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Cranial Capacity Related to Sex, Rank, and Race in a Stratified Random Sample of 6,325 U.S. Military Personnel

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The issue of whether human populations differ in brain size remains controversial. Cranial capacities were calculated from external head measurements reported for a stratified random sample of 6,325 U.S. Army personnel measured in 1988. After adjusting for the effects of stature and weight, and then, sex, rank, or race, the cranial capacity of men averaged 1,442 and women 1,332 cm^3; that of officers averaged 1,393 and enlisted personnel 1,375 cm^3; and that of Mongoloids averaged 1,416, Caucasoids 1,380, and Negroids 1,359 cm^3.

After a long hiatus following World War II, research is beginning again on the relation between brain size (mass or volume) and intelligence, as well as on the question of whether human populations reliably differ in brain size. Although a very strong case can now be made for a positive relation between brain size and intelligence (Jensen & Sinha, in press; Lynn, 1990; Rushton, 1990; Van Valen, 1974; Willerman, Schultz, Rutledge, & Bigler, 1991), the question of group differences in brain size remains controversial.

Brain sizes have typically been estimated using three procedures: weight at autopsy, within-skull volume, and external head volume. These data tend to converge on the same conclusion, namely, that men average larger and heavier brains than do women, persons from higher socioeconomic status (SES) levels average larger and heavier brains than do those from lower SES levels, and persons descended from northeast Asian ancestry (Mongoloids) average larger and heavier brains than do Caucasoids and Negroids (Beals, Smith, & Dodd, 1984; Ho, Roessmann, Straumfjord, & Monroe 1980; Jensen & Sinha, in press; Jerison, 1982; Lynn, 1990; Rushton, 1988, 1990). Criticism, however, has been vigorous, with claims made that if corrections are allowed for disparities in body size and other variables, the differences in brain size disappear (Cain & Vanderwolf, 1990; Gould, 1981; Tobias, 1970).

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The null hypothesis, however, does not hold. With respect to sex differences, subsequent to Willerman et al.'s (1991) tentative result using magnetic resonance imaging, Ankney (1992) challenged the widely accepted view that there are no sex differences in brain size once body size is controlled. Ankney reexamined the brain-weight analyses of autopsy data published by Ho et al. (1980) on 1,261 adult subjects aged 25 to 80. Ankney found that at any given surface area or height, brains of white men are heavier than those of white women as are brains of black men heavier than those of black women. For example, the brain weight of 5 ft 8 in. (173 cm) men averaged about 100 g heavier than those of women of the same height in both racial groups. Ankney showed that a serious statistical error had been made, one that permeates this literature. The mistake is to examine sex differences in brain weight using brain-weight–body-size ratios because these ratios decline as body size increases so that the mean ratios do not differ between men and women.

With respect to SES differences, Jensen and Sinha (in press) reported that although early studies showed that people in higher status occupations typically averaged a larger head circumference than those in lower ones (e.g., Hooton, 1939), the relationship had only recently been examined while controlling for body size. The largest set of data (approximately 10,000 white and 12,000 black 4-year-old children) from a study by Broman, Nichols, and Kennedy (1975) showed a small but significant correlation between head circumference and SES of origin within both the white and the black populations, even when height was controlled ($r = .10$). Jensen and Sinha also reanalyzed autopsy data reported by Passingham (1979) on 734 men and 305 women and found an overall correlation between directly measured brain weight and achieved occupational level of about .10 after controlling for height. Although these correlations are small, they are lower bound estimates uncorrected for reliability of measurement.

Recent evidence of racial differences in brain size comes from three converging sources. For brain weight at autopsy, Ho et al. (1980) summarized data for 1,261 American subjects aged 25 to 80 after excluding obviously damaged brains. They reported a significant sex-combined difference between 811 whites with a mean of 1,323 g ($SD = 146$) and 450 blacks with a mean of 1,223 g ($SD = 144$). This difference remained after controlling for age, stature, body weight, and total body-surface area. With endocranial volume, Beals et al. (1984) computerized the world database of 20,000 crania and found sex-combined brain cases differed by continental area. Those from Asia averaged 1,380 cm^3 ($SD = 85$), those from Europe averaged 1,362 cm^3 ($SD = 35$), and those from Africa averaged 1,276 cm^3 ($SD = 84$).

A parallel racial ordering in brain size is to be found from analyses of external head measurements gathered in anthropometric surveys. Aggregating data published by Herskovits in 1930, Rushton (1990) showed statistically significant average differences in (male only) cranial capacity with a mean for Mongoloids of 1,651 cm^3 ($SD = 20$, $n = 6$), for Caucasoids of 1,621 cm^3 ($SD = 49$, $n = 13$), and for Negroids of 1,495 cm^3 (SD = 44, n = 17). Subsequently, Rushton (1991) calculated cranial capacities for (male only) military personnel for 24 international samples collated in 1978 by the U.S. National Aeronautics and Space Administration. Adjusting for the effects of height, weight, and total body-surface area, he reported a mean for Mongoloids of 1,460 cm^3 and 1,446 cm^3 for Caucasoids.

These recent data on race differences do not go undisputed. Concerns range from the representativeness of the samples to the appropriateness of the controls for body size (Vanderwolf & Cain, 1991; Willerman, 1991). Even the critics, however, acknowledge that "some" of the data are "trustworthy" and in the direction claimed.

Group differences in brain size are important because a relationship is thought to exist between brain size and mental ability. International as well as U.S. data show that on many measures of cognitive performance, Mongoloid populations score higher than do Caucasoids who, in turn, score higher than do Negroids (Jensen, 1985; Lynn, 1987; Steen, 1987). Similarly, groups from higher SES levels score higher in mental ability than groups from lower SES levels (Jensen, 1980). Moreover, several studies have demonstrated small positive correlations (rs = .10–.30) between head perimeter measured by tape and scores on IQ tests, now within an Oriental sample (Rushton, 1992) as well as within white and black samples (Jensen & Sinha, in press; Lynn, 1990; Rushton, 1990; Van Valen, 1974). Many of these studies controlled for extraneous factors such as body size. A study by Willerman et al. (1991) measured brain size *in vivo* using magnetic resonance imaging and found that larger brain size, corrected for body size, was associated with higher IQ scores in 40 healthy, white, middle-class university students (r = .35).

METHOD

I report here a study that allows a more definitive answer to the question of sex, SES, and race differences in cranial capacity. Using a large stratified random sample from a known population, I calculate cranial capacities from recently gathered external head measurements using Lee and Pearson's (1901) "pan-racial" equations. Lee and Pearson carried out what may have been the earliest investigation of whether internally measured skull capacity could be estimated from head length, breadth, and height by entering cranial capacities and skull dimensions for 941 men and 516 women of various "races" (p. 246, Table XX) into regression equations. Although Lee and Pearson repeatedly emphasized the need for caution, the amount of error involved, and the difficulties of generalizing from one local race to another, they empirically demonstrated that owing to "the personal equation" (error) in other methods, that their "panracial" (p. 260) equation (p. 252, No. 14) provided estimates of cranial capacity (CC) more accurate than the direct method of estimating endocranial volume using sand, seed, or shot.

$$\text{For men: CC (cm}^3) = 0.000337\,(L - 11\text{ mm})(B - 11\text{ mm})(H - 11\text{ mm}) + 406.01$$
$$\text{For women: CC (cm}^3) = 0.0004\,(L - 11\text{ mm})(B - 11\text{ mm})(H - 11\text{ mm}) + 206.6$$

where L, B, and H are length, breadth, and height in millimeters and 11 mm is subtracted for fat and skin around the skull. Lee and Pearson (1901, p. 244) showed that these equations produced errors of less than 0.5% when used to estimate the mean cranial capacity from various samples of skulls.

The raw data had been gathered in a 1988 stratified random anthropometric survey of 9,000 U.S. Army personnel (Clauser, Tebbetts, Bradtmiller, McConville, & Gordon, 1988; Gordon et al., 1989). I winnowed the pool to 6,325 to eliminate ambiguous categories, thus facilitating between-group comparisons. Excluded were those with rank of Warrant Officer, thus leaving officers (Lieutenant to Colonel) and enlisted personnel (Private to Sergeant Major). Also excluded were those who defined themselves on a biographical questionnaire as Hispanic, American Indian, or as Mixed/Other, thus leaving those who defined themselves as Asian/Pacific (Mongoloids), white (Caucasoids), or black (Negroids).

Cranial capacities and other measurements were provided by Dr. Bruce Bradtmiller of Anthropology Research Project, Inc. (ARP), the commercial firm commissioned by the U.S. Army to conduct the survey. (All original measurements for this study are filed at the ARP, Yellow Springs, OH 45387; an interim report of summary statistics is also available in Gordon et al., 1989.) The anthropometric measures, and the ARP variable number and description from Gordon et al. (1989) are, to the nearest 10th of a millimeter: *head length* (62, measured with a spreading calliper from the glabella landmark between the brow ridges to the posterior point on the back of the head); *head breadth* (60, measured with a spreading calliper above the attachment of the ears for maximal distance); and *head height* (H44, measured vertically from the trigone landmark on the cartilaginous flap in front of the ear canal to the horizontal plane tangent to the top of the head); *stature* (99, measured from a standing surface vertically to the top of the head while at the maximum point of quiet respiration, to the nearest 10th of a cm); and *weight* (124, from the subject standing on a scale, to the nearest 10th of a kg).

RESULTS

Mean values for the measured and calculated variables for the various subgroups are shown in Table 1. For the entire sample, the unadjusted cranial capacity was 1,375 cm^3. The range was from 981 cm^3, a black woman, to 1,795 cm^3, a white man.

Analysis of variance (ANOVA) of *unadjusted* cranial capacity measures showed that military rank was highly significant, $F(1, 6313) = 32.98, p < .001$; officers have, on average, larger cranial capacities than do enlisted personnel (weighted Ms = 1,384, 1,374 cm^3; unweighted Ms = 1,387, 1,367 cm^3); sex was highly significant, $F(1, 6313) = 6,634.18, p < .001$; men have, on average, larger cranial capacities than do women (weighted Ms = 1,462, 1,266 cm^3; unweighted Ms = 1,471, 1,282 cm^3). Race was also highly significant, $F(2, 6313) = 16.98, p < .001$; Mongoloids have, on average, larger cranial capacities than Caucasoids, and Caucasoids have, on average, larger cranial capacities than Negroids (weighted Ms = 1,425, 1,382, 1,358 cm^3; unweighted Ms = 1,391, 1,378, 1,362 cm^3). There was also a two-way interaction for Race × Sex, $F(2, 6313) = 9.48, p < .001$; Caucasian men have, on average, a larger cranial capacity than do their Mongoloid counterparts, whereas Mongoloid women have a larger cranial capacity than do Caucasian women. Negroid men and women have smaller cranial capacities than do Mongoloid and Caucasoid men and women (Table 1).

The races, ranks, and sexes differed in average stature and body weight (Table 1). The correlations between cranial capacity and body size within each of the 12 Sex × Rank × Race categories ranged from .22 to .64, with a mean across categories of .40 for stature and .41 for weight. For the entire sample the correlation between body weight and cranial capacity was .66. Because cranial capacity covaries positively with body weight and stature, I did further analyses to determine (a) if the relation between those covariates and cranial capacity differed among the aforementioned categories; and (b) if, after correcting for the effect of the covariates, the categories still differed in cranial capacity. For these analyses, a general linear model (SAS Institute, 1985) was used and significance

TABLE 1
Mean Cranial Capacity (cm^3), Height (cm), and Weight (kg) by Sex, Rank, and Race for 6,325 U.S. Military Personnel

Sex and Rank		Cranial Capacity		Height		Weight	
Race	n	M	(SE)[a]	M	(SE)[a]	M	(SE)[a]
Female, Enlisted							
Negroid	1206	1260	(2.73)	163.0	(0.18)	62.2	(0.23)
Caucasoid	1011	1264	(2.84)	162.9	(0.20)	61.6	(0.25)
Mongoloid	116	1297	(9.38)	158.1	(0.61)	58.6	(0.91)
Female, Officer							
Negroid	89	1270	(10.05)	164.0	(0.66)	64.4	(0.85)
Caucasoid	270	1284	(5.49)	164.7	(0.37)	62.3	(0.55)
Mongoloid	16	1319	(34.20)	157.1	(1.44)	56.2	(2.20)
Male, Enlisted							
Negroid	1336	1449	(2.64)	175.5	(0.18)	78.4	(0.31)
Caucasoid	1302	1468	(2.52)	176.0	(0.18)	77.9	(0.30)
Mongoloid	388	1464	(4.74)	168.9	(0.32)	73.2	(0.60)
Male, Officer							
Negroid	45	1467	(14.17)	176.5	(1.10)	80.3	(1.29)
Caucasoid	288	1494	(5.48)	177.6	(0.39)	80.5	(0.57)
Mongoloid	23	1485	(17.60)	169.4	(1.64)	71.4	(2.05)

[a] ± 1 SE.

tested with Type 3 sum of squares. This procedure tests for the independent effect of a variable in the model by adjusting for the effects of all other variables. The general form of the model was:

Cranial Capacity = Covariate(s), categorical variables, plus all interactions.

Higher order interactions were excluded from the model when nonsignificant and the analysis was repeated. For example, in the model

Cranial Capacity = Stature, Sex, Race, Rank, Interactions,

the four-way interaction was not significant. Thus, the analysis was repeated with only three-way interactions, which also proved to be not significant. But, when the analysis was repeated with only two-way interactions, I found, as I did in most analyses, that a two-way interaction was significant. Thus, I present results of that analysis and a final analysis done with only main effects in the model. For each analysis, the least square mean cranial capacity for each group included in the model is calculated. Because significant two-way interactions involving sex, race, but not rank, frequently resulted, I did separate regressions of cranial capacity on stature and on body weight for each Sex × Race category.

Besides using body weight as a covariate, I also used it to create several new covariates in order to correct for possible sexual and/or racial differences in the relation between cranial capacity and body weight (Table 2). On average, women in good physical condition (which is assumed to be true of military personnel) have about 20% of their body weight as fat whereas only 10% of male body weight is fat. Thus, to account for this difference in largely noninnervated tissue, I subtracted 20% from the body weight of each woman and 10% from that of each man. The new value was termed *Adjusted Weight.*

The exponent in the allometric relation between body weight and mammalian brain weight is not 1.0 (Jerison, 1982) and ranges from .20 in comparisons of similar species to .67 in comparisons of diverse species (Pagel & Harvey, 1989). Thus, I used those two exponents and the constant .12 (Jerison, 1982) as other ways to adjust body weight of each person in the sample:

$$\text{Corrected Weight 1} = .12\ (\text{Weight})^{.67}$$
$$\text{or, Corrected Weight 2} = .12\ (\text{Weight})^{.20}$$
$$\text{or, Corrected Weight 3} = .12\ (\text{Adjusted Weight})^{.67}$$
$$\text{or, Corrected Weight 4} = .12\ (\text{Adjusted Weight})^{.20}$$

After adjusting for the effects of stature and weight, and then race, rank, or sex, Mongoloids averaged 1,416, Caucasoids 1,380, and Negroids 1,359 cm^3; officers averaged 1,393 and enlisted personnel 1,375 cm^3; and men averaged 1,442 and women 1,332 cm^3. None of the adjustments shown in Table 2 altered the overall pattern of the results (see Table 3, p. 408). The results of the analyses

TABLE 2
Summary of Statistical Tests Used to Analyze the Relation Between Cranial Capacity and Sex, Rank, and Race (Predictor Variables) With Various Measures of Body Size (Covariates)

Analysis Number	Model	R^2	Significant Interactions
1	(Raw means)	—	—
2	CC (Males) = Stature, Weight, Race, Rank	.20	None
2	CC (Females) = Stature, Weight, Race, Rank	.20	None
3	CC (Mongoloids) = Stature, Adjusted Weight, Sex, Rank	.50	Stature × Sex
3	CC (Caucasoids) = Stature, Adjusted Weight, Sex, Rank	.64	None
3	CC (Negroids) = Stature, Adjusted Weight, Sex, Rank	.58	None
4	CC (Mongoloids) = Stature, Adjusted Weight, Sex, Rank	.49	(Interactions Deleted)
4	CC (Caucasoids) = Stature, Adjusted Weight, Sex, Rank	.64	(Interactions Deleted)
4	CC (Negroids) = Stature, Adjusted Weight, Sex, Rank	.58	(Interactions Deleted)
5	CC = Stature, Sex, Race, Rank	.58	Sex × Race
6	CC = Stature, Sex, Race, Rank	.58	(Interactions Deleted)
7	CC = Weight, Sex, Race, Rank	.60	Sex × Race; Weight × Sex
8	CC = Weight, Sex, Race, Rank	.60	(Interactions Deleted)
9	CC = Adjusted Weight, Sex, Race, Rank	.60	Sex × Race; Adjusted Weight × Sex
10	CC = Adjusted Weight, Sex, Race, Rank	.60	(Interactions Deleted)
11	CC = Stature, Adjusted Weight, Sex, Race, Rank	.61	Sex × Race
12	CC = Stature, Adjusted Weight, Sex, Race, Rank	.61	(Interactions Deleted)
13	CC = Corrected Weight 1, Sex, Race, Rank	.60	Corrected Weight 1 × Race; Corrected Weight 1 × Sex
14	CC = Corrected Weight 1, Sex, Race, Rank	.60	(Interactions Deleted)
15	CC = Corrected Weight 2, Sex, Race, Rank	.60	Sex × Race; Corrected Weight 2 × Sex
16	CC = Corrected Weight 2, Sex, Race, Rank	.60	(Interactions Deleted)
17	CC = Corrected Weight 3, Sex, Race, Rank	.60	Corrected Weight 3 × Sex
18	CC = Corrected Weight 3, Sex, Race, Rank	.60	(Interactions Deleted)
19	CC = Corrected Weight 4, Sex, Race, Rank	.60	Sex × Race; Corrected Weight 4 × Sex
20	CC = Corrected Weight 4, Sex, Race, Rank	.60	(Interactions Deleted)

Note. All analyses based on Type 3 sum of squares (SAS Institute, 1985). Adjusted Weights: Men = Weight − 10%; Women = Weight − 20%. Corrected Weights: 1 = .12 $(\text{Weight})^{.67}$; 2 = .12 $(\text{Weight})^{.20}$; 3 = .12 $(\text{Adjusted Weight})^{.67}$; 4 = .12 $(\text{Adjusted Weight})^{.20}$. All R^2 significant at $p <$ .0001.

for race and sex (but not for rank) are summarized in Figure 1 (p. 408). They show that the group differences in cranial capacity remain robust despite 19 different ways of controlling for the effects of several variables and their interactions.

TABLE 3
Ranges of Least Square Means From all Analyses Wherein Race, Sex, and Rank Were Examined Together (Analyses 5–20 in Figure 1)

Sex and Rank Race	Range (All Groups–Corrected for Size)
Female, Enlisted	
Negroid	1288–1319
Caucasoid	1299–1330
Mongoloid	1326–1387
Female, Officer	
Negroid	1293–1324
Caucasoid	1315–1346
Mongoloid	1341–1417
Male, Enlisted	
Negroid	1405–1424
Caucasoid	1419–1445
Mongoloid	1464–1473
Male, Officer	
Negroid	1400–1438
Caucasoid	1429–1453
Mongoloid	1463–1487

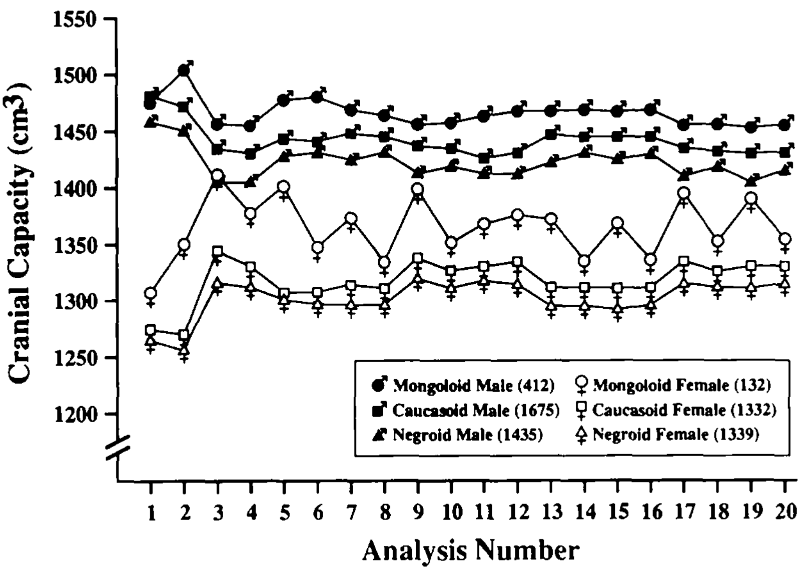

Figure 1. Cranial capacity figures for six Sex × Race groupings collapsed across rank for 20 different analyses (see Table 2).

I also carried out several additional analyses, none of which made a difference to the pattern shown in Table 3 or Figure 1. For example, ANOVAs carried out separately within each sex, while covarying the effects of age and body-surface area in addition to stature, weight, and rank, produced adjusted cranial capacities for Mongoloid men of 1,486, for Caucasoid men of 1,462, and for Negroid men of 1,441 cm^3. For women, the adjusted cranial capacities were 1,319, 1,259, and 1,250 cm^3, respectively. Combining the sexes yielded 1,403 for Mongoloids, 1,361 for Caucasoids, and 1,346 cm^3 for Negroids.

DISCUSSION

The data from this study join those from other investigations to support the view that human populations differ in brain size. The data are recently gathered, they are massive, and they considerably narrow the margin of uncertainty on conclusions about brain-size differences. As one reviewer noted, they may be the most valuable set of data in this whole literature. The major source of variation in the data was sex; race was second, and rank last. Interactions explained very little of the variance (see R^2 values, Table 2).

The human brain is a metabolically expensive organ, using nearly 20% of the body's basal metabolic rate, but representing only 2% of body mass. It could be argued, therefore, that unless large brains substantially contributed to evolutionary fitness (defined as increased survival of genes through successive generations), they would not have evolved. One view is that big brains add fitness by increasing the speed and efficiency with which information is processed. Evidence for the relation between brain size and mental ability was presented in the Introduction.

Examining why some populations have larger brains than others may shed light on evolutionary processes (Wilson, 1975). Across species, the evolution of a bigger brain typically demands a more stable environment, longer gestation, higher offspring survival, lower reproductive output, and longer life (Pagel & Harvey, 1988). Some of the population variance within the human species may reflect such life history differences. Rushton (1988) found that Caucasoids average consistently between Mongoloids and Negroids not only in brain size, but also in intelligence test scores, speed of maturation, personality traits, reproductive effort, social organization, and other life-cycle traits. The selection pressures leading to racial differences may be similar to those leading to SES and military rank differences (Rushton, 1985; see also Lynn, 1987).

Whereas brain size may mediate the known mental ability differences among social rank and racial groups, sex differences are hardly thought to exist in general intelligence. However, two recent studies examining sex differences in the standardization samples of the WISC-R showed boys to have nearly 2 IQ points more than girls in Full-Scale IQ, in both Scotland (Lynn & Mulhern, 1991) and in the United States (Jensen & Reynolds, 1983). More often, a compensatory model is proposed. Although men are considered to be better on spatial visualization tasks, tests of mathematical reasoning, and motor skills requiring accurate targeting of distant stimuli, such as throwing, women are considered to excel on certain verbal activities, to be faster in "perceptual speed" (matching identities), and to be better in fine eye–hand motor coordination (Jensen, 1980; Kimura & Hampson, in press). Men also show more variance than women on many tests with a higher representation at both extremes of the distribution (Jensen, 1980).

The most striking observation from our analyses involves sex differences that show almost no overlap in distribution. This is opposite to the findings with IQ where sex differences are a small-magnitude phenomenon as compared with racial and social class differences (Jensen, 1980). Because brain weight (g) = 0.87 cm^3 (Jensen & Sinha, in press), the sex difference of 110 cm^3 (96 g) observed here is remarkably similar to the one of 100 g obtained by Ankney (1992), who reanalyzed Ho et al.'s (1980) autopsy study of 1,216 men and women aged 25 to 80 years. These results may be best understood, as Ankney suggested, within the context of evolutionary pressures for sexual dimorphism in the hunter-gathering society in which human brains evolved. Men roamed from the home base to hunt, which would select for accurate targeting ability and navigational skills; women were relatively stationery, taking care of children as well as attending to food, clothing, and household activities. This scenario has been suggested as explaining the male advantage in spatial ability (Jardine & Martin, 1983; Kimura & Hampson, in press; Kolakowski & Malina, 1974). It may simply require more neurons to process spatial information.

It is not known, however, whether women have fewer neurons than do men; there may be greater cortical packing density in women, and thus, it is myelin thickness or some other variable that is responsible for the sex difference in brain size (Haug, 1987). More generally, as Lee and Pearson (1901) conjectured so long ago, it may be the complexity of the convolutions of the brain, and the variety and efficiency of its commissures, rather than its actual size, that is related to intellectual ability and that differentiates populations. Work such as that of Willerman, Schultz, Rutledge, and Bigler (1992) using magnetic resonance imaging techniques should soon be able to answer these questions more fully.

One reviewer questioned the validity of using the "antiquated 1901 technology" of measuring heads externally and using regression equations to predict internal capacity. He worried, in particular, that the sex difference was an artifact of the panracial equations, presented in the Method section, having added constants that are twice as large for men as for women. This, however, is to misconstrue the nature of a regression equation with its compensatory multiplicative coefficients at the beginning and constants at the end providing the "best fit" for varying data sets.

Inspection of Table XVIII in Lee and Pearson (1901, p. 244) shows that the equations we used predicted male and female cranial capacity with equally small errors, that is, < 1%. These errors *averaged* 2 to 5 cm^3 on cranial capacities of 1,300 to 1,500 cm^3, an average error rate considerably less than the typical error of two observers measuring the same series of skulls using an internal "packing" procedure (with sand, seed, or shot) where averages differed by 30 cm^3 (p. 245). And, of course, as Lee and Pearson stated: "The averaging of a number of series would tend to eliminate the large personal equations [nonsystematic error] which I feel sure exist in measurements of this kind" (p. 246). Our U.S. army data obviously constitute an enormously large series based on well-standardized head measurements.

Most importantly, the accuracy of the predictions from Lee and Pearson's (1901) regression equations can be validated against other data. As noted, the 110-cm^3 (96-g) difference between the sexes found in our military data using equations from 1901 are virtually identical in magnitude to the 100-g difference found in Ankney's (1992) reanalysis of Ho et al.'s (1980) autopsy data based on totally different procedures. Such congruences cannot occur with equations that produce unreliable results. Additional validity information is provided by finding the racial group and military SES differences so much in accord with existing data. Lee and Pearson (1901) should be consulted for additional validity information on their equations (e.g., p. 244, Table XIX). Their various formulas have also been used in other studies to provide meaningful results (e.g., Passingham, 1979; Rushton, 1991). The results, reported here, of course, constitute only one set of data. Those who wish to challenge them should do so with even better data including those derivable from more recent technologies.

To conclude, human populations differ in relative cranial capacity, that is, cranial capacity corrected for body size. Mongoloids average larger than Caucasoids, who average larger than Negroids; officers average larger than enlisted personnel, and men average larger than women. It must be emphasized, however, that there is enormous overlap in most distributions (Loehlin, 1992). For example, because race is only a weak predictor of cranial capacity (a 4% difference between the Mongoloid and Negroid average in this study) and head size is a weak predictor of intelligence (r = .30), it is clearly problematic to generalize from a racial group average to any particular individual. However, because there is about a .30 correlation between head size and intelligence test scores, these systematic and possibly causal relationships are of great scientific interest.

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