm and from such origin may be considered as having the same heredity. Fraternal (dizygotic) twins are those from two ova fertilized by separate sperms—the embryos developing side by side, each with its own placenta and chorin. For the latter type of twins the heredities will be different. Professor Newman, who is an eminent authority on the biology of twinning, was chiefly interested in the separation of twins into these two classes. A large number of criteria were used by him in classifying twins according to these two types, a full report of which will appear later. The final number of identical twin pairs secured was fifty, while the number of fraternal (like-sexed) twin pairs obtained was fifty-two. These numbers, of course, do not correspond to the proportions of the two types in the general population, but the data were increased to get samples of comparable size.

The tests made consisted of a large number of physical and mental measurements, palm prints, records of physical likeness and peculiarities, scholastic standing, and considerable data on interests in social and mental activities. The chief measurements used in the present

TABLE I.—SUMMARY OF CERTAIN CONSTANTS

| Constant | Identical, 50 pairs | Fraternal, 52 pairs | Difference |
|---|---|---|---|
| Mean age | 13 yr., 4.1 mo. | 13 yr., 5.4 mo. | −1.3 ± 3.3 |
| SD age | 34.9 mo. | 34.0 mo. | .9 ± 2.3 |
| Mean school grade | 7.9 | 7 9 | 0.0 |
| Mean finger ridges (both) | 83.2 | 74 0 | 9.2 ± 2.4 |
| Mean cephalic index | .795 | .800 | − .005 ± .004 |
| Mean standing height | 151 6 cm. | 152 1 cm. | − .5 ± 1.4 |
| Mean weight | 97 9 lb. | 98.6 lb. | − .7 ± 2.6 |
| Mean Binet IQ | 101.6 | 96.1 | 5 5 ± 1.6 |
| SD Binet IQ | 17.3 | 15.7 | 1.6 ± 1.1 |
| Mean Otis IQ | 103 7 | 99 0 | 4.7 ± 1.5 |
| Mean EA | 13 yr., 4 4 mo. | 13 yr., 2 0 mo. | 2.4 ± 3 0 |
| Mean motor | 308.1 | 307.2 | .9 ± 4.5 |
| Mean Woodworth-Mathews | 14 7 | 14.9 | − .2 ± .8 |

TABLE II.—CORRELATIONS (AGE CONSTANT)

| Variable | Identical $N = 50$ (pairs) | Fraternal $N = 52$ (pairs) |
|---|---|---|
| Standing height[1] | 93 ± .01 | .65 ± .05 |
| Sitting height | .88 ± .02 | .50 ± .07 |
| Weight | .92 ± .01 | .63 ± .06 |
| Head length | .91 ± .02 | .58 ± .06 |
| Head width | .89 ± .02 | .54 ± .07 |
| Cephalic index[1] | 89 ± .02 | .58 ± .06 |
| Finger ridges (both)[1] | .97 ± .01 | .46 ± .08 |
| Binet MA[1] | 86 ± .02 | .60 ± .06 |
| Binet IQ | .88 ± .02 | .63 ± .06 |
| Otis score | .90 ± 02 | .57 ± .06 |
| Otis IQ | .92 ± .01 | .62 ± .06 |
| Word meaning | .86 ± .02 | .56 ± .06 |
| Arithmetic | .73 ± .04 | 69 ± .05 |
| Nature study | .77 ± .04 | .65 ± .05 |
| History and literature | .82 ± .03 | .67 ± .05 |
| Spelling | .87 ± .02 | .73 ± 04 |
| All, EA[1] | .89 ± .02 | .70 ± .05 |
| Woodworth-Mathews[1] | .56 ± .07 | .37 ± .08 |
| Downey judgment | .31 ± .08 | .37 ± .08 |
| Downey motor index | .51 ± .07 | .53 ± .07 |
| Downey coordinated impression | .48 ± .07 | .51 ± .07 |
| Tapping total[1] | .69 ± 05 | .38 ± .08 |

[1] Values are variables studied in detail later.

study are indicated in Table I and II. These include (1) total number of finger ridges (from the tri-radius) on both hands, (2) cephalic index, (3) standing height, (4) mental age on the Stanford-Binet individual test, (5) educational age on the Stanford Achievement Tests, (6) motor test giving rates of tapping with finger and wrist (results from both hands combined), and (7) the Woodworth-Mathews Questionnaire which is a measure of emotional stability.

## General Characteristics of the Two Groups

The identical and fraternal groups appear to be very much alike in certain general characteristics indicated in Table I. The agreement in mean age, mean grade, mean height and weight is remarkable. From the differences and their probable errors given in the last column it is apparent that the intelligence and total number of finger ridges of the mean values for the identical group are significantly larger than those for the fraternal group. Professor Terman found for 905 "unselected" children that the mean IQ was 101.5 ± 0.3 with a standard deviation of 13.0 ± 0.2. If the corresponding constants for the identical twins be compared with these values we find

$$\text{Identical mean IQ} - \text{Terman mean IQ} = 0.1 \pm 1.2$$
$$\text{Identical SD} - \text{Terman SD} = 4.3 \pm 0.9$$

We may therefore conclude that identical twins here studied have the same average intelligence as unselected children, but are somewhat more variable.

The correlations in Table II give evidence of the closer genetic relationship of identical as compared with fraternal twins. The typical correlation (holding age constant by the usual formula) is about .90 while the average correlation for fraternal twins is approximately .60. Some of the coefficients are smaller than these values partly on account of the unreliability of certain of the tests. For the more reliable of the mental tests such as Binet and the Stanford Achievement Test, the correlations are approximately equal to those found in the case of physical traits such as height and weight.

## The Relative Importance of Nature and Nurture in Determining Mean Differences

The chief purpose of this paper is to present certain formulas for the study of the relative effect of nature and nurture upon twin differences. These formulas will then be applied to the twin data and the relative importance of the two factors determined for certain physical and mental traits.

It is first assumed the heredity of the twins classified as *identical* is sufficiently similar so that a difference between a pair of twins in a certain trait may be thought of as almost entirely due to nurture designated as $B$. A difference between pair of fraternal twins for this trait is considered as a linear function of $B$ and of a nature factor $A$. Identical and fraternal twin differences may then be set down as follows:

| Identical | Fraternal |
| --- | --- |
| ${}_iX = {}_iA + {}_iB + {}_iE$ | ${}_fX = {}_fA + {}_fB + {}_fE$ |
| ${}_iX' = {}_iA + {}_iB' + {}_iE'$ | ${}_fX' = {}_fA' + {}_fB' + {}_fE'$ |
| ${}_iD = {}_iB' - {}_iB = {}_iD_b$ | ${}_fD = {}_fD_a + {}_fD_b$ |

The front subscripts $i$ and $f$ refer to identical and fraternal twins. Primes are used to distinguish members of a pair, $E$ is an accidental error (to be subsequently ignored). $D$ is difference in the trait. $D_a$ is a difference due to nature and $D_b$ is a difference due to nurture.

The first formula may then be written

$$T = \frac{{}_f\bar{\bar{D}} - {}_i\bar{\bar{D}}}{{}_iD} = \frac{{}_f\bar{D}_a + {}_f\bar{D}_b - {}_iD_b}{{}_i\bar{D}_b} = \frac{{}_f\bar{\bar{D}}_a}{{}_fD_b} \tag{1}$$

where $\bar{\bar{D}}$ is the mean absolute difference, $X - X'$. It has been assumed that the mean nurture difference $\bar{D}_b$ is the same for identical and fraternal twins. Formula (1) gives an approximate measure of the relative effectiveness of nature and nurture in determining mean twin differences.

It will be noted that nature, or $A$, is a factor here considered as the same for identical twins,[1] but different for fraternal twins. The factor $A$ may, of course, change with age and differ for various twin pairs, but it is assumed that for a given identical twin pair it is the same. The $B$ factor, on the other hand, represents the effect of environment or nurture. Such environment is considered as the sum of all influences producing differences in twins effective

[1] If the separation of the twins into the identical and fraternal classes is not exact, or if identical twins have only approximately the same heredity, ${}_iD$ will be a function of ${}_iD_b$ and a small value ${}_iD_a$ The presence of this additional ${}_iD_a$ quantity will make obtained values of $T$ slightly smaller than the true values.

before and after birth. As an example, take the intelligence of a pair of identical twins. With only nature, or $A$, operative, these two would be identical in intelligence at any age, but with the additional influence of nurture, or $B$, a difference between the two will be revealed by any measurement, and such a difference is here regarded as a result of differential effect of $B$ upon each twin. A value of 1.00 from formula (1) indicates that nature and nurture have been equally effective in producing mean twin differences.

A few mean differences have been set forth in Table III for illustration. The differences are much greater in the case of fraternal twins and there is a little evidence that differences are greater for older than for younger twins. The values of $T$ from formula (1) are given in Table IV. For finger ridges and height nature is more important than nurture, while for the four mental traits nurture appears slightly more effective than nature. There is also some evidence that nurture is more effective for younger than for older twins. The above results are not obtained from large samples and the probable

TABLE III.—MEAN DIFFERENCES BETWEEN PAIR MEMBERS

| Variable | Identical | | | Fraternal | | |
|---|---|---|---|---|---|---|
| | Younger | Older | All | Younger | Older | All |
| Finger ridges (both) | 3.2 | 3 6 | 3.4 | 21 7 | 22 9 | 22 4 |
| Cephalic index | ... | ... | .02 | . . | ... | .03 |
| Height | 1.7 | 1.6 | 1 7 | 4 4 | 4 4 | 4.4 |
| MA | 7.2 | 9 8 | 8.4 | 10 6 | 19.9 | 15 9 |
| EA | 5 5 | 7 5 | 6.5 | 6 5 | 15 1 | 11.6 |
| Motor | .. | ... | 19.0 | .... | .... | 29.0 |
| Woodworth-Mathews | ... | ... | 5 6 | .... | ... | 6.8 |

TABLE IV.—VALUES OF $T$ FROM FORMULA (1)

| Variable | Younger | Older | All |
|---|---|---|---|
| Finger ridges (both) | 5 8 | 5 4 | 5 6 |
| Cephalic index | . | . . | .7 |
| Height | 1.6 | 1.7 | 1.7 |
| MA | .5 | 1 0 | .9 |
| EA | 2 | 1.0 | .8 |
| Motor | . | . . | 5 |
| Woodworth-Mathews | . . | | .2 |

errors have not been found, but the consistency of the findings is very suggestive.[1]

## The Relative Importance of Nature and Nurture in Determining Variability of Twin Differences

Instead of studing the mean twin differences of a group, we may investigate the variability of these differences. More particularly we shall derive a formula which gives approximately the ratio of the standard deviation of $D_a$ to the standard deviation of $D_b$.

Let

$r$ = the correlation between $X$ and $X'$,
$R$ = the correlation between $D_a$ and $D_b$,
$S$ = the standard deviation of $X$,
$S_d$ = the standard deviation of $D$,
$S_a$ and $S_b$ = the standard deviations of $D_a$ and $D_b$, all values being found from double entry tables.

We may then write

$$ {}_iS_d^2 = {}_iS_b^2 \quad \text{and} \quad {}_fS_d^2 = {}_fS_a^2 + {}_fS_b^2 + 2R_f S_a \cdot {}_fS_b $$

Two familiar formulas relating variance to correlation may be readily derived and written in the form

$$ \frac{{}_iS_d^2}{{}_iS^2} = 2(1 - {}_ir) \tag{2} $$

$$ \frac{{}_fS_d^2}{{}_fS^2} = 2(1 - {}_fr) \tag{3} $$

We next set up a function, $t^2$, involving the variance of $D$ relative to the variance of $X$. Thus

$$ t^2 = \frac{\dfrac{{}_fS_d^2}{{}_fS^2} - \dfrac{{}_iS_d^2}{{}_iS^2}}{\dfrac{{}_iS_d^2}{{}_iS^2}} = \frac{{}_fS_a^2 + 2R_f S_a \cdot {}_fS_b}{{}^fS_b^2} \tag{4} $$

If the correlation $R$ between $D_a$ and $D_b$ is zero, this reduces to

$$ t^2 = \frac{{}_fS_a^2}{{}_fS_b^2} = U^2 \tag{5} $$

If $R$ is not zero, we may write

$$ t^2 = U^2 + 2RU \tag{6} $$

[1] A much more detailed report will appear in a forthcoming monograph.

A still more convenient form of formula (4) may be found by substituting therein the values given by formulas (2) and (3). This yields

$$t^2 = \frac{(1 - {}_f r) - (1 - {}_i r)}{(1 - {}_i r)} = \frac{{}_i r - {}_f r}{1 - {}_i r} \qquad (7)$$

This last formula is very easy to apply and is capable of simple interpretation. If no nurture factor, *B*, were operative in the case

TABLE V.—CORRELATIONS AND VALUES OF $t^2$ FROM FORMULA (7)
(All Coefficients Corrected for Age)

| Variable | Correlation | | $t^2$ | PE of $t^2$ |
|---|---|---|---|---|
| | Identical | Fraternal | | |
| Standing height | .93 | .65 | 4.0 | 1.2 |
| Weight | .92 | .63 | 3.6 | 1.1 |
| Head length | .91 | .58 | 3.7 | 1.1 |
| Total finger ridges | .97 | .46 | 17.0 | 4.2 |
| Binet MA | .86 | .60 | 1.9 | 0.7 |
| Binet IQ | .88 | .63 | 2.0 | 0.7 |
| Word meaning | .86 | .56 | 2.1 | 0.7 |
| Arithmetic | .73 | .69 | 0.2 | 0.3 |
| Nature study | .77 | .65 | 0.5 | 0.3 |
| History and literature | .82 | .67 | 0.8 | 0.4 |
| Spelling | .87 | .73 | 1.1 | 0.5 |
| EA | .89 | .70 | 1.7 | 0.7 |
| Woodworth-Mathews | .56 | .37 | 0.4 | 0.3 |
| Motor | .69 | .38 | 1.0 | 0.4 |

of identical twin differences, then the correlation ${}_i r$ would be +1.00. The quantity $1 - {}_i r$ therefore measures the effect of the *B* factor alone. In the case of fraternal twins, both *A* and *B* factors are operating and $1 - {}_f r$ measures the combined influence of the two. Formula (7) therefore measures the relative influence of *A* to *B* factors in producing differentiation.

The probable error of $t^2$ from formula (7) has just been derived and is given here without proof.

$$\text{PE of } t^2 = .6745 \frac{1 - {}_f r}{1 - {}_i r} \sqrt{\frac{(1 + {}_i r)^2 + (1 + {}_f r)^2}{N}} \qquad (8)$$

Illustrations of the use of formula (7) are given in Table V. It will be noted that nature is much more effective than nurture for physical traits. In the case of mental age, IQ, and word-meaning, the value of $t^2$ is approximately 2.00 with a disconcerting large probable error. There is some evidence from the regularity of these values, however, that nature is somewhat more effective than nurture in the determination of difference variability for mental traits.

In the case of achievement tests, the values of $t^2$ are not very significant, but their trend indicates that nature is hardly more effective than nurture in determining difference variability.

## Summary

Formulas for studying the relative effect of nature and nurture upon mean twin differences and their variability.

The application of these formulas to the present twin data suggests the following conclusions:

1. For intelligence, nature is about equally effective with nurture in producing mean twin differences, but nature is somewhat more effective than nurture in determining variability of such differences. Nurture influences would thus seem to play a large part in the modification of intellect.

2. In the case of scholastic achievement, the relative influences of nature and nurture probably changes with the trait. On the whole, nature would appear little, if any, more effective than nurture. The question has often been asked, "What per cent of a person's success in achievement is due to nature and what per cent is due to nurture?" Such a percentage comparison may be impossible and even meaningless, but the above results would suggest a 50–50 division rather than a 97–3 division as given by Courtis in his book, "Why Children Succeed."