Associations between localized variation in brain anatomy and social behavior in healthy human subjects

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Introduction

Since the divergence from our last common ancestor, the hominid brain has increased in size despite the expensive evolutionary costs of neural tissue. Understanding the relationship between brain morphology and function is critical for interpreting evolutionary changes in the human brain. It has been suggested that social group size and complexity has played an important role in this. The social brain hypothesis proposes that as primate social organization becomes more complex, a larger brain (specifically neocortex) is needed to successfully navigate this increasingly-complex social environment (Dunbar, 1998). Previous studies both within and between species have attempted to asses this hypothesis.

However, assessing the relationship between social complexity and brain anatomy is further complicated by the the possibility of behavioral associations caused by purely environmental factors. Socioeconomic status (SES), for example, could affect brain development and social behaviors in similar ways, resulting in a non-genetic correlation between the two variables (Figure 1). In order to control for such effects, we compared pairs of siblings on both social and neuroanatomical measures. If sibling differences in brain structure correlate with sibling differences in behavioral measures, there is a stronger case that the two are genetically mediated, thereby strengthening the social brain hypothesis.

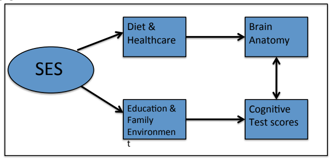


Figure 1

Materials and Methods

36 healthy female sibling pairs were recruited (n=72, mean age=23.2 years, age range 18-43). The mean sibling age difference was 2.7 years. Magnetic resonance imaging (MRI) was performed on each subject. Three measurements of sociality were taken:

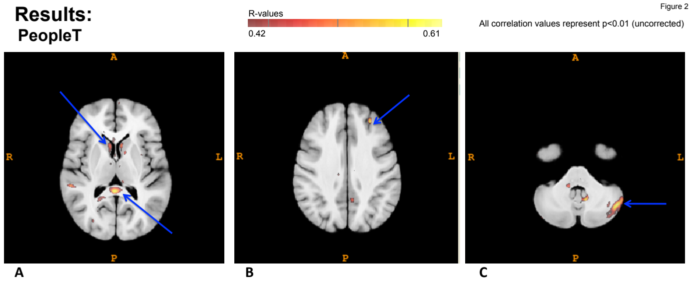
1) How often the subject talk with another person for more than five minutes in one week (PeopleT)
2) How often the subject saw another person (brief, but minimal conversation) in one week (PeopleS).
3) How many individuals were listed in the subject's address book (Address).

Anatomical variation at each point was assessed via a non-rigid deformation technique using the Advanced Normalization Tools package (ANTS; http://picsl.upenn.edu/ANTS/), an open source software package:

- First, a population average was created by morphing individuals into better and better approximations of the population average. The resulting individual mappings were used to adjust the estimated population average.
- Jacobians (natural log transformed) were calculated on each voxel of each of the distortion maps. Jacobians are localized scaling factors that indicate how much each voxel of the final template needs to be expanded or shrunk to match each individual subject's brain image.
- Within-family correlations were calculated (rather than simple correlations between individuals) to control for between-family environmental effects, such as SES. This was done by correlating sibling differences for all variables. Statistical calculations were accomplished using the R statistical software package.
- For additional information on materials and methods, see Schoenemnann *et al*, 2000.

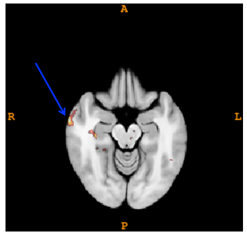
Results:

PeopleT

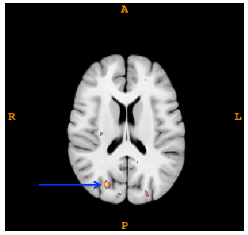


Within-family correlations between anatomical variation and PeopleT. Positive correlations are seen in the corpus callosum and caudate nucleus (**A**), left dorsolateral prefrontal cortex (**B**), and the left lateral hemisphere of the cerebellum (**C**).

PeopleS



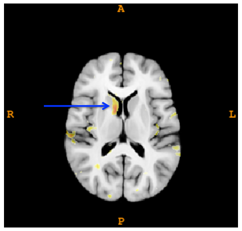
D



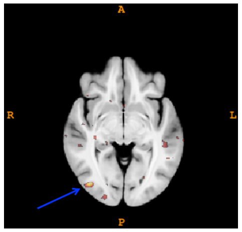
E

Within-family correlations between anatomical variation and PeopleS. Positive correlations were found in the right temporal (D) and right occipital (E).

Address



F



G

Within-family correlations between anatomical variation and Address. A strong negative correlation occurs in the caudate nucleus (F); a positive correlation in the right posterior temporal (G).

A Word on Statistical Significance

The correlations described in Figure 2 are uncorrected for multiple comparisons. However, because many voxels are not truly independent (e.g., because of proximity and shared anatomy and function), simple Bonferroni correction is not appropriate. Further statistical analysis using False Discovery Rate and/or other methods is needed to better assess the significance of these associations.

Discussion

People T:

- Strong positive correlations between increased reported sociality and the splenium of the corpus callosum was observed within families (Figure 2A).
- Sexual dimorphism in corpus callosum size has been shown in both humans and primates (de Lacoste and Holloway, 1982). Holloway et al, (1993) hypothesize that this anatomical difference stems from differences in emphasis on social realms. Several studies have in fact reported that women have larger social networks then men (Powell et al. 2012).
- Positive correlations found in the prefrontal cortex (Figure 2B) support previous studies that have shown that regions in the prefontal are important for theory of mind (Lewis *et al*, 2011) and influence social network size and complexity (Powell *et al*, 2012).
- A relationship between increased sociality and an increase in size in the left cerebellum was observed. Previous studies have shown that the cerebellum is important for the adaptation of play behavior during childhood and the maintenance adult relationships (Lewis and Barton, 2004).
- Positive correlations in the caudate nucleus indicate that the caudate nucleus is an influential component of working memory (Provost *et al*, 2010), as well as the motivation and emotional systems involved in romantic love (Aron *et al.*, 2005).

People S:

- Positive correlations were found in the right temporal and right occipital lobes, regions primarily responsible for object recognition (temporal) and visual processing (occipital).

Address:

- A strong negative correlation was found between the size of the caudate nucleus and numbers of individuals listed in a participant's address book. The caudate nucleus is a part of the basal ganglia system and is important for the formation of working memory (Provost *et al.*, 2010).
- Positive correlations were also found in the right temporal lobe, which is involved in object recognition and connecting words to concepts.

Comparisons with previous studies:

- Powell *et al.* (2012) found that the volume of the orbital prefrontal cortex is most highly correlated with social network complexity while Lewis *et al.* (2011) showed that social network size correlated most with the ventromedial frontal gyrus. Additionally, Sallet *et al* (2011) found an association between social network size and the mid superior temporal sulcus, inferior temporal gyrus, and rostral prefrontal cortex in macaques.
- By contrast, the present study found areas of correlation in the dorsolateral prefrontal and the right posterior temporal lobe (Figure 2).
- These differences in areas of localization might be explained by differences in the type of sociality measurements taken, method differences (within-family vs. individuals), as well as the influence of spurious environmental factors (which our study controls for).

Acknowledgements

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