

By combining this relation with equation (1) and remembering the equality of  $N_p$  and  $N_e$ , we obtain

$$(2 + x)(1 + x)^{-1/2} = (m_p/m) \times e^2/(\hbar c). \quad (7)$$

The empirical value of the right-hand side is 2.13 and the solution of equation (7) is a value of  $x$  slightly above unity. It would just be equal to one if we could put the right-hand side of equation (7) equal to 2.12, thus diminishing its empirical value by half a per cent.

Thus, if the equations derived by Eddington and by Sitte and Glaser hold, we arrive at the conclusion that in the state of equilibrium the number of neutrons nearly equals the number of protons. On the other hand, a relation, first pointed out by the author,<sup>4</sup> which connects purely atomic constants and which is fulfilled to within an error of about half a per cent, i.e.,

$$m_p/m \times e^2/(\hbar c) = 3/\sqrt{2} \quad (8)$$

may be derived from the formulae of Eddington and Sitte and Glaser by assuming the equality of the numbers of neutrons and protons in the equilibrium state.

<sup>1</sup> A. S. Eddington, *Proc. Roy. Soc. London*, **A135**, 605 (1931).

<sup>2</sup> K. Sitte and E. Glaser, *Zeitschr. Physik*, **88**, 103 (1934).

<sup>3</sup> Concerning the details, cf. the paper by Sitte and Glaser.

<sup>4</sup> A. E. Haas, *Science*, June (1938): The classical radius of the electron is related to the Compton wave-length of the proton as 3 to  $\sqrt{2}$ .

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## ON THE RELATIVE CONTRIBUTIONS OF NATURE AND NURTURE TO AVERAGE GROUP DIFFERENCES IN INTELLIGENCE

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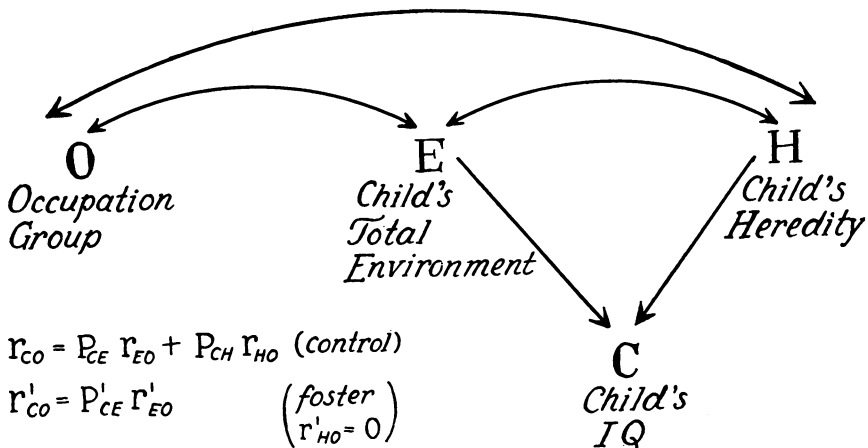
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It has become a more or less accepted commonplace that environmental differences, although having a demonstrable influence upon individual differences in IQ, are less potent than natural differences under the conditions ordinarily met in our urban culture. No wholly satisfactory quantitative estimate of the relative rôles of nature and nurture has yet been possible, but various estimates agree in placing the contribution of nurture under 50 per cent, and probably considerably under. (See references 1 to 5.)\*

Far less satisfactory is the present position of the problem of average socio-economic *group* differences in intelligence—in fact it is only in the last few years that it has been generally recognized and discussed as a separate problem requiring its own techniques for solution. There is no simple correspondence between the contributions of nature and nurture to group and individual differences, but the same types of data are crucial for both problems. The writer has drawn upon two sources of data applicable to the problem of average group differences in IQ with respect to father's occupation—her previous study conducted at Stanford University of the IQ's of foster children and "own" children in relation to parental intelligence and home background, and the more recent study by Leahy at University of Minnesota dealing with the same type of material.

The comparisons involved are unusually straightforward, for it can be shown that the difference in mean IQ of "own" children grouped according to father's occupation is composed of two additive heredity and environment factors, the latter being given by the corresponding difference in group means of foster children. Wright has kindly furnished a proof, which depends upon the use of path coefficients, as follows:

Child's IQ can be represented as completely determined by the two factors—heredity (i.e., the *child's* genetic constitution) and total environment, which may be (and undoubtedly are) more or less correlated with each other. Occupational status of father is clearly correlated with the child's total environment. The increased differences in the control data indicate that it is also correlated with the child's heredity in the controls. The reasons (involving father's intelligence) need not be represented. The following diagram represents these essential points:



The observed differences in IQ in relation to given differences in occupation group are of the nature of regression coefficients.

$$b_{co} = r_{co} \frac{\sigma_c}{\sigma_o} = (p_{ce}r_{eo} + p_{ch}r_{ho}) \frac{\sigma_c}{\sigma_o} \text{ (control),}$$

$$b'_{co} = r'_{co} \frac{\sigma'_c}{\sigma'_o} = (p'_{ce}r'_{eo}) \frac{\sigma'_c}{\sigma'_o} \text{ (foster).}$$

The partial regression coefficients measuring the concrete effects of *H* and *E* on *C* should be the same in foster and control data in spite of differences in correlations, path coefficients or standard deviations.

$$p_{ce} \frac{\sigma_c}{\sigma_o} = p'_{ce} \frac{\sigma'_c}{\sigma'_o}, \quad p_{ch} \frac{\sigma_c}{\sigma_o} = p'_{ch} \frac{\sigma'_c}{\sigma'_o}.$$

If now we assume that the correlation between total environment and occupation group is the same in the two bodies of data but that there is no correlation between child's heredity and occupation group in the foster data (no effective selection of children):

$$r_{eo} = r'_{eo}, \quad r'_{ho} = 0,$$

$$b_{co} = p_{ce}r_{eo} \frac{\sigma_c}{\sigma_o} + p_{ch}r_{ho} \frac{\sigma_c}{\sigma_o} \text{ (control),}$$

where  $p_{ce}r_{eo} \frac{\sigma_c}{\sigma_o} = b'_{co}$  given by the foster data.

Thus the difference in the controls can properly be analyzed into two additive portions tracing through the correlation of occupation group with child's environment, which is the same as the total difference in the foster data, and tracing through the correlation with child's heredity.

The published Minnesota study provides the needed tabulations for occupational group comparisons. It was necessary to go back to the original data of the Stanford study and tabulate them according to a similar scheme.†

The results are shown in tabular form. Table 1 contains the group means and dispersions of intelligence test scores; those of the parents as well as of the children are included by way of additional interest. Table 2 contains derived estimates of the relative contributions of nature and nurture to occupational group differences. The "nurture" column of table 2 is simply the ratio (in per cent) of group difference in foster children to group difference in control "own" children. The "nature" column is 100 minus this ratio, or the ratio of increment of control difference to control difference. In table 3 are presented estimates of the relative contribu-

tions of nature and nurture based upon the total data of the Stanford and Minnesota studies, singly and in combination. Sampling errors of these estimates are also included.

Two methods, giving virtually the same results, were used for obtaining combined estimates of the nature and nurture contributions (table 3).

1. The occupational group differences shown in table 2 were summed for the control and foster groups separately, and the ratio of the foster sum to the control sum was computed. This procedure is sufficiently ac-

TABLE 1  
MEANS AND DISPERSIONS OF INTELLIGENCE SCORES BY OCCUPATIONAL GROUP

	STANFORD STUDY OCCUPATION OF FATHER (OR FOSTER FATHER)				MINNESOTA STUDY OCCUPATION OF FATHER (OR FOSTER FATHER)				
	HIGHER BUS., SEMI- PROF.	LOWER BUS.	SKILLED LABOR	PROFESS.	HIGHER BUS., SEMI- PROF.	LOWER BUS.	SKILLED LABOR	PROFESS.	SLT. SKILLED & DAY LABOR
	I.	II.	III.	IV.	I.	II.	III.	IV.	V.
Foster children									
Mean (IQ)	109.1	108.6	108.0	104.6	112.6	111.6	110.6	109.4	107.8
S. D. (IQ)	17.2	14.5	14.3	16.7	11.8	10.9	14.2	11.8	13.6
No.	32.0	47.0	41.0	43.0	43.0	38.0	44.0	45.0	24.0
Control children									
Mean (IQ)	118.7	118.5	115.5	106.1	118.6	117.6	106.9	101.1	102.1
S. D. (IQ)	15.4	12.2	18.6	12.4	12.6	15.6	14.3	12.5	11.0
No.	18.0	33.0	27.0	18.0	40.0	42.0	43.0	46.0	23.0
Foster parents*									
Mean	221.8	207.3	201.2	184.7	59.6	59.6	49.6	39.7	38.4
S. D.	22.6	30.8	29.7	30.3	8.0	6.7	11.9	12.3	11.2
No.	24.0	40.0	34.0	34.0	...	...	...	...	...
Control parents*									
Mean	221.6	221.8	192.0	176.2	64.6	57.1	51.8	44.0	38.3
S. D.	24.4	30.4	33.4	31.6	5.4	10.0	11.5	11.5	9.0
No.	18.0	32.0	27.0	18.0	...	...	...	...	...

\* In the case of the Stanford study, data are for Stanford-Binet mental age in months of foster fathers and control fathers. In the case of the Minnesota study, data are for mid-foster parent and mid-parent point score on the Otis Test of Mental Ability.

curate for an over-all appraisal when the population numbers and standard deviations of the sub-groups do not differ in an extreme manner. The sampling errors of the estimates thus obtained, however, are difficult to determine because of the lack of independence of the group differences entering the sums.

2. Using the relation,†

$$\frac{\overline{x_F} - \bar{x}_F}{\sigma_F} = r \frac{x_C - \bar{x}_C}{\sigma_C} \quad (1)$$

and assuming a true  $r$  of unity (i.e., a constant proportional effect upon IQ of nurture and nature in the small range of IQ levels with which we are concerned), we may estimate the proportional contributions by the ratio\*\*

$$R = \frac{\sigma_F}{\sigma_C}. \quad (2)$$

The sampling variance of  $R$  is found by squaring and averaging logarithmic differentials, viz.,

$$V_o(R) = R^2 \left[ \frac{V_o(\sigma_F)}{\sigma_F^2} + \frac{V_o(\sigma_C)}{\sigma_C^2} \right]. \quad (3)$$

$\sigma_F$ ,  $\sigma_C$  represent the dispersions of sets of scores in which each score is drawn from a unique universe of given central tendency and sampling

TABLE 2

ESTIMATES OF THE RELATIVE CONTRIBUTION OF NATURE AND NURTURE TO DIFFERENCES IN MEAN INTELLIGENCE SCORE OF CHILDREN GROUPED ACCORDING TO FATHER'S OCCUPATION

GROUPS COM- PARED	STANFORD STUDY					MINNESOTA STUDY				
	CONTROL	FOSTER	CONTROL MINUS FOSTER	CONTRIB. OF NURTURE	CONTRIB. OF NATURE	CONTROL	FOSTER	CONTROL MINUS FOSTER	CONTRIB. OF NURTURE	CONTRIB. OF NATURE
I-II	0.2	0.5	..	..	..	1.0	1.0	..	..	..
I-III	3.2	1.1	2.1	34.4	65.6	11.7	2.0	9.7	17.1	82.9
I-IV	12.6	4.5	8.1	35.8	64.2	17.5	3.2	14.3	18.3	81.7
I-V	..	..	..	..	..	16.5	4.8	11.7	29.1	70.9
II-III	3.0	0.6	2.4	20.0	80.0	10.7	1.0	9.7	9.3	90.7
II-IV	12.4	4.0	8.4	32.3	67.7	16.5	2.2	14.3	13.3	86.7
II-V	..	..	..	..	..	15.5	3.8	11.7	24.5	75.5
III-IV	9.4	3.4	6.0	36.2	63.8	5.8	1.2	4.6	21.7	79.3
III-V	..	..	..	..	..	4.8	2.8	2.0	58.4	41.6
IV-V	..	..	..	..	..	-1.0	1.6	..	..	..

fluctuation. Hence their sampling variances (to be used in formula 3) cannot be calculated by the usual formula. A formula for  $V_o(\sigma_F)$ ,  $V_o(\sigma_C)$  may be derived as follows:

$$\begin{aligned} \sigma^2 &= S \frac{(x_i - \bar{x})^2}{n - 1} \\ &= \frac{(x_1 - \bar{x})^2 + \dots + (x_n - \bar{x})^2}{n - 1}. \end{aligned} \quad (4)$$

Taking differentials, squaring and averaging,

$$V_o(\sigma) = S \frac{[(x_i - \bar{x})^2 (V_o(x_i) + V_o(\bar{x}) - 2/n V_o(x_i))] }{\sigma^2(n - 1)^2}$$

$[V_o(x_i) = \sigma^2 x_i / n_i$ , obtainable from table 1].

The difference in estimated contributions of nature and nurture yielded by the Stanford study ( $<2/3, >1/3$ ) and the Minnesota study ( $>3/4, <1/4$ ) may be due to sampling error alone, although examination of the slope of the regression of foster means upon control means in the two studies suggests that the estimate of the potency of nurture is rather consistently lower in the Minnesota study than in the Stanford study. This may perhaps be accounted for by the fact that there was less opportunity for "selective placement" in the Minnesota foster children, who were limited to those placed in adoptive homes under 6 months of age, than in the California foster children who were placed up to 12 months of age.

TABLE 3

ESTIMATES OF THE RELATIVE CONTRIBUTION OF NATURE AND NURTURE BASED UPON TOTAL DATA, WITH TESTS OF SIGNIFICANCE

	STAN- FORD STUDY	MINNE- SOTA STUDY
Unweighted sum of control group differences	40.8	99.0
Unweighted sum of foster group differences	14.1	23.6
Estimated contribution of nurture $\left( \frac{\text{foster grp. diff.}}{\text{control grp. diff.}} \right)$	<b>0.345</b>	<b>0.238</b>
Estimated contribution of nature (1-nurture contrib.)	<b>0.655</b>	<b>0.762</b>
Dispersion of control group means ( $\sigma_C$ )	5.92	8.37
Dispersion of foster group means ( $\sigma_F$ )	2.03	1.87
Estimated contribution of nurture ( $R = \sigma_F/\sigma_C$ )	<b>0.344</b>	<b>0.224</b>
Estimated contribution of nature ( $1 - R$ )	<b>0.656</b>	<b>0.776</b>
Sampling variance of $R$ ( $V_o(R)$ )	0.054	0.017
Sampling error of $R$ ( $\sqrt{V_o(R)}$ )	<b>0.232</b>	<b>0.131</b>
Information ( $1/V_o(R)$ )	18.59	58.82
Combined $\bar{R}$ (weighted according to information)	<b>0.253</b>	
$1 - \bar{R}$	<b>0.747</b>	
$V_o(\bar{R})$	0.013	
Sampling error ( $\sqrt{V_o(\bar{R})}$ )	<b>0.114</b>	

Combining the estimates in the two studies according to the amount of information yielded by each (inversely as their sampling variances), we arrive at an estimated  $3/4, 1/4$  as the relative contributions of nature and nurture, with approximately even chances that the contribution of nurture is in truth between 18 and 33 per cent.

Finally, it may be pointed out that differences in mean intelligence scores of the parents according to occupational group might be expected to derive from natural differences in a higher proportion than do those of their offspring, since intelligence is one of the components that enters directly into

the selection of an occupation, or the selection of a person by an occupation. This truism is borne out by the higher regression of intelligence on occupation in the parent groups than in the offspring groups.

\* Reference 3 contains quantitative estimates of the contributions of nature and nurture which have been strongly criticized. However, the simple correlation, 0.67, between the intelligence scores of identical twins reared apart—which would rise even higher if corrected for attenuation, and for the restricted range of talent—is in itself weighty evidence for the predominant influence of natural inheritance.

† To avoid the slightest possibility of bias, the classification of fathers' occupations from the Stanford data was made "blind," i.e., with no knowledge as to the intelligence of the fathers, mothers, their children or foster children.

‡ In the formulae which follow,  $\bar{x}$ ,  $\bar{z}$  and  $\sigma$  refer to the occupational group means, the mean of the means and the standard deviation of the means, respectively.

\*\* This formula neglects a small error factor involving the magnitude of the obtained  $\sigma$ 's in relation to the true  $\sigma$ 's [i.e.,  $\sigma_{\infty}^2 = \sigma^2(r)$ , where  $r$  is a reliability coefficient].

<sup>1</sup> Burks, B. S., *27th Yearbook Nat. Soc. Stud. Educ.*, Part I, 219–316 (1928).

<sup>2</sup> Leahy, A. M., *Genet. Psychol. Monog.*, 17, 235–308 (1935).

<sup>3</sup> Newman, H. H., Freeman, F. N., and Holzinger, K. J., *Twins*, Univ. Chicago Press, pp. xvi + 369 (1937).

<sup>4</sup> Willoughby, R. R., *27th Yearbook Nat. Soc. Stud. Educ.*, Part I, 55–59 (1928).

<sup>5</sup> Wright, S., *Jour. Amer. Stat. Assoc. Suppl.*, 26, 155–163 (1931).

## A METAGALACTIC DENSITY GRADIENT

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1. In a discussion of the evidence bearing on the isotropic distribution of galaxies it was shown four years ago that at a distance of about  $10^8$  light-years to the north of the galactic plane the density is thirty or more per cent greater than at the same distance to the south.<sup>1</sup> Several different ways of discussing the extensive observational material yielded the higher density in the north. Similar inequalities were found to be present also at shorter distances, but beyond  $10^8$  light-years both the Harvard and the Mount Wilson data suggest tentatively the disappearance of the north-south inequality.

Quantitatively the north-south difference is not closely determined by the early work because the nebular counts were made in relatively small sample areas; but the existence of the difference is unquestionable, as is also the occurrence of non-uniformity in nebular distribution arising from the metagalactic clouds.<sup>2</sup> These well-established large-scale inequalities have been pretty generally ignored in discussions of the expanding uni-