Where is the other hippocampus?

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Background

Many functional MRI studies investigating hippocampal function show bilateral activation in the anterior hippocampus *[1–2]*. Whilst in MEG studies using similar paradigms, the responses are typically unilateral *[3–4]*. Between 1990-2020, 49/83 published source-level MEG studies reported unilateral hippocampal activation, of which the majority use beamformers *[5]*. ***Hypothesis:*** *this is artefactual and due to the correlated source suppression of beamformers.*

Theory

MEG sensor-level data, ***Y***, can be modeled as a set of distributed sources, whose activity ***J*** can be estimated as

$$\hat{\boldsymbol{J}} = \underset{\text{source covariance}}{\boldsymbol{Q}_j}\boldsymbol{L}^T\left(\underset{\text{noise covariance}}{\boldsymbol{Q}_\epsilon} + \boldsymbol{L}\boldsymbol{Q}_j\underset{\text{dipole forward model}}{\boldsymbol{L}^T}\right)^{-1}\boldsymbol{Y}$$

The Empirical Bayesian Beamformer (EBB *[6]*) models the source covariance matrix assumes all sources are independent (off-diagonals equal 0) and their variance follows beamformer definitions, such that for the nth modeled source

$$\boldsymbol{Q}_{j|EBB}(n,n) = \frac{1}{\boldsymbol{l}_n^T\boldsymbol{l}_n}\left(\boldsymbol{l}_n^T\underset{\text{data covariance}}{\boldsymbol{Q}_y^{-1}}\underset{\text{dipole forward model, for source } n}{\boldsymbol{l}_n}\right)^{-1}$$

Here we introduce the correlated EBB (cEBB) which assumes a dipole field pattern is shared between source *n* and source *m* to mimic a dual source beamformer

$$\boldsymbol{Q}_{j|cEBB}(n,n) = \boldsymbol{Q}_{j|EBB}(n,n) + \frac{1}{\{\boldsymbol{l}_n^T+\boldsymbol{l}_m^T\}\{\boldsymbol{l}_n+\boldsymbol{l}_m\}}\left(\{\boldsymbol{l}_n^T+\boldsymbol{l}_m^T\}\boldsymbol{Q}_y^{-1}\{\boldsymbol{l}_n+\boldsymbol{l}_m\}\right)^{-1}$$

Aim: *Use the associated model evidence of these source inversions to test for the presence of correlated sources in the hippocampus.*

Simulations

Three types of simulation based on a head in a CTF-257 system as a proof-of-principle for our correlated source test.

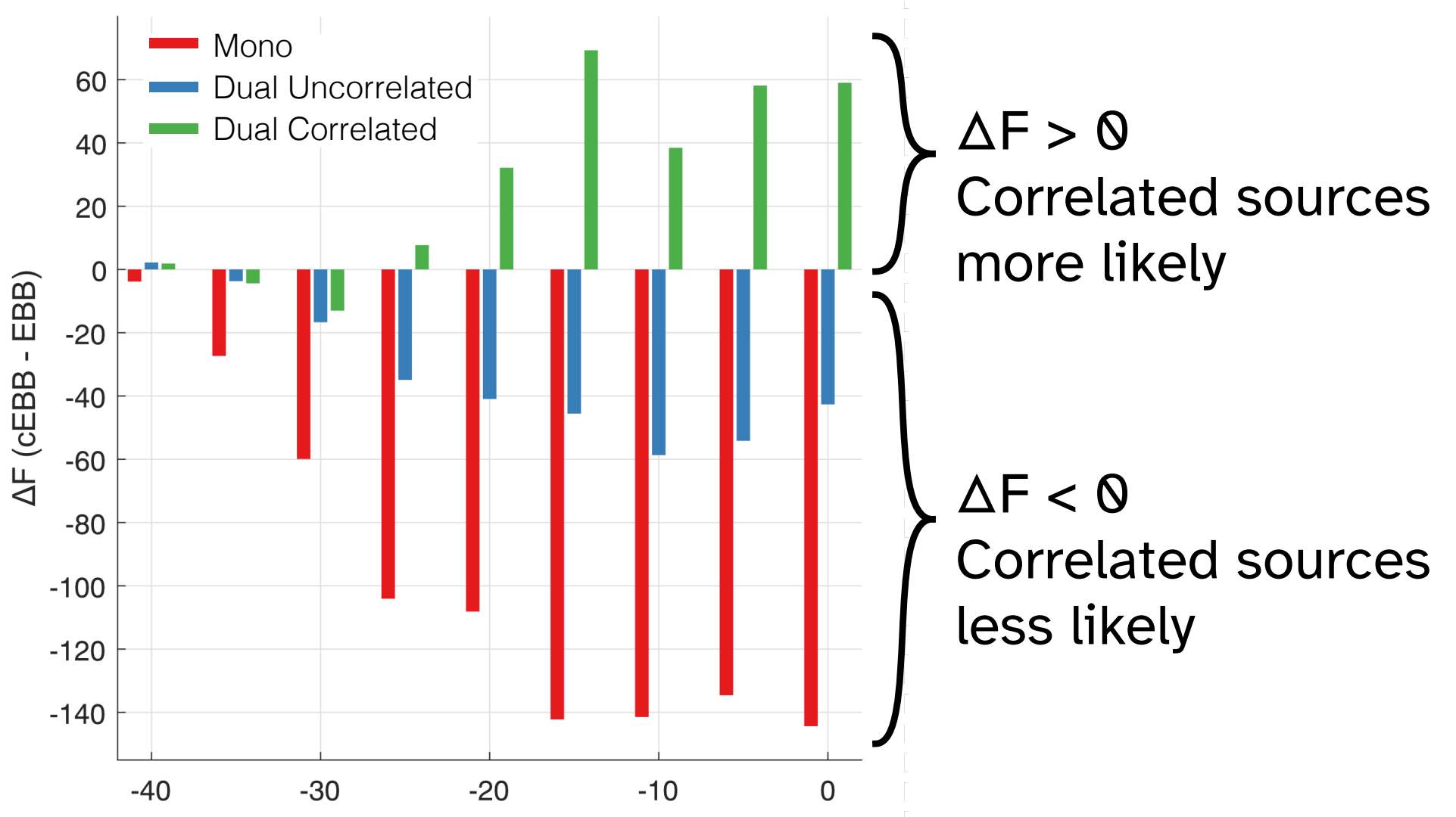
1. Single uncorrelated source;
2. Bilateral uncorrelated sources;
3. Bilateral correlated sources.

Simulations were either tested on shallow sources in Heschl's Gyrus or deep sources across the hippocampus.

Results

Cortical Simulations

Comparing the model evidence of the EBB and cEBB models shows its sensitivity to correlated sources in Heschl's Gyrus



ΔF > 0
Correlated sources more likely

ΔF < 0
Correlated sources less likely

Fig. 1

Results

Subcortical Simulations

Correlated sources can be detected all over the hippocampus envelope ***except*** in the anterior hippocampus, where it can only detect the presence of bilateral sources (Fig. 2A-C). This may be due to highly correlated lead fields arising from non-optimal sensor placement for this region (Fig. 2D).

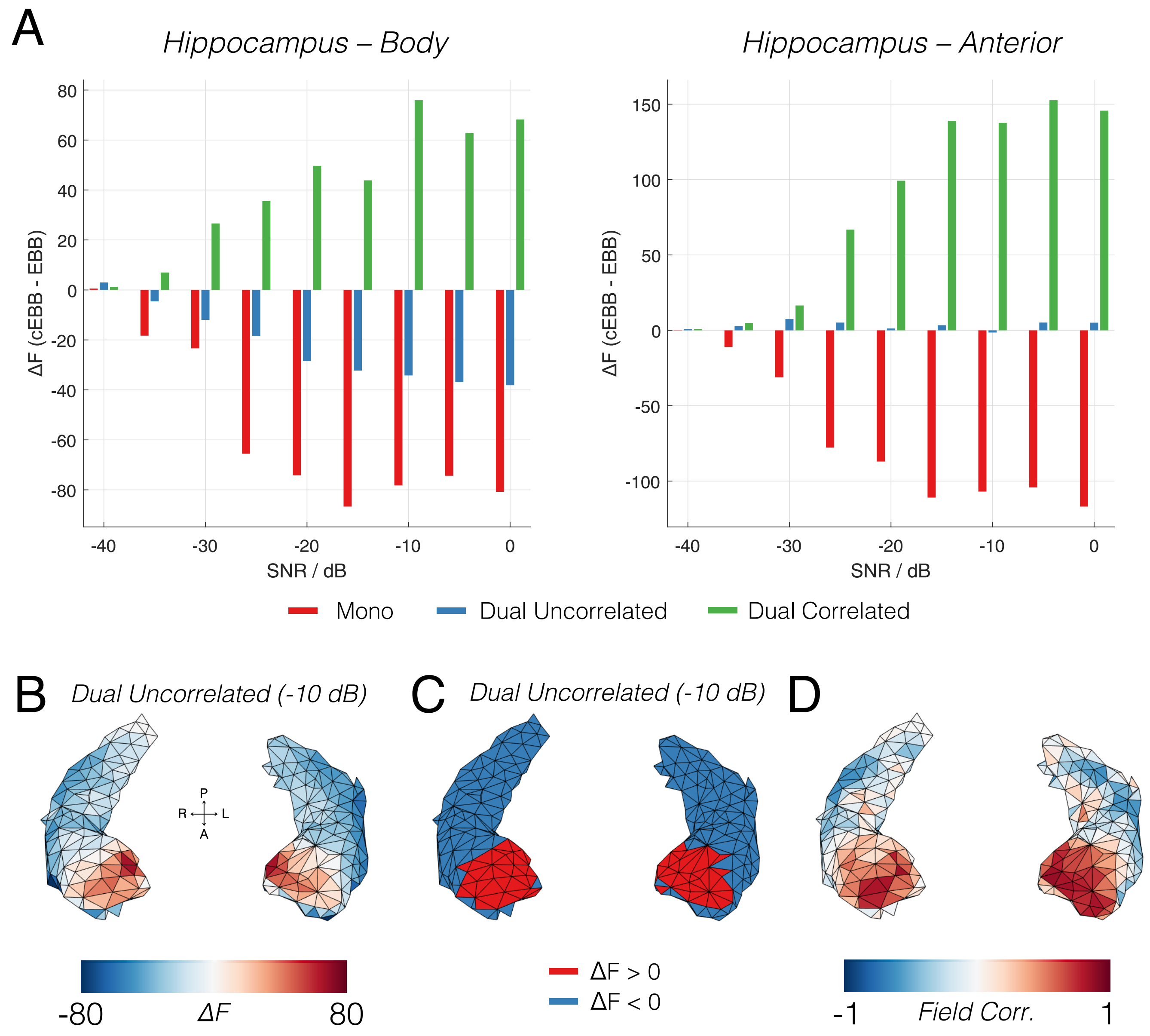


Fig. 2

Experimental Data

22 volunteers took part in a MEG study relating to novel scene and object imagery. We localised theta band (4-8 Hz) power. We tested differing models of correlated sources involving the cortex, hippocampus and compared them to a completely uncorrelated model.

Random effects analysis *[7]* showed that correlated hippocampal sources, whilst showing modest improvements in model evidence, were consistent across the group, whereas cortical correlated were occasionally a less plausible model (in 5/22 subjects; Fig. 3).

T-contrasts of the correlated source models showed significantly increased theta band power in the anterior hippocampus and temporal poles (Fig. 4).

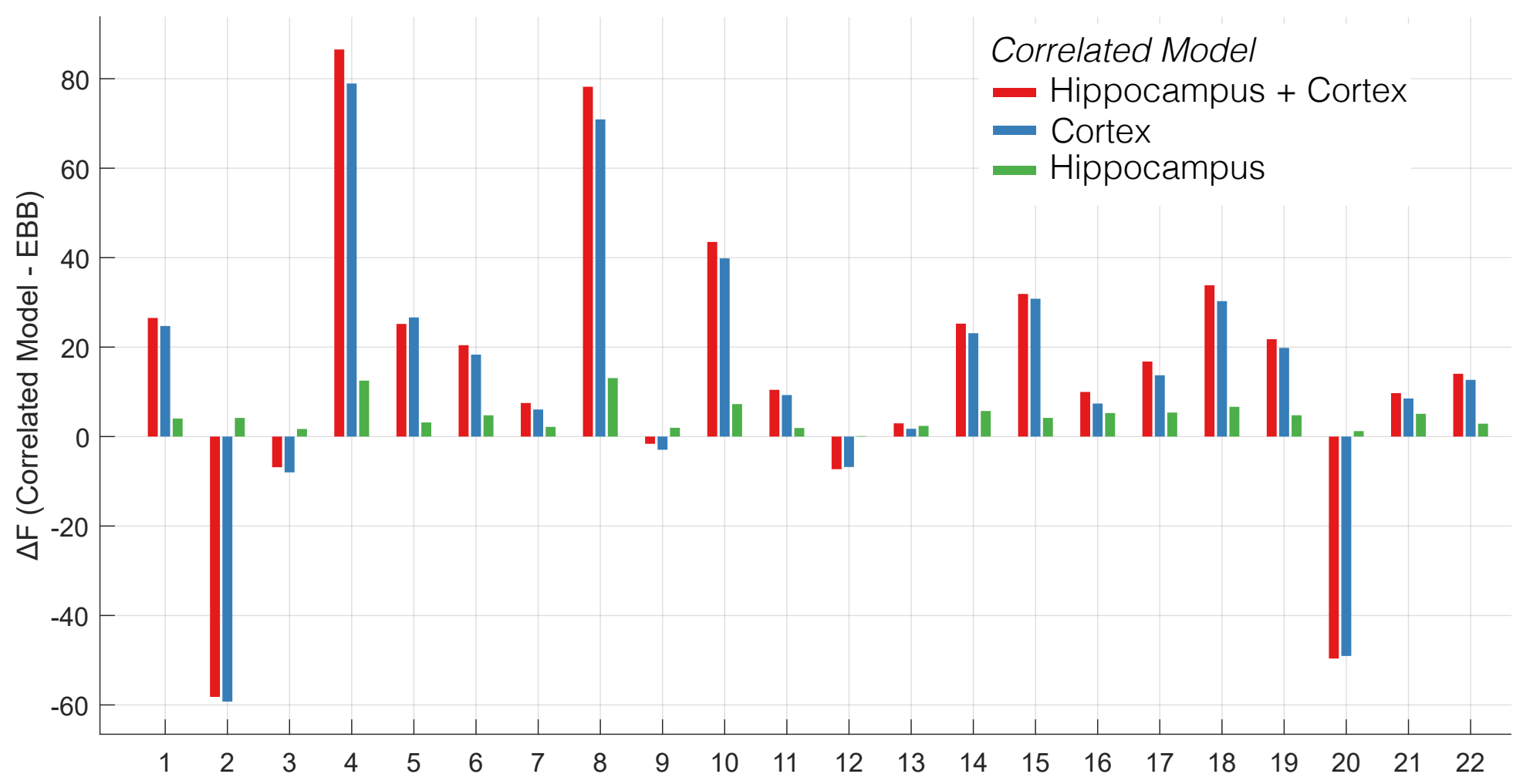


Fig. 3

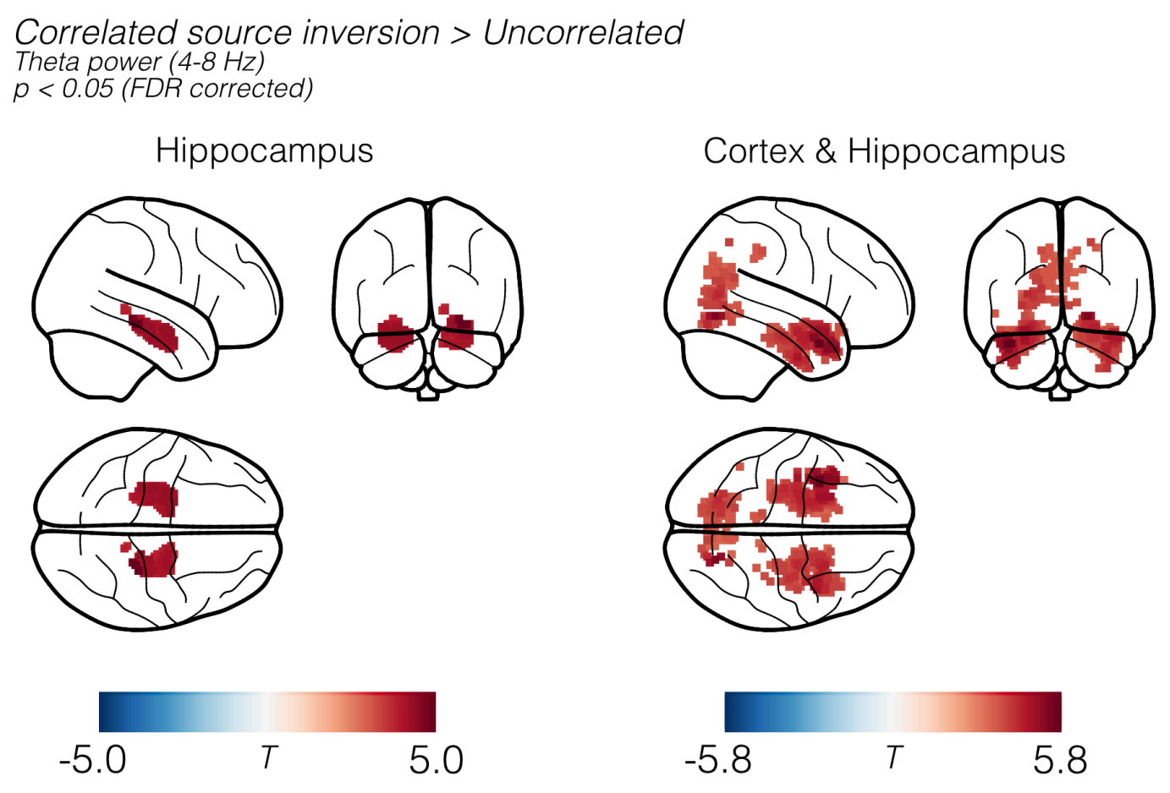


Fig. 4

Summary

Analysis of simulated and expeirmental MEG data suggests that adding a correlated source constraint to the hippocampus is beneficial to recover more oscillatory power from the area. ***However****, It is still unclear whether this is due to genuinely correlated sources or due to the anterior hippocampi being hard to separate with conventional MEG.*

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