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RACE, BRAIN SIZE AND INTELLIGENCE: A REJOINDER TO CAIN AND VANDERWOLF

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Summary—Cain and Vanderwolf (*Personality and Individual Differences 11*, pp. 777–784, 1990) commit a Grand Type II Error in denying the relation between the variables juxtaposed in the title of this rejoinder. This reply (a) presents 20 studies showing a positive correlation between brain size and IQ, one of which used magnetic resonance imaging to scan the brain, (b) re-examines whether the races differ in brain size from data not previously presented including a reanalysis of a 1930 study using external head measurements and a 1984 study of endocranial volume and confirms that the ranking is Mongoloids > Caucasoids > Negroids, (c) suggests that when the appropriate brain-body allometric regressions are taken into account, sex differences in brain size disappear while race differences remain, and (d) explains the evolution of brain size, intelligence and race from a broad-based r/K life-history perspective.

INTRODUCTION

> "No one, I presume, doubts that the large size of the brain in man, relatively to his body, in comparison with that of the gorilla or orang, is closely connected with his higher mental powers. We meet with closely analogous facts with insects, in which the cerebral ganglia are of extraordinary dimensions in ants; these ganglia in all the Hymenoptera being many times larger than in the less intelligent orders, such as beetles. . . .
>
> The belief that there exists in man some close relation between the size of the brain and the development of the intellectual faculties is supported by the comparison of the skulls of savage and civilized races, of ancient and modern people, and by the analogy of the whole vertebrate series".
>
> CHARLES DARWIN, Vol. 1, pp. 145–146, 1871.

While Darwin's data were considerably poorer than those now available, his judgement was accurate. Moreover, he knew that continuity across individual, sub-species, and species differences were essential for his theory of evolution, for without such variation natural selection would have nothing to act on. Darwin's ideas were applied immediately to human faculties by his half-cousin Francis Galton (1869, 1883), the founder of both the biometric tradition in genetics and the psychometric one in psychology. In his Anthropometric Laboratory Galton pioneered many measurement techniques including those of head size; during the 1880s and 1890s more than 17,000 individuals of all ages from diverse walks of life were tested. This tradition was continued by his protegé Karl Pearson in the journal *Biometrika* which they jointly established in 1901 to promulgate statistical techniques for the study of biological variation.

The hypothesis that differences in brain size may mediate differentials in cultural achievement thus has notable origins which historical and ideological events, rather than scientific ones, have largely negated (Rushton, 1990). From the beginning, the data suggested a racial ranking. Thus Lee and Pearson (1901, p. 246, Table XX) provided cranial capacities for 941 men and 516 women of various ethnic groups which I averaged (by first taking an n weighted average within sex, then adding across the sexes, and finally dividing by 2) to observe Mongoloids averaged 1385, Caucasoids averaged 1371, and Negroids averaged 1343 cm^3. Early studies using culture-reduced maze-tracing performance tests, suggested that this was also the ranking for intelligence (Porteus, 1937, e.g. p. 223).

A previous debate on race, brain size and intelligence was limited by time pressures, then space allowance (Rushton, 1988a, b; Zuckerman & Brody, 1988). The present exchange, following on several at The University of Western Ontario, examines the hypotheses more fully although it is unfortunate that Cain and Vanderwolf (1990) did not incorporate previous rebuttals to their position (e.g. Cain, 1989a, b; Vanderwolf, 1989; Rushton, 1989a, b, c). These rebuttals included (a) the study of brain size using magnetic resonance imaging by Willerman, Shultz, Rutledge and Bigler (1989), (b) the demonstration that white infants have heavier brains than black infants when the data are considered across all gestation times, (c) the comprehensive study of 20,000 endocranial specimens from around the world by Beals, Smith and Dodd (1984), (d) the fact that when body size is taken into account sex differences in brain size disappear but race differences do not, and (e) the analysis of the evolution of brain-body ratios in mammals by Pagel and Harvey (1988). This rejoinder follows the order of Cain and Vanderwolf's (1990) critique, as outlined in the summary.

BRAIN SIZE AND INTELLIGENCE

On the basis of reviews by Van Valen (1974) and Passingham (1982), Rushton (1988a) concluded: "It seems reasonable, therefore, to assume a positive relation between brain size and intelligence" (p. 1010). Cain and Vanderwolf (1990) pick away at this conclusion stating that Van Valen had only 'estimated' a correlation of 0.30 not 'calculated' it, that the empirical findings showed a 0.10 correlation which it was dubious to correct for measurement error, that the assessments of intelligence were often crude, etc. However, as shown in Table 1, there have been at least 20 investigations of the question, some quite recent, including two by Bogaert and me. Ours were carried out on university students with intelligence adequately measured by Jackson's (1984) *Multidimensional Aptitude Battery* and with maximal horizontal head circumference measured by tape. The correlations between IQ and head circumference after controlling for the effects of sex and stature were $r = 0.18$ and 0.20 ($P < 0.01$).

Of importance to note in Table 1 is the study by Willerman *et al.* (1989) who, after controlling for stature, found (a) a tape measure of head circumference correlated $r = 0.17$ with IQ and (b) magnetic resonance imaging of brain size correlated $r = 0.35$ with IQ. Measuring head size by tape and ignoring skull thickness or head height can be, of course, only a very crude estimate of the size of the internal brain. However, in light of these consistent findings, many of which controlled for the effects of age, stature etc. and used *S*s with a restricted range of scores, there seems little reason to alter Van Valen's (1974) estimate that, after corrections are made for the imperfect reliability of intelligence tests and for head circumference as a measure of brain size, that the 'true' figure is about 0.30. Even head circumference at birth relates to (a) brain weight at birth measured by autopsy, (Cooke, Lucas, Yudkin & Pryse-Davies, 1977; Winick & Rosso, 1969), and (b) to IQ at age 4, (Broman, Nichols & Kennedy, 1975).

A relation between brain size and intelligence is also supported by well known parallels between age trends in IQ and brain size, both of which increase during childhood and early adolescence,

Table 1. Summary of studies on head size and intelligence

Reference	Sample		Correlation r
Pearson (1906)	4486	British children	0.11
Pearson (1906)	1011	British university students	0.11
Pearl (1906)	935	Bavarian soldiers	0.14
Murdoch and Sullivan (1923)	595	American children	0.19
Reed and Mulligan (1923)	449	university students	0.08
Sommerville (1924)	105	university students	0.10
Porteus (1937)	200	Australian children	0.20
Schreider (1968)	326	French farmers	0.23
Klein *et al.* (1972)	170	Guatemalan children	0.27
Weinberg *et al.* (1974)	334	American boys	0.35
Broman *et al.* (1975)	26,760	American children	0.17
Fisch *et al.* (1976)	2010	American children	0.23
Passingham (1979)	415	British adults	0.03
Susanne (1979)	2071	Belgian conscripts	0.19
Henneberg *et al.* (1985)	302	Polish students	0.14
Lynn (1989)	310	Irish children	0.18
Bogaert and Rushton (1989)	216	Canadian university students	0.18
Rushton and Bogaert (1990)	284	Canadian university students	0.20
Willerman *et al.* (1989)	40	American university students (a)	0.17*
		(b)	0.35†

*(a) Measured by tape.

†(b) Measured by magnetic resonance imaging.

then slowly and finally more quickly decrease. The average weight of the brain increases rapidly from 397 g at birth to 1180 g at age 6 yr (Ho, Roessman, Straumfjord & Monroe, 1980a). Growth then slows, and the brain weight reaches a peak of about 1450 g around age 25 yr. The weight declines slowly but in a steady fashion from age 26 to 80 yr, an average of 2 g/yr; after 80 yr, the loss is 5 g/yr. These relations between age, intelligence, brain size and head size have been considered for decades (Pearson, 1906).

Finally, evidence for the relation between intelligence and head size comes from the parallel between the increase in head size in the populations of the economically advanced nations over the course of the last half century and that of intelligence test scores. The head circumference of babies, children and young adults has increased by around 1–2 cm in Britain, Japan and Hong Kong, perhaps as a result of improvements in nutrition together with a reduction in infectious diseases (Lynn, 1990) or perhaps as a result of outbreeding vigor and other variables. Whatever the causes, the increases in head size over the last 50 yr are of the order of 1 SD and may well be the principal factor in the secular increases of approximately the same magnitude which have taken place in intelligence over the same time period (Lynn & Hampson, 1986; Flynn, 1987). Converging sources of evidence thus support the relation between brain size and IQ.

BRAIN SIZE AND RACE

After averaging across several published data sets Rushton (1988a) concluded that for sex combined cranial capacity, typically measured from inside the skull, Mongoloid populations averaged 1448, Caucasoids 1408, and Negroids 1334 cm^3; and for sex combined brain weight measured at autopsy, Mongoloids averaged 1351, Caucasoids 1336, and Negroids, 1286 g. Converging validity can be demonstrated for these independently derived sets of figures by estimating brain weight from cranial capacity using an equation given by Baker (1974, p. 429):

$$\text{Brain weight [g]} = 1.065\ \text{cm}^3 - 195$$

Using this formula, the Mongoloid 1448 cm^3 becomes 1347 g, the Caucasoid 1408 cm^3 becomes 1305 g, and the Negroid 1334 cm^3 becomes 1226 g, all similar to the directly measured brain weights. Most of the evidence comes from skull size, for as Baker (1974) remarks, "Skulls are many, freshly removed brains few" (p. 429).

In a reply to Zuckerman and Brody's (1988) critique of these data, Rushton (1988b) added estimates of the number of 'excess neurons' available to different populations for processing information after dealing with body functioning, to find, in millions of excess neurons: Mongoloids averaged 8900, Caucasoids averaged 8650, and Negroids averaged 8550. Estimated racial differences involving millions of neurons might be sufficient to underlie some of the observed cultural differences. While the existing data are far from perfect, none the less, from around the world they consistently incline toward the reported rank ordering. What is required now is better data, as could be gained from the new computer-assisted brain imaging techniques increasingly available.

Despite the consistency of converging evidence based on thousands of data points from around the world, Cain and Vanderwolf (1990) object to the averages presented because some of them (a) originate from 'suspect' secondary sources which failed to control variables such as age, sex, nutrition, height, cause of death, etc., (b) did not take into account the intentions of the original authors, (c) are based on inappropriate averaging procedures, and (d) highlight a racial difference while ignoring an equally large sex difference for which there is no apparent differential in IQ score.

Cain and Vanderwolf (1990) begin by referring to the study by Herskovits (1930) which Zuckerman and Brody (1988) had used to provide apparent examples of how different orderings of race by brain size could be made in order to support the null hypothesis. Rushton (1988b) dismissed Zuckerman and Brody's presentation for its use of "uncertain measures of brain size . . . which, in any case, found no difference" (p. 1035). Because Cain and Vanderwolf (1990) cite Zuckerman and Brody (1988) favorably on this issue, let us consider the Herskovits study more fully. Table 2 summarizes the data from Herskovits (1930) for length, width and height of head for various male populations which I categorized by race or geographical area with the aid of *The Human Relations Area Files* (Murdock, Ford, Hudson, Kennedy, Simmons & Whiting, 1961). For length, spreading calipers were used to measure the maximum from glabella to opisthocranion; for

Table 2. Cranial capacities† in cm^3 calculated from head length and width (mm) provided by Herskovits (1930) for various male samples and classified by race or geographical region

		Length		Width		Height		
		Mean	SD	Mean	SD	Mean	SD	Capacity
Mongoloids and Asian								
540	Pure Sioux	194.90	6.16	155.10	5.39	—	—	1653
77	Half-blood Sioux	194.40	7.12	154.30	5.04	—	—	1641
50	Montagnais-Naskapi	194.00	6.92	157.10	4.55	134.00	4.67	1670
83	Marquesans	193.20	7.00	153.20	4.87	—	—	1620
86	Hawaiians	191.25	7.22	158.93	4.80	—	—	1672
—	Chinese	—	—	—	—	124.00	—	—
	Mean	193.55		155.73		129.00		1651
Caucasoids and European								
727	Old Americans	197.28	6.04	153.76	5.20	140.50	5.82	1654
263	Scotch foreign-born	196.70	5.90	153.80	4.70	—	—	1651
959	Oxford students	196.05	6.23	152.84	4.92	—	—	1635
493	Aberdeen students	194.80	5.73	153.40	4.69	—	—	1633
46,975	Swedes	193.84	6.19	150.40	5.10	—	—	1593
1000	Cambridge students	193.51	6.16	153.96	5.05	—	—	1631
802	Cairo natives	190.52	5.90	144.45	4.67	—	—	1502
450	Foreign-born Bohemians	189.80	6.40	159.10	5.90	—	—	1665
100	W.R.U. White cadavera	188.30	7.52	—	—	—	—	—
60	American-born Bohemians	188.00	6.20	156.50	5.20	—	—	1623
2348	English criminals	—	—	—	—	132.29	8.01	—
—	Egyptians	—	—	—	—	132.00	—	—
—	Lithuanians	—	—	—	—	131.00	—	—
	Mean	192.88		153.13		133.95		1621
Negroids and African								
961	American Negroes	196.52	6.51	151.38	5.74	134.02	4.64	1622
91	Masai	194.67	5.28	142.49	5.37	—	—	1508
34	Lotuko	192.90	6.05	141.30	4.70	—	—	1482
100	W.R.U. Negro cadavera	192.60	6.08	—	—	—	—	—
55	Kajiji	192.31	6.72	144.56	4.66	—	—	1515
27	Somali	191.81	4.75	143.19	4.34	—	—	1496
19	Ekoi	191.05	4.11	143.16	5.42	146.40	8.02	1491
110	Embu	189.08	6.52	—	—	—	—	—
40	Vai	188.85	6.25	142.45	5.07	—	—	1468
384	Akikuyu	188.72	6.13	143.25	4.93	—	—	1476
72	Kagoro	188.19	6.12	142.43	4.07	—	—	1463
128	Akamba	187.80	5.24	143.63	5.09	—	—	1474
48	Ashanti	187.33	4.66	145.01	4.41	—	—	1487
30	Acholi	187.30	6.05	141.80	4.60	—	—	1450
50	Bahiru	—	—	—	—	123.24	—	—
—	Bugu	—	—	—	—	120.00	—	—
—	Batua	—	—	—	—	118.00	—	—
	Mean	190.65		143.72		128.33		1495

†Cranial capacity (cm^3) = 6.752 × L (mm) + 11.421 × W (mm) − 1434.06 (from Lee and Pearson, 1901).

width, spreading calipers to measure the maximum from euryon to euryon; and for height, a head-spanner to estimate bregma height from a point in a line perpendicular to another line lying on the eye–ear plane. Unfortunately data were not provided on stature or body weight.

A variety of formulae exist for estimating cranial capacity from external head measurements. Thus, Lee and Pearson (1901, p. 252) provide a formula (Number 14) for calculating male cranial capacity (CC) across different races:

$$\mathrm{CC}\ (\mathrm{cm}^3) = 0.000337\ (L - 11\ \mathrm{mm})(B - 11\ \mathrm{mm})(H - 11\ \mathrm{mm}) + 406.01$$

where L, B, and H are length, breadth, and height in millimeters and 11 mm is subtracted as representing the average skull thickness. (For discussion on the validity of using external head measurements for estimating brain size and the relation of brain size to height and intelligence see Lee & Pearson, 1901, and Jensen & Sinha, 1990). Herskovits (1930) provides complete data on these three externally measured head-size variables for only four samples: one Mongoloid, one Caucasoid, and two Negroid. Applying the formula we find Mongoloids = 1514, Caucasoids = 1567 and Negroids = 1489 cm^3. Averaging all the lengths, widths and heights within each of the racial categories and applying the formula to the resulting means, we find Mongoloids average 1457, Caucasoids average 1477, and Negroids average 1349 cm^3.

Because the data for height of head are so incomplete, we can use more of the data to estimate cranial capacity (CC) with a formula from Lee and Pearson (1901, p. 235, Table VII, Number 5) based on German males, as also used by Passingham (1979):

$$\mathrm{CC}\ (\mathrm{cm}^3) = 6.752 \times L(\mathrm{mm}) + 11.421 \times B(\mathrm{mm}) - 1434.06$$

The results of applying this formula to each sample are shown in the fourth full column of Table 2 such that Mongoloids average 1651 cm^3 ($n = 5$, SD = 20), Caucasoids average 1621 cm^3 ($n = 9$, SD = 49), and Negroids average 1495 cm^3 ($n = 12$, SD = 44). While these estimates based on males are on the high side of the estimates made from internal measures, the rank ordering is as predicted by Rushton (1988a) and not as predicted by Cain and Vanderwolf (1990).

If each of the sample means is treated as an independent entry, a 1-way ANOVA reveals that overall the races differ significantly in brain size [$F(2,23) = 33.66$, $P < 0.001$] with a highly significant trend in the predicted direction, Mongoloids > Caucasoids > Negroids [$F(1,23) = 60.57$, $P < 0.001$]. For readers preferring a non-parametric analysis, a χ^2 can be calculated for the number of scores in each group above the median of the combined population (i.e. 1607 cm^3). When this is done, the Mongoloids have 5/5 above the median, the Caucasoids 7/9 above the median, and the Negroids 1/12 above the median, and the calculated $\chi^2 = 16.11$ (d.f. = 2, $P < 0.001$). It must be concluded from Herskovits' (1930) data, therefore, that while Negroid samples average the smallest head size of the three groups, the ranking of Mongoloid and Caucasoid samples varies; with more data cumulated, Mongoloids average largest.

How then is it possible for Zuckerman and Brody (1988) and Cain and Vanderwolf (1990) to cite the Herskovits study against the Rushton (1988a, b) conclusions? The answer lies in inappropriate data selection. By choosing Negroid samples having the largest head length and width, and Caucasoid samples having intermediate lengths and widths, the racial rank ordering seen by Rushton (1988a) can be missed. The data presented in Table 2, collected by different investigators, contains much error due to 'the personal equation'. It is better, therefore, to use the principle of aggregation and average across the numerous exemplars. The sum of a set of multiple measurements is a more stable and unbiased estimator than any single measurement from the set because aggregating causes specificity and error variance to cancel out, leaving only true score variance to remain. This obvious principle, known since the 19th Century, requires continual repetition (e.g. Rushton, Brainerd & Pressley, 1983).

Cain and Vanderwolf (1990) cite as 'suspect' the endocranial data Rushton (1988a) averaged from Coon (1982) and Molnar (1983) because these were based on secondary sources and it is "impossible to know where all of the data came from". However, Coon's data were based on detailed information provided by Howells (1973) after a tour of the world's museums which can be consulted for sample characteristics and dimensional measurements. Coon's book begins with a Preface from Howells warning readers not to be too easily dismissive. Molnar's data are based on that of anthropologist Ashley Montagu, by anybody's standard no friend of the study of race differences. This latter work was cited because I judged it to be the 'received view' of standard anthropology texts.

Cain and Vanderwolf (1990) make much of the endocranial data and analyses by S. J. Gould, the Harvard paleontologist and anti-sociobiological ideologue, as have other critics of the view that the races differ in brain size (e.g. M. Lynn, 1989a, b). Consider, therefore, the data in Table 3. The first column presents Gould's (1978) 'corrected' figures from a paper alleging 'unconscious ...

Table 3. S. J. Gould's 'corrected' final tabulation of Morton's assessment of racial differences in cranial capacity

	Cubic inches	
Population	1978 version	1981 version
Native Americans	86	86
Mongolians	85	87
Modern Caucasians	85	87
Malays	85	85
Ancient Caucasians	84	84
Africans	83	83

finagling' and 'juggling' of internally measured cranial capacity measures in the work of S. G. Morton (1799–1851), America's great 19th Century contributor to physical anthropology. The second column presents Gould's (1981) update of these figures after he acknowledges that his biases incline him to making directional errors. In both his 1978 and 1981 writings, Gould dismisses the difference in Table 3 as 'trivial'. When the principle of aggregation is applied to Gould's figures, however, the results show that in size of brain case, Mongoloids (Native Americans + Mongolians) > Caucasoids (Modern Caucasians + Ancient Caucasians) > Negroids. After excluding 'Malays' due to uncertainty as to their racial category, the figures from column 1, in cubic inches, average 85.5, 84.5, and 83, respectively, and from column 2, 86.5, 85.5, and 83, respectively. (The figures do not change appreciably if Malays are included as either Mongoloids or Caucasoids.) Endocranial differences of 1 or more cubic inch (16 cm^3) should not be dismissed as 'trivial'. Gould's analysis and conclusions are misleading.

If one accepted Cain and Vanderwolf's argument that it is unjustified to combine Ancient Caucasians with Modern Caucasians (although this is standard practice in contemporary anthropology; Michael, 1988), this would leave a 4 in^3 difference in internally measured cranial capacity between Mongoloids and Caucasoids on the one hand and Negroids on the other. Even if this is somewhat overestimated, the residual cannot be ignored. Moreover, if body stature is controlled, the rank ordering would again place Mongoloids ahead of Caucasoids because in stature, at least in the United States, Negroids and Caucasoids > Mongoloids (Eveleth & Tanner, 1976).

Cain and Vanderwolf (1990) cite Michael's (1988) examination of Gould's analysis of Morton's data. Michael (1988) remeasured a random sample of the Morton collection of human crania to check Gould's charge that Morton 'unconsciously' doctored his results to show Caucasian racial superiority and found that, in fact, very few errors occurred and these were not in the direction Gould had asserted. Instead, errors were found in Gould's assessment, and Michael concluded that "Morton's research was conducted with integrity . . . (while) . . . Gould is mistaken" (p. 353). Morton was trying to understand racial variation and not, as Gould claimed, trying to prove Caucasian superiority. Cain and Vanderwolf (1990) do not emphasize Gould's unreliability as a scholarly guide, but instead cite Michael's belief that a failure to define 'race' makes Morton's work scientifically meaningless. But it is the very predictability of 'race' across diverse measurements which makes the concept useful. To ignore it not only obscures higher level conceptual order but totally neglects the approach of population biologists studying other species (see Mayr, 1970, pp. 186–204).

The predictability of race also overrides Cain and Vanderwolf's (1990) discussion of the work of Tobias (1970). Tobias, like Gould, set out to destroy certain 'myths'. Tobias concentrated on wet brains and drew conclusions that applied primarily to wet brains. He ignored the more extensive data on the less error-prone internally measured cranial capacity and he enumerated a long list of variables that could be confounding the observed relationship between race and brain weight, a list reiterated by Cain and Vanderwolf. The fact is, however, that when all these apparently error-filled data are averaged by taking the mean of the midpoints of the ranges (not quite the problematic procedure that Cain and Vanderwolf imply), the brain weight data parallel those obtained from skulls, with Mongoloids and Caucasoids larger than Negroids. If the results are due to 'true score' variance being swamped with 'error' variance as Cain and Vanderwolf claim, the ordering sometimes should be the complete opposite to that found. Random errors of measurement are normally distributed.

Then we turn to the data by Ho *et al.* (1980a, b) and Ho, Roessman, Hause and Monroe (1981) who avoided most of the problems cited by Tobias (1970) and provided original brain weight data for 1261 adult *S*s aged 25–80 and for 782 infants collated from autopsy records after excluding those brains obviously damaged. These authors reported significant sex-combined mean differences between 811 American whites (1323 g, SD = 146) and 450 American blacks (1223 g, SD = 144), a differential which held when controlling for age, stature, body weight, and total body-surface area. This 100 g difference gathered under well controlled conditions, as acknowledged by Cain and Vanderwolf, can validate the externally measured cranial capacity figures calculated in Table 2. Brain weight in grams may be estimated from externally assessed cranial capacity by multiplying the capacities by 0.87 (Jensen & Sinha, 1990; the earlier cited formula by Baker is used when capacity is estimated *internally*, e.g. through mustard seed). Thus the Caucasoid 1621 cm^3 becomes

1410 g and the Negroid 1495 cm^3 becomes 1301 g, a difference of 109 g, showing once again, much consistency.

With the infant data, Ho *et al.* (1981) found that, on average, the white babies had heavier brains than the black babies: 274 and 196 g, respectively. It is true that many of these babies were premature (49% of the white sample, 77% of the black sample) and that if a gestational age of 38 weeks or more is imposed to define 'full term', these infant differences disappear. However, since black babies have a biologically based shorter gestation than whites (for example, they are physiologically more mature than white babies even at earlier births; Papiernik, Cohen, Richard, De Oca & Feingold, 1986), the advisability of imposing a 38 week criteria on all cases can be doubted. It is also true that Ho *et al.* themselves prefer an environmental explanation for their findings but this in no way diminishes the accuracy of the general observation. Furthermore, if trait differences fail to show up at birth this does not imply that their later emergence is not genetic.

Cain and Vanderwolf's final table is quite inappropriate and only illustrates once more the importance of taking proper averages. Their stated purpose in selecting a 1923 series of Caucasoid crania to compare with a 1986 Negroid series is "to illustrate that by drawing from other studies one can arrive at different conclusions than Rushton did" and to show that Negroid crania were 'sometimes' greater than Caucasoid crania. Yet their own data show Negroid adults have the smallest brains. After converting the cubic centimeters to grams using the formula from Baker (1974) cited earlier, and then taking a simple average across the sexes and measures, we find Mongoloids = 1297 g, Caucasoids = 1304 g, and Negroids = 1199 g, a difference of 100 g between the Negroids and the other two populations.

Since the Rushton (1988a, b) reviews were published, a comprehensive new analysis has come to my attention. With respect to internally measured cranial capacity, Beals *et al.* (1984, p. 306, Table 2) computerized the entire world database of 20,000 crania gathered by 1940 (after which data collection virtually ceased because of its presumed association with racial prejudice), grouped them by continental area, and found statistically significant differences. Sex-combined brain cases from Asia averaged 1380 cm^3 (SD = 83), Europe averaged 1362 cm^3 (SD = 35), and Africa averaged 1276 cm^3 (SD = 84). The difference between these estimates and those reported by Rushton (1988a) is due in part to Beals *et al.* (1984) making a standard 6% reduction for the data gathered using Broca's method of filling the crania with shot so as to make them comparable to the more numerous data gathered using mustard seed. When this 6% reduction is taken into account, the confirmation of the pattern found by Rushton (1988a) seems striking. Thus estimates from diverse sources converge to show that in brain size, Mongoloids > Caucasoids > Negroids.

BRAIN-BODY ALLOMETRIC REGRESSIONS

Cain and Vanderwolf (1990) assert that because there is a significant difference in brain size between women and men for which no apparent difference in IQ score exists it is therefore not logical to interpret race differences in brain size as mediating intelligence. The unworthiness of this argument has been pointed out twice before (Rushton, 1989a, b) which Cain and Vanderwolf ignore. Consider the data by Ho *et al.* (1980a) which showed a 136 g difference between women and men and a 100 g difference between blacks and whites. When body height, weight and surface area were controlled for by Ho *et al.* (1980b), the sex difference in brain size was removed but the race difference in brain size remained. So there is really nothing that needs to be explained about the sex difference as compared with the race difference, when body size is properly controlled.

Similar considerations concern the comparison across species. Absolute brain size cannot be the crucial variable because some mammals such as elephants have larger brains than humans. Most of these larger brains, however, go to control larger bodies. It is for this reason that attempts are made to scale brains to bodies using ratios such as the encephalization quotient (EQ) (Jerison, 1973; Passingham, 1982). These were discussed in Rushton (1988a). Cain and Vanderwolf (1990) reject these attempts at scaling as 'inadequate' because there are deviations from the straight line drawn among species. This is pedantry. Advances in knowledge and empirical improvements in goodness-of-fit have also occurred since Jerison's (1973) original efforts. When the slope is fitted across species from different orders, brain to body ratios are now thought to scale with a 0.75 exponent, not the 0.67 previously believed; slopes fitted to species of the same genus are now thought to be about 0.20 to 0.40 (Pagel & Harvey, 1988, 1989). The important point is that by most standards humans have very large brains, a fact which it is incumbent on scientists to explain.

THE EVOLUTION OF BRAIN SIZE, INTELLIGENCE AND HUMAN RACIAL DIFFERENCES

The human brain is a metabolically expensive organ, using 20% of the body's supply of energy while representing only 2% of body mass. Unless large brains substantially contribute to fitness, therefore they would not have evolved. One view is that big brains add fitness by increasing the speed and efficiency with which information is processed, including as measured using conventional IQ tests. Support for this view comes from studies showing that IQ scores behave like a Darwinian fitness character, demonstrating genetic dominance in studies of inbreeding depression in cousin marriages in Japan (Jensen, 1983) and hybrid vigour in Caucasoid–Mongoloid crosses in Hawaii (Nagoshi & Johnson, 1986). Moreover inbreeding depression scores calculated from children in Japan are found to predict the magnitude of the Negroid–Caucasoid difference on the same tests in the United States (Rushton, 1989d). This implies that genetic influences on intelligence are more robust across populations, languages, time periods and measurement specifics than has previously been acknowledged.

Across species, brain size seems to have evolved as part of a package of life-history characteristics. Building a bigger brain demands a more stable environment, a longer gestation, a higher offspring survival, a lower reproductive output, and a longer life (Pagel & Harvey, 1988). It is within this r/K life-history context that we should seek a unifying principle to order the interfaces among the neurosciences, psychology, and population biology. Thus as populations moved north, they may have encountered more predictable and more challenging environments, including the ice ages which ended only about 10,000 yr ago, and these environments may have selected for larger brains. Predictable environments are an ecologial precondition for K-selection. Tropical savannahs, due to sudden droughts and devastating viral, bacterial, and parasitic diseases, are generally less predictable for long lived species than are temperate and Arctic conditions. Although the Arctic climate varies greatly over 1 yr, it is highly predictable among years. Social class differences, in turn, may arise because of intra-group competition with those at the higher end having the edge on fitness when selection pressures mount.

Adjunct, non-exclusionary views have also been put forward. For example, Beals *et al.* (1984) interpreted their impressive collation of the worldwide data on human cranial capacity in terms of thermoregulation, arguing that it is easier to keep large heads warm and small heads cool. Their regression analyses showed increments of about 2.5 cm^3 in cranial capacity per degree of distance from the equator. Altogether, temperature explained 30–40% of the variance of their Asian > European > African data. Their perspective does not account for the within-group differences nor the 3-fold increase in hominid brain size over the last 3 million yr.

CONCLUSION

The hypothesis that the more complex the nervous system and the larger the brain the more complex will be the behaviour is one that goes back to at least Darwin (1871) and Galton (1869). Cain and Vanderwolf (1990) seem to have to argue for a most unlikely combination of null hypotheses: (a) that large brains evolved for no particular reason, (b) that there is much functionless variation within populations, and (c) that the means will be identical across populations. It is difficult to avoid the conclusion that Cain and Vanderwolf (1990) strain after what Jensen (1973) has called *environmentalism*, "the scientifically anomalous attitude that ignores, shuns, or denigrates any hypothesis of genetic causation in specific classes of human individual or group differences" (p. 231). That across human races brain size covaries with intelligence test scores and with a suite of r/K life-history attributes, the whole being predicted on the basis of evolutionary theory backed by empirical studies of animals (and plants) is unlikely to be credibly explained by invoking artifacts for particular variables in isolation of the general pattern.

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