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Comparative analysis of selected linear measurements of human and baboon brains

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Summary

The morphometric parameters of the brains of several mammals and primates show differences that are likely to be associated with cognitive and other functions necessary for survival as well as evolution. Seven human and eight baboon formalin-fixed brains were used to show comparative aspects. The whole brains were weighed, 3 from humans and 3 from baboons were separated into components -cerebrum, cerebellum and brainstem- and their weights were recorded. The linear measurements of the cerebrum were occipito-frontal (O-F), fronto-temporal (F-T) temporo-occipital (T-O), height of temporal lobe (HTL), inter: frontal pole (F-F), occipital pole (O-O), parietal (P-P), temporal pole (T-T), and occipital lobe (OL-OL) from superior, lateral and inferior aspects. The proportions of brain weight relative to body weight and those of the brain components were mostly higher in the humans. The length, height and width of the human brains were higher than in the baboons. F-F was six times O-O in humans while other parameters were nearly double in humans as compared to baboons. The ratio of P-P to F-F was nearly 20 times in baboons as compared to 6 times in humans. The overall increase in human brain length, width and size of lobes could be related to increased body size, functional complexity, upright posture, and evolution. The lateral expansion in the size of the frontal, temporal and occipital lobes may be due to the complex circuitry associated with cognitive functions and life style. Several approaches have been proposed to determine factors related to increases in brain size, function and intelligence. Morphometry could be one tool to "explain" specific increases in brain areas.

Key words: Comparative – Measurements – Human – Baboon – Brains

Introduction

The morphometric parameters of the brains of several different mammals and primates show differences that are likely to be associated with the functions necessary for sustenance (Bear et al., 2001).

Several factors appear to influence the functional and evolutionary aspects of the brain in mammals and primates (Finlay and Darlington, 1995). Variations in the size of the whole brain, its components as well as its structures in the species, may reflect the process of adaptation, evolution, and functions (Clark et al., 2001)). Body size and weight have been associated with the size of the brain and its com-

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ponents, but this has not been addressed explicitly (Blinkov and Glezer, 1968).

The differences in brain parameters among species may have occurred due to specific adaptive patterns and changes in brain parameters result in increases in the surface area that can be attributed either to an increase in the number of neurons, the size of such neurons and/or their connectivity (Kaas, 2000).

The parameters of the various parts of the cerebral hemisphere may show differences that reflect their functional aspects between and within species (Kaas and Collins, 2001). These morphometric changes have been observed in the size of the primary and association visual cortices in the occipital lobes (Sanides, 1970).

Some asymmetrical aspects have been observed in the brain parameters of primates that may be associated with the functions of the right and left sides of the brain (Fitzgerald, 1996).

There are many morphometric parameters that are considered to be important for understanding the relationship between various parts of the cerebrum (Clark et al., 2001).

The aim of present study is to analyse comparative morphometric differences in the brains of humans and baboons using selective linear measurements. This may reflect structural, functional, and evolutionary aspects of the brain in primates.

Material and methods

Human Brains

Seven formalin-fixed whole brains of adults were obtained from the Department of Human Anatomy. The brains were taken from bodies obtained for educational purposes as per the Human Anatomy Act. The bodies were fixed by perfusion with 10% formalin. The average body weight for humans was used (65kg).

Baboon Brains

Whole formalin-fixed brains of 8 baboons were obtained from the institute of Primate Research. The baboons were from a group sacrificed following a 90-day quarantine period and were tested for infectious agents.

The baboons weighed between 13 kg and 14 kg and included 6 males and 2 females. The animals were sedated with a mixture of ketamine (10mg/kg) and Rompun (0.5 mg/kg) administered at a dose of 0.1ml/kg. They were then sacrificed with Euthatal at a dose of 0.5 mg/kg, followed by perfusion through the left ventricle with 10% formalin. Whole brains were removed and stored in 10% formalin.

Brain weights and components

All the human and baboon brains were weighed as whole brains using a weighing scale (g). Of these, 3 human brains and 3 baboon brains were separated into the components of the cerebral hemispheres, cerebellum and brainstem. The components were weighed and the mean values for the whole brain and components were obtained (gm).

Linear measurements (cm)

Linear measurements were carried out using Vernier calipers and dividers on 4 human and 5 baboon brains from the lateral (right and left sides), superior and inferior aspects, as shown in Figs. 1, 2 and 3.

Two medical students performed the measurements. Inter-and intraobserver errors were determined. The inter-observer error was 3% while intra-observer error was 2%.

The following linear measurements were taken from the lateral, superior and inferior aspects.

Lateral Aspects (Fig. 1)

Occipito-Frontal (O-F): The distance between the poles of the occipital and frontal lobes (length).

Occipito-Temporal (O-T): the distance between the poles of the occipital and temporal lobes.

Frontal-Temporal (F-T): the distance between the poles of the frontal and the temporal lobes.

Height of Temporal Lobe (HTL): The perpendicular distance from the point (X) where the central sulcus (CS) meets the lateral sulcus (LS) to the inferior margin of the temporal lobe (Y).

Superior Aspect (Fig. 2)

Inter-Frontal (F-F): The distance between the poles of the frontal lobes.

Inter-parietal (P-P): Maximum distance between the parietal lobes (width).

Inter-occipital (O-O): The distance between the poles of the occipital lobes.

Inferior Aspect (Fig. 3)

Inter-temporal (T-T): The distance between the right and left temporal poles.

Inter-occipital lobe (OL-OL): Maximum distance between the occipital lobes.

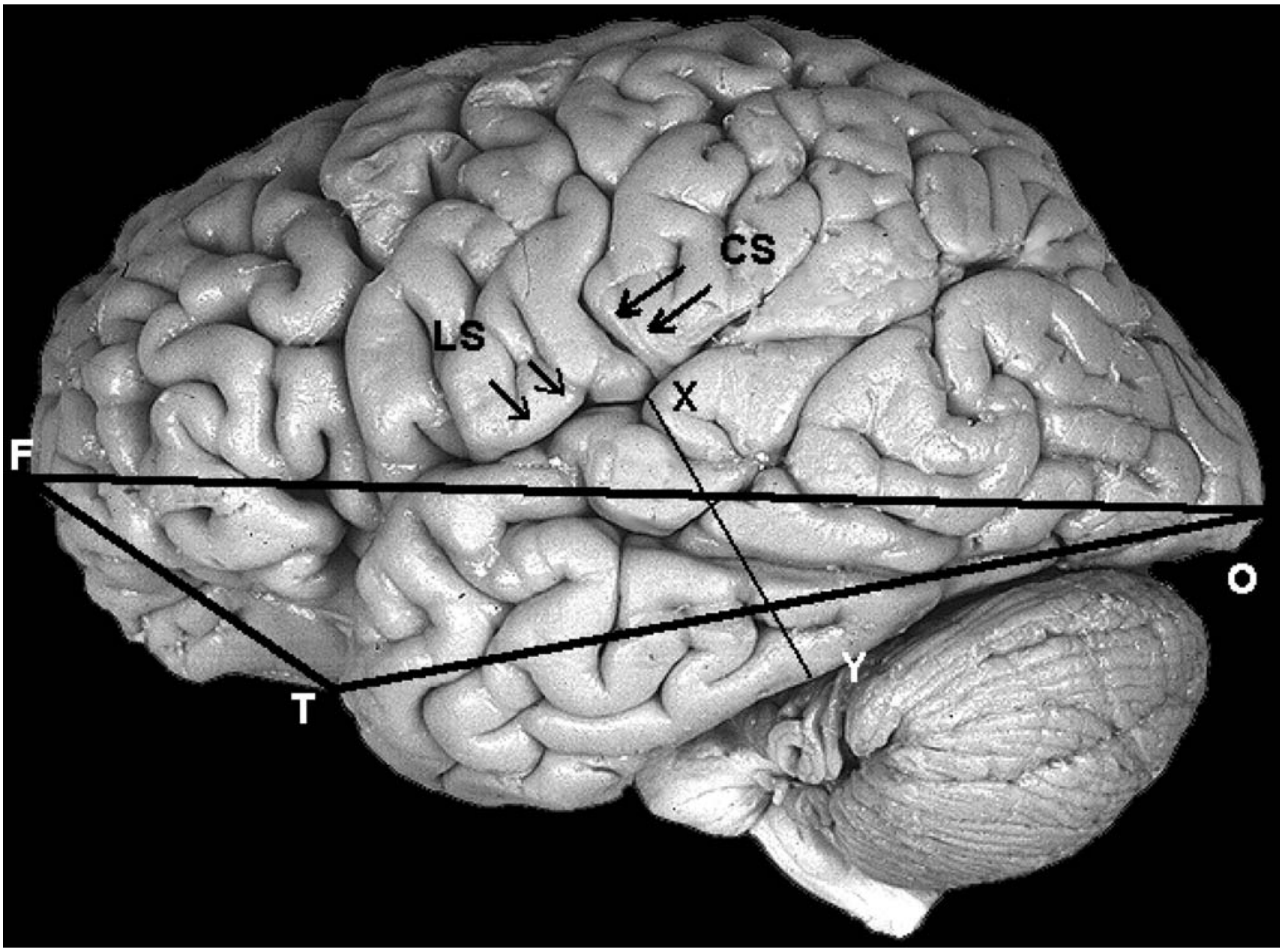


Fig. 1. Linear measurements of the cerebrum from the lateral aspect. O-F: Occipito-Frontal; T-O: Temporo-Occipital; F-T: Fronto- Temporal; X-Y: Height of Temporal Lobe (HTL); LS: Lateral Sulcus; CS: Central Sulcus.

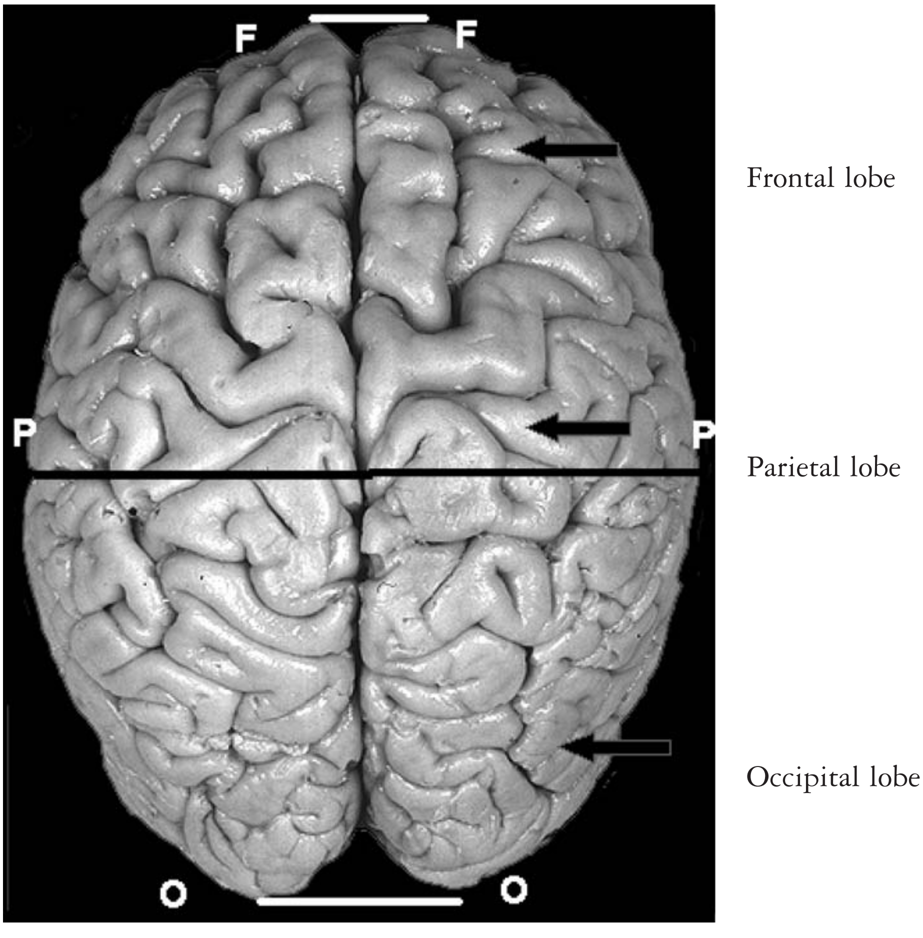


Fig. 2. Linear measurements from the superior aspect of cerebrum. F-F: Inter-Frontal Pole; O-O: Inter-Occipital Pole; P-P: Maximum Inter-Parietal width.

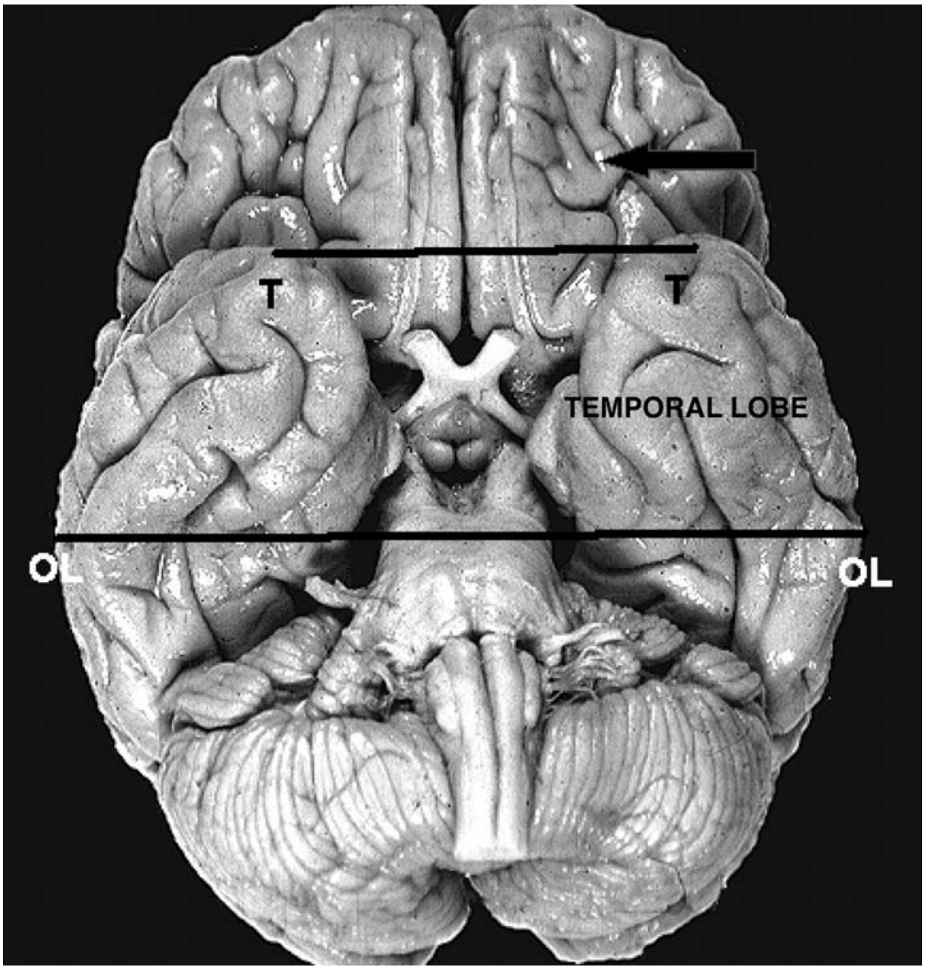


Fig. 3. Linear measurements of the cerebrum from the inferior aspect. T-T: Inter-Temporal Pole; OL-OL: Maximum Inter-Occipital Lobe width.

RESULTS

Table 1 shows that the proportion of brain weight to body weight was relatively higher (2.11) in humans than in baboons (0.845). The weight proportions of the cerebrum (89.4% vs. 84.82%) and of the brain stem (2.37% vs. 1.48%) were higher for baboons than in humans. The percentage weight of cerebrum was found to be more than one and half times (13.7% vs. 8.23%) in humans than in baboons.

The mean length (O-F) and width (P-P) of the human brains were 170 mm and 130 mm, whereas for the baboon brains these parameters were 85 mm and 68 mm respectively.

Table 2 shows the mean values and ratios of the linear measurements (O-F, O-T, F-T and HTL) for the right and left hemisphere from the lateral aspect shown in Fig. 1; (F-F, P-P and O-O) from the superior aspect in Fig. 2, and (T-T and OL-OL) from the inferior aspect shown in Fig. 3 for human and baboons.

Figs. 4, 5 and 6 show comparative measurements of human and baboon brains from the lateral, superior and inferior aspects. It maybe noted that from the lateral aspect, the measurements from the right and left hemispheres and their ratios are individually comparable in both humans and baboons. Fig. 4 compares O-F, O-T and HTL values for humans and baboons. It was found that, O-F, O-T, and HTL values were nearly double for humans than for baboons. The F-T values were nearly one and half times for humans than for baboons (see Fig. 7a).

In terms of symmetry, there was no marked difference in the linear measurements of the parameters in the right and left hemispheres in the baboon, whereas these measurements were slightly higher in the left hemisphere in humans.

Table 2 and Fig. 5 show that from the superior aspect, the F-F values were about six and three quarter times higher in humans than in baboons. The P-P values were less than double

Fig. 4. Comparative mean values (cm) of linear measurements from the lateral aspect in the Baboon and Human (right and left hemispheres combined).

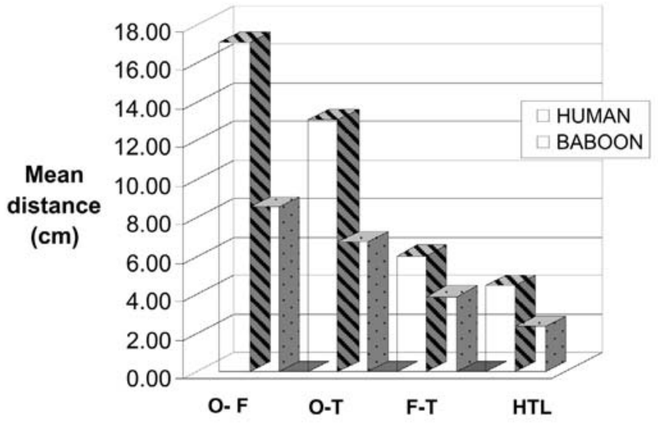


Fig. 5.- Comparative mean values (cm) of linear measurements from the superior aspect in the Baboon and Human.

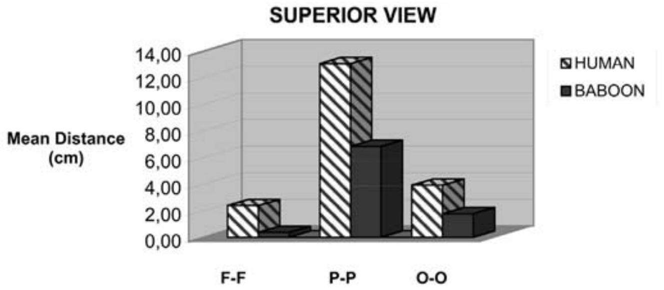
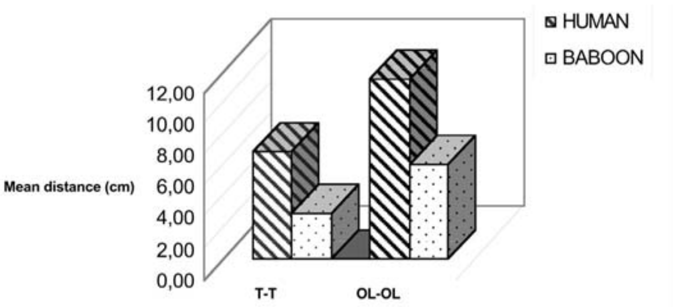


Fig. 6.- Comparative mean values (cm) of linear measurements from the inferior aspect in the Baboon and Human.



whereas the O-O values were more than double for humans than for baboons. The ratio of P-P to F-F (6.81 vs.0.35) was nearly 20 times for baboons, whereas the same ratio (13.03 vs. 2.37) was nearly 6 times for humans (see Fig. 7b).

The ratio of P-P to O-O is almost four times (6.81 vs. 1.74) for baboons, whereas the same ratio was less than three and half times (13.03 vs. 3.90) for humans.

The ratio of O-O to F-F values was almost five times (1.74 vs. 0.35) for baboons whereas this ratio was more than one and half times (3.90 vs.2.37) for humans.

Table 2 and Fig. 6 show T-T and OL-OL measurements as well as their ratios from the inferior aspect. It was found that OL-OL to T-T values were nearly two times (6.02 vs. 2.90) for baboons where as this ratio was more than one and half times (11.44 vs. 6.86) for humans (see Fig. 7c).

Discussion

The proportion of brain weight relative to body weight and that of the three components, cerebellum, cerebrum and brain stem are mostly higher in humans than in baboons (Blinkov and Glezer, 1968). Since many factors including genes, contribute to brain and body size, it is difficult to determine any direct correlation between body and brain size (Deacon, 1990).

The present study compares the lengths, widths and other linear parameters of the cerebrum for humans and baboons. The lin-

Table 1. Mean values of body weights, brain weights (gms), their ratios and proportions(%) of the 3 brain components in the baboon and human.

BABOON

BODY WEIGHT	BRAIN WEIGHT	CEREBRUM WEIGHT	% of the TOTAL WEIGHT	CEREBELLUM WEIGHT	% of the TOTAL WEIGHT	BRAIN STEM WEIGHT	% of the TOTAL WEIGHT
13433	112,62	100,64	89,4	9,32	8,23	2,66	2,37

RATIO OF BRAIN WEIGHT TO BODY WEIGHT(%): 0.84%

HUMAN

BODY WEIGHT	BRAIN WEIGHT	CEREBRUM WEIGHT	% of the TOTAL WEIGHT	CEREBELLUM WEIGHT	% of the TOTAL WEIGHT	BRAIN STEM WEIGHT	% of the TOTAL WEIGHT
65000	1350	1145,07	84,82	185	13,7	20	1,48

RATIO OF BRAIN WEIGHT TO BODY WEIGHT(%): 2.11%

Table 2. Mean values (cm) of selected linear measurements of the cerebrum and their ratios from the lateral, superior and inferior aspects in the baboon and human.

LATERAL	ASPECT

RIGHT HEM.		O-F (A)	O-T (B)	F-T (C)	HTL(D)	A:B	A:C
	BABOON	8.50	6.70	3.83	2.31	1.27	2.22
	HUMAN	17.04	12.94	5.88	4.39	1.32	2.90
	RATIOS	**2.00**	**1.93**	**1.54**	**1.90**		
LEFT HEM.		O-F (A)	O-T (B)	F-T (C)	HTL(D)	A:B	A:C
	BABOON	8.48	6.74	3.90	2.35	1.26	2.17
	HUMAN	17.06	13.17	6.06	4.48	1.30	2.81
	RATIOS	**2.01**	**1.94**	**1.55**	**1.91**		

SUPERIOR ASPECT		F-F (x_1)	P-P (x_2)	O-O (x_3)	x_2:x_1	x_2:x_3
	BABOON	0.35	6.81	1.74	19.66	3.91
	HUMAN	2.37	13.03	3.90	5.72	3.34
	RATIOS	**6.73**	**1.91**	**2.24**		

INFERIOR ASPECT		T-T (Y_1)	OL-OL(Y_2)	Y_2:Y_1
	BABOON	2.90	6.02	2.08
	HUMAN	6.86	11.44	1.66
	RATIOS	**2.36**	**1.90**	

ear measurements indicate that the length (O-F) and width (P-P) of the brain (cerebrum) and the height of the temporal lobes (HTL) in humans are higher than in the baboon. The values for humans agree with previous findings (Blinkov and Glezer, 1968).

The overall increase in human brain length, width, the temporal lobe and occipital lobe may be related to the increase in proportional body size and the functional complexity of the humans (Brunnner, 2004; Kaas and Collins, 2001).

Fig. 7(a) compares the lateral aspects of the human and baboon brain. The cerebrum shows an increase in the frontal, parietal and occipital lobes as well as the temporal lobes in humans. The volume proportions of the different lobes of the cerebral cortex in humans have been reported to be: frontal 41%, temporal 21%, parietal 20% and occipital 18% (Caviness Jr et al., 1998).

Fig. 7(b) compares the superior aspects of human and baboon brains. The inter-frontal (F-F) measurements are increased six-fold in humans as compared with baboons, which may be associated with an increase in the corresponding size of the frontal lobe and cognitive functions (Kaas and Collins, 2001). The larger size of the neo-cortex can be associated with neurons that may be bigger, with longer axons and more connectivity with respect to the target functional areas (Kass, 2000).

The inter parietal (P-P) and inter occipital pole (O-O) values (primary visual cortex) are not proportionally increased as compared to the (F-F) values in humans. A proportional increase has been described in the association visual area (OL-OL) in humans with respect to the same area in baboons (Brunner, 2004; Kass, 2000; Sanides, 1970).

The increase in the inter-parietal (P-P) width for humans may be related to upright posture, complex movements, functions, and evolution. The inter parietal and inter frontal widths show a size-related pattern of variation during hominid evolution (Brunner, 2004).

The relative increases in the sizes of the functional areas of the cerebrum may reflect evolutionary patterns in primates, where neuron size and connectivity would be dependent on some process of natural selection (Northcutt and Kaas, 1995; Catania et al., 1999).

Fig. 7(c) compares the inferior view for human and baboon. The values for the inter-temporal poles (T-T) and inter occipital lobes

Fig. 7a. Lateral aspect: Human Lateral aspect: Baboon

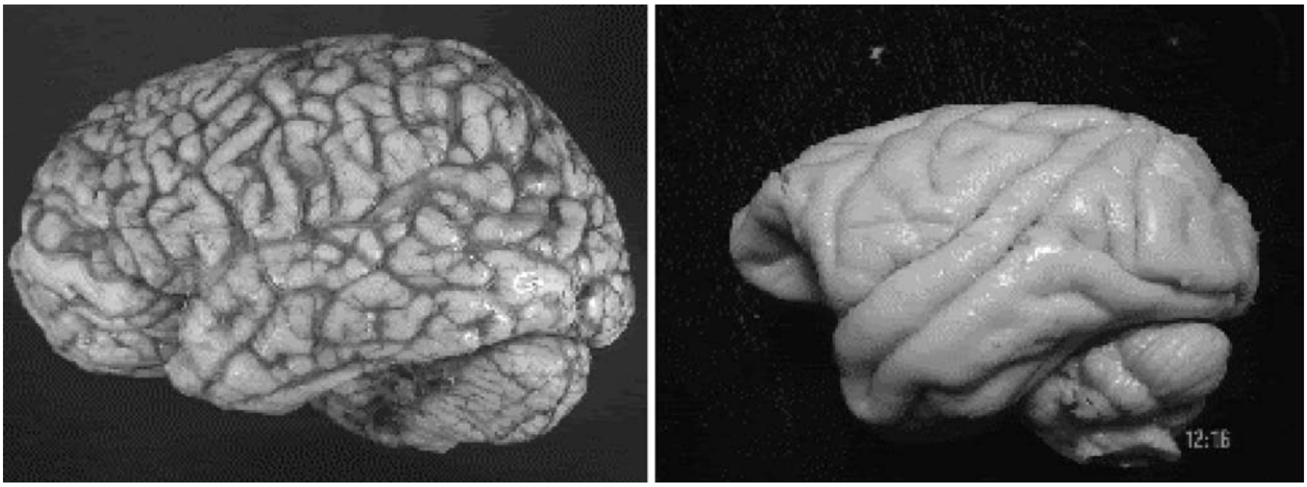


Fig. 7b. Superior aspect: Human Superior aspect: Baboon

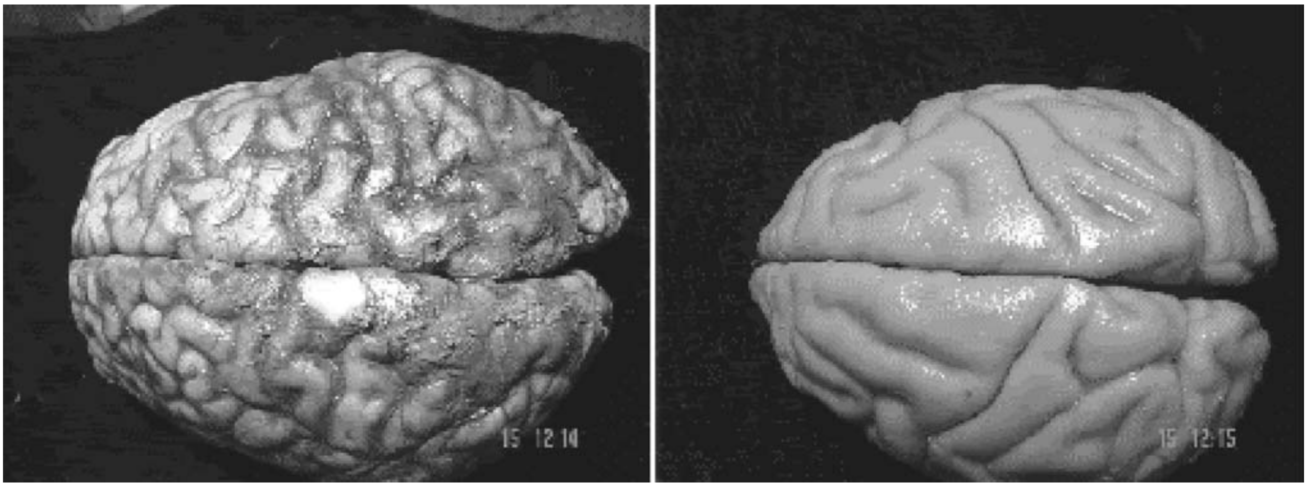


Fig. 7c. Inferior aspect: Human Inferior aspect: Baboon

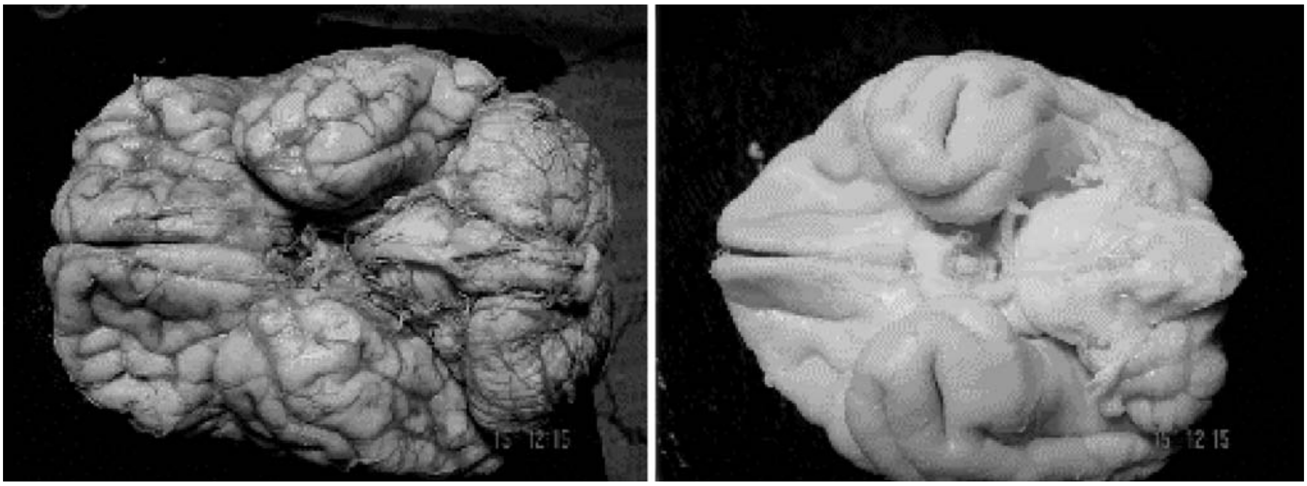


Fig. 7. Human and Baboon brains from (a) lateral aspect Human x 0.67 and Baboon x 1; (b) Superior aspect Human x 0.5, Baboon x 1, and (c) Inferior aspect Human x 0.67, Baboon x 1.3.

(OL-OL) are double in humans. This may be associated with the lateral expansion in the size of the temporal and occipital lobes. This is the area where major connections associated with memory, speech, hearing, emotions and behaviour are integrated.

Specific areas of a brain may also change as a result of reduced or increased functional demands due to varied life style (Kurska, 1998; Kuhlenbec, 1973).

The measurements of the left side were slightly higher for humans, possibly reflecting a dominance of the left hemisphere (Blinkov and Glezer, 1968).

The present study attempts to find differences in particular functional areas of the brain (cerebrum) of humans and the baboons in the antero-posterior, medial-lateral, and other linear dimensions. Several approaches have been proposed to determine the factors related to increases in brain size, function, and intelligence. Morphometry could be one tool to "explain" specific increases in brain areas. Additional data on the curvatures, cortical thickness and surface folding pattern of functional areas may reflect the neuronal density, size, and connectivity of the brain. Such a study could be extended to computer simulations to demonstrate comparative brain and body sizes in animals.

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