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

Radboud University Nijmegen
Frequency specific EEG power-BOLD correlations

Scheeringa et al., 2011

Fries et al., 2008
Frequency specific EEG power-BOLD correlations

ICA Denoised EEG Data

High Frequencies

Low Frequencies

FMRI Data

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Results

**EEG-BOLD RELATION**

Relation between frequency bands

![Graphs showing the relationship between frequency bands and BOLD signal](image)

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 assess 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
- Blinking not allowed
  - 1600 ms

Fixation dims
- 75%
- 25%
- 100 ms

75% 25%

Cue
- 2/3 chance of speed change
- or
- 25%
- 100% no speed change
- 100 ms

Inward movement
- Blinking not allowed
- 400 ms

1200ms (25%)/1400ms (25%)/1600ms (50%; after !/=)

Speed change
- Only after 1200/1400 ms, max 500 ms

Feedback
- early!
- ok!
- late!
- Blinking allowed

Button press
- Only after speed change
Task

3.8 s

fMRI acquisition

3 volumes in 11.4 s

Trial

Trial

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

Convolution with canonical HRF

Visual Stimulation

Frequency (Hz)

Log Rel. Pow.

1200 ms 1400 ms 1600 ms

1200ms 1200 ms 1600ms

1600 ms

0 1 2 3 4 5 6 7 8 9 10

0 0.5 1 1.5 2

3 4 5 6 7 8 9 10

0

0.5

1

1.5

2

2.5

3

3.5

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

Select ROIs based on retinotopy task activation (10% most activated vertices)
To determine cortical depth of a voxel we need to know where WM/GM and GM/pial interfaces are: FreeSurfer

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

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

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

Select ROIs based on functional localizers and retinotopy

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

Combine with EEG data

EEG power regressor
Statistical design

BOLD signal (dependent variable), varies over cortical depth

EEG power regressor, varies over frequencies

Time/Volumes

Task and confound regressors, fixed

Beta weights
EEG power regressor

Cortical depth

Frequency
Results

V1+V2+V3

Boundary CSF/Gray

Boundary Gray/White

Frequency (Hz)

Cortical depth

Deep $\rightarrow$ superficial

T-Value

-3

3

T-Value

Bar = 0.5 mm

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Results

V1

V2

V3

Cortical depth
Deep ⇔ superficial

Frequency (Hz)

10 20 30 40 60 80 100 120

10 20 30 40 60 80 100 120

Cortical depth
Deep ⇔ superficial

Frequency (Hz)

10 20 30 40 60 80 100 120

Cortical depth
Deep ⇔ superficial

Frequency (Hz)

10 20 30 40 60 80 100 120

T-Value

-3 3

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

- Laminar lever effective and functional connectivity between regions
- Relation between laminar effects in early sensory cortex and attentional /cognitive 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!

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