INTELLIGENCE **18**, 309–333 (1994)

Race and Sex Differences in Head Size and IQ

ARTHUR R. JENSEN
FRED W. JOHNSON
University of California, Berkeley

An analysis of IQ in relation to head size (and by inference, brain size) was performed on some 14,000 children and their full siblings, almost evenly divided by race (white and black) and sex, on whom data were obtained at ages 4 and 7 years in the National Collaborative Perinatal Project. Within each race × sex group, IQ is significantly correlated with head size, age and body size having been partialed out. A significant positive correlation between IQ × head size exists not only *within* subjects (at ages 4 and 7) but also *within* families and *between* families (at age 7 only). The within-families correlation (at age 7) is consistent with an intrinsic or pleiotropic correlation between the mental and physical variables. No significant positive correlation within families appeared at age 4, despite a significant within-subjects correlation at that age. As yet, there are only speculative explanations of the disparity between the age 4 and age 7 within-family correlations of head size with IQ. Although general body size is also correlated with IQ within subjects and between families, the correlation does not exist *within* families in either age group, which rules out a pleiotropic correlation between body size and IQ. There are both race and sex differences in head size, although the sex difference in IQ is nil. White and black children who are matched on IQ show, on average, virtually zero difference in head size.

The relationship of individual differences in brain size to intelligence has been one of the classic controversies in psychology throughout its history. Only in recent years has it appeared to be close to a scientific resolution. Thorough reviews and metaanalyses of past studies now leave no doubt of a positive correlation, at least between head size and IQ (Jensen & Sinha, 1993; Table 4.10; Johnson, 1991; Rushton, 1990, Table 2; Van Valen, 1974). In all of the 25 independent studies we have found in the literature, nonzero positive correlations between head measurements and intelligence measurements have been found, all but five with correlations significant beyond the .05 confidence level. The average correlation between various external measures of head size and IQ is close to +.15. But external head size is a rather weak proxy for brain size. Two recent studies have measured brain size per se by means of magnetic resonance imaging (MRI) and found correlations with IQ in the .30 to .40 range (Andreasen et al., 1993; Willerman, Schultz, Rutledge, & Bigler, 1991). Although it would now be

Correspondence and requests for reprints should be sent to Arthur R. Jensen, School of Education, University of California, Berkeley, CA 94720.

hard to doubt the correlation between head or brain size and IQ, puzzles remain, and the interpretation of the correlation depends on further crucial information not found in previous studies.

Between- and Within-Family Correlations

Probably the most crucial item of information that is lacking in earlier studies is whether the correlation exists *within* as well as *between* families. The correlations typically reported in the literature are *within-subjects* correlations. Such correlations, based on unrelated individuals, could be entirely attributable to differences between families. Within-subject correlations obtained in an entire population are theoretically composed of two major components: between-families (BF) and within-families (WF), although the WF component could be nil. A BF correlation is attributable to whatever genetic and environmental factors make for differences between families in each of the correlated variables, in this case head (or brain) size and IQ. It can be entirely due to population heterogeneity or stratification on each of the variables, which can be correlated by happenstance, without indicating any causal or functional or intrinsic relationship between the variables whatsoever.

A correlation between two traits that is only BF and shows no WF correlation would be of little, if any, interest to geneticists, even if each of the traits had very high heritability, although it might be of interest to sociologists or cultural anthropologists to discover why the genes for the two traits got assorted together. Genes for two distinct traits may show common assortment through positive cross-assortative mating; for example, persons of above-average IQ tending to select mates with above average height, and persons of below average IQ tending to mate with persons of below average height. This condition generates in the offspring population a positive within-subjects correlation between IQ and height. But, as explained elsewhere, the correlation is not "intrinsic" (Jensen, 1980a; Jensen & Sinha, 1993). There is a BF correlation, but not a WF correlation. Because of Mendel's law of independent assortment of genes and each offspring receiving a random sample of one-half of each parent's genes, the two traits are uncorrelated *within* families, at least genetically. Any WF correlation would be due to environmental factors that alter both traits in one member of a sibling pair but not in the other, and the same phenomenon would have to occur within many families. An illness severe enough to stunt both physical and mental growth that afflicted one sibling but not the other would, if occurring in a sizable proportion of families, create an environmental WF correlation. There is no statistically significant evidence of such a WF environmental correlation as a component of the well-established within-subjects correlation between height and IQ, which seems to be entirely attributable to BF correlation (Jensen & Sinha, 1993). A WF correlation, to the extent that it is genetic, could only be due to pleiotropy, that is, one gene affecting two (or more) distinct phenotypic traits. The positive WF correlation between myopia and IQ, for example, appears to be pleiotropic

(Cohn, Cohn, & Jensen, 1988). The two reported studies of WF correlation between head size and IQ have been unable to reject the null hypothesis, as they were based on samples much too small to test any reasonably expected value of a WF correlation without high risk of Type II error (Clark, Vandenberg, & Proctor, 1961; Johnson, 1991).

If it were established that the within-subjects correlation between head (or brain) size and IQ is entirely a BF correlation and had no significant WF component, it would be of little further interest to neuroscience. The observed correlation would not be a problem for neuroscience but would remain to be explained in terms of the sociological or cultural factors that bring about a BF correlation between distinct phenotypic traits. Only if there is a WF correlation can it be said there is an intrinsic, that is, causal or functional, relationship between brain size and IQ, a phenomenon that would need to be explained in neurological terms. The main aim of the present study, with its enormous sample size, is to determine definitively whether there exists a WF correlation between head size and IQ.

Race and Sex Differences

These massive data also allow a look at race and sex differences. Previous literature on this has been reviewed elsewhere and seems fairly conclusive, but it still remains somewhat controversial, particularly as regards allometric methods of controlling for race and sex differences in general body size, which is correlated with head and brain size, as well as with IQ, and therefore complicates the interpretation of observed brain–IQ correlations (Ankney, 1992; Jensen & Sinha, 1993; Rushton, 1992).

Controlling Body Size

The literature on the IQ × head size correlation is quite inconsistent in the way body size is treated, most likely because controlling for body size is theoretically problematic. For one thing, head size itself, at least in its height dimension, is a part of overall stature and of body weight, so that correcting for height and weight could be regarded to some degree as an overcorrection. Then there is the question of the degree to which head or brain size accommodates body size, or vice versa. A study in which randomly selected laboratory rats were subjected to selective breeding only for maze learning ability for 12 generations found that, by the 12th generation, the maze-bright and maze-dull rats differed markedly in brain weight and in cranial size, both groups deviating about equally from the mean of unselected rats on these variables (Hamilton, 1935). But the selectively bred groups also differed in overall body size, although only about one-third as much as in brain size. Apparently, breeding rats for fast and slow learning ability increased body size as well as brain size, although both strains received identical treatment. This would be expected if the body serves to some extent as a power pack for the brain. In the same study, among unselected rats there was a correlation of +.25 between maze ability and brain weight, which is somewhat less than the correlation found in MRI studies of human brain volume in relation to IQ. However, in a study in which rats were tested on several diverse cognitive tasks, from which a general factor was extracted, the rats' factor scores were correlated +.48 with their brain weights (Anderson, 1993). But one must be wary of generalizing from rats to humans on this point. The very small (though possibly real) positive WF correlation between stature and IQ scarcely indicates a *functional* relationship between body size and intelligence in humans.

Therefore, to err on the conservative side, if at all, we have scrupulously removed body height and weight from all analyses involving head size and IQ. Both variables have been adjusted for overall body size (i.e., height and weight), as well as for age. The analyses were also done with raw scores for scores adjusted for age only but are not reported here. The body-size adjustments make surprisingly little difference in any analysis, despite the fact that body size and head size are more highly correlated in children (r of about +.35) than in adults (r of about +.20), a difference attributable to individual differences in growth rates. Head size (and *ipso facto* brain size) is more independent of general body size than any other skeletal body parts. In a factor analysis of 17 distinct body measurements, for example, head length and breadth have markedly lower loadings than any of the other body measurements on the first two orthogonal factors (I = general body size; II = girth independent of general size) (Eysenck, 1953, pp. 164–172).

Beals's Hypothesis

All of this is related to a potentially important hypothesis that the present data may be able to throw some light upon. For convenience we will dub it "the Beals hypothesis." Beals (1987), a physical anthropologist, has stated, "It is doubtful that normal variation with human brain size has more significance to intellectual ability than do randomly selected anthropometric traits" (p. 159). He entertained the idea that a generally better environment has a "fertilizer effect," leading to a larger body, larger brain, and higher IQ, without necessarily implying causal connections between these variables. And he suggested a testable hypothesis, using randomly selected noncranial anthropometrics:

> If there does exist some special connection to head or brain size with intelligence, then the expectation is that such measurements would have higher correlations with IQ than do body size traits selected at random. Simply measuring heads and correlating test scores does not answer the question of whether brain size has itself a functional connection to intelligence. (p. 158).

Although Beals has elsewhere reported some remarkable relationships of cranial capacity to climatic and cultural variables, they do not answer the question posed in the quoted statements (Beals, Smith, & Dodd, 1983; Smith & Beals, 1990). If the main environmental factor with a "fertilizer effect," in Beals's words, that accounts for the correlations among body size, head (or brain) size, and IQ is nutrition, then the *within*-family correlation between head size and IQ (with body size partialed out) should be reduced to near-zero and should certainly be smaller than the *between*-families correlation of body size with IQ (both unadjusted for head size). The data here seem well suited for testing this hypothesis.

Limitations

There are three limitations to the study over which we had no control, because we did not collect the data ourselves but obtained it from the data bank of the National Collaborative Perinatal Project (NCPP). The net effect of these limitations is to somewhat attenuate all of the statistical results when they are compared with analyses based on adults and using direct measurements of brain size or at least more detailed measurements of head size.

The first limitation is the age at which the variables of interest were measured: at 4 and 7 years of age. Although brain size in this age range has attained some 80% to 90% of its adult size, the correlation between brain and head size increases from early childhood to maturity. Race and sex differences in cranial capacity also increase over the same period. Also, the correlation between body size and head size is larger in children than in adults, so that adjusting the IQ × head size correlation for body size reduces the correlation more for children than for adults.

The second limitation is that externally measured head size in studies such as this serves as a proxy for brain size. The best estimates reported in the literature for the correlation between externally measured head size and actual brain size measured post mortem is about +.50. Hence, doubling all of the IQ × head size correlations reported in the present study should give an approximate estimate of the correlation of brain size with IQ.

The third limitation is that the only measure of head size is head circumference (measured with a metal tape). If only one measurement can be made, circumference is probably the best choice, and it is correlated about +.5 with actual brain size. However, caliper measurements of head length, width, and height permit a more accurate assessment and, by use of regression equations, yield a better estimate of cranial capacity than circumference alone. We have found with other data that including head length and width in addition to circumference results in a correlation with IQ about .02 to .03 larger than the correlation of IQ with head circumference alone. But the main shortcoming of measuring only head circumference is that, unlike head length (L) and width (W), circumference does not reflect the cephalic index (CI = 100 W/L). For any given head circumference, cranial capacity (and brain volume) increases with the CI. In the present study, the biasing effect of using head circumference alone is that it underestimates the difference in cranial capacity between blacks and whites, because, on average, CI is larger for whites than for blacks (Harrison, Weiner, Tanner, & Burnicott, 1964, p. 209). And it is cranial capacity, more than circumference, that is related to IQ, within or between racial groups. The use of circumference, on the other hand, should not bias comparison of the sexes, as they do not differ in CI.

METHOD

Subjects

Data for the present study were obtained from the National Collaborative Perinatal Project, a large-scale epidemiological study sponsored by the United States National Institutes of Health, that prospectively followed the course and outcome of more than 56,000 pregnancies and performed examinations assessing the physical growth and cognitive development of many of the children at ages 4 and 7 years (Myrianthopoulos, Nichols, Broman, & Anderson, 1972). Analyses of the kind that we report have not appeared in any of the published literature from the NCPP (Broman, Nichols, & Kennedy, 1975; Broman, Nichols, Shaughnessy, & Kennedy, 1987).

The study sample was about 45% white, 47% black, and the rest of other racial or ethnic background. Children from families of lower socioeconomic status than the general average of the U.S. population are slightly overrepresented in this sample obtained at 12 medical centers throughout the United States.

Physical measurements obtained in the NCPP study and used in the present analyses are height, weight, and head circumference, each measured at age 4 and again at age 7. The cognitive measures are Stanford-Binet IQ at age 4 and WISC (Wechsler Intelligence Scale for Children) IQ at age 7. The WISC IQ is based on 7 of the 11 WISC subscales: 4 verbal scales (Information, Comprehension, Vocabulary, and Digit Span) and 3 performance scales (Block Design, Picture Arrangement, and Coding).

Procedure

Because the NCPP study was prospective from each mother's pregnancy, the sample included children with congenital malformations and other abnormalities. To include just children that were normal and healthy in the present analysis, only those were selected for the study who met the following criteria: (a) no major malformations, (b) no more than one minor malformation, and (c) no cerebral palsy, mental retardation,[1] or learning disorders. Outliers (i.e., more that $\pm 3\sigma$ from sex $\times$ race mean) on *all* variables were removed. So that only singletons would be included in the analysis, all twins were eliminated from the

[1]Only subjects who could be considered, with reasonably high probability, to be of genetically and organically normal intelligence were included in the analyses. Thus, all the statistics are based on the large proportion of each age $\times$ race $\times$ sex sample most representative of the vast majority of normal persons in their respective populations. Subjects whose IQ was 2σ or more below the mean of their respective age $\times$ race $\times$ sex group were excluded. They comprised 2.7% of the white sample

study sample. Only black children and white children were retained for the analysis, creating four race × sex groups: white males (WM), white females (WF), black males (BM), and black females (BF). The composition of the resulting samples used in the present analysis is shown in Table 1. The reader will note that the sample sizes of all four groups are larger at age 7 than at age 4. The documentation for the NCPP data offers no explanation for the different sample size. Presumably the follow-up of subjects at age 7 included new subjects.

Treatment of Data. To control for the effects of age on all the measures and for the effects of body size (height and weight) on head circumference and IQ, data adjustments were made. By means of regression procedures, linear, quadratic, and cubic effects of age, height, and weight were removed from the total raw data on head circumference and IQ. To preserve group differences, the residualized variables were then restandardized to their original within-race × sex means and standard deviations (*SD* shrunken by the removal of variance associated with the controlled variables). The residualization and standardization were done separately for the data at age 4 and at age 7 in the total samples of males, females, blacks, and whites at each age. Hence, the reported correlations are *partial* correlations, unless stated otherwise; that is, age effects are removed from IQ, height, and weight where IQ is correlated with height and weight (the variables are thus termed *age-adjusted*), and age, height, and weight are removed from both IQ and head circumference where IQ is correlated with head circumference (termed *fully-adjusted*).

Sibling Data. The sibling analyses were done with the scores adjusted in the total samples of 4-year-olds and 7-year-olds. Only full siblings were selected for the sample, as determined in interviews with their mothers. Siblings were selected from each family in which there were at least two sibs meeting the aforementioned health criteria. If there were three or more siblings who met these criteria, the two nearest in age were selected. The order of sibs within a pair, that is, which became sib 1 and which sib 2, was randomized for reasons made apparent in the next paragraph. All sib pairs were same-sexed and all sib analyses were done within the four race × sex groups, thereby controlling for race and sex differences. It is an important feature of these data that the measurements on each member of a sib pair were obtained when the sibs were within 2 months of each other in chronological age, regardless of their difference in birth dates. The composition of the sibling samples is shown in Table 2.

(IQs $\leq$ 71) and 3.3% of the black sample (IQs $\leq$ 63). The average IQ of the excluded blacks was 3.3 points lower than that of the excluded whites. If anything, this exclusion criterion would seem to bias the black mean slightly upward, but the percentages are so small that the mean IQs of the white and black study samples were each raised only about 1 point, leaving the overall white–black difference, with and without excluded subjects, the same (12.9 or 0.98σ) to within 0.1 IQ point.

TABLE 1
Race and Sex Composition of Sibling Samples

	Age 4		Age 7	
Group	*N*	%	*N*	%
White males	5,686	23.4	7,090	24.5
White females	5,874	24.2	7,353	25.4
Black males	6,149	25.3	7,024	24.2
Black females	6,608	27.2	7,525	26.0
Whites	11,560	47.5	14,443	49.8
Blacks	12,757	52.5	14,549	50.2
Males	11,835	48.7	14,114	48.7
Females	12,482	51.3	14,878	51.3
Total	24,317		28,992	

Between-Family and Within-Family Analysis. Sibling sums for the BF correlations were computed by adding their standardized residual scores, and sib differences for the WF correlations were computed by subtracting their standardized residual scores, using the same order of subtraction (sib 1 − sib 2) for all variables. As noted, siblings were randomly assigned to sib 1 and sib 2 (with the same assignment for every variable), to avoid any bias that could result from a systematic ordering of the siblings, such as by birth order, that could include a spurious nonrandom component in the sibling differences. Because the reliability of sums is greater than the reliability of differences, Jensen (1980a) gave formu-

TABLE 2
Number of Same-Sex Sibling Pairs in Each Race × Sex Group at Ages 4 and 7 Years

	Age 4		Age 7	
Group	*N*	%	*N*	%
White males	409	29.7	546	28.2
White females	435	31.6	577	29.8
Black males	250	18.2	397	20.5
Black females	283	20.3	416	21.5
Whites	844	61.2	1,123	58.0
Blacks	533	38.7	813	41.9
Males	659	47.9	439	48.7
Females	718	52.1	993	51.3
Total	1,377		1,936	

las to correct for attenuation of the correlation of sums and the correlation of differences. These corrections were used to make the BF and WF correlations directly comparable.

RESULTS

Sibling Resemblance in Physical and Mental Variables

The sibling intraclass correlations, shown in Table 3, are quite typical of the values reported in the literature for sibling correlations on these variables measured in childhood and are close to theoretically expected values for highly heritable traits. This attests to the general reliability and validity of the measurements in these samples. The slightly lower correlations of black siblings on the physical variables is not in the least attributable to restriction of variance in the black sample on any of these variables (see Table A-1 in the Appendix and Table 6). It should be noted that, in Table 3, the height and weight measures have been adjusted only for age, whereas head circumference has been adjusted for height and weight, as well as for age. When head circumference is adjusted only for age, the sibling correlations are increased on average by .03.

Correlations Among Physical Variables

As can be seen in Table 4, head circumference has rather surprisingly low correlations with general body size as indicated by height and weight. The overall average correlation between height and weight is .70, whereas the average correlation of head circumference with height and weight is only .36. (In adults, the correlation between body size measures and a direct postmortem measure of brain size is only about +.20; see Ho, Roessmann, Straumfjord, & Monroe, 1980b.) A general factor extracted from the correlations among the three physi-

TABLE 3
Intraclass Correlation Between Same-Sex Siblings on Age-Adjusted Height, Weight, Head Circumference (HC), and IQ at Ages 4 and 7 Years

	Age 4				Age 7			
Group	Ht.	Wt.	HC	IQ	Ht.	Wt.	HC	IQ
White males	.52	.50	.34	.48	.49	.46	.40	.42
White females	.49	.48	.41	.51	.52	.40	.37	.53
Black males	.42	.34	.35	.35 (.41)	.38	.33	.38	.36 (.41)
Black females	.51	.46	.27	.37 (.44)	.45	.43	.30	.40 (.46)
M	.49	.45	.34	.43 (.46)	.46	.41	.36	.43 (.45)

Note. Head circumference adjusted for age, height, and weight. Intraclass correlation (r_i) in parentheses is corrected for restriction of IQ variance in the black samples, to make the r_i directly comparable for the black and white samples.

TABLE 4
Correlations Between Age-Adjusted Height, Weight, and Head Circumference (HC) in White (W) and Black (B) Males (M) and Females (F) at Ages 4 and 7 Years

Correlated Variables	Age 4				Age 7			
	WM	WF	BM	BF	WM	WF	BM	BF
Ht. × Wt.	.68	.65	.71	.69	.71	.67	.73	.68
Ht. × HC	.29	.34	.25	.28	.36	.36	.30	.33
Wt. × HC	.40	.45	.37	.39	.41	.43	.40	.39

Note. For all correlations, $p < .001$, two-tailed test.

cal measures has the following average loadings for height, weight, and head circumference: at age 4, .70, .98, .41; at age 7, .75, .94, .44. The loadings are remarkably alike in the four race × sex groups and at ages 4 and 7. Evidently head size (and by inference, brain size) is relatively independent of general body size.

IQ in the Study Samples

Although IQ has been age-standardized in the normative samples for these tests, the IQ scores may not be perfectly age-standardized in the present study sample to the extent that they may differ from the normative samples. Therefore the IQ scores from the Stanford-Binet (at age 4) and WISC (at age 7) were adjusted for age in the present samples. The means and standard deviations of the unadjusted and age-adjusted IQs are shown in Table 5. Although the size of the age adjustments appears practically negligible, age-adjusted IQs were used in all of our

TABLE 5
Mean and Standard Deviation of Unadjusted IQ and Age-Adjusted IQ for Each Race and Sex Group at Ages 4 and 7 Years

Group	Age 4				Age 7			
	Unadjusted		Age-Adjusted		Unadjusted		Age-Adjusted	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
White males	104.7	15.5	104.7	15.5	104.3	13.3	104.2	13.3
White females	108.0	15.7	107.9	15.8	103.2	13.3	103.1	12.9
Black males	91.5	12.8	91.6	12.8	91.1	11.3	91.2	11.4
Black females	93.8	12.9	93.9	13.0	91.7	10.9	91.8	10.9
Whites	106.4	15.7	106.3	15.7	103.7	13.1	103.6	13.1
Blacks	92.7	12.9	92.8	12.9	91.4	11.1	91.5	11.1
Males	97.9	15.6	97.9	15.6	97.7	14.0	97.5	14.0
Females	100.5	16.0	100.5	16.0	97.4	13.2	97.4	13.2

Note. IQ measured by Stanford-Binet at age 4 and WISC at age 7.

analyses, because the zero-order correlation between any two age-adjusted measures is identical to a partial correlation between the unadjusted variables with age partialed out.

Head Circumference and Estimated Cranial Capacity

Summary statistics are given in Table 6. Cranial capacity (in cm^3) was estimated from circumference by a formula (essentially a regression equation) given by Lee and Pearson (1901), but these estimates have not entered into any of the statistical analyses. Although the absolute magnitude of these estimates of cranial capacity (CC) may be questionable, because the Lee and Pearson equations were based on adults, they are, in fact, fairly similar to direct postmortem measures obtained on children of comparable age (Ho et al., 1980a). Approximately 80% of adult CC is attained by age 4 and 90% by age 7 (Harrison et al., 1964, p. 309), and the average value of the CC in Table 6, when divided by .8 and by .9 for 4-year-olds and 7-year-olds, respectively, is close to the CC typically reported for adults. At least the data afford an indication of the differences in cranial capacity associated with differences in head circumference that may be useful for comparison with other studies. Obviously, quite small differences in circumference correspond to much larger differences in CC.

Within-Subject Correlation Between Head Circumference and IQ

Table 7 shows the correlations between head circumference and IQ within subjects, first adjusted only for age, then for age, height, and weight. The body-size

TABLE 6
Mean and Standard Deviation of Head Circumference (in cm) and Estimated Cranial Capacity (CC in cm^3) for Each Race and Sex Group at Ages 4 and 7 Years

	Age 4			Age 7		
	Circumference			Circumference		
Group	*M*	*SD*	CC	*M*	*SD*	CC
White males	50.51	1.47	1101	51.93	1.46	1201
White females	49.60	1.44	1051	50.95	1.41	1131
Black males	50.05	1.57	1069	51.39	1.51	1163
Black females	49.90	1.62	1069	51.04	1.58	1137
Whites	50.05	1.51	1073	51.43	1.51	1163
Blacks	49.97	1.60	1068	51.21	1.56	1149
Males	50.27	1.54	1084	51.66	1.51	1182
Females	49.76	1.54	1060	51.00	1.50	1135

Note. Head circumference adjusted for age, height, and weight. Cranial capacity estimated from the following formulas derived from Lee and Pearson (1901). Where **C** is head circumference in cm: For males, CC = 70.60**C** − 2464.95; for females, CC = 59.74**C** − 1912.18; for both males and females, CC = 65.17**C** − 2188.57.

TABLE 7
Within-Subject Correlations of IQ With Head Circumference, Age-Adjusted (A-Adj) and Fully-Adjusted for Age, Height, and Weight (AHW-Adj) in Each Race and Sex Group at Ages 4 and 7 Years

	Age 4		Age 7	
Group	**A-Adj**	**AHW-Adj**	**A-Adj**	**AHW-Adj**
White males	.16 (.17)	.13 (.14)	.24 (.25)	.20 (.21)
White females	.18 (.20)	.14 (.16)	.24 (.25)	.20 (.21)
Black males	.11 (.12)	.06 (.07)	.18 (.20)	.13 (.14)
Black females	.12 (.13)	.07 (.07)	.19 (.20)	.14 (.15)
Mean r	.12 (.15)	.10 (.11)	.21 (.23)	.17 (.18)

Note. IQ measured by Stanford-Binet at age 4 and WISC at age 7. Correlations corrected for attenuation in parentheses. All correlations significant at $p < .0001$, two-tailed.

adjustments make little difference, reducing the unadjusted correlation by about .04 to .05. The overall average of the correlations ($r = .15$) is within one standard error of the mean$r = .14$ ($SE = .03$) obtained from a metaanalysis of 14 studies (total $N = 12,108$) of the correlation between head size and psychometric intelligence (Jensen & Sinha, 1993, p. 192).

It is important to note, however, that in the present data the correlations at age 7 are markedly and consistently larger than at age 4. That the relationship between head size and IQ increases with age during childhood is undoubtedly a real phenomenon. It is important to determine whether this increase in the IQ × head size correlation shows up as a between-families or a within-families phenomenon, or both.

Within-Subject Correlation Between Body Size and IQ

As seen in Table 8, there is a slight tendency for IQ to be more correlated with height and weight at age 7 than at age 4, although in the case of weight the age difference in correlation with IQ is neither significant nor consistent across groups. Comparing Tables 7 and 8, it is also conspicuous that head size is more correlated with IQ than is body size, again indicating the relative independence of these physical variables.

Between-Family and Within-Family Correlation of Head Size With IQ

The following analyses are based on only one same-sex, full-sibling pair per family. The number of sib pairs in each race × sex group are shown in Table 2.

When the number of sibling pairs in a sample is equal to one-half the total number of subjects in the sample, the within-subjects covariance of variables x

TABLE 8
Within-Subject Correlations of IQ With Age-Adjusted Height and Weight in Each Race and Sex Group at Ages 4 and 7 Years

	Age 4		Age 7	
Group	**Height**	**Weight**	**Height**	**Weight**
White males	.07	.09	.15	.12
White females	.12	.14	.16	.13
Black males	.12	.14	.14	.15
Black females	.14	.16	.14	.15
Mean r	.11	.13	.15	.14

Note. Correlations corrected for attenuation (IQ only); corrected rs average .01 larger than uncorrected. IQ measured by Stanford-Binet at age 4 and WISC at age 7. All correlations significant at $p < .0001$, two-tailed.

and y can be partitioned into two additive components: the covariance of x and y *between families* and the covariance of x and y *within families*. The correlation r_{xy} is simply the standardized covariance.

BF correlations in the following analysis were calculated as the Pearson r_{xy} between the mean head circumference of each sibling pair (x), and the mean IQ of each sibling pair (y). The WF correlation is the Pearson r_{xy} between the signed difference of sib 1 − sib 2 in head circumference (x), and the signed difference of sib 1 − sib 2 in IQ (y). Because mean scores have higher reliability than difference scores, the appropriate corrections for attenuation (Jensen, 1980a) were applied to the BF and WF correlations to permit direct comparison.

Table 9 shows the BF and WF correlations between head circumference and IQ. At age 4 the correlations are rather nondescript, with only two of the eight coefficients barely significant ($p < .05$) and positive, and both the mean BF and WF correlations are nonsignificant. The presence of several (nonsignificant) negative correlations (3/4 of the WF correlations) further highlights the tenuous relationship of head size to IQ at age 4. At age 7, however, the correlations become significant and relatively substantial. (The overall significance level of the WF correlation in the four race × sex groups is $p < 10^{-5}$, two-tailed.) This leaves no doubt of a WF correlation between head circumference and IQ, although it is consistently and significantly smaller than the BF correlations. At age 7, the ratio of the WF/BF correlations between head circumference and IQ is +0.57.

Between-Family and Within-Family Correlations of Body Size With IQ

In view of the finding in the previous section, it is interesting to compare those correlations with the correlations between IQ and body size measures in the very same samples, shown in Table 10. The pattern of correlations in Table 10 is

TABLE 9
Between-Family (BF) and Within-Family (WF) Correlations of IQ With Head Circumference, Fully Adjusted for Age, Height, and Weight, in Each Race and Sex Group at Ages 4 and 7 Years

	Age 4		Age 7	
Group	BF	WF	BF	WF
White males	.08 (.09)	.06 (.08)	.26 (.27)	.18 (.20)
White females	.18 (.19)	−.03 (−.04)	.30 (.31)	.11 (.12)
Black males	.11 (.12)	−.11 (−.12)	.13 (.14)	.09 (.10)
Black females	−.08 (−.09)	−.08 (−.09)	.11 (.12)	.06 (.07)
Mean *r*	.07 (.08)	−.04 (−.04)	.20 (.21)	.11 (.12)

Note. IQ measured by Stanford-Binet at age 4 and WISC at age 7. Correlations corrected for attenuation in parentheses. Significance: $r > .10, p < .05$; $r > .17, p < .001$, two-tailed.

rather the opposite of the pattern seen in Table 9. In Table 10 we see overall larger correlations at age 4 than at age 7 and markedly larger BF than WF correlations. In fact, at age 7 most of the IQ–body size correlation is BF, whereas the much smaller WF correlations fall short of significance even with these large populations. For height, the ratio of WF/BF correlation is +0.27, or less than half of the corresponding ratio for head circumference (+0.57) (for weight, the ratio is +0.37). (And note that height and weight were partialed out of the correlations between head circumference and IQ, whereas head circumference has not been partialed out of the correlations between body size and IQ.) This is all consistent with the general finding in the literature on physical correlates of IQ (Jensen & Sinha, 1993); a significant WF correlation between height or weight and IQ has yet to be found, even in studies with populations in the thousands (e.g., Jensen, 1980a). Again, the marked contrast between Tables 9 and 10 underlines the relative independence of body size and head size in development and in their correlations with IQ.

Effect Size of Sibling Differences

Another kind of examination of the WF correlation between IQ and physical measurements can be achieved by comparing the physical measurements of siblings who differ from one another by at least 1 *SD* in IQ. We refer to this as the *effect size* (*ES*) of the sibling IQ difference on the sibling difference in physical measurements. Effect size is the standardized mean difference, that is, the mean difference between the higher and lower IQ groups on the physical measure, divided by the average *SD* of the lower and higher IQ groups on the physical measure. Note that *ES* should not be ascribed any meaning beyond this precise definition and does not itself imply causality.) The question to be answered is:

How different in head circumference (or in height or weight) are siblings who differ by at least 1 *SD* in IQ? (The average sib difference in IQ is about 12 points.)

Table 11 shows the *ES*s for height, weight, and head circumference for siblings differing by at least 1 *SD* in IQ. (The corresponding means for head circumference are given in the Appendix, Table A-2.) At age 4 the *ES* is small and inconsistent on the three physical variables, even *negative* for head circumference in three out of the four groups. The overall *ES* for weight, however, is significant ($p = .039$). At age 7, the *ES*s are largest (and highly significant) on head circumference but not much different from age 4 on height and weight. By age 7, sibling differences in head circumference are clearly related to sibling differences in IQ.

The reverse comparisons are made in Table 12, that is, how different in IQ are siblings who differ from one another by at least 1 *SD* in height, or weight, or head circumference? (The corresponding IQ means for sibs differing at least 1 *SD* in head circumference are given in the Appendix, Table A-3.) Again, at age 4 the *ES*s are inconsistent and nonsignificant except for weight, which has a quite significant *ES* on IQ. The *ES* for head circumference is nonsignificant negative.

TABLE 10
Between-Families (BF) and Within-Families (WF) Correlations of IQ With Age-Adjusted Height and Weight in Each Race and Sex Group at Ages 4 and 7 Years

	Age 4				Age 7			
	BF		WF		BF		WF	
Group	Ht.	Wt.	Ht.	Wt.	Ht.	Wt.	Ht.	Wt.
White males	.07	.18	.01	.07	.14	.15	.07	.09
R^a	.20		.08		.15		.09	
White females	.06	.14	.17	.11	.14	.15	.09	.02
R	.14		.17		.16		.10	
Black males	.18	.23	−.06	.06	.16	.18	.04	.01
R	.23		.12		.18		.03	
Black females	.18	.17	.07	.06	.18	.16	−.04	.01
R	.17		.07		.16		.07	
Mean r	.12	.18	.05	.07	.15	.16	.04	.06
Mean R	.19		.11		.16		.07	

Note. Correlations corrected for attenuation (IQ only). IQ measured by Stanford-Binet at age 4 and WISC at age 7. The IQ is age-adjusted; hence the correlations in this table are identical to partial correlations between IQ and the physical variables with age partialed out.

[a] R is the multiple correlation of height and weight with IQ (age partialed out). Significance: $r > .09$, $p < .05$; $r > .13$, $p < .02$, two-tailed test; $R > .13$, $p < .05$; $R > .15$, $p < .01$.

TABLE 11
Effect Size on Height, Weight, and Head Circumference (HC) of Sibling Differences of at Least 1 Standard Deviation in IQ

	Age 4				Age 7			
Group	NP[a]	Ht.	Wt.	HC	NP[a]	Ht.	Wt.	HC
White males	120	.02	.12	.09	183	.05	.11	.23
White females	130	.17	.18	−.06	172	.19	.16	.18
Black males	82	−.04	.14	−.10	129	.12	.05	.16
Black females	103	.01	−.06	−.12	141	.00	.05	.13
M	435	.05	.10	−.05	625	.09	.10	.18
t		1.07	2.06	−0.99		1.91	2.44	4.42
Two-tailed p		.287	.039	.322		.056	.015	10^{-5}

Note. Sibling differences are higher sibling minus lower sibling.
[a]*NP* = number of sibling pairs.

At age 7 the *ES* for weight is near-zero, but for height the *ES* is significant, and the largest *ES* is clearly for head circumference *ES*, with a two-tailed *p* beyond 10^{-7}. Indeed, the age differences in *ES*s seen in Table 12 are most striking. The fact that the *ES*s for height, weight, and head circumference do not show the same age trends further underlines the low degree of dependency of the IQ × head size relation on the general body size variables.

Race and Sex Differences in Physical and Mental Measurements

Height and Weight. These, along with age, were the controlled variables in all analyses of head circumference, but it is instructive to examine them in their

TABLE 12
Effect Size on IQ of Sibling Differences of at Least 1 Standard Deviation in Height, or Weight, or Head Circumference (HC)

	Age 4				Age 7			
Group	NP[a]	Ht.	Wt.	HC	NP[a]	Ht.	Wt.	HC
White males	127	−.06	.11	.06	163	.10	.08	.27
White females	141	.21	.16	−.02	176	.17	.07	.19
Black males	83	−.16	.10	−.15	142	.09	.00	.15
Black females	99	.04	.15	−.07	136	.00	−.03	.20
M	450	.03	.13	−.05	617	.09	.03	.20
t		0.59	2.81	−1.06		2.37	0.85	5.07
Two-tailed p		.551	.005	.289		.018	.854	$< 10^{-7}$

Note. Sibling differences are higher sibling minus lower sibling.
[a]*NP* = Number of sibling pairs.

own right in relation to race and sex. The *ES*s of race and sex on height and weight (each adjusted for age) are shown in Table 13. At both age 4 and age 7, black children of both sexes are taller than white children, and at age 7 the difference is more than a third of an *SD*. The race difference in weight, whites being heavier, is comparatively small and is even nonsignificant at age 7. At ages 4 and 7 males of both races are taller and heavier than females; but the sex difference in weight is conspicuously large at age 4, and this is true for both races.

Head Circumference and IQ. The contrasting *ES* of race and of sex on IQ and head circumference, shown in Table 14, clearly displays what has often been called a paradox: Although there is a positive correlation between head size and IQ within both races and within both sexes, there is a relatively small race difference in head size, despite a comparatively large race difference in IQ, whereas there is a comparatively large sex difference in head size, despite a negligible difference in IQ. Also, at both ages 4 and 7, the sex difference in head circumference is considerably larger in the white than in the black sample. With the present sample sizes and replication across age, this is undoubtedly a real phenomenon. Because sex per se is completely determined genetically, the fact that the sexes differ much more in head circumference in one race than in the other suggests that variance in head size is predominantly determined by genetic factors, and the sexual dimorphism with respect to head size (and by inference, brain size) is greater in white than in black children. But the sex difference in head circumference within each race appears to be either unrelated or inversely related to IQ.

In Table 15 are shown the race and sex differences as actually measured in centimeters, although adjusted for age, height, and weight. To give some basis

TABLE 13
Effect Size of Race and Sex on Age-Adjusted Height and Weight

	Height		Weight	
Contrasted Groups	**Age 4**	**Age 7**	**Age 4**	**Age 7**
Race				
WM–BM	−.275	−.352	.040	.009, n.s.
WF–BF	−.361	−.396	.089	.021, n.s.
W–B	−.322	−.374	.105	.019, n.s.
Sex				
WM–WF	.192	.123	.279	.090
BM–BF	.097	.078	.258	.102
M–F	.139	.095	.265	.094

Note. Significance of *ES*: $> .025, p < .05$; $> .034, p < .01$; $> .044, p < .001$, two-tailed test. WM = White male, BM = black male, WF = white female, BF = black female.

TABLE 14
Effect Size of Race and Sex on IQ and Head Circumference

	IQ		Head Circumference	
Contrasts	**Age 4**	**Age 7**	**Age 4**	**Age 7**
Race				
WM–BM	.922	1.049	.302	.363
WF–BF	.968	.946	−.196	−.060[a]
W–B	.939	.997	.051	.143
Sex				
WM–WF	−.204	.084	.625	.683
BM–BF	−.178	−.054[b]	.094	.226
M–F	−.165	.007[c]	.331	.439

Note. Effect Size (*ES*) = (mean difference)/(mean squared *SD*s within groups)$^{1/2}$. IQs adjusted for age. Head circumference adjusted for age, height, and weight. WM = white male, BM = black male, WF = white female, BF = black female.

Significance: Every *ES* is significant beyond $p < .00001$ (two-tailed test) except those indicated by superscripts.

[a]$t = 3.67$, $p < .0002$ (2-tailed). [b]$t = 3.24$, $p < .0012$ (2-tailed). [c]Nonsignificant ($t = 0.62$, $p > .05$).

for evaluating their magnitudes, they are also shown as a proportion of the mean increase (within sex × race groups) in head circumference between ages 4 and 7 years, which is 1.313 cm. Both the race and the sex differences in head circum-

TABLE 15
Race and Sex Differences in Head Circumference at Ages 4 and 7 Years Expressed as a Proportion of Overall Mean Increase in Head Circumference Within Race and Sex and Between Ages 4 and 7

	Raw Difference (cm)		Proportion of Age Diff.	
Contrast	**Age 4**	**Age 7**	**Age 4**	**Age 7**
Race				
WM–BM	0.46	0.54	0.35	0.41
WF–BF	−0.30	−0.09	−0.23	−0.07
W–B	0.08	0.23	0.06	0.17
Sex				
WM–WF	0.91	0.98	0.69	0.75
BM–BF	0.15	0.35	0.11	0.27
M–F	0.53	0.67	0.40	0.51

Note. Head circumference (in cm) adjusted for age, height, and weight. Within-race × sex groups mean increase in head circumference between ages 4 and 7 years = 1.313 cm. WM = white male, BM = black male, WF = white female, BF = black female.

ference increase by about the same amount between age 4 and age 7. As in Table 14, the most conspicuous feature of Table 15 is the large sex difference, as compared with the race difference.

Head Circumference of Racial Groups Matched on IQ. How different in head circumference are white and black groups that have been closely matched on IQ? To counteract regression effects due to the imperfect reliability (+.90) of IQ, white and black subjects were matched on regressed true-score IQ at the overall white mean IQ (105) and at the overall black mean IQ (92). The IQ-matched whites and blacks were then compared on head circumference, as shown in Table 16. Matching whites and blacks on IQ considerably reduces the racial difference in head circumference (by 43% in males) or reverses (by −146% in females), compared with the differences between the unmatched racial groups (Table 15). The striking sex × race interaction shows up in every one of the four comparisons, which are based on completely independent sets of subjects. Consequently, at age 4 the overall white–black difference in head circumference for the IQ-matched groups is slightly reversed (−0.095 cm), and at age 7, the overall white to black difference is reduced to virtually zero (+.005 cm).

The mean differences in head circumference between the members of each racial group who were matched to the overall white IQ (higher IQ group) or to the overall black IQ (lower IQ group) are shown in Table 17. The differences in head circumference are fairly uniform across all four race × sex groups. However, these differences in head circumference between racially homogeneous groups that differ in IQ by the same amount that the racial groups differ do not

TABLE 16
Head Circumference (HC) (in cm) of White (W) and Black (B) Groups Matched on IQ at the White Mean IQ and at the Black Mean IQ

	Age 4 Matched on:				Age 7 Matched on:			
	W Mean IQ		B Mean IQ		W Mean IQ		B Mean IQ	
Group	*N*	HC	*N*	HC	*N*	HC	*N*	HC
White males	322	50.59	206	50.34	411	51.93	226	51.67
Black males	216	50.35	335	50.07	221	51.60	438	51.36
WM–BM		0.24		0.27		0.33		0.31
White females	321	49.57	146	49.29	416	51.03	243	50.73
Black females	293	49.94	408	49.81	251	51.34	547	51.04
WF–BF		−0.37		−0.52		−0.31		−0.31
W–B		−0.065		−0.125		0.010		0.000

Note. Both head circumference and IQ adjusted for age, height, and weight.

TABLE 17
Mean Difference in Head Circumference (in cm) Between Higher and Lower IQ Groups

Group	Age 4	Age 7
White males	0.25	0.26
Black males	0.28	0.24
White females	0.28	0.30
Black females	0.13	0.30
M	0.235	0.275

Note. Higher IQ Group comprises white and black subjects matched for IQ on the overall white mean IQ. Lower IQ Group comprises subjects matched for IQ on the overall black mean IQ. Both head circumference and IQ were adjusted for age, height, and weight.

evince the very marked sex × race interaction seen in the racial group differences in head circumference (Table 15). This argues cogently for studying head size (or brain size) relations with mental abilities separately in the two sexes.

DISCUSSION AND CONCLUSIONS

The unique contribution of this study is that the correlation between head size (and by inference, brain size) and IQ is established as a *within*-families correlation, and therefore necessarily exists independently of whatever genetic and environmental effects influence differences *between* families in head size and IQ. The average ratio of the WF/BF correlations is +0.57. The existence of a WF correlation between head size and IQ and the fact that both variables are highly heritable is consistent with a pleiotropic connection between the two variables.

The head size × IQ correlation increases significantly between ages 4 and 7 years, averaging .10 and .17, respectively, when fully adjusted for age, height, and weight. At age 7 the correlations are also more consistent across the four race × sex groups than at age 4. The absence of significant positive within-family correlations (and even some negative correlations) between head size and IQ at age 4 (Table 9) is indeed puzzling, especially considering that larger (and significant) positive within-subjects correlations were found at age 4. This disparity in correlations between ages 4 and 7 is seen in both racial groups and both sexes, indicating that it is a real phenomenon.

One of the referees on this article (L. Willerman, personal communication, July 22, 1993) suggested a speculative hypothesis, namely, that head size is not as good an index of brain size at age 4 as at age 7. He noted that skull growth is not entirely driven by increasing brain size, and in early childhood there may be greater discrepancies in individual and familial differences in the growth rates of brain size and head size. Then catch-up brain growth occurs in later childhood, stabilizing the headsize–brainsize relationship as their growth curves approach asymptote. An added refinement to the analysis, taking account of a racial difference in rates of premature birth, would adjust head circumference and IQ for age measured from the date of conception rather than from birth. Any differences that would result from such adjustments in the present analyses would probably be too minute to detect at a significant level, even with the large sample sizes used in this study. Just the demonstration of significant headsize–IQ correlations depends on a very large sample size. The more subtle hypotheses just mentioned actually call for investigation by means of MRI and PET techniques, which are capable of measuring brain size directly.

Head size (adjusted for age, height, and weight) is more highly correlated with IQ (adjusted for age, height, and weight) than is general body size (with height, weight, and IQ adjusted only for age); this is true within subjects as well as between families and within families. Also, the IQ × body size correlation *decreases* between ages 4 and 7, whereas the IQ × head size correlation *increases* with age.

All these findings seem inconsistent with what one should predict from Beals's hypothesis (1987), which states that normal variation in human brain size has no more significance for mental ability than do randomly selected anthropometric traits. Height and weight have the largest factor loadings on the general factor of a large number of anthropometric measurements (Eysenck, 1953), and they are also the most affected by chronic adverse environmental effects such as poor nutrition. Height and the weight/height ratio have been found to be generally the highest correlates of mental test scores in undernourished populations (Pollitt, Mueller, & Leibel, 1982). In well-nourished populations, IQ is more highly correlated with head size than with height, weight, or skeletal age. In a sample ($N = 360$) of 9-year-old boys, head circumference correlated more with WISC IQ than height, weight, or skeletal age (also true *within* each of five social-class categories). The head circumference × IQ correlation was +.35, whereas the correlations of height and weight with IQ were +.21 and +.11, respectively (Weinberg, Dietz, Penick, & McAlister, 1974). In brief, a strong case has not yet been made for Beals's hypothesis, but the relevant evidence we have found does not support it. If any anthropometric variables besides head (or brain) size could be found that show comparable or higher correlations with IQ, both within and between families, it would be most astonishing, and our negative conclusion regarding Beals's hypothesis would certainly have to be reconsidered.

The race difference in head circumference is highly significant but differs markedly for males and females, white males having about one-third of an *SD* larger circumference than black males and white females having about one-eighth *SD smaller* head circumference than black females. Whites and blacks who are matched on IQ show virtually no difference in head circumference (.005

cm). But when whites and blacks are matched on head circumference, they still differ in IQ, but the difference is considerably less than in unmatched samples. These two findings are consistent with the hypothesis that brain size is only one of a number of brain factors involved in IQ, hence when groups are matched on IQ, they do not differ at all in brain size, but when matched on brain size, they do still differ in IQ, but to a lesser degree than unmatched groups.[2]

The overall racial difference in head size, in standard units, is considerably smaller than has been found in adult samples, which do not show the disordinal race × sex interaction with respect to brain size (Ho et al., 1980a, 1980b). The present finding is most likely related to the differential growth rates of boys and girls in this age range. Even if head circumference were fully adjusted for age and body size, this adjustment would not completely eliminate differences due to growth rates, because during childhood the growth of the head (and brain) follows a much steeper trajectory than body size. Both race and sex differences in head circumference might be confounded with race and sex differences in growth rates. The study of race and sex differences in brain size and its relation to IQ would be based most ideally on the use of MRI in representative samples of young adults.

The male–female difference of about 0.4 *SD* in head circumference, even after adjustment for age, height, and weight, is considerably larger than the race difference, but it is consistent with head measurements based on adult samples (Ankney, 1992; Rushton, 1992). This appears to be a true sexual dimorphism independent of general body size. It remains a major unsolved puzzle in differential psychology and neuroscience that the large sex difference in head and brain size is not reflected by the mean IQ difference between males and females, which is virtually nil. Yet brain size and IQ are positively correlated to about the same

[2]The finding that groups matched on IQ do not differ on head size but groups matched on head size still differ (though less than unmatched groups) on IQ could also result if the reliability (r_{xx}) of head measurements were considerably lower than the r_{xx} of IQ. Test manuals show the r_{xx} of Stanford-Binet IQ at age 4 to be .88 and of WISC IQ at age 7 to be .92. We have not been able to find the r_{xx} of the head circumference measurements reported anywhere in the literature on the NCPP. However, we can logically infer a good lower bound estimate of the r_{xx}, as follows. Head circumference was reportedly measured with a metal tape and recorded to the nearest centimeter (Broman et al., 1975, p. 124). Assume that the total distribution of measurement error extends ±1 cm from the true value. Therefore, measurement errors would normally be distributed around the true value, extending over a range of 2 cm. For finite data, a normal curve subtends about 6σ. The standard error of measurement (SE_m) is defined as 1 σ of the normal distribution of measurement errors. Reliability is defined as $r_{xx} = 1 - (SE_m/SD)^2$, where *SD* is the standard deviation of the measurements in the subject sample. Therefore, if measurement error is assumed to have a range of 2 cm, the $SE_m = 2/6 = .333$ cm. The overall average *SD* of head circumference in the present samples is 1.55 cm. Therefore, the estimated $r_{xx} = 1 - (.333 \text{ cm}/1.55 \text{ cm})^2 = .95$. This estimate of .95 for the reliability of the head-circumference measurements is at the top of the range of reliability coefficients reported for IQ (Jensen, 1980b). Consistent with this estimate of the reliability of head size are the correlations of .910 and .908 found between head size measurements (length and width) of monozygotic twins (Newman, Freeman, & Holzinger, 1937, p. 97).

degree *within* each sex. So far there is no scientifically accepted explanation for this phenomenon, although several speculative hypotheses have been suggested. For example, Ankney (1992, pp. 335–336) mentions "some unknown effect related to body size difference," "IQ tests biased to favor women" (or to equalize the sexes), "women have more efficient brains than men." and "the sex difference in relative brain size relates to those intellectual abilities at which men excel" (e.g., spatial visualization). To this list can be added a greater density of neurons in the female brain or other structural, organizational, and hormonal differences that allow the smaller female brain to process information as efficiently and perform as well on IQ tests as the larger male brain (e.g., Kimura & Hampson (1993). The explanation can almost certainly be found through the concerted methodologies of psychometrics and neuroscience.

REFERENCES

Anderson, B. (1993). Evidence from the rat for a general factor that underlies cognitive performance and that relates to brain size: Intelligence? *Neuroscience Letters, 153,* 98–102.

Andreasen, N.C., Flaum, M., Swayze, V., II, O'Leary, D.S., Alliger, R., Cohen, G., Ehrhardt, J., & Yuh, W.T.C. (1993). Intelligence and brain structure in normal individuals. *American Journal of Psychiatry, 150,* 130–134.

Ankney, C.D. (1992). Sex differences in relative brain size: The mismeasure of woman, too? *Intelligence, 16,* 329–336.

Beals, K.L. (1987). Problems and issues with human brain size, body size and cognition. *Homo, 37,* 148–160.

Beals, K.L., Smith, C.L., & Dodd, S.M. (1984). Brain size, cranial morphology, climate and time machines. *Current Anthropology, 25,* 301–325.

Broman, S.H., Nichols, P.L., & Kennedy, W.A. (1975). *Preschool IQ: Prenatal and early developmental correlates.* Hillsdale, NJ: Erlbaum.

Broman, S.H., Nichols, P.L., Shaughnessy, P., & Kennedy, W. (1987). *Retardation in young children.* Hillsdale, NJ: Erlbaum.

Clark, P.J., Vandenberg, S.G., & Proctor, C.H. (1961). On the relationship of scores on certain psychological tests with a number of anthropometric characters and birth order in twins. *Human Biology, 33,* 163–180.

Cohn, S.J., Cohn, C.M.G., & Jensen, A.R. (1988). Myopia and intelligence: A pleiotropic relationship? *Human Genetics, 80,* 53–58.

Eysenck, H.J. (1953). *The structure of human personality.* London: Methuen.

Hamilton, J.A. (1935). *The association between brain size and maze ability in the white rat.* Unpublished doctoral dissertation, University of California, Berkeley.

Harrison, G.A., Weiner, J.S., Tanner, J.M., & Barnicott, N.A. (1964). *Human biology.* London: Oxford University Press.

Ho, K-c., Roessmann, U., Straumfjord, J.V., & Monroe, G. (1980a). Analysis of brain weight. I. Adult brain weight in relation to sex, race, and age. *Archives of Pathology and Laboratory Medicine, 104,* 635–639.

Ho, K-c., Roessmann, U., Straumfjord, J.V., & Monroe, G. (1980b). Analysis of brain weight. II. Adult brain weight in relation to body height, weight, and surface area. *Archives of Pathology and Laboratory Medicine, 104,* 640–645.

Jensen, A.R. (1980a). Uses of sibling data in educational and psychological research. *American Educational Research Journal, 17,* 153–170.

Jensen, A.R. (1980b). *Bias in mental testing*. New York: Free Press.
Jensen, A.R., & Sinha, S.N. (1993). Physical correlates of human intelligence. In P.A. Vernon (Ed.), *Biological approaches to research on human intelligence*. Norwood, NJ: Ablex.
Johnson, F.W. (1991). Biological factors and psychometric intelligence: A review. *Genetic, Social, and General Psychology Monographs, 117*, 313–357.
Kimura, D., & Hampson, E. (1993). Neural and hormonal mechanisms mediating sex differences in cognition. In P.A. Vernon (Ed.), *Biological approaches to the study of human intelligence*. Norwood, NJ: Ablex.
Lee, A., & Pearson, K. (1901). Data for the problem of evolution in man: VI. A first study of the correlation of the human skull. *Philosophical Transactions of the Royal Society of London, 196*, 225–264.
Myrianthopoulos, N.C., Nichols, P.L., Broman, S.H., & Anderson, V.E. (1972). Intellectual development of a prospectively studied population of twins and comparison with singletons. In J. de Grouchy, F.J.G. Ebling, & I.W. Henderson (Eds.), *Human genetics: Proceedings of the Fourth International Congress on Human Genetics*. Amsterdam: Excerpta Medica.
Newman, H.H., Freeman, F.N., & Holzinger, K.J. (1937). *Twins: A study of heredity and environment*. Chicago: University of Chicago Press.
Pollitt, E., Mueller, W., & Leibel, R.L. (1982). The relation of growth to cognition in a well-nourished preschool population. *Child Development, 53*, 1157–1163.
Rushton, J.P. (1990). Race, brain size, and intelligence: A reply to Cernovsky. *Psychological Reports, 66*, 659–666.
Rushton, J.P. (1992). Cranial capacity related to sex, rank, and race in a stratified random sample of 6,325 U.S. military personnel. *Intelligence, 16*, 401–413.
Smith, C.L., & Beals, K.L. (1990). Cultural correlates with cranial capacity. *American Anthropologist, 92*, 193–200.
Van Valen, L. (1974). Brain size and intelligence in man. *American Journal of Physical Anthropology, 40*, 417–424.
Weinberg, W.A., Dietz, S.G., Penick, E.C., & McAlister, W.H. (1974). Intelligence, reading achievement, physical size, and social class. *Journal of Pediatrics, 85*, 482–489.
Willerman, L., Schultz, R., Rutledge, H.N., & Bigler, E. (1991). *In vivo* brain size and intelligence. *Intelligence, 15*, 223–228.

APPENDIX

TABLE A-1
Mean and Standard Deviation of Age-Adjusted Height (cm) and Weight (kg) in Each Race and Sex Group at Ages 4 and 7 Years

	Age 4				Age 7			
	Height		Weight		Height		Weight	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
White males	101.1	4.1	16.8	1.8	121.0	5.1	23.9	3.4
White females	100.3	4.1	16.2	1.8	120.4	5.1	23.5	3.7
Black males	102.2	4.0	16.6	1.9	122.8	5.3	23.8	3.4
Black females	101.9	4.0	16.1	1.9	122.4	5.3	23.5	3.8
Whites	100.7	4.1	16.5	1.9	120.7	5.1	23.7	3.6
Blacks	102.0	4.0	16.3	1.9	122.6	5.3	23.6	3.6
Males	101.7	4.1	16.7	1.9	121.9	5.3	23.9	3.4
Females	101.1	4.1	16.1	1.9	121.4	5.3	23.5	3.8

TABLE A-2
Mean Head Circumference (cm) of Siblings Differing by at Least 1 Standard Deviation in IQ and Effect Size (ES) of IQ for Each Race and Sex Group at Ages 4 and 7 Years

	Age 4			Age 7		
Group[a]	Higher IQ	Lower IQ	*ES**	Higher IQ	Lower IQ	*ES**
White males	50.48	50.34	.09	51.92	51.59	.23
White females	49.54	49.62	−.06	51.08	50.83	.18
Black males	49.77	49.93	−.10	51.45	51.19	.16
Black females	49.70	49.88	−.12	50.92	50.72	.13
M	49.87	49.94	−.05	51.34	51.08	.18

Note. Head circumference adjusted for age, height, and weight. IQ measured by Stanford-Binet at age 4 and WISC at age 7; IQs adjusted for age, height, weight. *ES* is the mean difference (H − L), divided by the square root of the mean within-group variance (V), that is, $ES = (\text{Mean H} - \text{Mean L})/[(V_H + V_L)/2]^{1/2}$.

[a]Sample sizes (number of sibling pairs): Age 4 = WM 116, WF 132, BM 81, BF 94; Age 7 = WM 185, WF 170, BM 134, BF 150.

*Significance of *ES*: $> +.11$, $p < .05$; $> .15$, $p < .01$; $> .16$, $p < .001$, two-tailed.

TABLE A-3
Difference in IQ Between Siblings Differing at Least 1 Standard Deviation in Head Circumference (HC) at Ages 4 and 7 Years in Each Race and Sex Group

	Age 4			Age 7		
Group[a]	Larger HC	Smaller HC	*ES*	Larger HC	Smaller HC	*ES*
White males	103.09	102.14	.06	103.98	100.46	.27****
White females	105.46	105.79	−.02	103.07	100.57	.19****
Black males	89.39	91.36	−.15*	92.05	90.38	.15**
Black females	93.70	94.54	−.07	93.07	90.94	.20***
M	97.91	98.46	−.05	98.04	95.59	.20

Note. IQ measured by Stanford-Binet at age 4 and WISC at age 7; IQs adjusted for age, height and weight. Head circumference adjusted for age, height, and weight. *ES* computed as in Table A2.

[a]Sample sizes (number of sibling pairs); Age 4: WM 138, WF 145, BM 92, BF 104; Age 7: WM 182, WF 196, BM 162, BF 151.

*$p < .04$, two-tailed. **$p < .01$, two-tailed. ***$p < .001$, two-tailed. ****$p < .0001$, two-tailed.