Highest cross-hemisphere correlations of resting-state FMRI in the awake macaque exhibit high correspondence to the pattern of callosal synaptic connections

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TARGET AUDIENCE

Researchers in Brain Imaging, Functional MRI, Neuroscience, and Brain Connectivity.

PURPOSE

In the previous study,[1] we reported that the resting brain activity of one hemisphere in human brain was maximally correlated with locations close to the corresponding anatomical location in nearly half of the cortex, and these locations are concentrated in particular cortical locations where maximally correlate with seed points in the contralateral hemisphere, which are highly overlapped with the locations of callosal connections revealed by horseradish peroxidase tracing in monkeys. To examine this phenomenon, we present that the maximum correlations of resting-state (RS) functional magnetic resonance imaging (FMRI) for individual monkeys can reflect the locations of axonal connections that were revealed by the existing studies of anatomical tracing experiments.

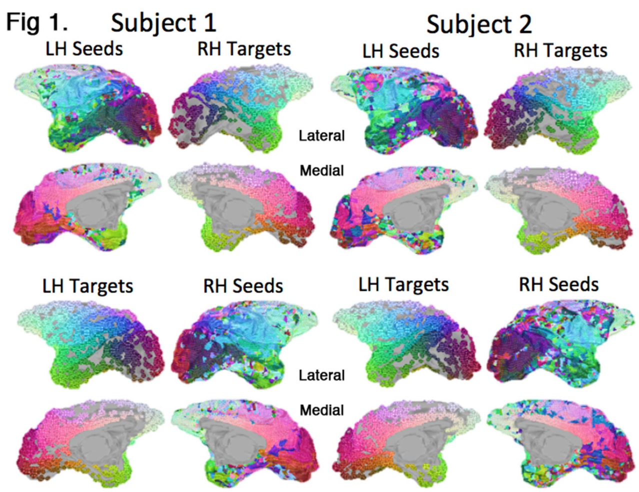
METHODS

Two adult monkeys were participated as subjects of this study. All MR image data were collected using a Bruker 4.7T scanner, and the subjects were awake and their heads were fixed in a head frame. For each subject, 10 sessions of RS time series were acquired using a T2*-weighted gradient echo pulse sequence (GE EPI; 1.5mm isocubic, TR=2.4s). Each of the RS scans lasted for 10 minutes. An MPRAGE sequence was used to acquire three T1-weighted anatomical images (0.5mm isocubic). Two FLASH images were also collected to support successful co-registration between T1-weighted and EPI data. The imaging data of each individual subject were aligned to each other, and then the images of one subject were non-linearly matched to those of another subject by AFNI's 3dQwarp program.[2] Aligned anatomical images were then processed with Caret/SureFit pipeline for cortical surface extraction.[3] The following procedures were carried out using AFNI's suite of programs.[2] Cortical surfaces were geometrically standardized by SUMA.[4] Preprocessing of the RS-EPI time series was carried out using the basic ANATICOR method with despiking and bandpass filtering ($0.01<f<0.1$Hz).[5] Corresponding cortical nodes in the two hemispheres were identified by finding nodes with the most similar pattern of relative distances from manually defined 64 within-hemisphere landmarks.[1] The residual time series from the ANATICOR were mapped onto cortical surfaces, and smoothed with a heat kernel (2.25mm FWHM). For each scanning session of each subject, we calculated the full cross-correlation matrix for the time series of every node on both hemispheres. These correlation matrices were then averaged to make a correlation matrix reflecting common characteristics of connectivity within a subject. For determining functional connectivity across hemispheres, each node in one hemisphere is the seed, and all nodes in the contralateral hemisphere are its target candidates. The functional correspondence of seed is defined as the contralateral target node whose time series is maximally correlated to that of the seed.

RESULTS

Throughout most of the cortex, functional correspondences are near their anatomical correspondences in the contralateral hemisphere, indicated by a similar color layout for seed and target hemispheres (Fig. 1). Neighboring seed nodes share the same precise functional correspondence in the contralateral hemisphere, leaving some target nodes without any corresponding seed. Discrepant colors in the seed maps of Fig. 1 indicate that the functional correspondence in the contralateral target hemisphere is not near the anatomical correspondence, with the precise color indicating the position of the functional correspondence in the target hemisphere. The target nodes that were maximally correlated with the seeds are located in near large sulci as an anatomy study revealed.[6] The patterns of highest correlations across hemispheres were quantified by Functional Asymmetry Distance (FAD).[1] Few regions showed high functional asymmetry in ventral visual areas and frontal cortex (Fig. 2).

Fig 1.



DISCUSSION

Most cortical areas have the functional correspondences in their contralateral locations, and this is highly relevant to the results of the same analysis in human brain. However, few areas in lateral frontal and parietal cortices showed different patterns in both subjects. We suggested that those regions might reflect the individual difference in functional lateralization, and the individual-level further analysis on that topic should be performed as described in the existing study on functional lateralization in human group.[7]

CONCLUSION

The RS activity of one hemisphere was maximally correlated with locations close to the corresponding anatomical location in nearly half of the cortex in macaque brain, locations which are strongly reminiscent of the locations of callosal connections revealed by horseradish peroxidase tracing in monkeys, particularly in occipital, temporal, and parietal cortex around large sulci.

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Fig 2.