A systematic relationship between intracortical myelin and functional connectivity in the human cerebral cortex

Julia M. Huntenburg[1], Pierre-Louis Bazin[1], Alexandros Goulas[2], Christine L. Tardif [3], Daniel S. Margulies[1]

1 Max Planck Institute for Human Cognitive and Brain Science, Leipzig, Germany, 2 University Medical Center Hamburg-Eppendorf, Hamburg, Germany,
3 Douglas Mental Health University Institute, McGill University, Montreal, Canada

huntenburg@cbs.mpg.de

MAX-PLANCK-GESELLSCHAFT

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

Introduction

A relationship between microstructural similarity and cortico-cortical connections has been demonstrated in the macaque, cat and mouse cortex [1-3].

We investigated this link in the human cortex using two high-resolution MRI measures:

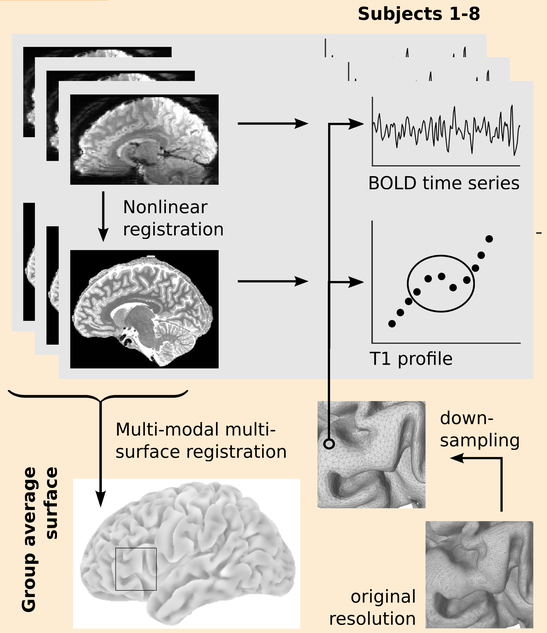
- qT1 maps, reflecting intracortical myelin content
- resting state functional connectivity (FC)

Data

MRI datasets of 8 subjects acquired at 7 Tesla :

- 4 resting state scans [4]
  (300 volumes, 70 slices, voxel=1.5 mm^3 , TR=3s, TE=17ms, FA=70°, GRAPPA=3)
- Quantitative T1 map [5]
  (MP2RAGE, voxel=0.5 mm^3 , TI1/2=900/2750ms, TR=5s, TE=2.45ms, FA1/2=5/3°)

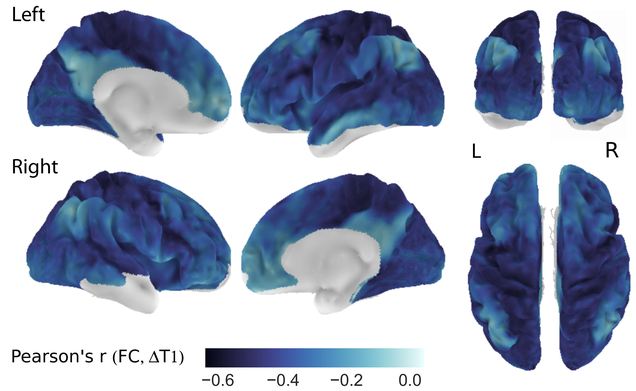
Methods



- Preprocessing and sampling of T1 and FC on study-specific surface template [6,7].
- Sampling of T1 on 11 volume-preserving intracortical surfaces [8] and averaging of 5 central values to reduce partial volume effects.
- Nonlinear dimensionality reduction of the FC matrix using diffusion maps [9].

Results

1 T1 difference and functional connectivity show an inverse relationship.



Each node's functional connectivity to all other nodes was correlated to its T1 difference to those nodes.

The two measures show a strong negative correlation in unimodal but not in (posterior) heteromodal regions.

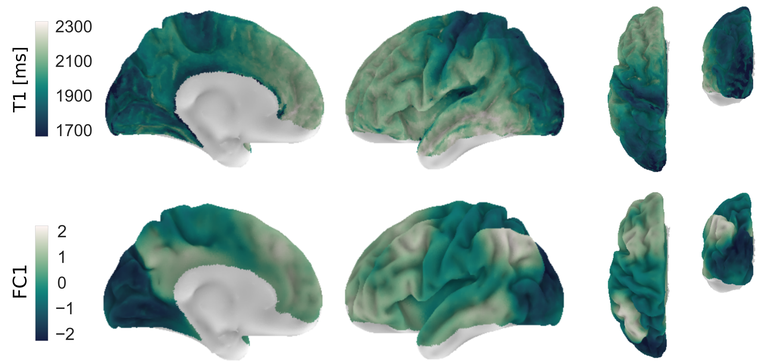
The overall correlation across the cortex is r = 0.34.

2 The principal gradient of functional connectivity is strongly related to T1.

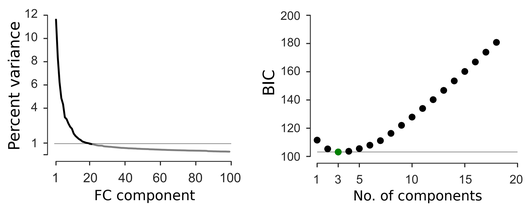
The principal gradient (FC1) captures the main variance in functional connectivity across the cortex [10].

Its spatial layout resembles the map of intracortical T1, except for posteriomedial and inferior parietal regions.

The spatial correlation of the two maps is r = 0.53.



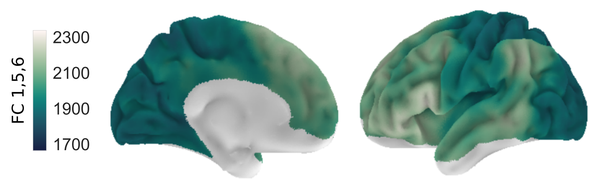
3 Including multiple functional connectivity components improves the fit.



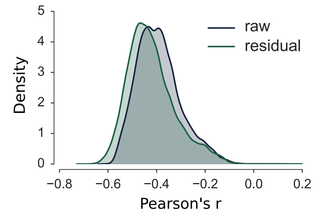
The best model, according to Bayesian Information Criterion, contains only three specific components : FC1, 5, and 6. Fit in previously diverging areas is improved (r = 0.67).

All possible linear combinations of the first 20 FC components were used to fit T1 :

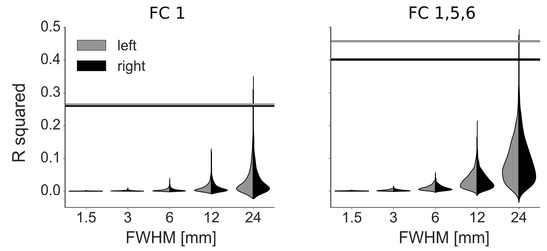
$$T1 = \beta_0 + \sum_j \beta_j FC_j + \epsilon$$



4 The relationship is not explained by physical distance or data smoothness.



Regressing Euclidean distance of nodes against the FC and T1 matrices does not alter their relationship substantially (r = -0.37).



Fit achieved for original T1 (horizontal lines) far exceeds that for randomly permuted, but strongly smoothed data.

Discussion

We demonstrated a systematic relationship between in vivo measures of intracortical myelin content and functional connectivity.

Lower correspondence in posteriomedial and inferior parietal regions is consistent across analytic approaches and might be related to the specific connectivity features and high plasticitiy of these areas.

Our results are in agreement with histological findings in different mammalian species and extend them to the human cerebral cortex.

References

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