Structural Asymmetries in the Human Brain Assessed via MRI

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Introduction

The human brain is structurally and functionally different between hemispheres. Developmental, evolutionary, and genetic factors are thought to influence these asymmetries. Behavioral traits such as manual dexterity, motor control, and aspects of language are usually lateralized in the brain, but the extent to which these can be directly linked to specific anatomical asymmetries has been the subject of debate. Analyses of fossil hominin endocasts have revealed anatomical asymmetries that are assumed to reflect asymmetries in underlying brain regions. Clarifying where - and by how much - extant human brains are asymmetrical will allow better interpretations of these fossil asymmetries, both with respect to suspected brain asymmetries as well as possible functional or behavioral implications.

Two areas of particular interest are Broca's and Wernicke's areas, because they play key roles in language production in modern humans. Previous research has suggested that these areas are asymmetric, but studies to date have had small sample sizes and often use brain scans of unhealthy patients.

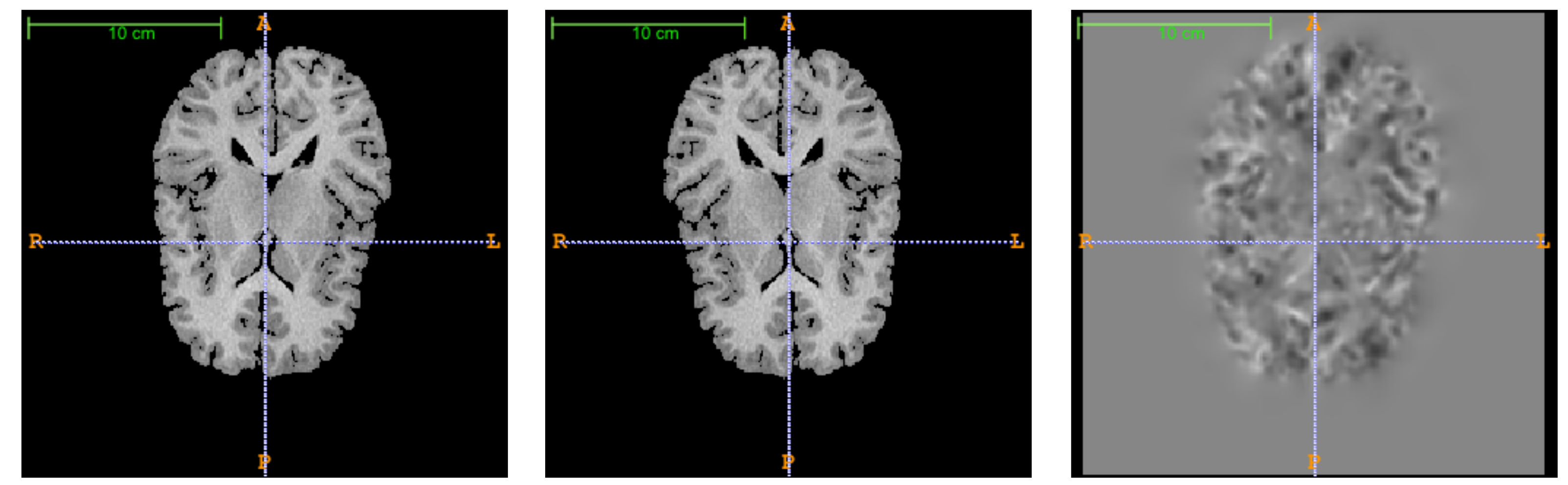
Methods

72 female subjects consisting of 36 sibling pairs were recruited (mean age = 23.2 years, age range 18-43). Each subject was treated as an individual.

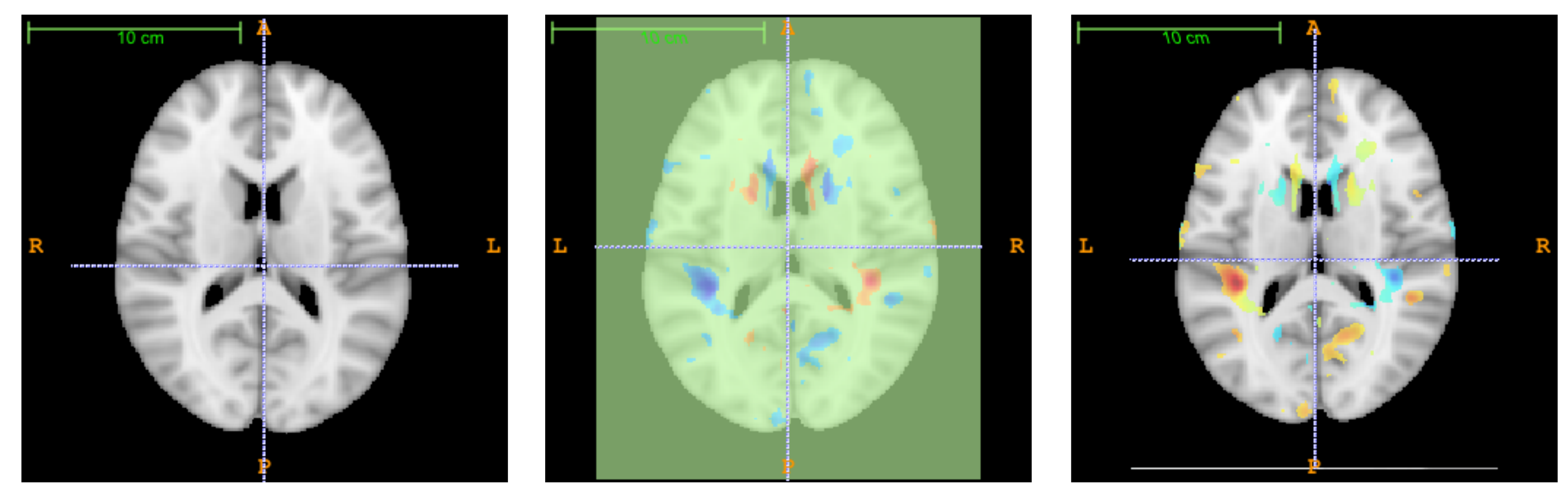
Anatomical variation at each point was assessed via a non-rigid deformation technique using the Advanced Normalization Tools package (ANTS; http://picsl.upenn.edu/ANTS/), an open source software package:

- A left-right reversed version was created of each scan.
- Each left-right reversed image was morphed into the corresponding original image, creating a distortion map.
- Jacobians (log transformed) were calculated on each voxel of each of the distortion maps. Jacobians are localized scaling coefficients that indicate how much each voxel of the left-right reversed image needs to be expanded or shrunk to match the original scan.
- The Jacobian maps for each individual were then morphed into an averaged template and then the standardized template MNI 152 space.
- T-tests were run on the log transformed values of each voxel to determine significant difference from zero.
- The probabilities of the t-values, corrected for false discovery rate, were calculated.
- Maps were created displaying the mean Jacobians (non-log transformed) in areas of significance past the .001 p-value threshold.

Methods



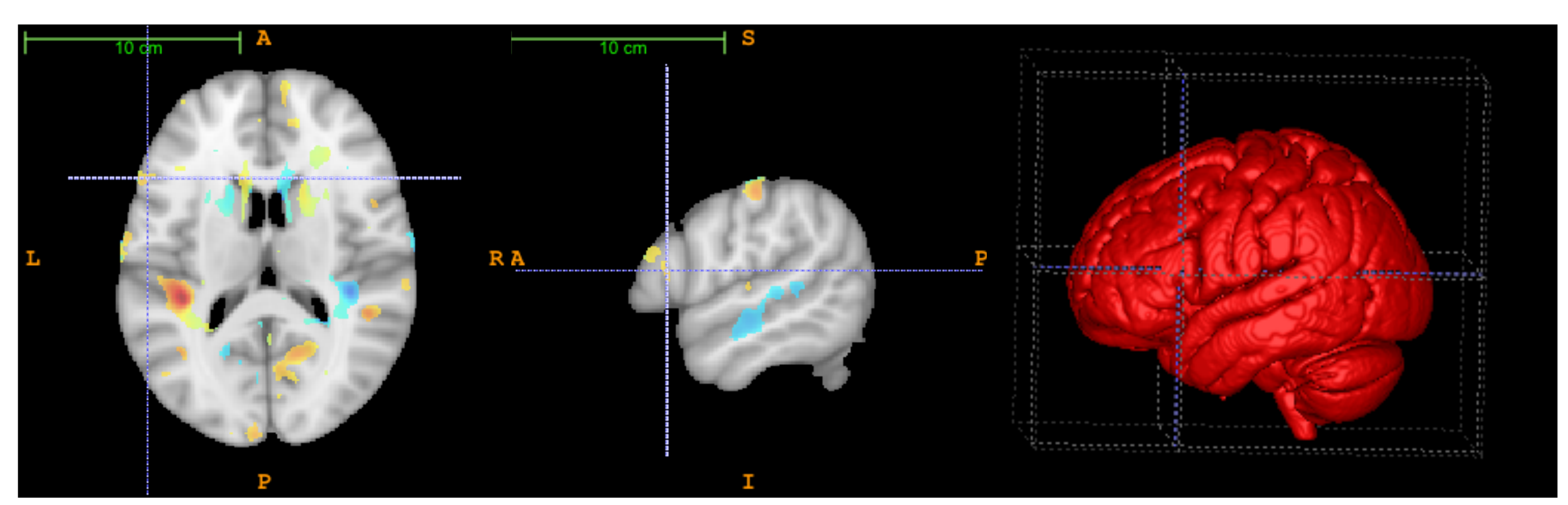
Original Scan | Left-Right reversed version | Distortion map of left-right reversed version morphed into original scan



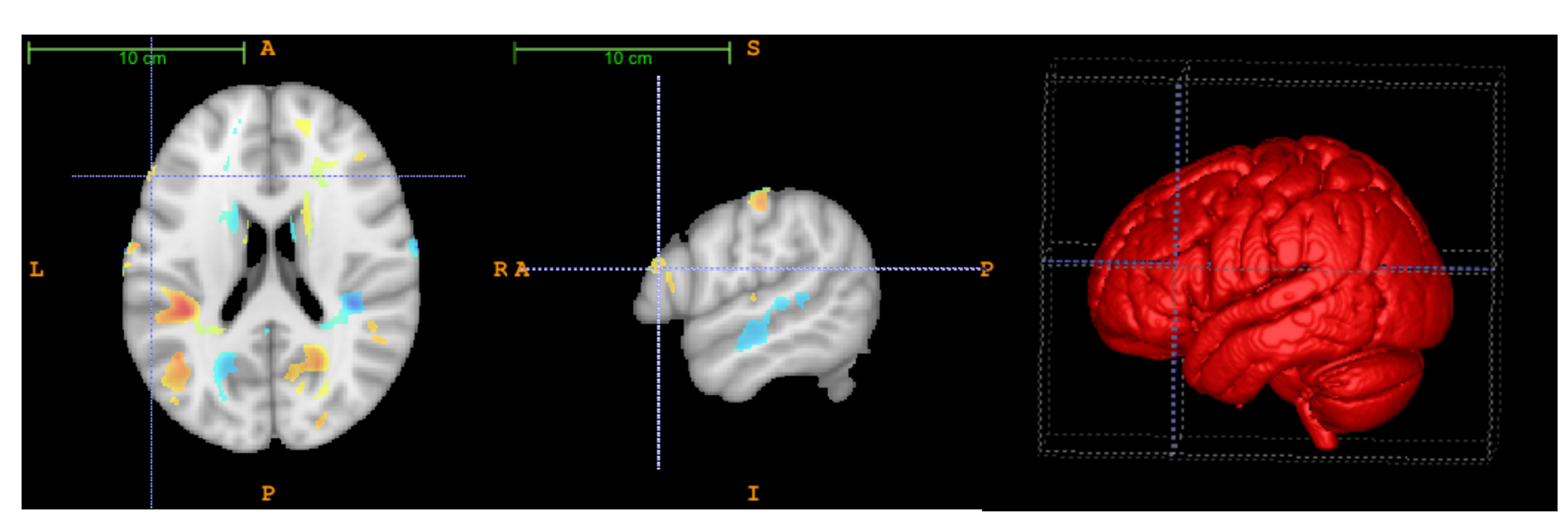
MNI 152 Template | t-vaues at p<.001 | Mean Jacobians at p<.001

Results

Broca's Area:



16 – 24% larger in the left hemisphere



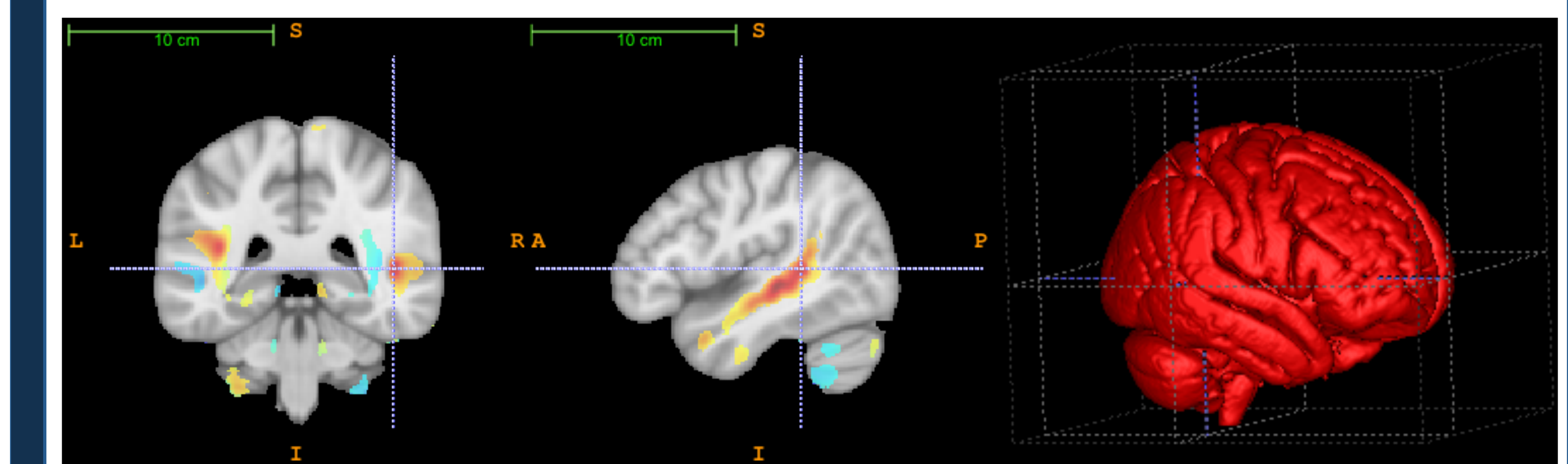
15-18% larger in the left hemisphere

p<.001, fdr-corrected, N=72

Results

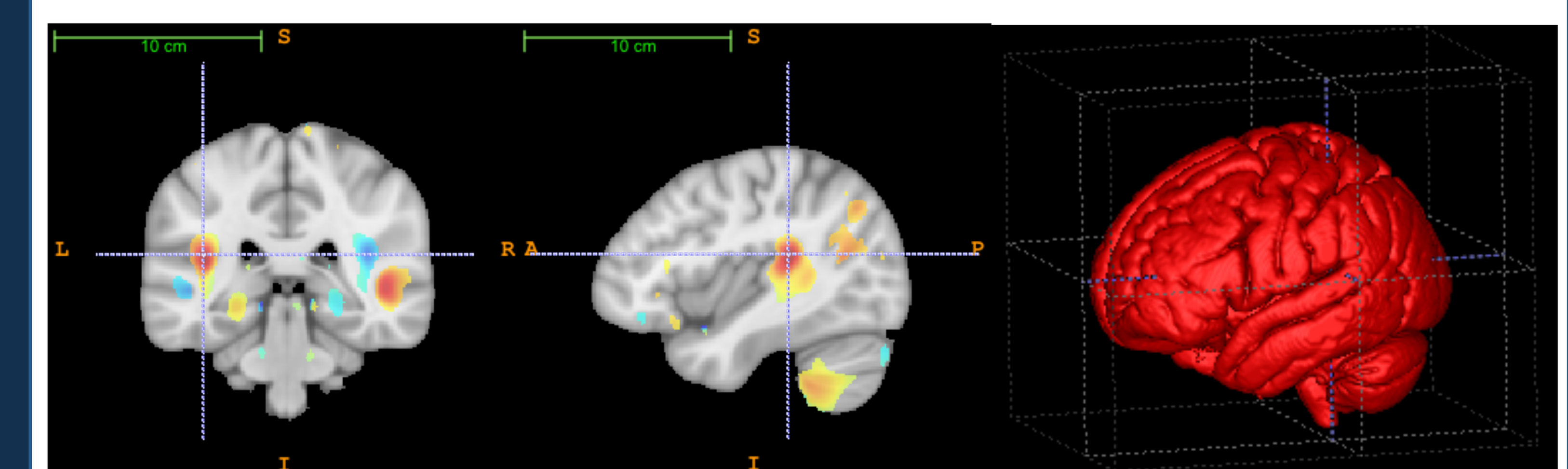
Wernicke's Area:

Superior Temporal Sulcus



20-58% larger in right hemisphere

Planum Temporale



20-60% larger in left hemisphere

p<.001, fdr-corrected, N=72

Conclusions

- Broca's area is asymmetric in two locations, and ranges from 15-20% larger in the left hemisphere than the right hemisphere.
- Wernicke's area is complicated. The superior temporal sulcus is rightward asymmetric (20-58%) while the planum is larger in the left hemisphere than the right hemisphere (20-60%).

Discussion

Based on previous studies, we expected to find asymmetries in the language areas of the brain. Our results showed Broca's area to be larger in the left hemisphere and showed a complicated asymmetry in Wernicke's area. Wernicke's area is not well defined, so depending on what is included it is either, rightward, leftward, asymmetric in both directions.

Whether or not language acquisition is the cause of the asymmetry of these two areas is an important question. The lack of asymmetry in Broca's area of chimpanzee brains suggests that this may be the case for Broca's area. Conversely, chimpanzee's do have a leftward asymmetry in the planum temporale, implying this region is not related to the lateralization of language.

Our next steps include investigating the remaining asymmetric areas and then comparing them with behavioral data. We will also separate the subjects based on handedness and compare the asymmetric areas of right and left handers.