Donders Institute
for Brain, Cognition and Behaviour

René Scheeringa

The relation between oscillatory EEG activity and the laminar specific BOLD signal

Peter Koopmans

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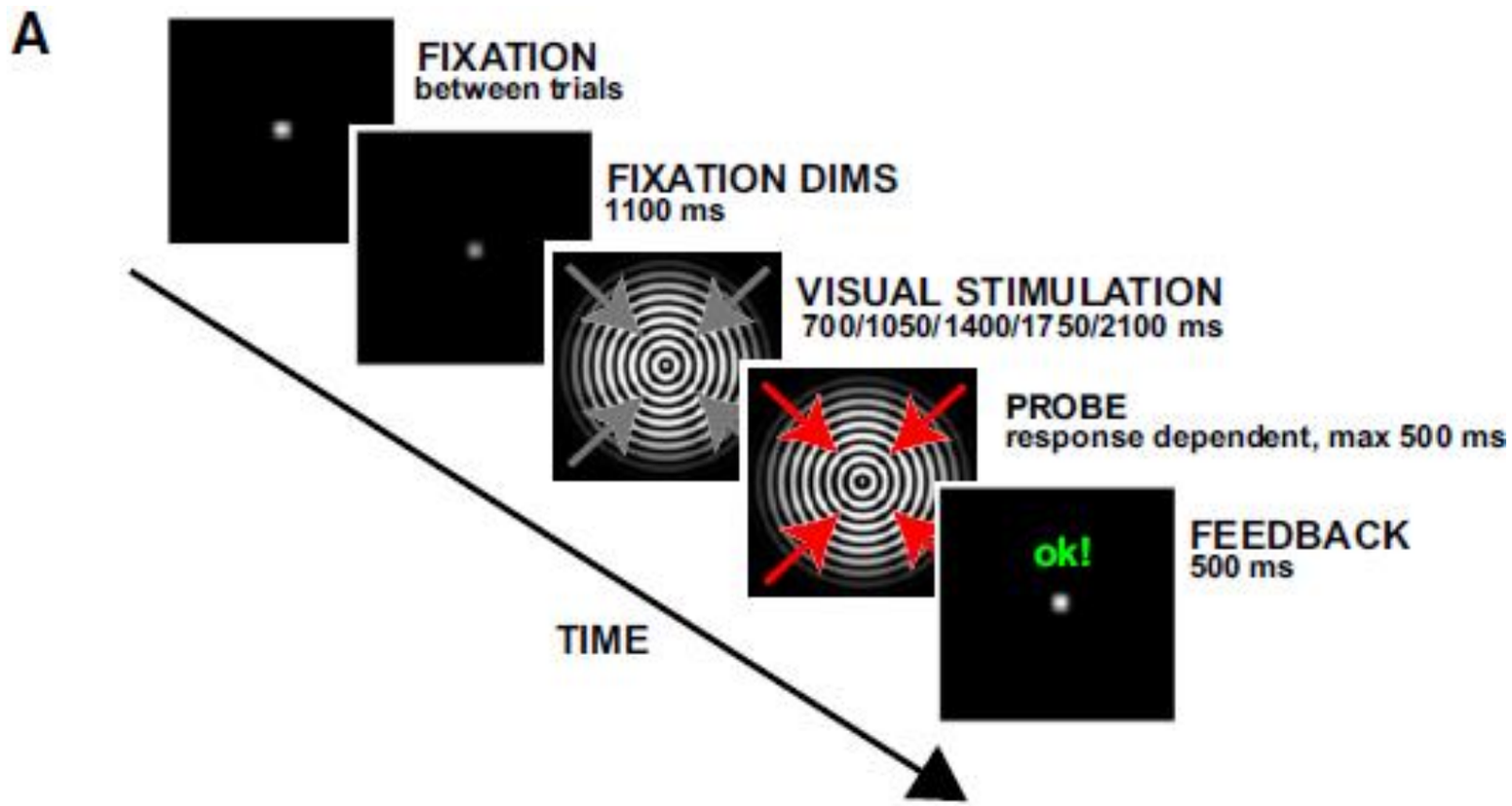
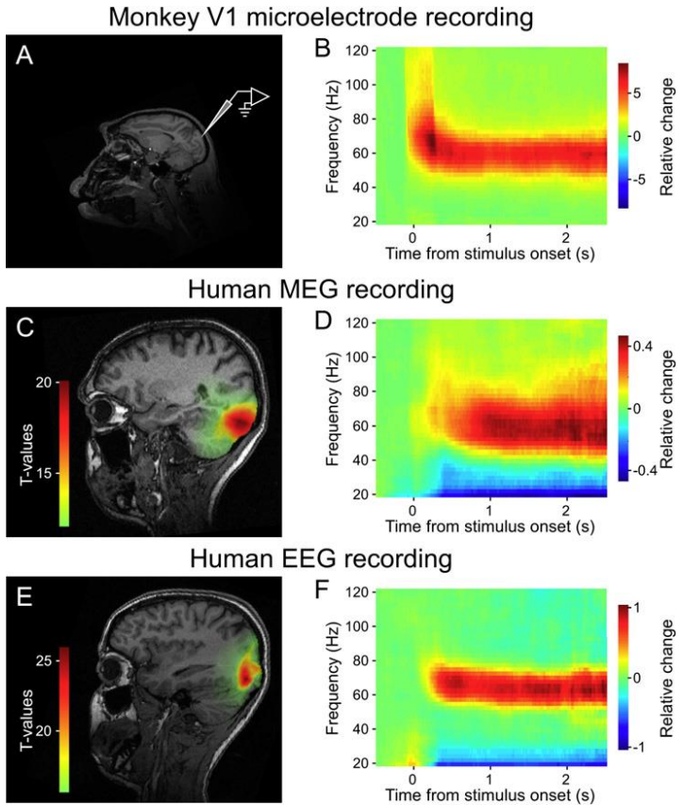
Frequency specific EEG power-BOLD correlations

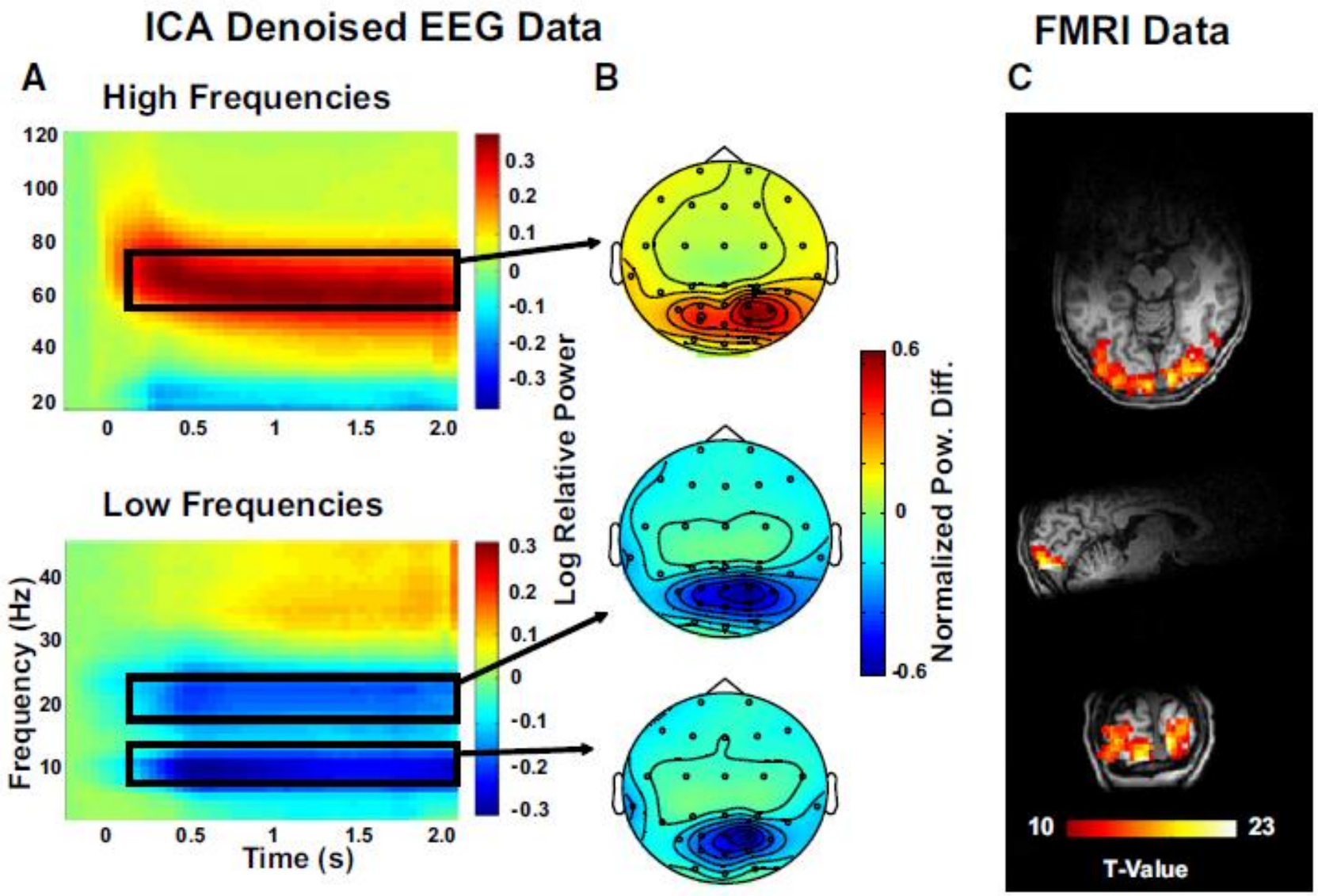


Scheeringa et al., 2011



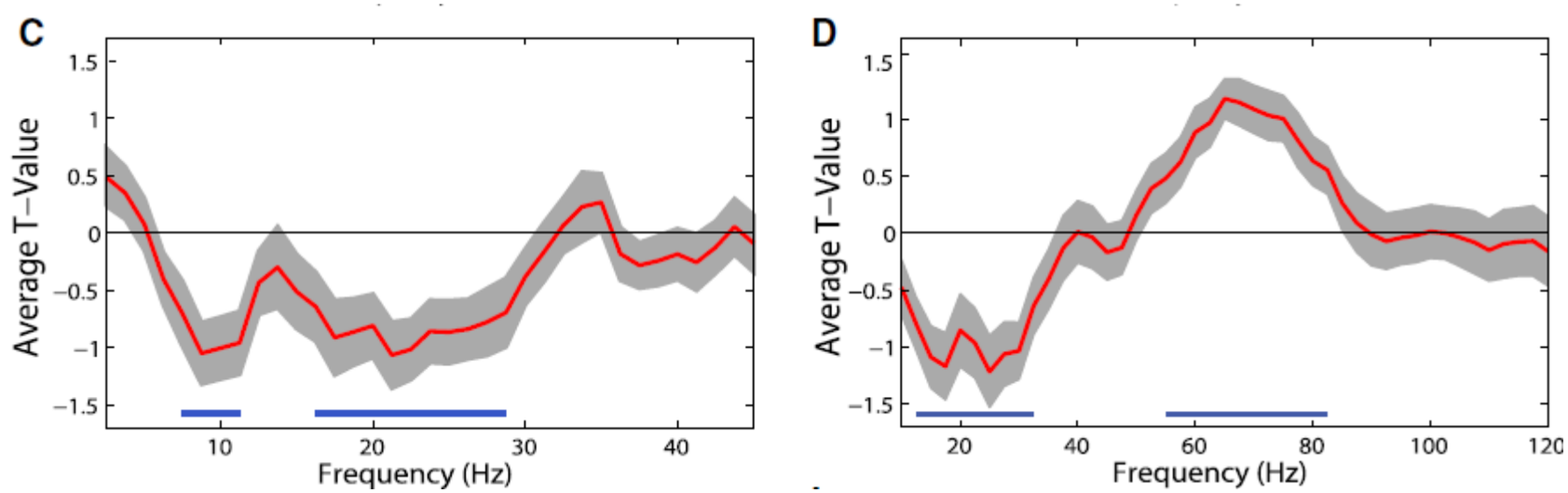
Fries et al., 2008

Frequency specific EEG power-BOLD correlations

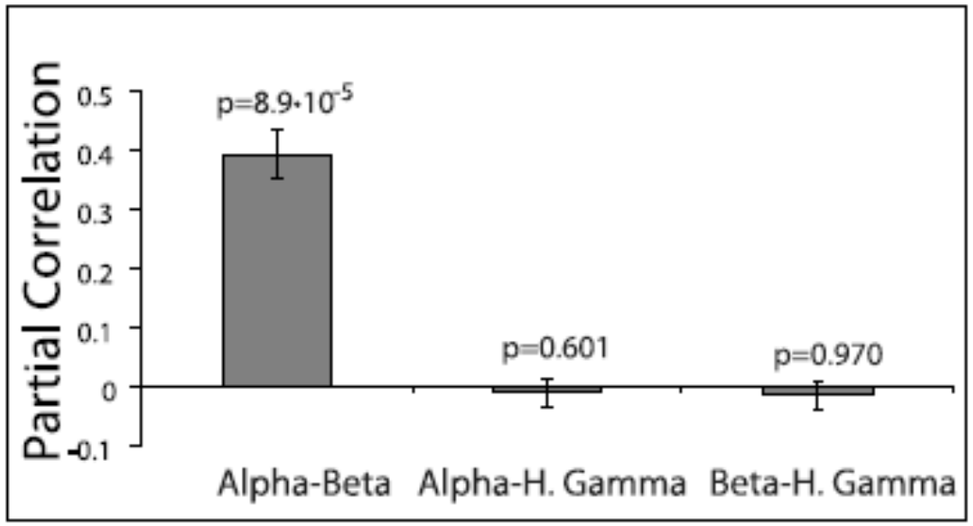


Results

EEG-BOLD RELATION

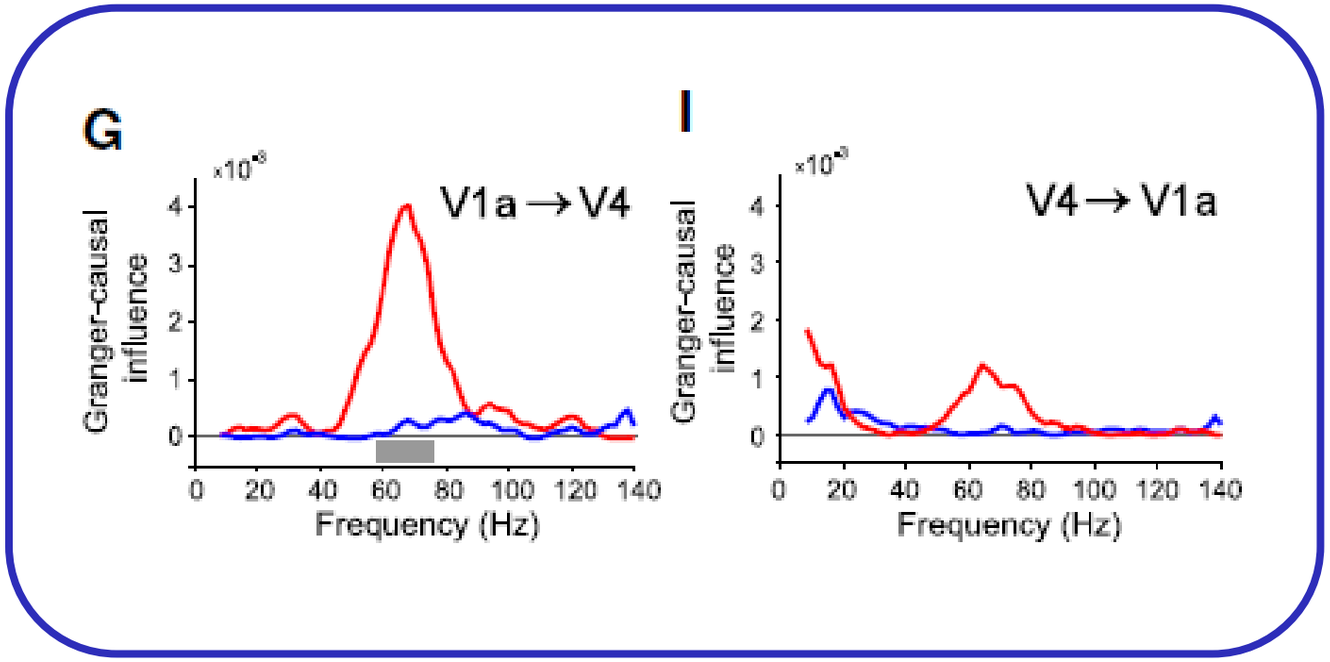


Relation between frequency bands

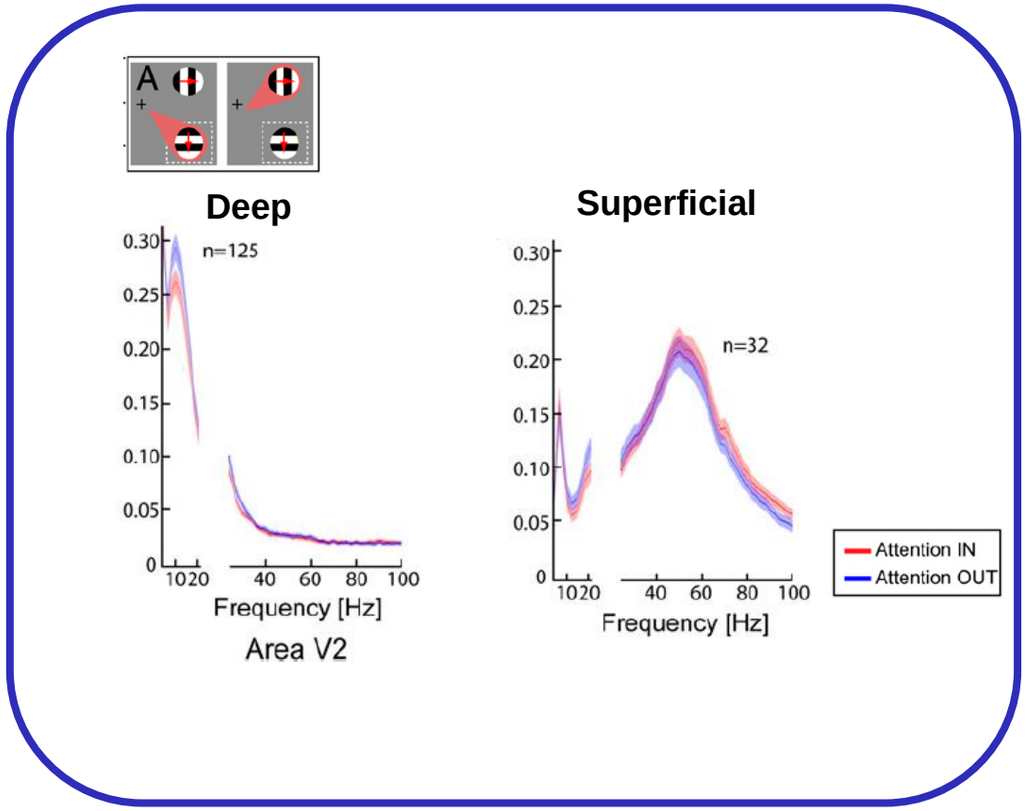


Alpha/beta power and gamma power contribute independently to the BOLD signal

Laminar electrophysiology



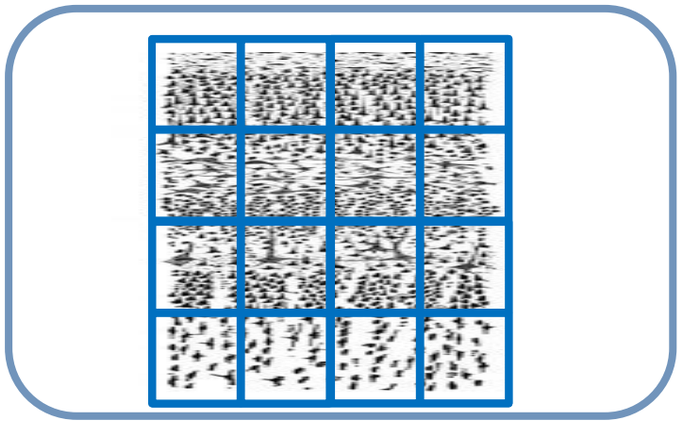
Bosman et al. (Neuron, 2012)

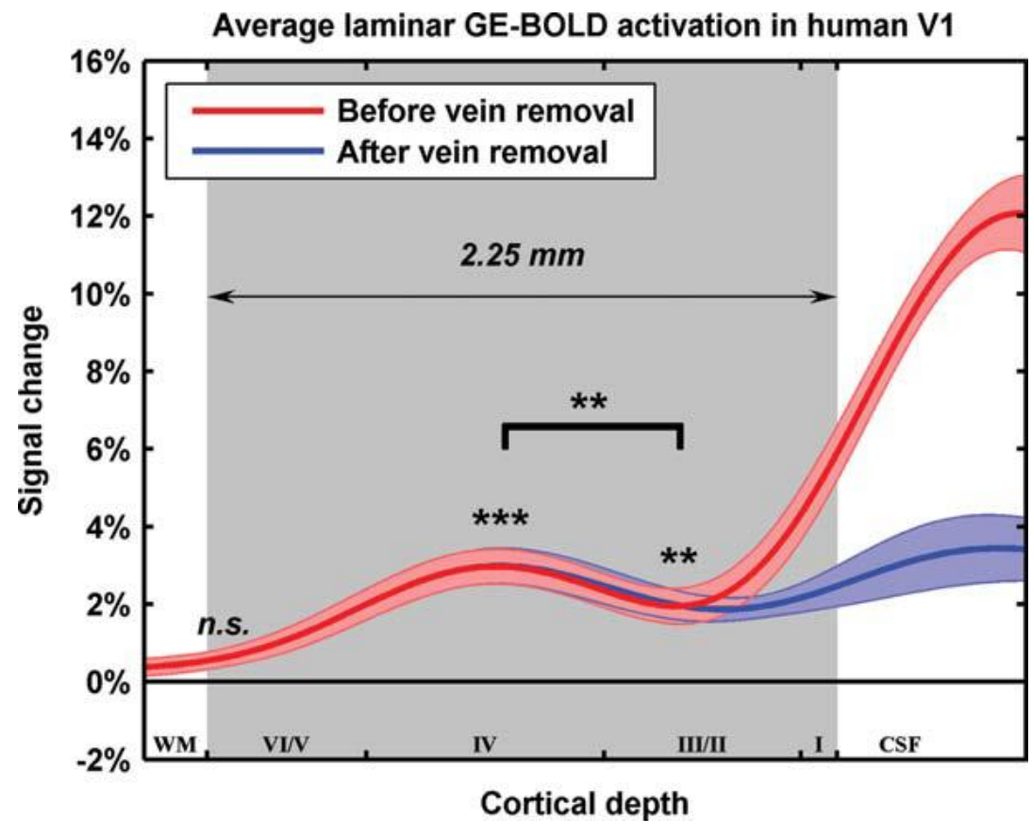


Buffalo et al. (PNAS, 2011)

Can we asses laminar activity non-invasively in humans?

Laminar resolution fMRI

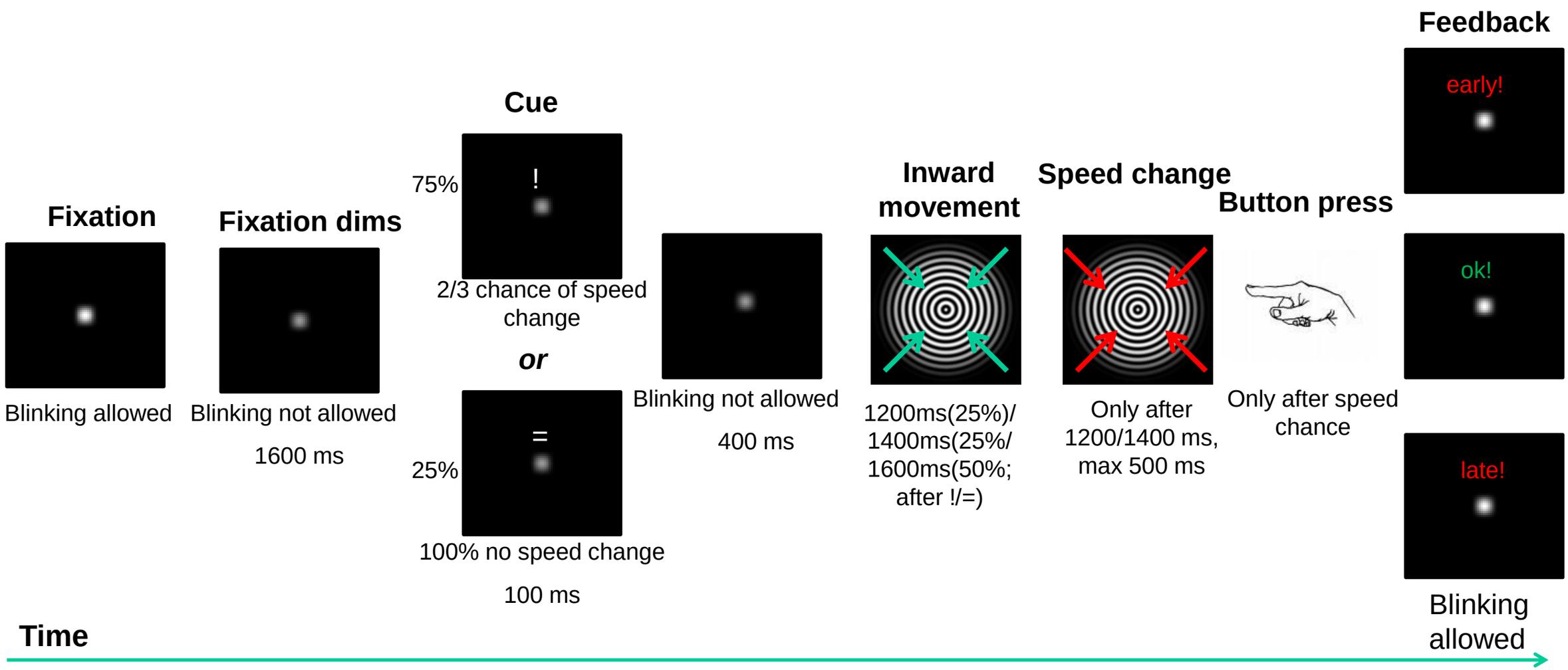




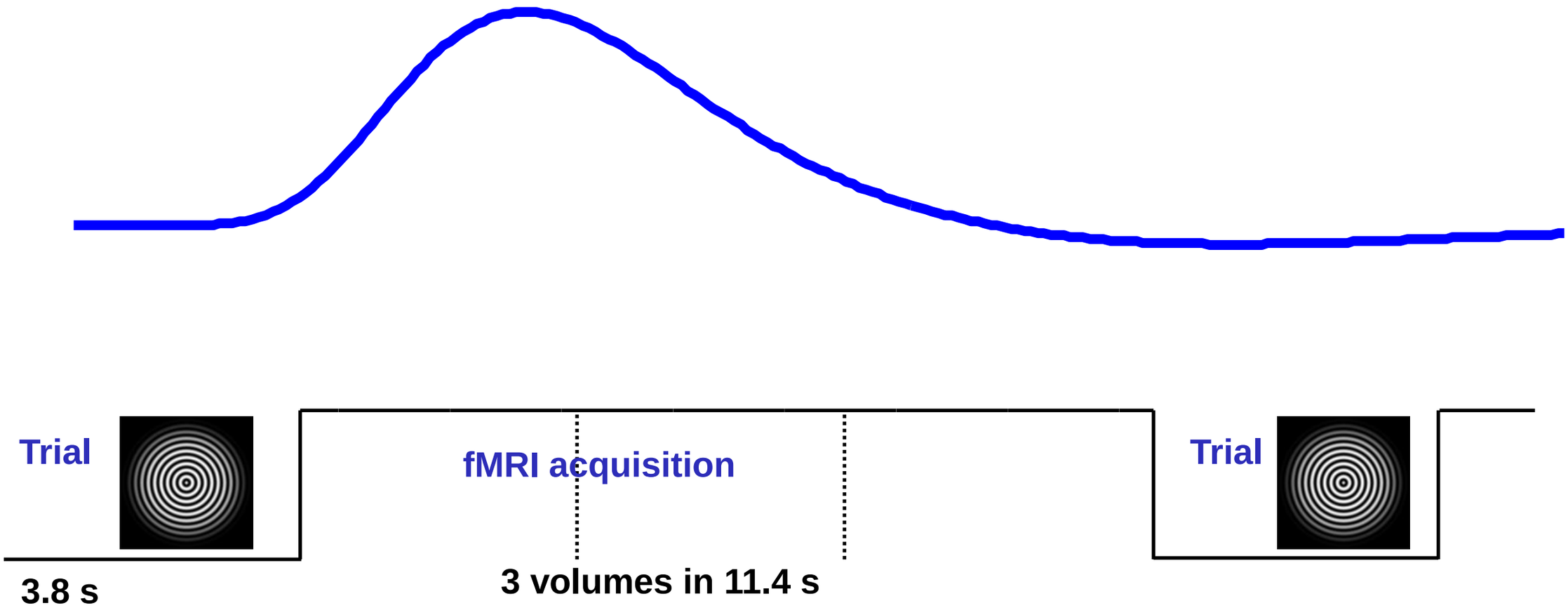
Koopmans et al., HBM 2010

Are there laminar differences in how the different EEG frequencies relate to the BOLD signal?

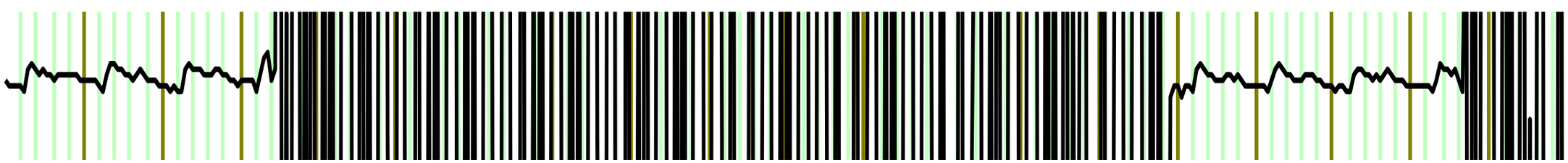
Task


Fixation
Blinking allowed
Fixation dims
Blinking not allowed
1600 ms
Cue
75%
!
2/3 chance of speed change
or
25%
=
100% no speed change
100 ms
Blinking not allowed
400 ms
Inward movement
1200ms(25%)/ 1400ms(25%/ 1600ms(50%; after !/=)
Speed change
Only after 1200/1400 ms, max 500 ms
Button press
Only after speed chance
Feedback
early!
ok!
late!
Blinking allowed
Time

Task



EEG Data

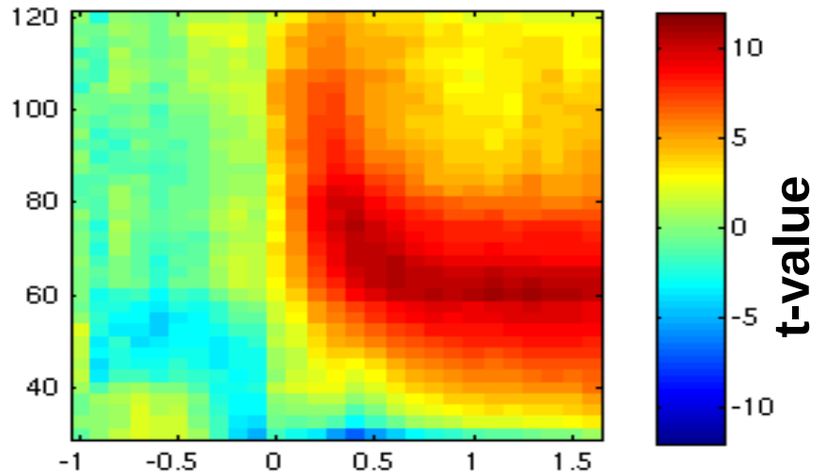


(f)MRI recordings

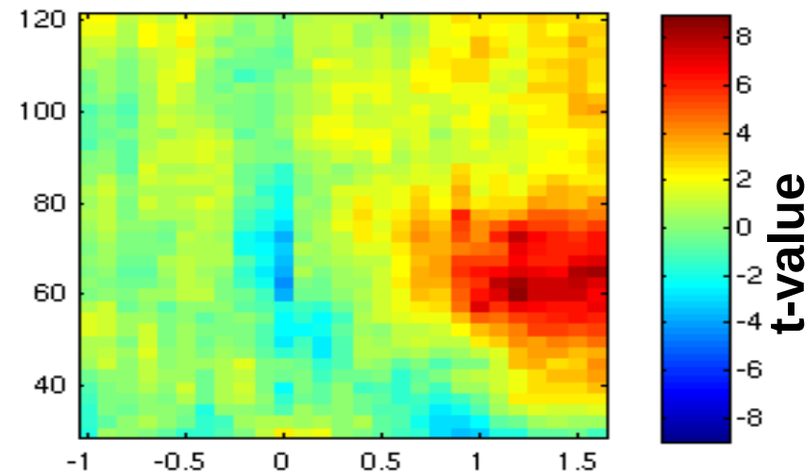
- fMRI at 3T with periods of no-scanning for EEG:
  - 1 OFF, 3 ON, the second volume optimally sensitive to activation at t=0 due to BOLD delay
- 0.75 mm isotropic EPI with 3D encoding
  - Pro: 3D sharper slice profile than standard 2D EPI when using such thin slices
  - TR=3.8s
  - Coverage: ~ 36 mm
- High resolution T1 (0.75 mm isotropic)
- Retinotopy
- Online localiser for placement of slices on top of activations

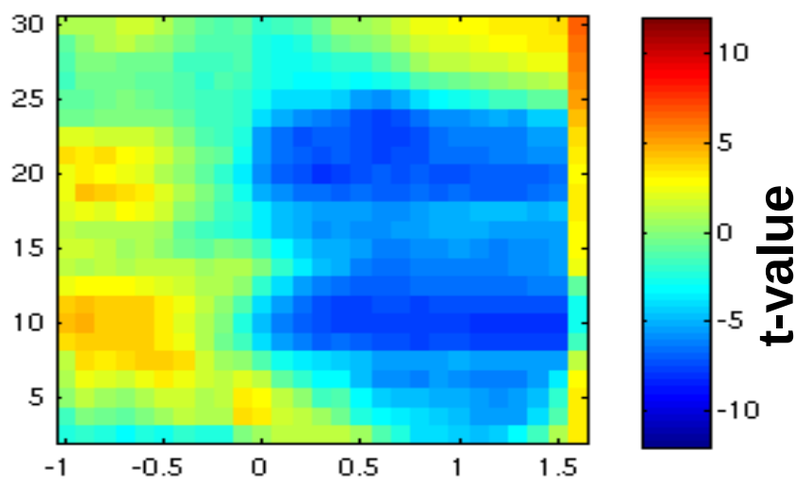
EEG power effects

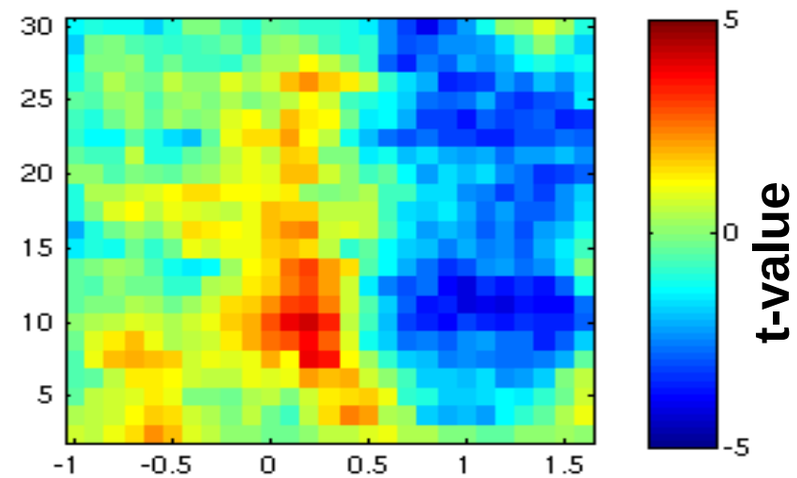
Power change from baseline
(collapsed over attention on/off)



Attention effect
(attention on vs. attention off)

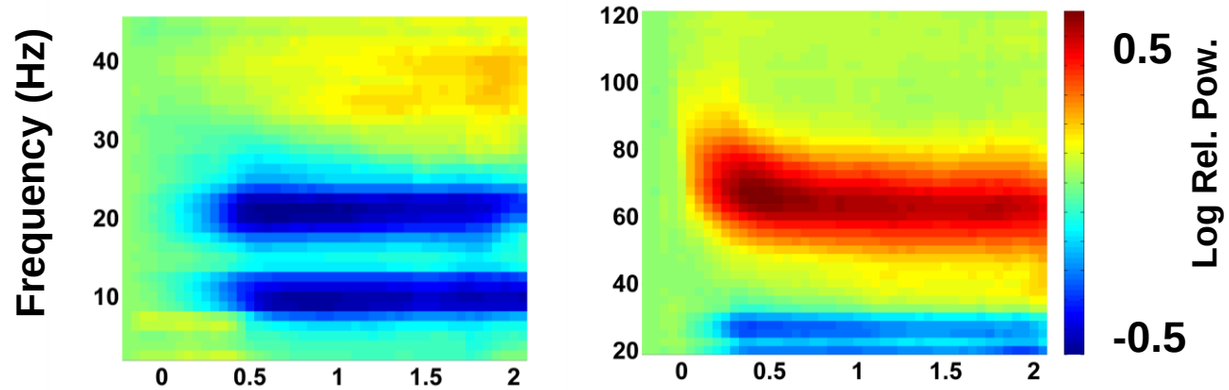




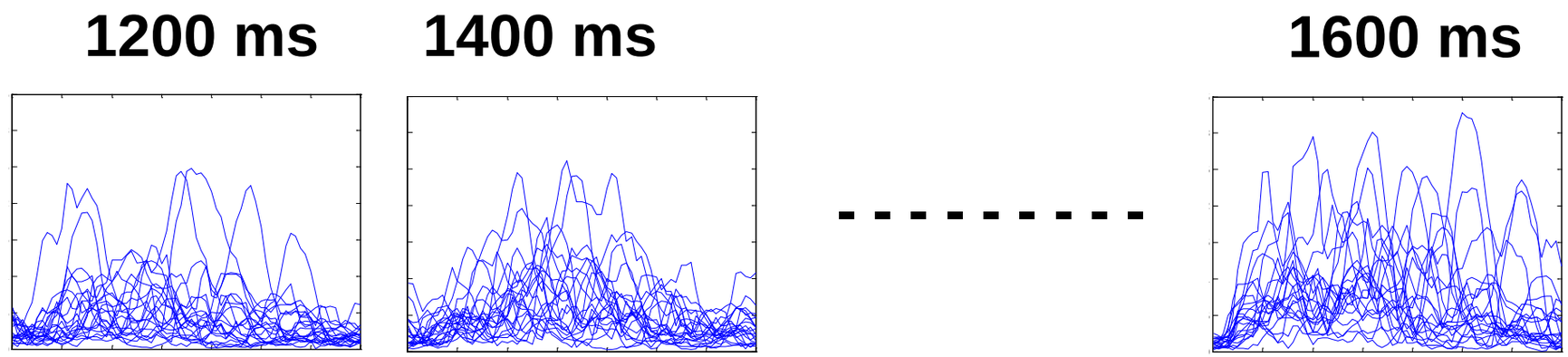


Regressor Construction

ICA denoised data

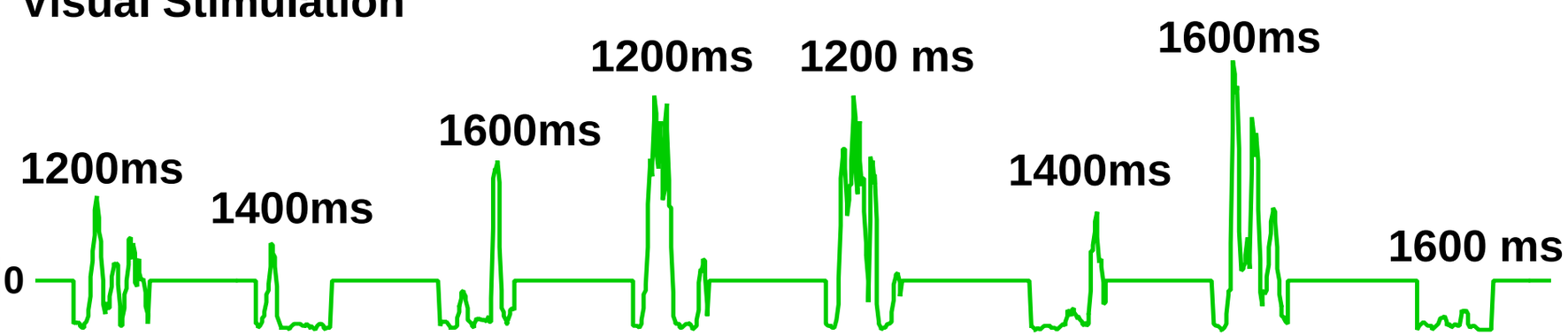


Extract single trial power time courses for each frequency

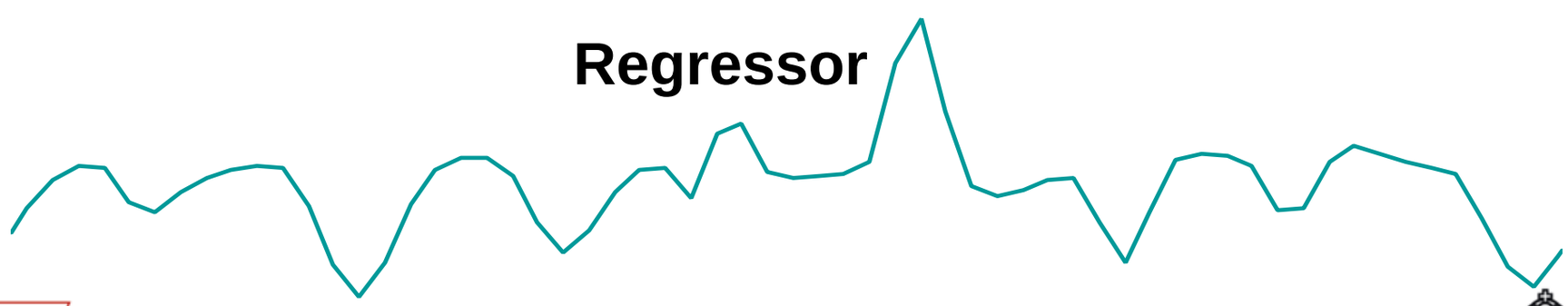


Construct time series from single trial power time courses maintenance interval

Visual Stimulation

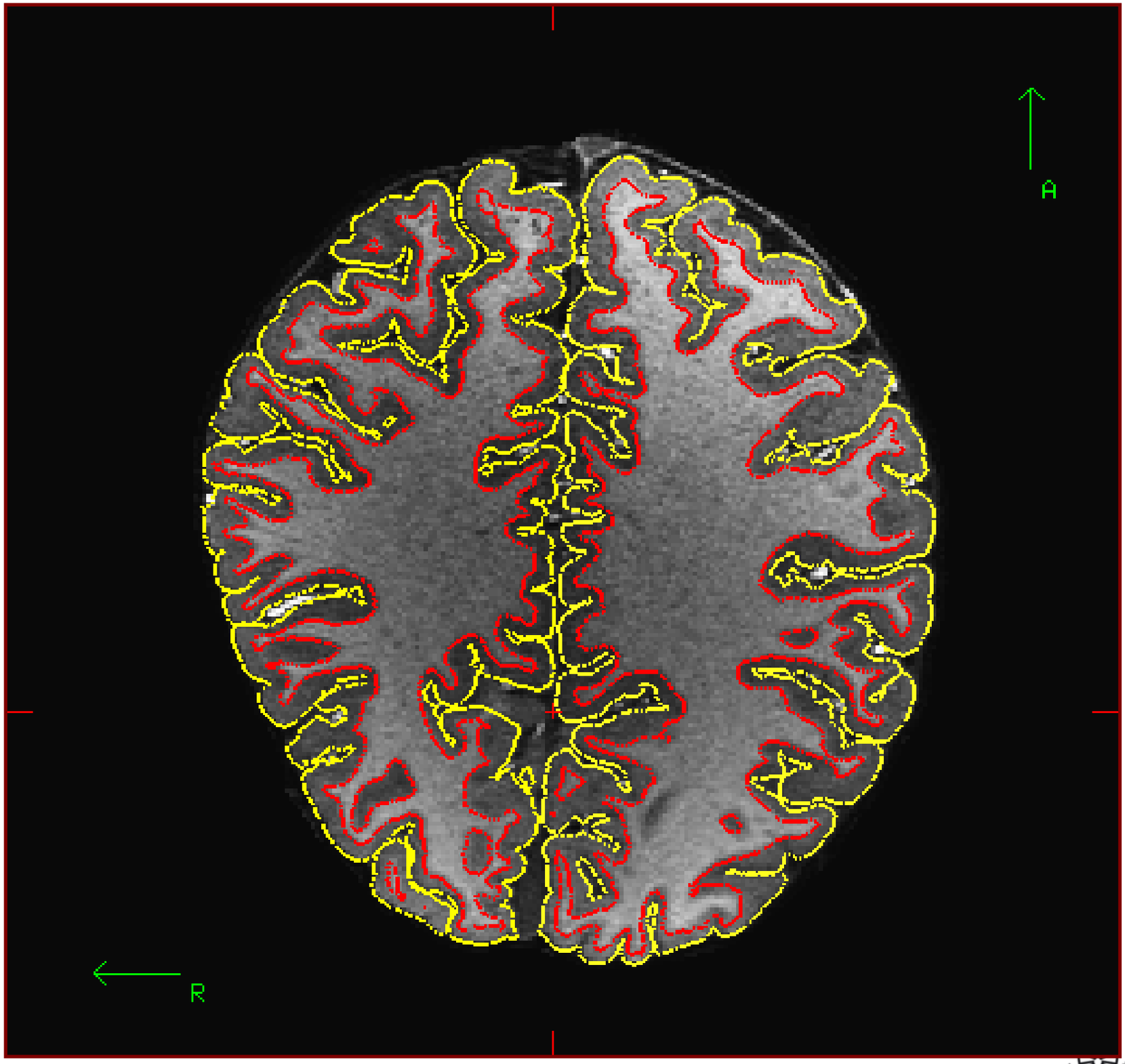


Convolution with canonical HRF



Laminar fMRI analysis pipeline

To determine cortical depth of a voxel we need to know where WM/GM and GM/pial interfaces are: FreeSurfer



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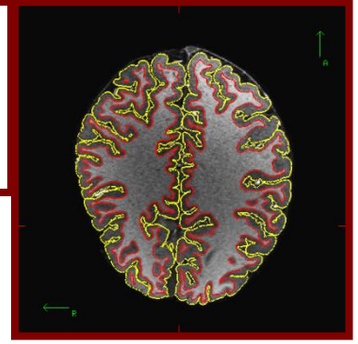
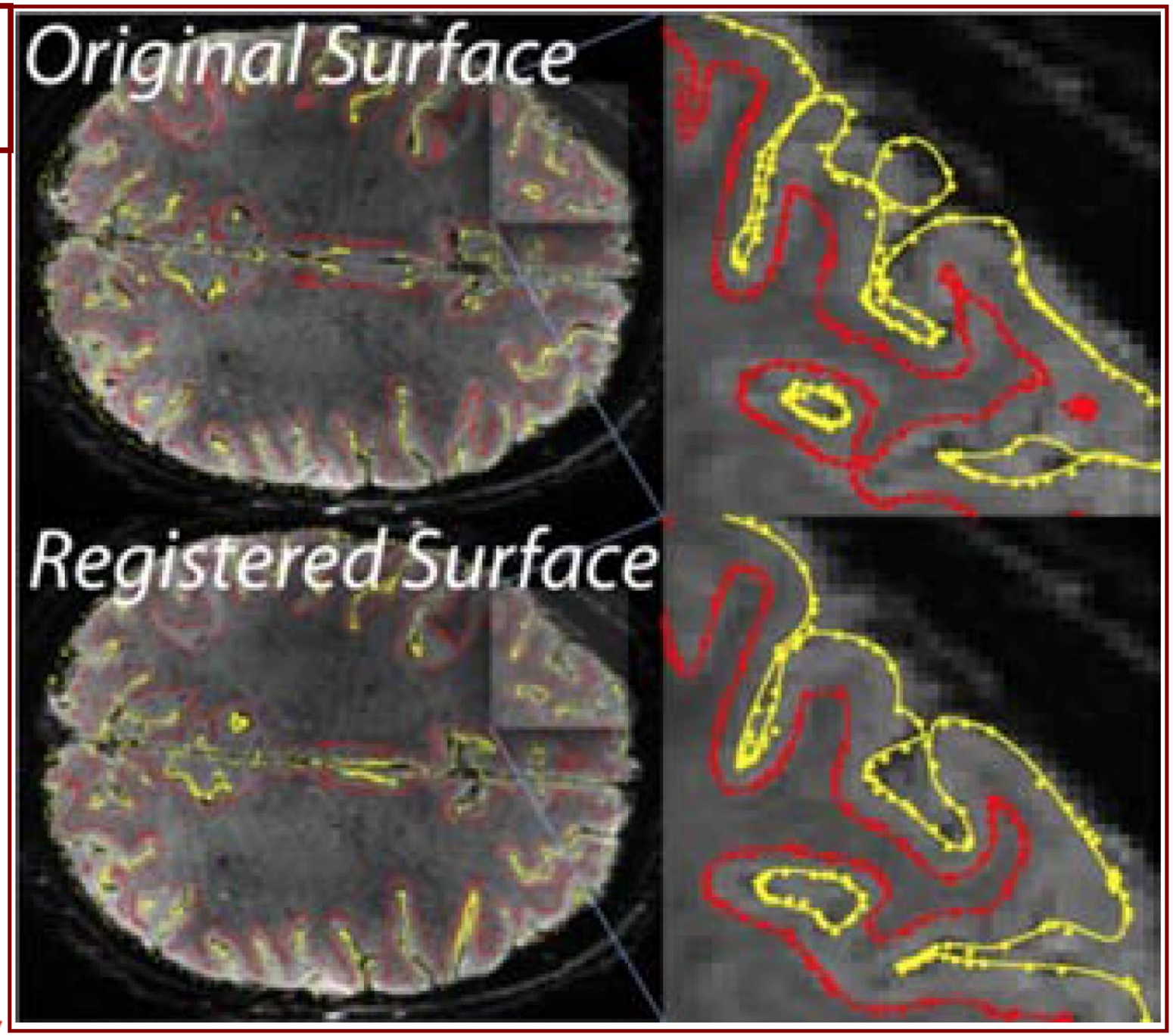


Transfer surfaces estimated on anatomical data to fMRI data and correct for EPI distortions



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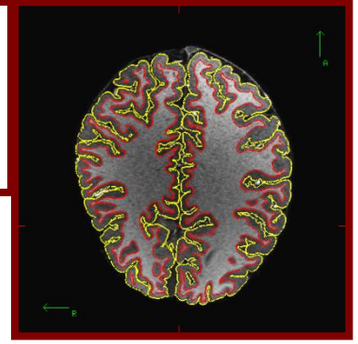

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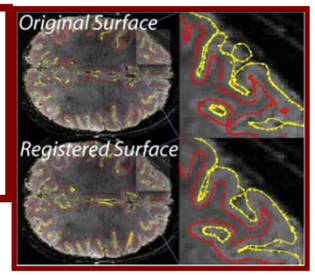
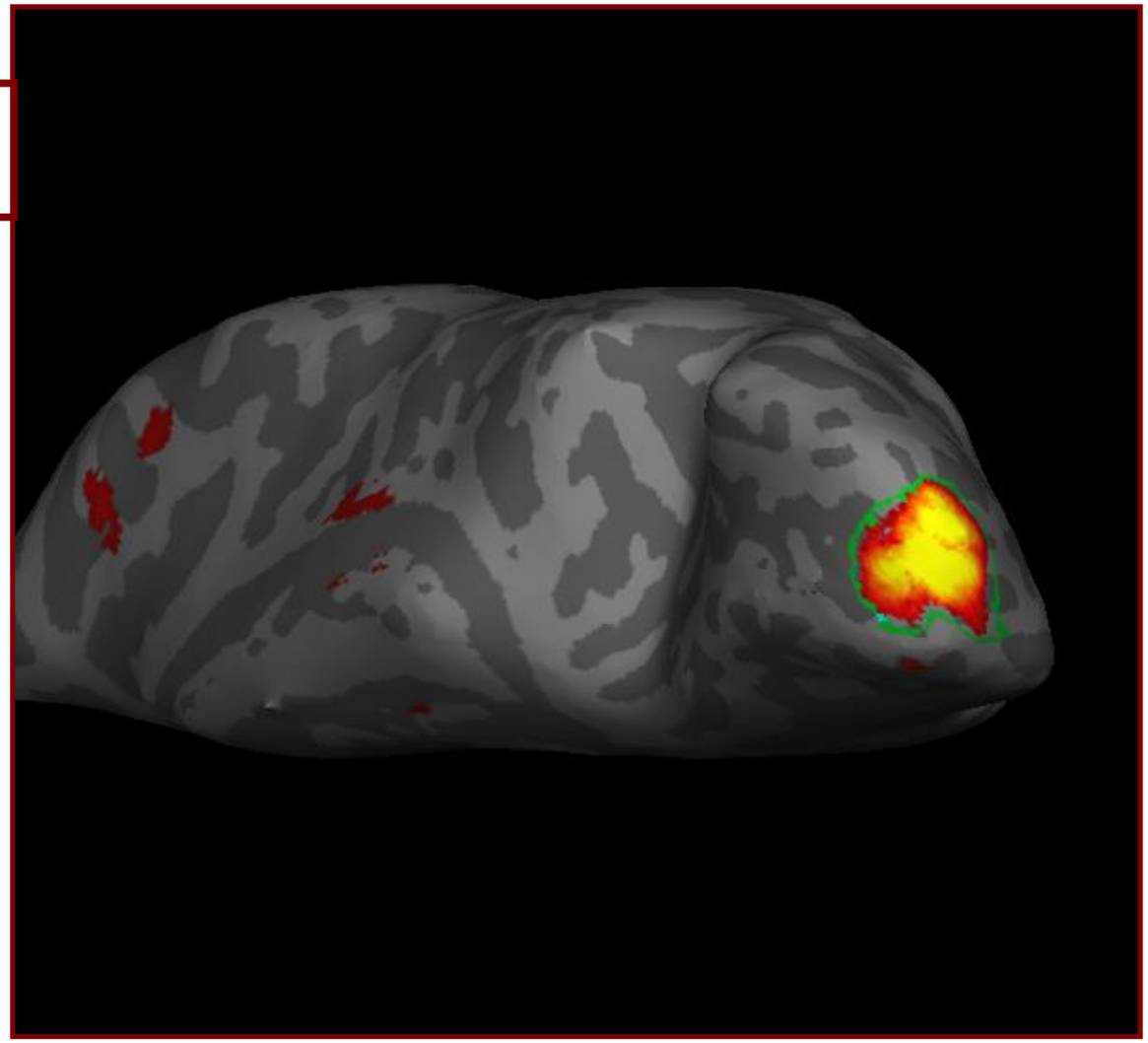


Select ROIs based on retinotopy task activation (10% most activated vertices)



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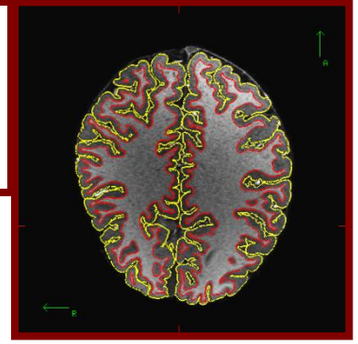

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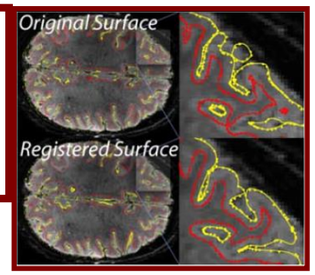
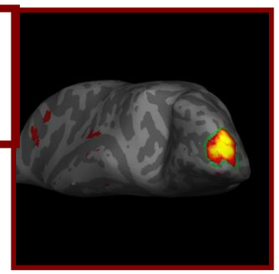


Select ROIs based on functional localizers and retinotopy



Average all voxels in ROI at a certain cortical depth (in bins)

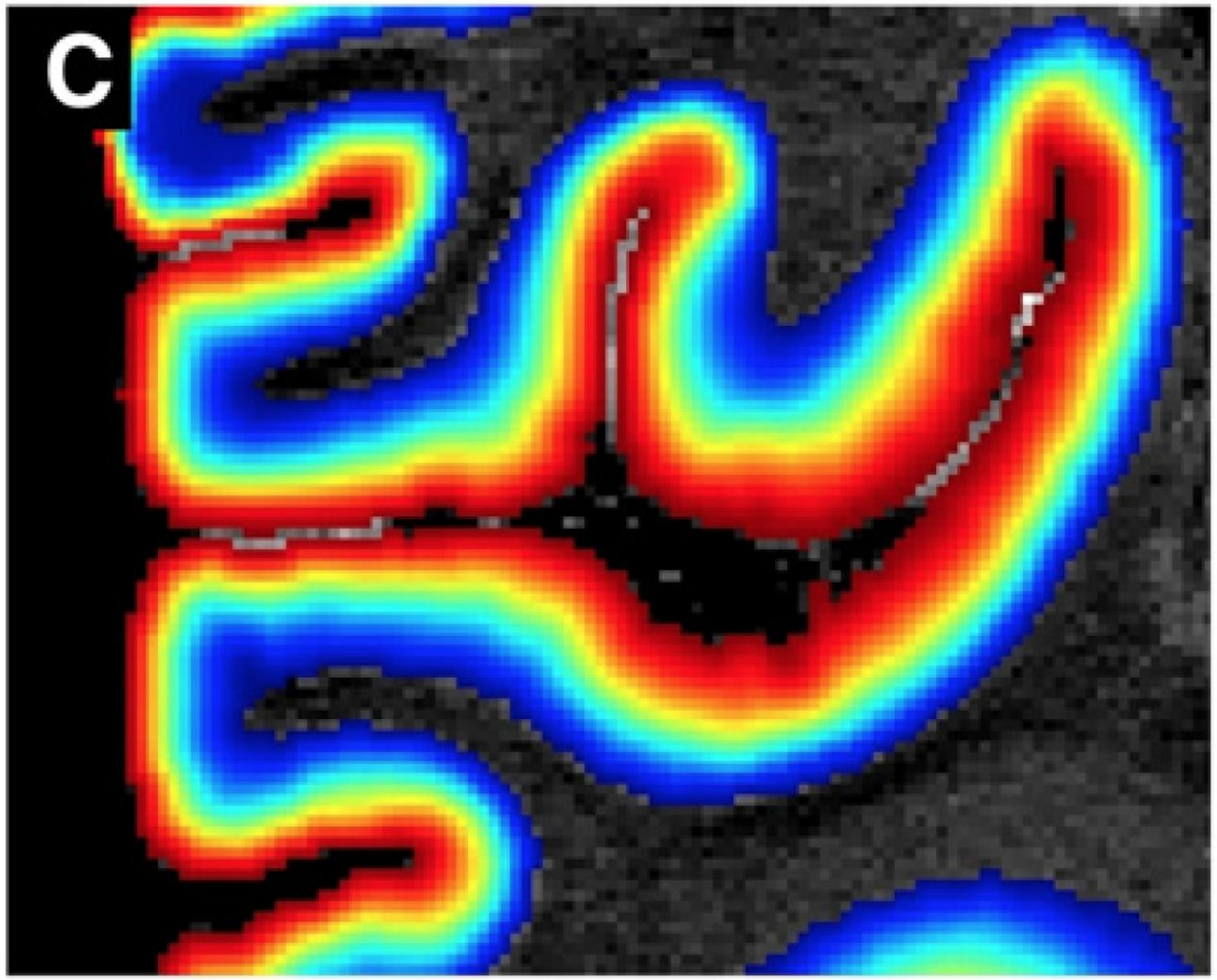


Image from: Waehnert et al., Neuroimage 2014

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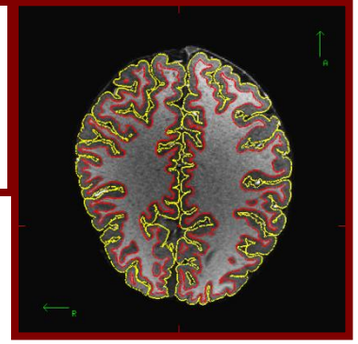

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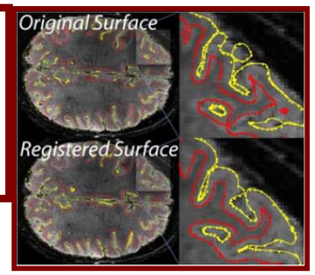

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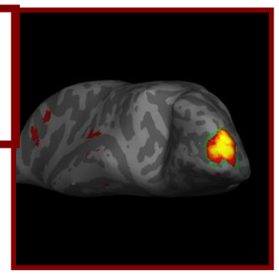

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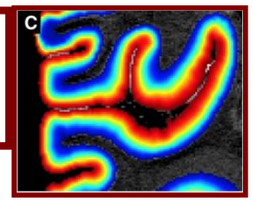
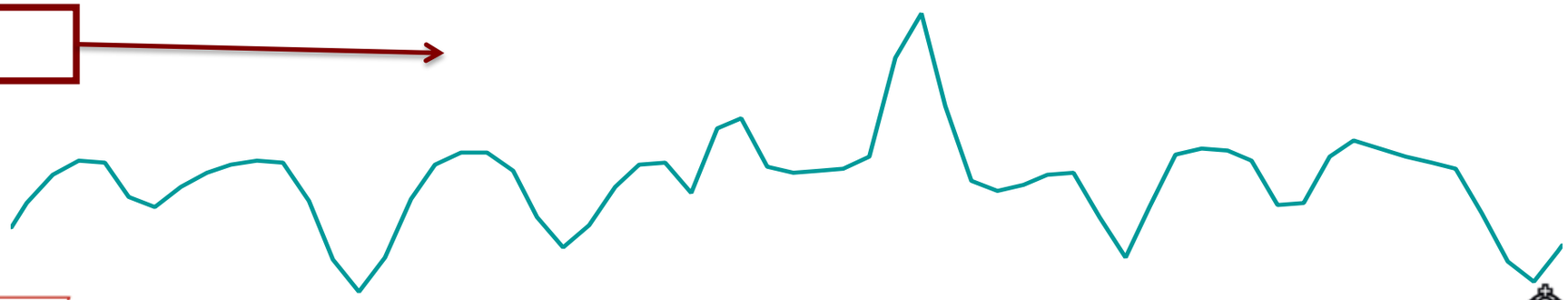


Combine with EEG data

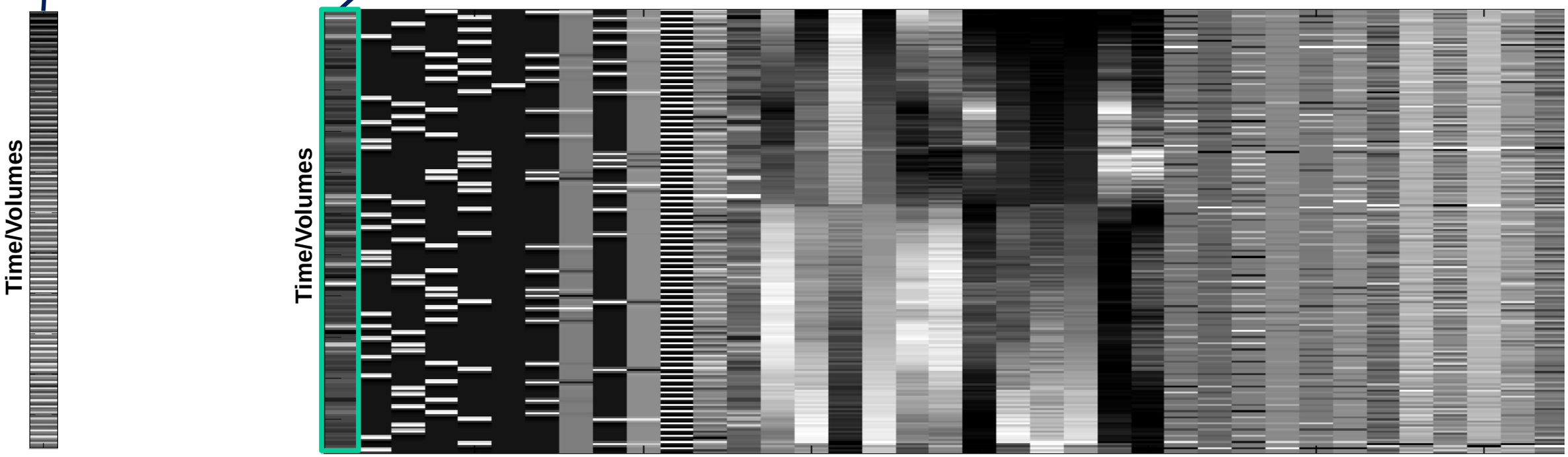
EEG power regressor



Statistical design

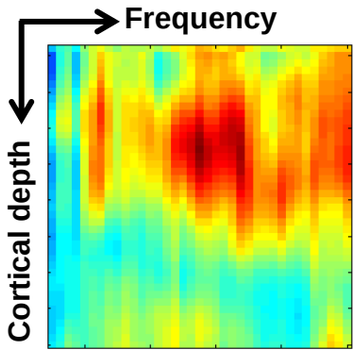
BOLD signal (dependent variable), varies over cortical depth

EEG power regressor, varies over frequencies

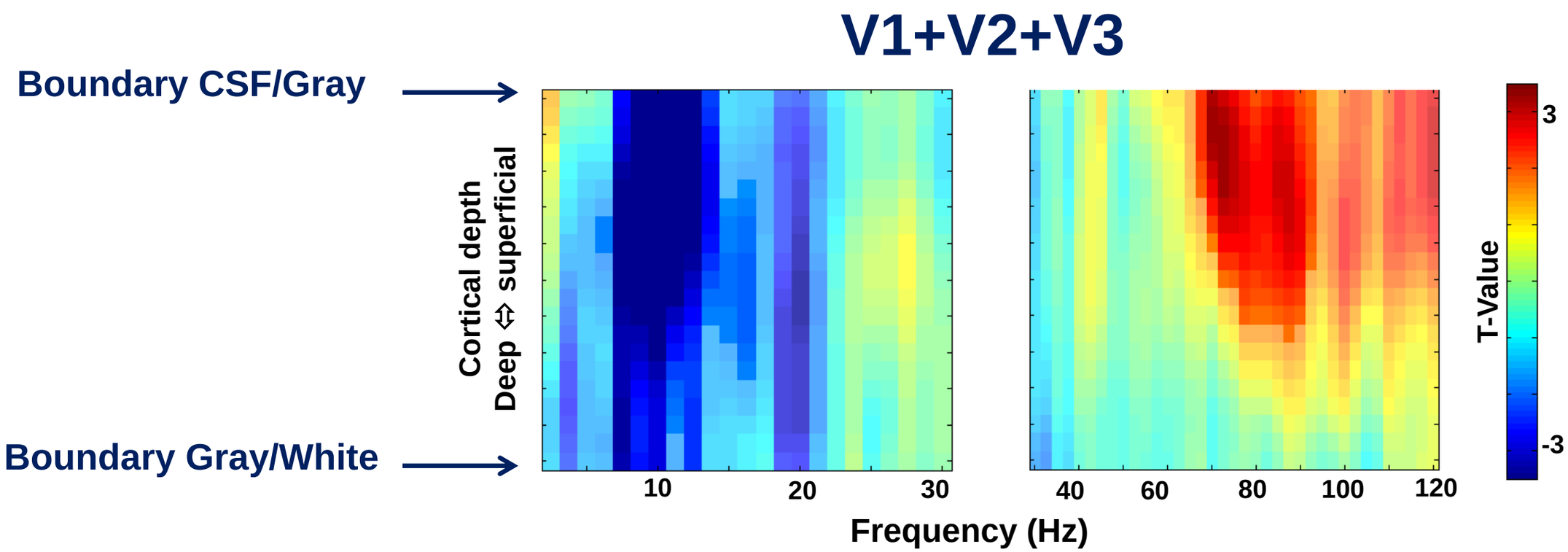


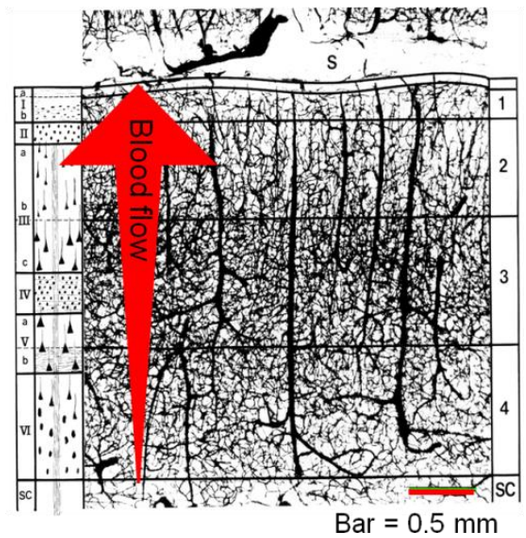
Task and confound regressors, fixed

Beta weights
EEG power regressor

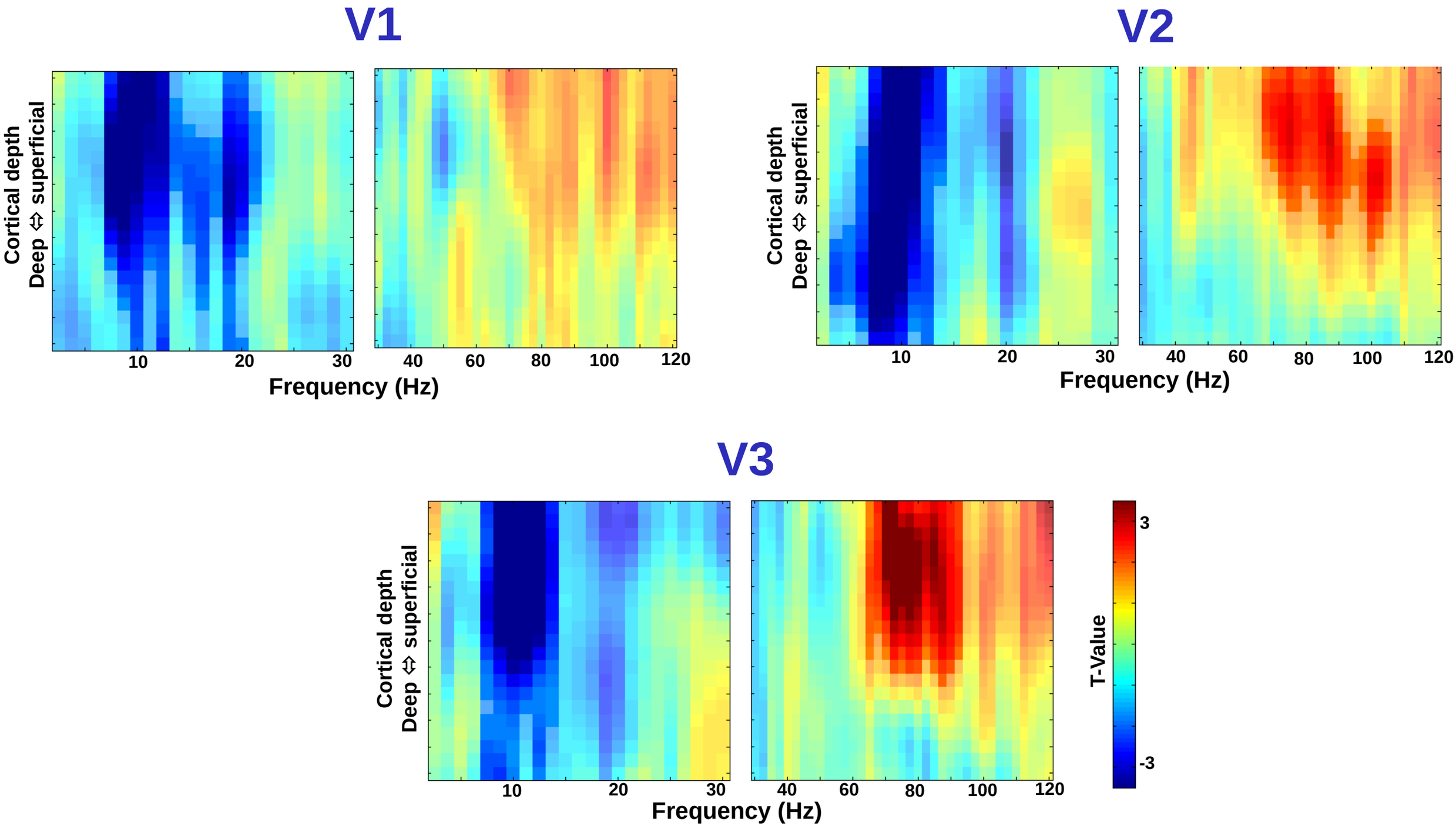


Results


V1+V2+V3
Boundary CSF/Gray
Boundary Gray/White
Cortical depth
Deep ⇔ superficial
10
20
30
40
60
80
100
120
Frequency (Hz)
T-Value
3
-3


Blood flow
S
1
2
3
4
SC
Bar = 0.5 mm

Results


V1
V2
V3
Cortical depth
Deep ⇔ superficial
10
20
30
40
60
80
100
120
Frequency (Hz)
T-Value
3
-3

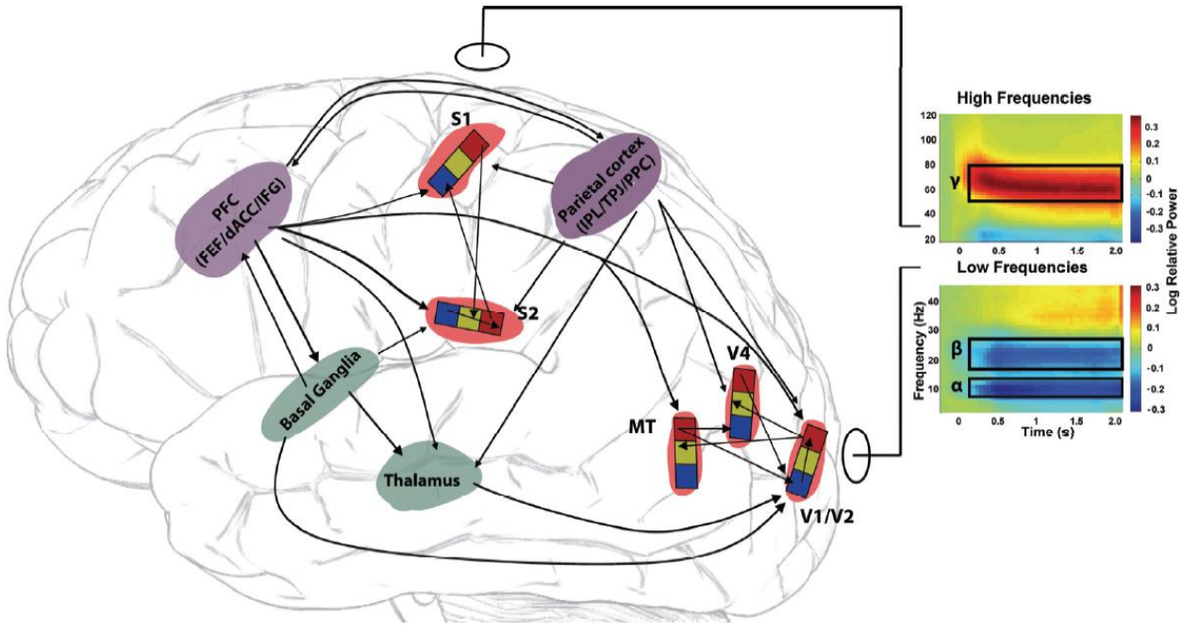
Conclusion/Discussion

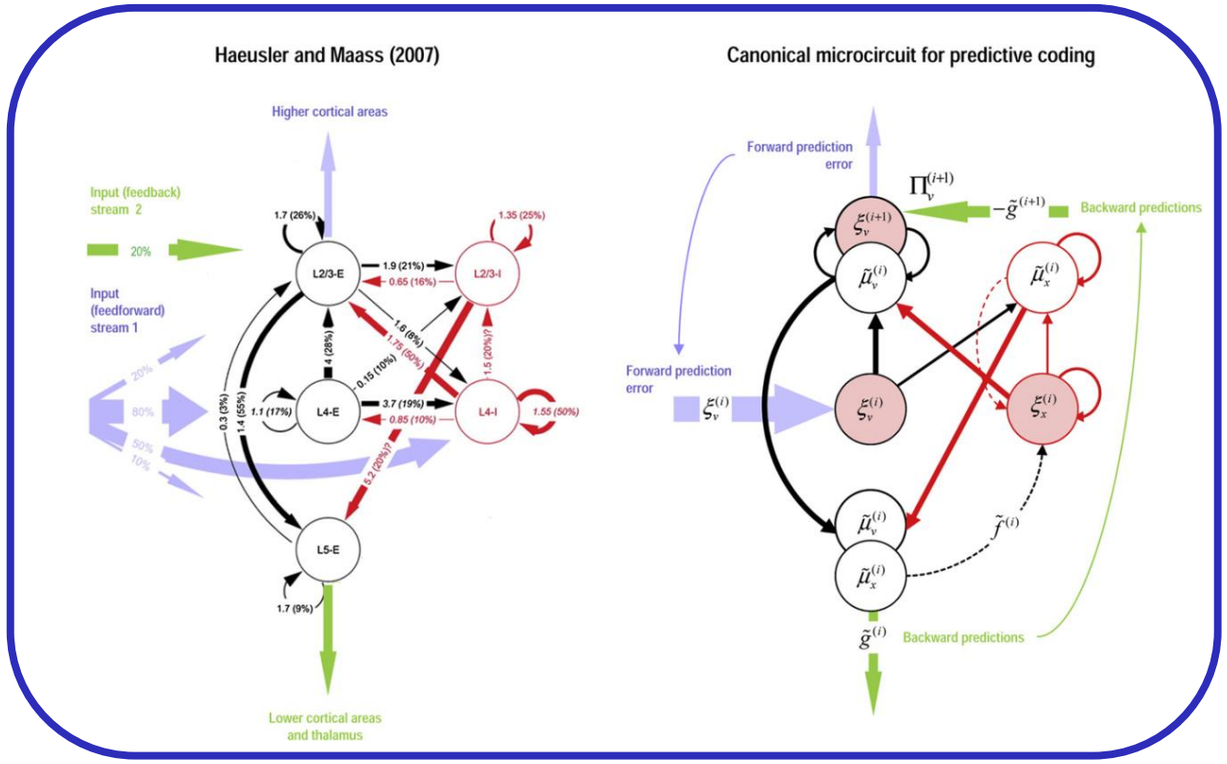
- Alpha and gamma band power show different profiles in their relation to the BOLD signal
  - Alpha power correlates negatively with deep and superficial layers
  - Gamma power correlates positively only with superficial layer
- Neurophysiological basis for laminar fMRI

The Future…?

Laminar (EEG/)fMRI as a new tool in systems/cognitive neuroscience?

- Laminar lever effective and functional connectivity beteween regions
- Relation between laminar effects in early sensory cortex and attentional /cognitive control networks control networks
- Test/investigate models that have explicit predictions in terms of laminar activity and electrophysiological effects
    - e.g. predictive coding framework





Bastos et al. (Neuron, 2012)

Thanks!

Peter Koopmans
(FMRIB Oxford)

Tim van Mourik

David Norris

Ole Jensen