Endocranial Regions Associated with Deception in Non-human Primates

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HUMAN BRAIN EVOLUTION LAB

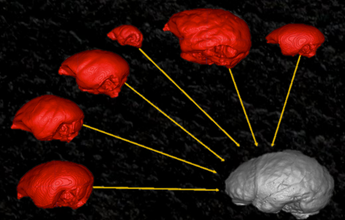
Introduction

Neural tissue is metabolically expensive. The human brain accounts for ~20% of metabolic expenditure, yet only accounts for ~3% of total human body weight [1]. Everything else being equal, species should evolve the smallest brains possible [2]. An important evolutionary question concerns what the behavioral benefits might have been allowing for the evolution of larger brains in primates as opposed to other non-primate mammals. Due to the complexity of navigating social relationships, the social environment as an influential force in neurocognitive evolution has been suggested [3-6]. Empirical tests of the 'social brain hypothesis' have shown that brain size (as well as various measures of relative size) is significantly associated with group size in primates [6-8]. The Machiavellian intelligence hypothesis postulates that deception played a major role in the evolution of primate social brains and previous research has shown direct relationships between neocortex ratio and deception in primates [9, 10].

Materials and Methods

Deception data were taken from Byrne and Whitten [11] in which 8 categories were defined: Concealment, Distraction, Concealment and Distraction, Attraction, Creating an image, Deflection, Using a social tool, Counter deception. The deception categories reported for each species (n=17) were summed and recorded as "level of deception" (0-8). Correlations were run in Excel for log transformed (ln) endocranial volumes and level of deception. Phylogenetic Generalized Least Squares (PGLS) was calculated using the CAPER package in R [12] and the consensus tree from the 10KTrees Project [13] to assess level of deception in relation to shared evolutionary history.

Assessment of species differences in endocranial morphology**:** Virtual endocasts were made from CT scans of 18 non-human primates using Analyze image processing software (AnalyzeDirect). Advanced Normalization Tools (ANTs) [14] was then used to morph each endocast individually into a common atlas (*Pan troglodytes*).



This resulted in mappings between each species' endocast and *Pan's.* These mappings are sets of vectors describing where specific voxels in *Pan* are mapped to in the species of interest. Jacobians (scaling factors) can then be derived from these mappings, indicating how corresponding localized areas in the two images differ in size.

Correlations between Jacobians at each voxel and level of deception were calculated using R. Color mappings were rendered using Paraview software. See [15] for more on morphing methods.

Results

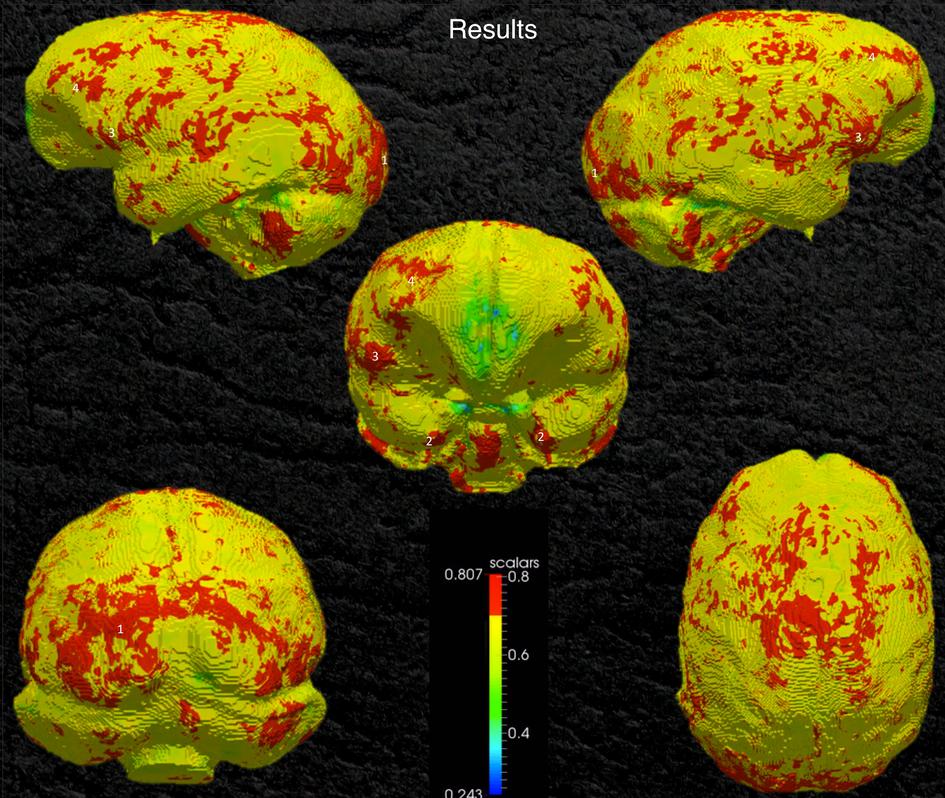


Figure 1: Correlation map between level of deception and Log Jacobians over *Pan* endocast. Correlations in red represent all correlation values over .695 (p=<.01). Scalars represent correlation coefficients.

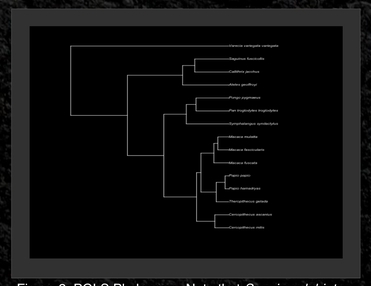


Figure 2: PGLS Phylogeny. Note that *Saguinus labiatus* was excluded as it was missing from the 10k tree data

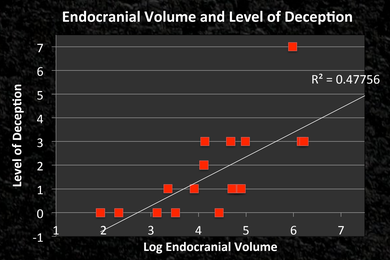


Figure 3: Scatterplot of endocranial volume and total level of deception

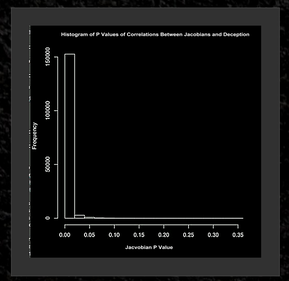


Figure 4: Frequency of p values for voxel correlations between total deception level and Jacobians

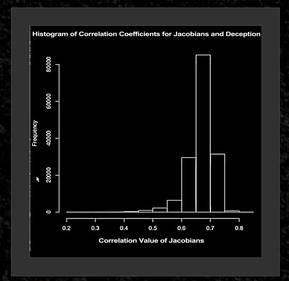


Figure 5: Frequency of voxel correlations between total deception level and Jacobians

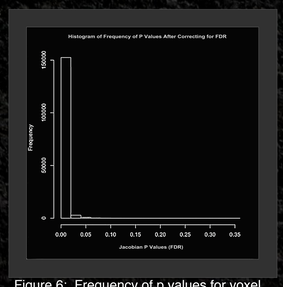


Figure 6: Frequency of p values for voxel correlations between total deception level and Jacobians corrected for multiple comparisons

Discussion:

Positive correlations are prevalent across the endocranial surface (Figure 1), consistent with the finding that increase in absolute brain size is linked to increased instances of deception (Figure 3). Certain highlighted regions demonstrate higher correlations than others, indicating some areas are better predictors of level of deception than others. The functions of brain areas underlying these some of these regional areas are discussed below (based on human functional areas of the brain, as there is less known about non-human primate brain functional brain anatomy).

1. Visual processing areas of the occipital lobe (BA 17, 18 and 19) show strong correlations favoring the left side; these areas have been researched extensively and linked to pattern recognition and spatial information in corresponding regions on the human brain [16]. The visual cortex has also shown to process information such as association between names and faces [17] and response to emotion in relation to visual processing [18]. However, studies using other proxies of sociality (group size) have found V1 correlates less significantly than the rest of the neocortex [19].
2. Strong correlations are seen bilaterally in the temporal polar cortex (BA 38). This area is associated with emotion as well as theory of mind and moral judgment [20] and deception [21] in humans.
3. In an fMRI study by Abe et. al., [21] found individuals involved in intentional social deception had particularly significant activation of the ventrolateral prefrontal cortex (left dominant). This area has also been found to be associated with both conscious and vocal deception [22-24].
4. Unlike studies in which subjects pretend to know, studies where subjects lie by omission and concealment have particularly strong right hemisphere involvement in the inferior frontal cortex [25]. Individuals pretending not to have heard another individual also have activation of this area (predominantly right side) [26].

Other areas of high statistical significance include a large portion of the superior parietals and right cerebellar region; however, the high correlation of all regions suggest deceptive behavior is not static, but rather requires an increase in total brain volume for non-human primates.

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