Cultural Correlates with Cranial Capacity

COURTLAND L. SMITH
KENNETH L. BEALS
Department of Anthropology
Oregon State University

The evolution of such factors as tool use, society, language, and intelligence is generally believed to have had some involvement in the paleontological trend of encephalization. Co-evolution of culture and brain size is standard to textbook presentations. Several pieces of indirect evidence suggest biocultural interpretations for encephalization (Beals 1987). First, expansion of the brain case has been greater than is explicable by the corresponding increase in body size. Second, average human relative endocranial volume (24.9 cm^3 per kg of body weight) is more than twice that of apes. "Biophysical" variables like body surface area, thermoregulation, and cranial geometry fail to fully explain the changes observed for hominid data (Beals, Smith, and Dodd 1984; Scarr-Salapatek 1971). Culture, then, may explain some of the variation of cranial capacity.

A vast body of (often controversial) literature exists on the general question of factors affecting cranial capacity. Most of the hypotheses we have tabulated relate to some type of cultural/cognitive explanation. For example, several independent studies with different populations and test instruments show significant (but low) correlations between cranial capacity and IQ scores. In reviewing these studies, Henneberg et al. (1985) suggest that where connections may exist, they are presumably due to cultural factors.

Previously, we demonstrated a relation between cranial capacity and coldness of climate (Beals, Smith, and Dodd 1983, 1984). Several commentators upon that paper indicated the desirability of merging our cranial capacity data base with the corresponding files that exist in cultural anthropology to more fully explain observed differences.

We therefore test biocultural hypotheses by correlating endocranial volume with cultural variables describing ethnographic populations. The specific questions are:

1. Are there any more significant associations between cranial capacity and cultural variations than one would expect by chance alone?
2. If so, is there a pattern that can be discerned for any particular class of cultural variation?
3. If so, does evidence exist that cranial capacity has more connections with cultural variations than other anthropometric traits?

Methods

Mean sex-combined reports on the cranial capacity for 122 populations[1] are matched with ethnographic data from 1,170 cultures coded by Murdock (1967)[2] and Barry.[3] Of the cranial capacity reports available, 87 can be matched with cultural information. As with virtually all distribution studies, the sample is not proportionally representative culturally or geographically, but is the best set of data currently available for these research questions. European populations are underrepresented, and we added the coding for 6 cultures, to bring the total sample to 93. The Appendix lists the sample groups.

The data set includes 62 cultural variables. These variables are coded as nominal categories. In most cases, the categories are ordered according to anthropological theory reflecting the evolution of cultures from small-sized, homogeneous, nonhierarchical, egalitarian societies to large-scale, heterogeneous, hierarchical, stratified state societies.

The anthropometrics examined comprise sex combined, observed cranial capacity (CC) or endocranial volume (ECV), cranial module (CM), cranial capacity adjusted by latitude (CCLAT), and cranial capacity relative to weight and stature (CC/Wt and CC/St). For comparison, we include cephalic index (CI), nasal index (NI), stature (St), weight (Wt), ponderal index (PI), and body surface area (SA)—calculated from weight and stature. All cases are combined, giving equal weight to both sexes. For all measures other than cranial capacity, sample size is substantially reduced. Only 31 cultures in the sample have data for weight and ponderal index, 53 for nasal index, 54 for stature and cephalic index, and 57 for cranial module. All of the correlations reported are Kendall's *tau* since the cultural data are ordinal, and the correlation needs to account for tied ranks. The correlations cannot be taken as demonstration of causal relationship. Their utility is with the question of whether the ethnographic data can provide clues in regard to explaining possible cultural factors in the trends and variance of the biological traits.

Results

The first hypothesis is a test of the number of significant correlations. In a theoretically independent (unrelated) set, the number of significant correlations expected by chance alone is 5%, if this is adopted as the standard level of significance. Since the number of cultural variables tested is 62, the theoretical expectation is 3.1 significant cases.

The purely empiric answer to the first basic question is "yes"; there are more significant associations with cranial capacity (CC) and cultural variables than can be explained by chance. Out of 62 trials, 11 correlations were significant at 0.05 or less. (At an arbitrary probability of 0.1, an additional 9 correlations exist.) The same circumstance applies to all the anthropometric measures. The lowest and highest number of significant correlations are 16% with weight and ponderal index and 34% with nasal index. Many of the cultural traits are correlated with climate, as are all of the biological ones. Such a high number of significant correlations is a reflection of the holistic process of adaptation.

None of the correlations with ECV are strong; the highest observed is -0.27. They are much weaker than occur with the body size and climatic associations. Table 1 reports all of the significant relationships with these ethnographic data. After abstracting only the variables that did produce a significant correlation from the lengthy total matrix, we arranged them into general clusters—those relating to family, subsistence, community, and other categories ("miscellaneous"). Four of the significant cases do occur with aspects of family life, but the overall pattern of the correlations is fundamentally random from the standpoint of clusters.

We then examined the correlations to see if they could be matched to hypotheses that have been suggested within the literature as having some explanatory relationship to cranial morphology. Well over 30 such hypotheses exist (e.g., Beals 1987; Calvin 1983). They include the invention of hats, projectile throwing, and many human cognitive abilities. None of the testable cognitive hypotheses could be verified with the available data. Moreover, the purely empiric results do not correspond with mechanisms hypothesized to explain the variation with endocranial volume.

In previous research (Beals, Smith, and Dodd 1984), the empirical associations between cranial capacity and a variety of climatic variables are reported. In general, the volume increases as one moves from warmer, equatorial climates to colder, arctic climates. The selective mechanism appears to be increasingly rounder head shape as adaptive for cold climates in combination with larger body size (Beals, Smith, and Dodd 1983). Spherical shape minimizes surface area. The rounding of head shape increases the volume. Climatic zone, isothermic zone, and latitude have very similar correlations with endocranial volume. Of these three related, general measures of climate, latitude is the most simple and objective. We adjusted ECV for latitude to see if a pattern among the cultural variables crosscuts either absolute (CC) or latitude adjusted (CCLAT) ECV reports. Body size, too, is a factor in cranial capacity; therefore, we also correlated the cultural variables with the ratios of cranial capacity by weight and stature.

As is apparent in Table 1, no clear cultural pattern emerges—significant correlations between cranial capacity, lati-

Table 1
Report of significant correlations, Kendall's *tau* at $P < 0.05$, between human cranial capacity and cultural variables.

Trait	*Ethnographic Atlas* (card, column)	CC	CCLAT	CC/Wt	CC/St
Family structure					
Family size	1,14	0.17			
Family type	1,15			−0.27	
Mode of marriage	1,16	−0.18			
Matrilineal kin groups	1,28	−0.27	−0.26		
Cousin marriages	1,33–34				−0.17
Preferential marriages	1,35–36	0.18			
Subsistence patterns					
Percent gathering	1,6		−0.20		
Percent hunting	1,7				0.20
Percent agriculture	1,10		0.15		
Intensity of agriculture	1,38				−0.19
Type of animal husbandry	1,51		0.13		
Sex participation—gathering	2,18			0.32	
Sex participation—hunting	2,20		−0.17		
Sex participation—fishing	2,22	0.18			0.25
Sex participation agriculture	2,26		0.17		
Community structure					
Settlement pattern	1,40		0.13		
Local community hierarchy	1,42		0.19		
Hierarchy beyond community	1,43		0.18		
Stratification	2,33		0.15		
Caste system	2,35	−0.17			−0.21
Slavery	2,37				0.20
Past slavery	2,38	0.20			0.25
Real property inheritance	2,41			−0.36	
Political succession	2,58–59			−0.31	
Miscellaneous					
Types of games	1,46		0.20		
Male genital mutilation	1,47	−0.18			−0.29
Adolescent segregation	1,49	−0.27			
Sex participation in housing	2,16			−0.60	
Language family	2,29–30			0.27	0.18
Roof shape	2,49	−0.18			−0.20
Roofing material	2,50	−0.24		0.31	
Premarital sexual behavior	2,45			−0.41	

tude-adjusted cranial capacity, and values relative to weight and stature are erratic and independent. There is also virtually no similarity in correlation patterns between absolute and latitude-adjusted cranial capacity. Out of the 11 significant relationships with observed cranial capacity, 10 of these fail when climatic effects are reduced by standardizing for equatorial distance. The single known cultural variable that significantly correlates with both observed and latitude-adjusted ECV is matrilineal kinship. But this has never been suggested as a possible causative factor, and it also fails with both the weight and stature relative measures of endocranial volume.

Since adaptation is to an ecological setting, it is not surprising that any trait describing body size or shape will correlate with cultural variables more often than randomly expected. For instance, tropical peoples select appropriate roof types (one of the correlations reported) for that particular climate.[4] Concurrently, long-term biological adaptation to the tropics selects for a particular morphology—small body size, small endocranial volume, and small ECV relative to stature; and large ECV relative to weight.

If cranial capacity has some special connection to culture, one might reasonably expect to find a higher percentage of correlations than with randomly selected traits. The evidence indicates that this is not the case. Taking only a statistical perspective, the shape of the nose better predicts cultural traits than does cranial capacity.

In searching the cultural evidence for clues, we did detect one pattern that clearly required detailed scrutiny. When we adjusted cranial capacity for latitude (CCLAT), correlations with subsistence pattern became intriguing (Table 1). Table 2 gives the averages for the seven subsistence patterns differentiated by Murdock (1967). Note the small ECV of gatherers and larger volume for hunters and fishers. Pastoralists and incipient, extensive, and intensive agricultural cultures have intermediate cranial capacities. Hunters and fishers in the sample live at latitudes farthest from the equator and have very similar cranial capacities. Pastoralists and agriculturalists in the sample have similar cranial capacities and significantly larger body sizes than do gatherers.

The general allometric relationship between body size and cranial capacity is clearly evident.[5] However, there is an intriguing observation that the mean ECV of hunters and fishers is higher than that of agriculturalists, and yet the body size is smaller.

Table 2 indicates that gatherers in the sample have an average absolute value of latitude that places them closer to the equator. Hunters and fishers are farthest away. Our analysis determines that a correction of 2.5 cm^3 per degree of latitude is the average world correction that should be made to adjust cranial capacity for the impacts of latitude.

The reason for latitude adjustment is that body size, cranial capacity, and head shape are all functionally connected, and all are also correlated with latitude. Statistical correction allows the "noise" between the interaction of the variables to be reduced. Table 3 makes this adjustment. Hunters and fishers are grouped because Murdock defined hunters of large aquatic fauna as fishers. Further, both have similar cranial capacities and average distances from the equator. Table 3 shows that gatherers have the smallest adjusted cranial capacity and agriculturalists have the largest. All the cultures depending on plant and animal domesti-

Table 2
Cranial capacity averaged by subsistence pattern.

Subsistence pattern	Cranial capacity (cm^3)	Latitude absolute value	Weight (kg)	Stature (cm)
Gathering (n = 7)	1,290	23	46.7	152
Hunting (n = 14)	1,373[a]	49[a]	49.0	156
Fishing (n = 21)	1,370[a]	50[a]	52.5	153
Pastoralism (n = 7)	1,340	27	56.3	158
Incipient agriculture (n = 10)	1,344	32	62.5[b]	159[b]
Extensive agriculture (n = 11)	1,331	19	58.0[b]	161[a]
Intensive agriculture (n = 23)	1,341[b]	32	55.1[a]	158[a]

[a]Significant at $P < 0.05 > 0.01$ compared with gathering.
[b]Significant at $P < 0.1 > 0.05$ compared with gathering.

Table 3
Cranial capacity corrected for latitude.

Subsistence pattern	Cranial capacity (cm^3)	Adjusted cranial capacity (cm^3)	Weight (kg)	Stature (cm)
Gathering (n = 7)	1,290	1,233	46.7	152
Hunting and fishing (n = 35)	1,371[a]	1,249	51.8	154
Plant and/or animal domestication (n = 51)	1,339[b]	1,268	56.4[a]	159[a]

[a]Significant at $P < 0.05 > 0.01$ compared with gathering.
[b]Significant at $P < 0.1 > 0.05$ compared with gathering.

cation are combined because of similar cranial capacities and the fact that this subsistence pattern is the most recent among human cultures. With the correction for effects of colder climate, hunters and fishers change their position from Table 2 and are intermediate between gatherers and those cultures relying on domestication technologies. Table 3 shows that each change in subsistence pattern, for example, gathering to hunting to domestication, has a small impact on cranial capacity—20 cm^3. This is about a 1.5% increase. Moving from the equator to 45° north latitude increases cranial capacity 112 cm^3 or 9%.

Weight increase has the same pattern as cranial capacity in Table 3 and correlates both with latitude (r = 0.38) and cranial capacity (r = 0.63). Weight could easily explain the increase in ECV with change in subsistence pattern. This also raises the question of whether the invention of domestication increases both weight and cranial capacity. It is not ascertainable from correlational data whether cranial capacity would be increased beyond the amount due to the effect of larger body size.

We experimented with a number of regression models that would predict observed cranial capacity. The previous discussion indicates that the regression equation should contain a subsistence variable, the absolute value of latitude (as a proxy for climate), and weight as explanatory variables. Including weight, however, reduces the sample size from 93 to 31.

Regression analysis relaxes the assumption of the ordinal nature of the cultural data. Murdock coded subsistence variables by the percent of subsistence coming from the activity. Quantities of 0–5% were coded 0; 6–15% were 1; 16–25%, 2; and so on with 86–100% coded 9. Primary subsistence activities coded were gathering, hunting, fishing, animal husbandry, and agriculture. The best regression fit was with gathering alone.

Deleting weight because of insufficient data, the best regression model to predict cranial capacity is by the percentage of subsistence from gathering and the absolute value of latitude. The regression is significant (F = 35.5, $P < 0.0001$; adjusted R^2 = 0.43). The regression equation is

$$\text{cm}^3 = 1{,}274 - 10.9\,(\text{gathering}) + 2.4\,(\text{latitude})$$

This equation indicates that each 10% of subsistence coming from gathering reduces cranial capacity by 10.9 cm^3. Each degree of latitude increases the cranial capacity by 2.4 cm^3. This is within 0.1 cm^3 of the full 122 sample reported by Beals, Smith, and Dodd (1984). The 1,274 cm^3 for the equatorial culture that is totally dependent on plant and animal domestication is very close to the adjusted 1,268 cm^3 cranial capacity in Table 3. This model (which includes both cultural and climatic variables) still explains less than half of the variance in ECV.

Discussion

Most tests for cultural associations between cranial capacity and cultural variables fail to provide meaningful explanations for increases in cranial capacity. The association with latitude, showing larger cranial capacity as head shape gets rounder with the habitation of cold climates, explains most of the variance. The relation with subsistence is suggestive, but more work is needed to distinguish the contribution of weight gain and other body form factors.

Clearly, cultural factors enabled humans to occupy cold climates. Agriculture and nutritional improvements result in larger body sizes. Testing these hypotheses requires much more cultural data in association with heterographic and paleontological observations. Subsistence is an underlying variable in common with all these changes. To explain the role of subsistence in these correlations, care must be taken to correct cranial capacity for factors such as climate and body size. So far, climate and body size empirically explain much more of the variance than do cultural variables. Changes in subsistence patterns have probably affected the endocranial volume variation by directly influencing body size.

Notes

[1]The data set used for the calculations is described and available on diskette from *World Cultures* (vol. 3, no. 3, 1987).

[2]Space limitation precludes listing all the cultural variables examined. The data description is available in Murdock (1967). The complete correlation matrix may be obtained by writing to the authors.

[3]Herbert Barry III prepared large portions of the ethnographic data in its original computerized form (*Ethnology* 6:489, 1967).

[4]Whiting, Sodergren, and Stigler (1982) show the association between cultural characteristics and climatic factors.

[5]Conventional interpretation of brain weight as a function of surface area is the equation: $E = K \times P^{0.67}$, where E is brain weight and P is body weight. However, more recent interpretation (Martin 1981) indicates metabolic rate as the determinate and taxonomically variable slopes with the allometric exponent. From the standpoint of human populations, the ECV to body weight relation is a variable that ranges from 20.8–33.8 cm^3 per kg.

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Appendix
Cranial capacity (CC) matched with *Ethnographic Atlas* cultures.

Comparative anthropometrics are cranial module (C^rM), stature (St), weight (Wt), body surface area in square meters (SA), cephalic index (CI), nasal index (NI), and ponderal index (PI). All data represent sex-combined means.

Murdock No./Culture	*CC*	*C^rM*	*St*	*Wt*	*SA*	*CI*	*NI*	*PI*
1 BUSHMEN (SAN)	1270	14.6	150	38	1.27	76	101	44.7
28 DUTCH	1373		160	60	1.62	83	67	40.9
31 KALMYK	1371		157	57	1.56	87	75	40.9
37 GILYAK	1443	15.1						
38 YAKUT	1478	15.0	154			83	74	
44 TAMIL	1254		154			77	77	
45 ANDAMANESE	1214	14.2	143	44	1.31	83	88	40.6
54 JAVANESE	1403		159	48	1.47	80	89	43.8
56 AUSTRALIANS (NT)	1232	14.7						
70 HAIDA	1358	15.0						
75 GROS VENTRE	1394							
79 HURON	1424	15.2						
83 TARAHUMARA	1404							
93 QUECHUA	1296	14.6	151	50	1.44	81	72	41.0
94 YAHGAN	1363	15.2	153			79	76	
102 HOTTENTOT	1330	14.8	161	49	1.49	74	97	44.1
117 AZANDE	1345		163			78	83	
119 MASAI	1245		165	57	1.62	73		42.9
124 EGYPTIANS	1379	14.9						
132 ARABS	1315							
135 CHUKCHEE	1380	15.4	157	56	1.55	82	74	41.1
136 SAMOYED	1458	15.3	151			83	77	
145 VEDDA	1195	14.4	148	48	1.39	71	75	40.8
146 BURMESE	1227	14.8	156			82	84	
163 NEW IRELAND	1250		155			80	81	
167 MAORI	1393	15.1	161	63	1.66	78	76	40.5
168 MARQUESANS	1336		163	58	1.62	79	82	42.2
171 KOSKIMO	1330							
183 ZUNI	1235	14.4	155	53	1.50	83	85	41.3
185 NAHUA	1390	14.7	153			79	81	
188 CARIB	1315		156	54	1.52	79	85	41.3
195 ARAUCANIANS (Chile)	1386	15.1						
222 NUBIANS	1235		166			74	80	
225 BASQUES	1368		158			83	64	
228 CZECHS	1341		160	58	1.60	83	67	41.4
235 KORYAK	1419	14.9						
236 YUKAGHIR	1439	15.1	150			80	73	
237 JAPANESE	1318		152	51	1.46	81	79	41.0
243 PAPUANS	1304	14.4						
245 SINHALESE	1222		156			79	75	
256 AUSTRALIANS (West)	1212							
263 NEW CALEDONIA	1311	15.0	161	57	1.59	76	99	41.9
269 INUIT (NUNIVAK)	1429	15.1						
275 CHEYENNE	1398	15.0						
277 WICHITA	1309	14.8						
279 DELAWARE	1411		165			80	80	
283 SERI	1390	15.2						
295 ONA	1391	15.5	167			79	68	

(continued on next page)

Appendix (continued)

Murdock No./Culture	*CC*	*C'M*	*St*	*Wt*	*SA*	*CI*	*NI*	*PI*
299 BOTOCUDO	1350		153			77	80	
325 AINU	1302	15.2	149	49	1.41	79	67	40.8
333 AUSTRALIANS (QL)	1215	14.8						
335 NEW BRITAIN	1232	14.6						
341 MANDAN	1382							
342 PAWNEE	1334							
345 MAYA	1342	14.9	152	51	1.46	85	76	41.0
359 BURYAT	1465	15.1	156	55	1.53	89	79	41.1
377 INUIT (St. Michael)	1377	15.0						
382 TETON	1454	15.0						
384 CADDO	1345							
391 GOAJIRO	1263	15.0	147			81	79	
396 ALACALUF	1397	15.4	151			79	71	
403 XHOSA	1344							
458 ALEUT	1518	15.0	155	61	1.59	84	74	39.4
476 SALISH	1284	14.9	161			84	74	
481 CHINOOK	1321							
485 INUIT (S. Hampton)	1474							
488 INUIT (Greenland)	1411	15.1						
499 CHIPPEWA	1418	15.0	160		79	72		
509 COWICHAN	1288							
562 NEZ PERCE	1483							
583 PAIUTE	1328	14.8						
590 GOSIUTE	1338	14.7						
617 ARIKARA	1399	15.0						
619 BLACKFOOT	1365							
625 PIEGAN	1381	15.0						
657 PAPUANS (Torres)	1270	14.4						
659 TAHITIANS	1380		166	61	1.67	85	80	42.2
687 MONGOL	1489	15.2	158			82	72	
702 MANGBETU	1247							
804 BATETELA	1274		162			80	101	
1094 LAWA	1413							
1109 OSTYAK	1416	14.9	151			84	75	
1110 CHINESE	1418	14.8	157	53	1.51	79	84	41.9
1136 HINDU	1362	14.3	159	49	1.48	78	72	43.5
1141 TASMANIANS	1239	15.0	153			75	109	
1142 AUSTRALIANS (NSW)	1228	15.0						
1159 CHOCTAW	1292	14.9	155	62	1.60	82	75	39.2
Cultural Coding Additions with Associated Anthropometrics								
FRENCH	1361	15.1	161	62	1.65	80	62	40.7
GERMANS	1391	14.9	161	60	1.63	80	64	41.2
ITALIANS	1411		160	58	1.60	84	68	41.4
POLES	1315		161	57	1.59	82	71	41.9
SCOTS	1316	15.2	167	58	1.65	79	67	43.2
SWISS	1408	15.1	162	59	1.62	84	65	41.7