

Investigating microstructural foundations of cortical speech tracking



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1 Background

- Low-frequency oscillatory activity in auditory cortex synchronizes to rhythmic patterns in the envelope of the acoustic input (Lakatos et al., 2005).
- Speech is quasi-rhythmic and neural activity in auditory cortex follows these rhythmic features, with prominent tracking occurring in the theta frequency range (4-8 Hz) for syllables rates and in the delta range (0.5-4 Hz) for prosodic rhythm (Ahissar et al. 2001; Gross et al., 2013).
- Speech tracking has been shown to be under the influence of top-down control from (pre-) motor and orbito-frontal areas (Park et al., 2015; Keitel et al., 2017).
- Stronger top-down influences lead to stronger entrainment in auditory areas (Park et al., 2015).
- Here we aim to investigate the microstructural foundations of top-down control in speech comprehension by relating local cortical myelination, as estimated by quantitative MRI (qMRI), to the strength of speech tracking across participants.

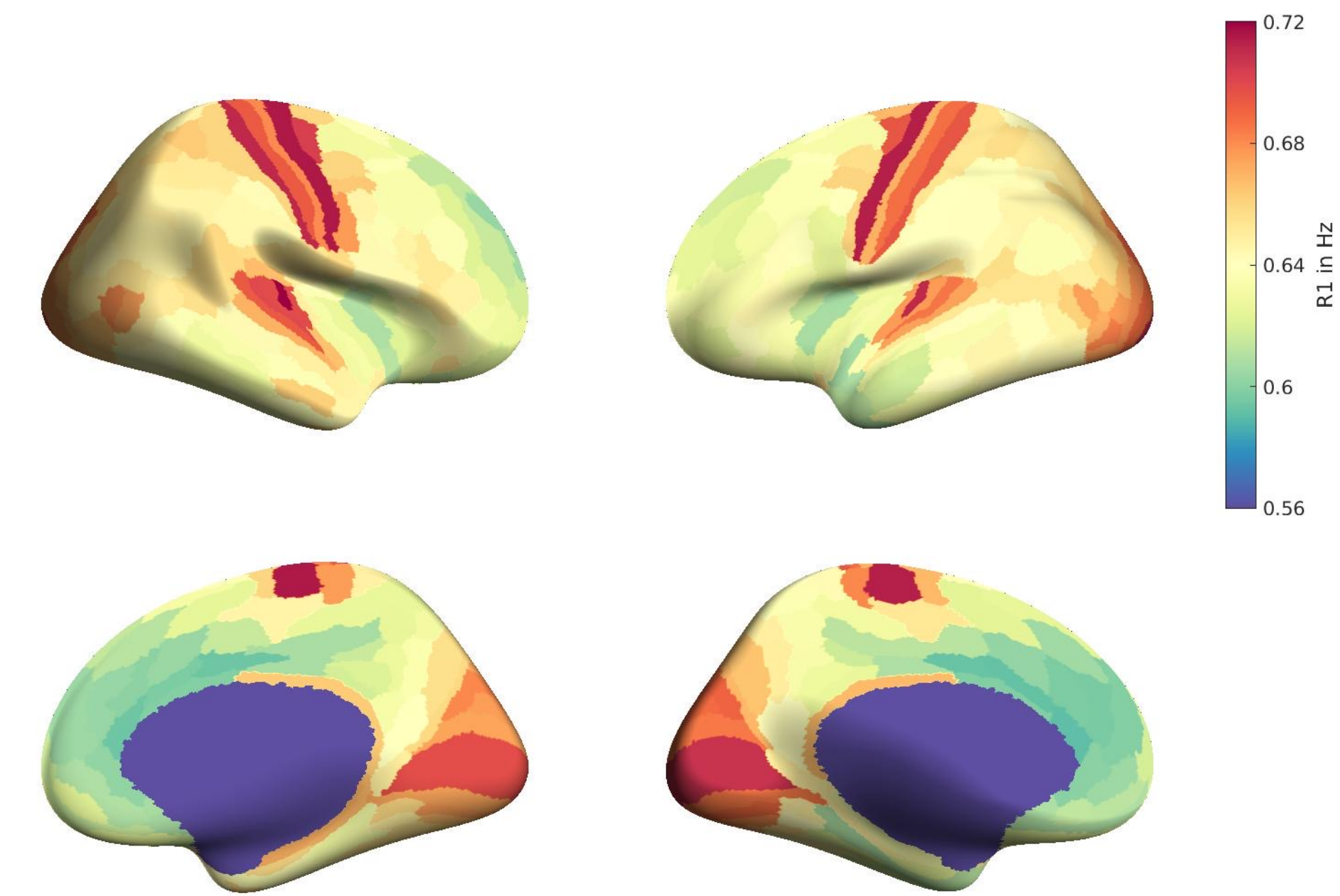
2 MEG and quantitative MRI data acquisition

- We acquired MEG data (Elekta-Neuromag, Helsinki, Finland) from 45 healthy participants while they passively listened to a short story.
- The short story (Das Schwimmteam, Miranda July, 11min 23 sec) was presented twice, once forward (story) and once backwards (backwards) in two separate blocks in randomly assigned order.
- For qMRI acquisition we used a multi-parameter map (MPM) protocol at a 3T Connectome scanner (Siemens Healthineers, Erlangen, Germany).
- The protocol includes 0.8mm isotropic FLASH scans of T1w, MTw, PDw images and calibration scans to correct for RF field and static magnetic field inhomogeneities (Weiskopf et al., 2013).

3 In vivo histology using qMRI

- Quantitative R1, R2* and MT maps were generated using the hMRI toolbox in SPM (<https://github.com/hMRI-group/hMRI-toolbox>).

- We used a custom-tailored FreeSurfer pipeline to obtain pial and WM surfaces from the MPMs.
- R1 values were sampled at 50% cortical depth as a marker for cortical myelination.

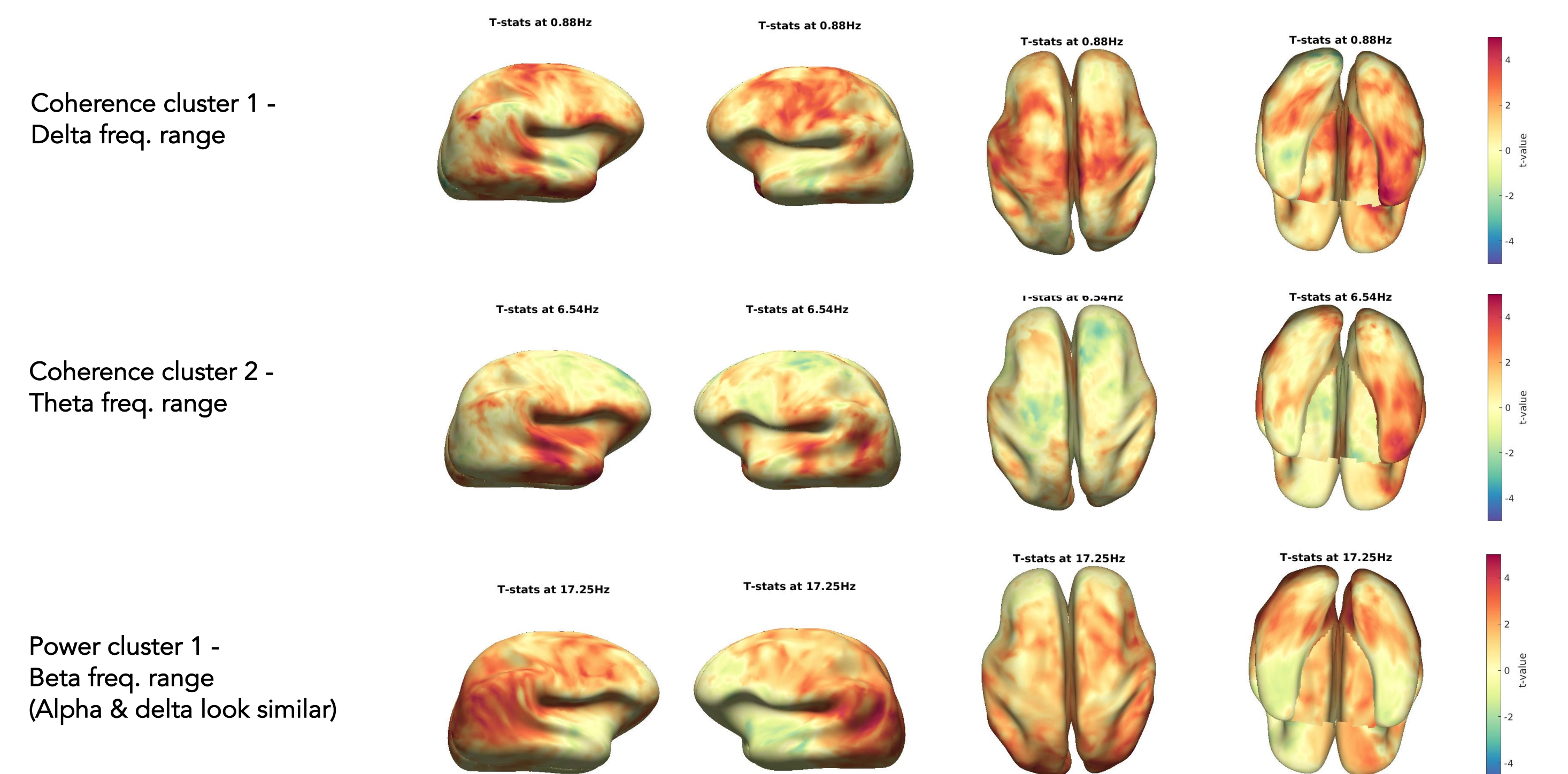


Quantitative MRI-based myelin estimates from the R1 map of longitudinal relaxation across the cortical surface. Plots show the mean over vertices and subjects in each area of the HCP MMP 1.0 parcellation.

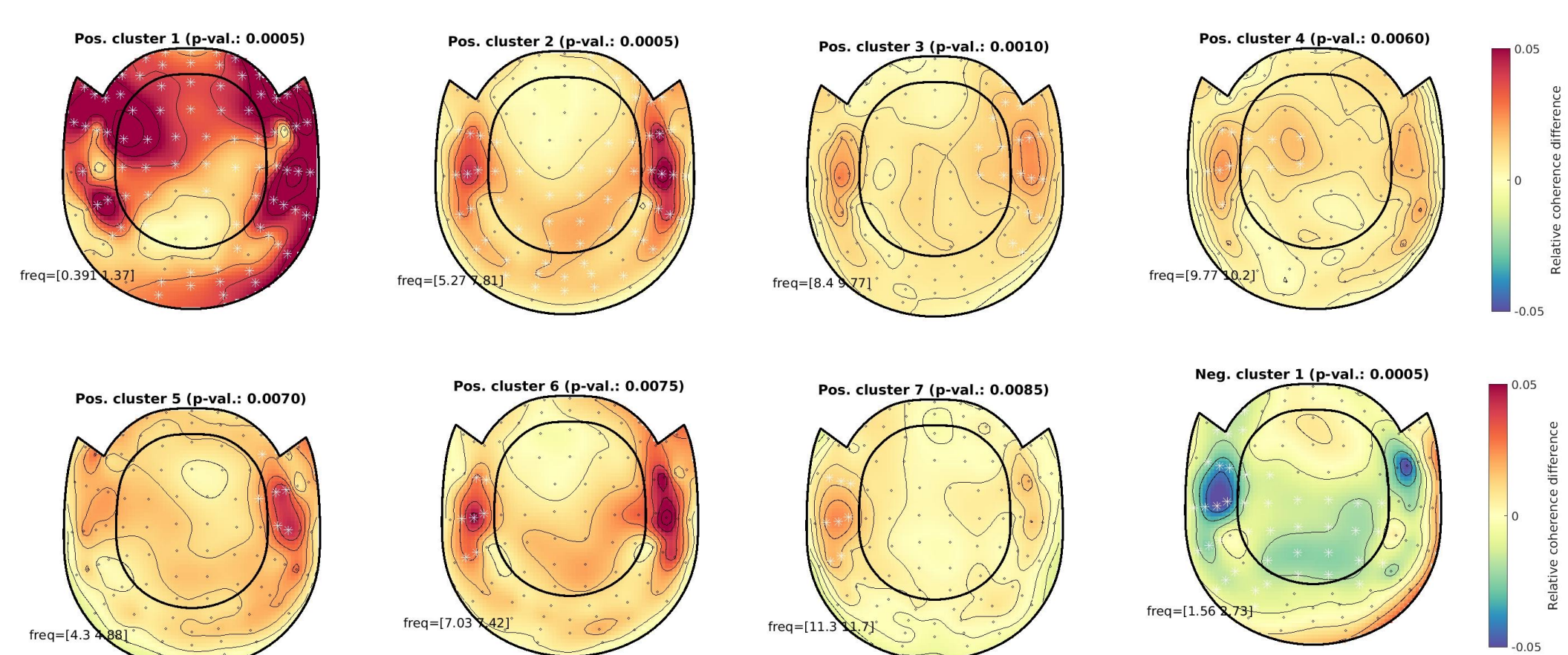
4 MEG processing pipeline

- Raw MEG data was converted to BIDS format and maxfiltered in MNE-Python.
- Eye movement and heart beat artefacts were semi-automatically rejected using an ICA based on the Picard algorithm
- Data were imported into Fieldtrip and epoched into segments of 5 sec
- Signal envelopes were constructed from the average of eight logarithmically spaced channels (100 - 10.000 Hz) using full-wave rectification and a low-pass filter of 100 Hz, and added to the epoched MEG datasets.
- We calculated sensor-level cerebro-acoustic coherence between the speech envelope and brain signals across a frequency range from 0.4 to 20 Hz.
- Cluster-based permutation statistics were used to identify significant differences in cerebro-acoustic coherence between *story* and *backwards* conditions (cluster-entry alpha level: 0.01).
- In addition, we also performed cluster-based permutation statistics on power differences between the two conditions.
- The mid cortical surface from our FreeSurfer pipeline was transformed to MEG space and down-sampled to approximately 8000 vertices using Workbench (<https://www.humanconnectome.org/software/connectome-workbench>).
- We applied a DICS beamformer to yield coherence and power values in source space at frequency bands of interest defined by the sensor level results.

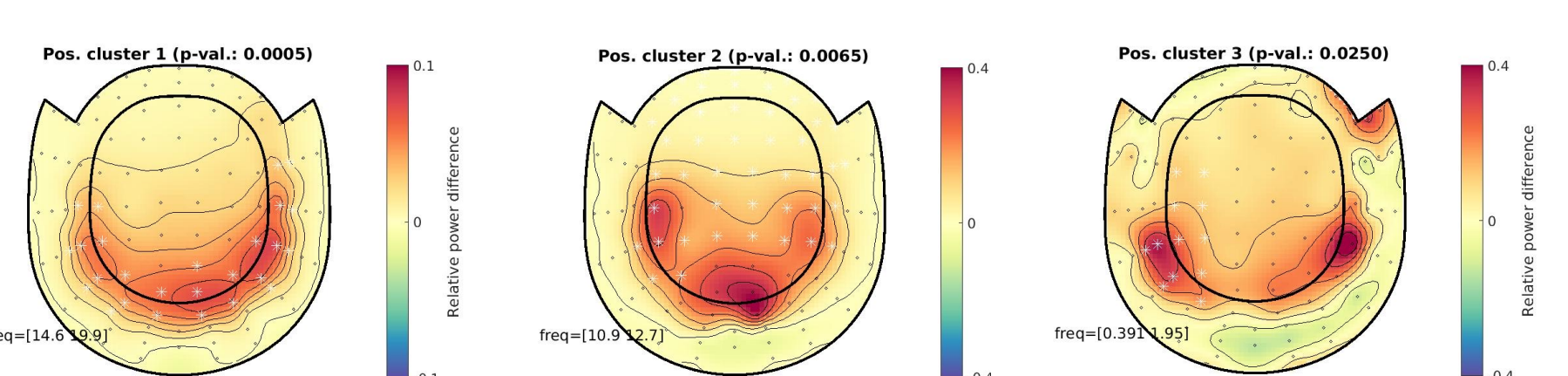
6 Speech tracking results: source level



5 Speech tracking results: sensor level



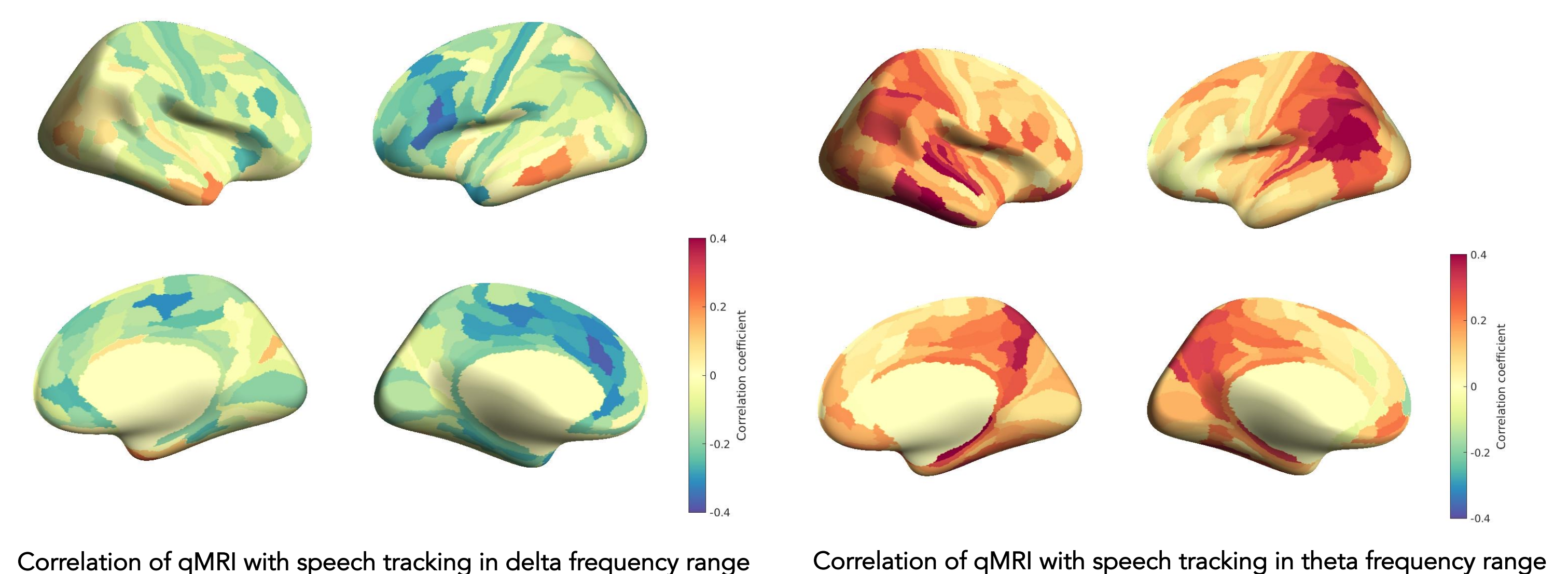
Significant clusters for coherence differences between *story* and *backwards* conditions.



Significant clusters for power differences between *story* and *backwards* conditions.

7 Correlations between speech tracking strength and in vivo histology

- To investigate the link between speech tracking strength and cortical myelination we first averaged coherence measures across all frequency bins and sensors within each significant cluster in sensor space for each participant separately.
- We then correlated this mean cluster coherence values with R1-based myelin estimates across participants at each of the 360 regions of interest (ROIs) defined by the HCP MMP 1.0 multi-modal parcellation (Glasser et al, 2016).
- We present correlation results at an uncorrected significance level of $p < 0.05$.
- We repeated the analysis for power but did not find any significant correlations with cortical myelination.



Correlation of qMRI with speech tracking in delta frequency range

Correlation of qMRI with speech tracking in theta frequency range

Conclusion and Outlook

- We replicate previous findings of cortical speech tracking in the delta and theta frequency range and provide the novel finding that the strength of speech tracking correlates with non-invasive estimates of local myelination.
- Myelination at inferior parietal cortex was related to speech tracking strength in the theta frequency range and to oscillatory power in frequency ranges previously linked to prediction signals.
- IPC has been shown to be involved in semantic processing and has been hypothesised to provide semantic constraints during language comprehension. Further it has been linked to verbal memory retrieval and violations of memory expectations (Seghier et al., 2013). Interestingly, we also found significant correlations for bilateral hippocampus.
- The negative correlations at inferior frontal regions, bilateral cingulate motor and anterior cingulate areas could be related to motor predictions in speech perception. The unexpected negative correlation can potentially be explained by the larger myelination at mid cortical layers at cortical areas linked to top-down signals (Goulas et al., 2018).
- We next want to further investigate the functional connectivity between the identified putative top-down areas and auditory areas showing cerebro-acoustic entrainment as well as the functional connectivity between the different top-down areas.