

Comparing the patterns of Cortical Thickness Correlation and Fibre Anatomical Connectivity in the Human Brain



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Introduction

Previous studies have repeatedly demonstrated correlations of morphometric features (e.g. cortical thickness) between specific brain areas (i.e. morphometric connectivity) [1-2]. Such morphometric connections might reflect underlying white matter fibre tract linkages [2-4]. However, the nature of relationship between these two modalities of connectivity has not been explicitly studied. In this study, we compared the patterns of cortical thickness correlation and white matter connectivity derived from diffusion tractography across the entire cerebral cortex in the same population.

Methods

The study included 95 neurologically normal adults (males/females: 47/48; age: 19-85 years). Structural MRI and diffusion MRI were acquired from a 1.5T scanner. The cerebral cortex was parcellated into 78 regions using the automated anatomical labeling (AAL) [5]. The cortical thickness across the entire cerebral cortex was computed by using local CIVET pipeline [6]. The Pearson correlation coefficient of regional cortical thickness was then calculated between each region pair, controlling for age, sex and mean overall cortical thickness. Using probabilistic diffusion tractography [7], we further estimated anatomical connectivity probabilities between each two cortical regions, as previously described [8]. These procedures resulted in one 78×78 symmetric correlation matrix for cortical thickness across the population and one 78×78 symmetric probability matrix of fibre connectivity for each subject. A modality-specific threshold, for cortical thickness correlation or probability of fibre connectivity at a population level [3, 8], was chosen to ensure the same proportion of supra-threshold connections (sparsity). There is no definitive choice for sparsity and we therefore compared the two matrices over a range of sparsities (8.9% ~ 33.3%). We analyzed the similarity of spatial distribution of connections between modalities and the percentage of overlapped connections, as a function of sparsity. Positive and negative correlation maps were analyzed separately.

The similarity of spatial distribution between the two modalities was defined as the ratio of the number of agreement connections (simultaneously showing presence or absence in both modalities) to the number of all possible regional pairs. The percentage of overlapped connections was calculated by dividing the number of overlapped connections by the number of all connections (identical for both modalities by choice of threshold).

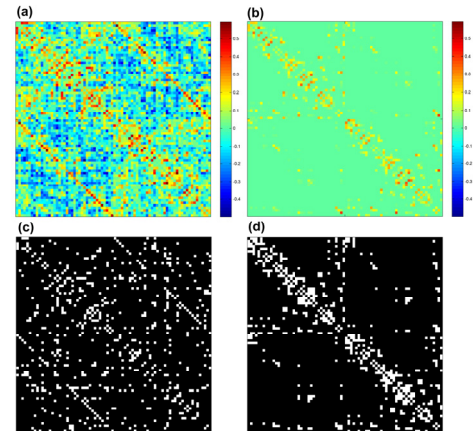


Fig 1. The matrices of cortical thickness correlation and averaged probability of fibre connectivity are shown in Fig 1a and Fig 1b, with their corresponding binary matrices at a specific sparsity (10%) in Fig 1c and Fig 1d, respectively. In these matrices, each row or column represents one AAL regions (see 8).

Results

As shown in Fig 2, the similarity and percentage of overlapped connections are significantly higher than expected ($p < 0.05$).

The percentage of positive or negative connections relative to all morphometric connections is shown as a function of sparsity in Fig 4a. In particular, we found that majority of negative morphometric connections (~80%) link inhomogeneous inter-hemispheric regions as shown in Fig 4b. As demonstrated in Fig 4c, more than 60% of the positive cortical correlation connections were matched by fibre connections (blue spots in Fig 3a). However the vast majority of negative cortical correlation connections (> 90%) had no underlying anatomical connections.

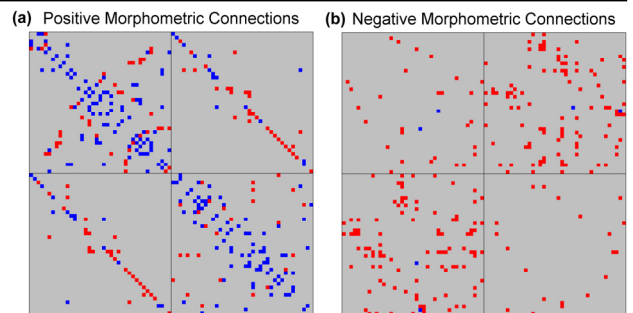


Fig 3. positive (a) and negative (b) matrices for cortical correlation at a sparsity of 10%. Blue or red colours indicate the presence or absence of a corresponding fibre connection.

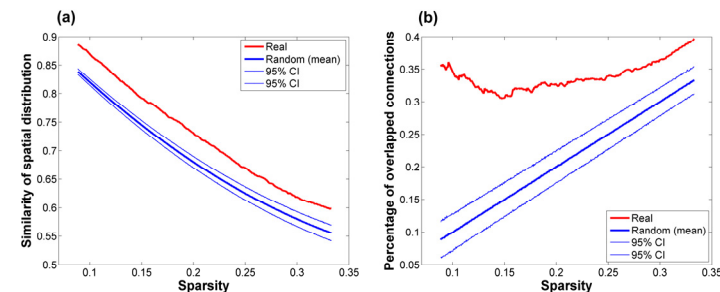


Fig2. The similarity (a) and percentage (b) of overlapped connections between morphometric and anatomical connections. Random binary matrices with the same sparsity were generated 1000 times to estimate the values that would be expected by chance.

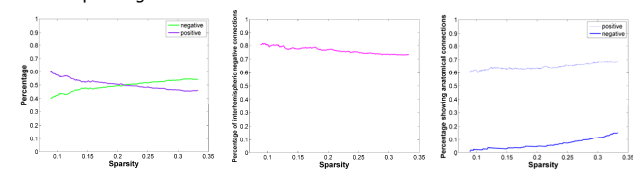


Fig4. Statistics between morphometric and fibre tract connections as a function sparsity: a) percentage of positive or negative connections relative to all morphometric connections; b) percentage of inter-hemispheric connections; c) percentage of positive and negative cortical thickness correlations having fibre tract connections, separately.

Conclusions

Our present study demonstrated the relationship between cortical correlation and fibre connectivity across the cerebral cortex. However, only 35-40% of cortical correlation connections (Fig 2b) correspond to fibre connections. Intriguingly, almost all (> 90%) of the negative cortical correlations have no corresponding fibre connection. This suggests that entirely different mechanisms might underlie the correlation and anti-correlation of cortical morphometry, the latter not being mediated by a direct fibre pathway. This finding may have significant implications for our understanding of how the brain is organized and what different forms of connectivity analysis (functional, cortical, DTI) might tell us about the dynamics of inter-regional communication in the brain.

References

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