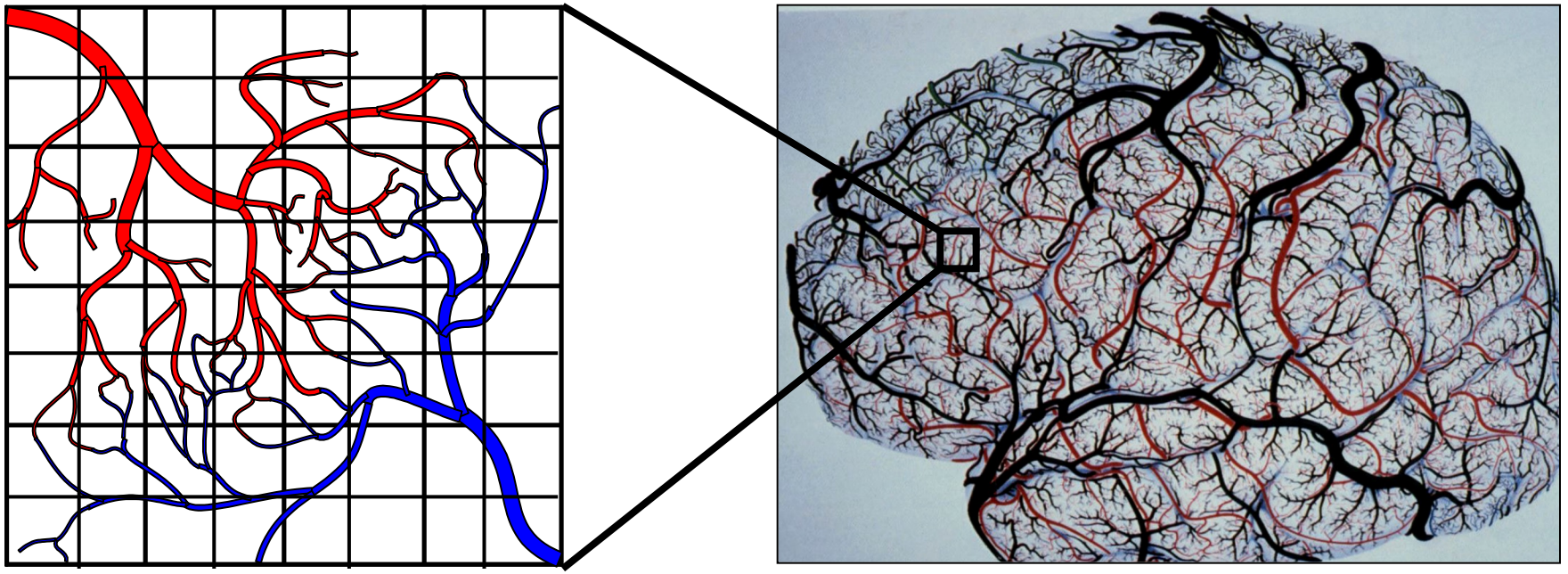
Neuronal Activation ? Measured Signal

? Hemodynamics ?

? Noise



1. Dynamics

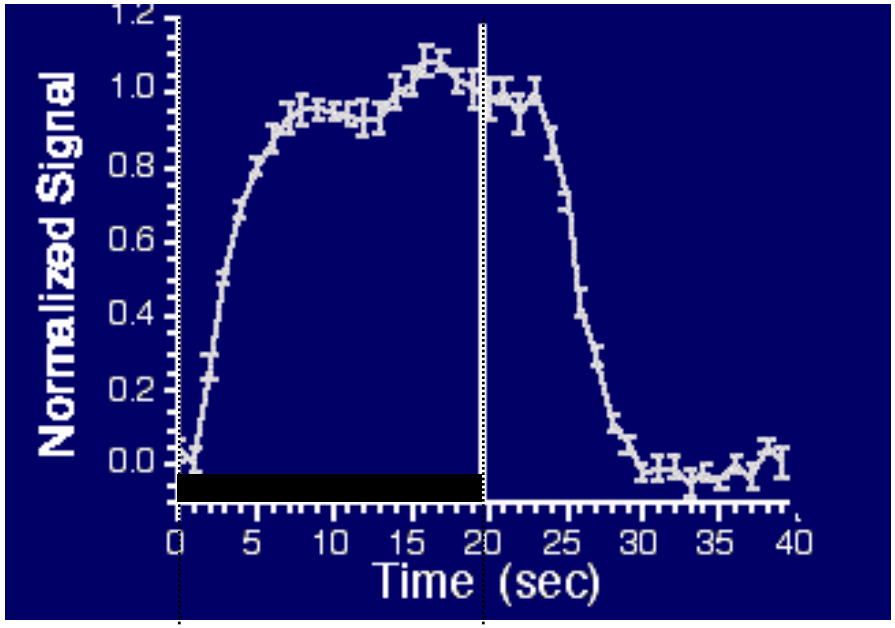
2. Fluctuations

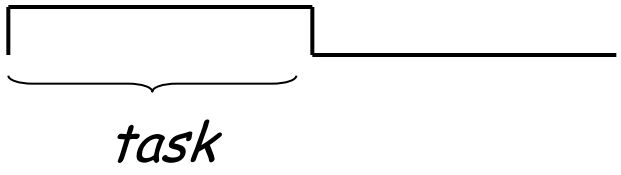
3. Pattern Information

4. Neuronal Current MRI

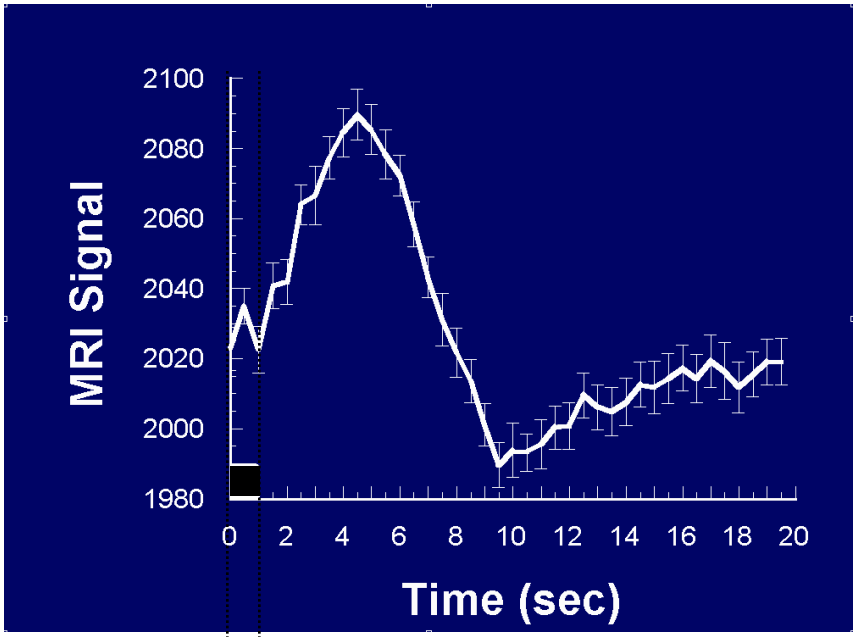
The BOLD Signal

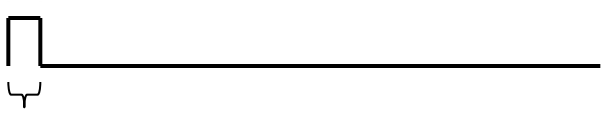
Blood Oxygenation Level Dependent (BOLD) signal changes





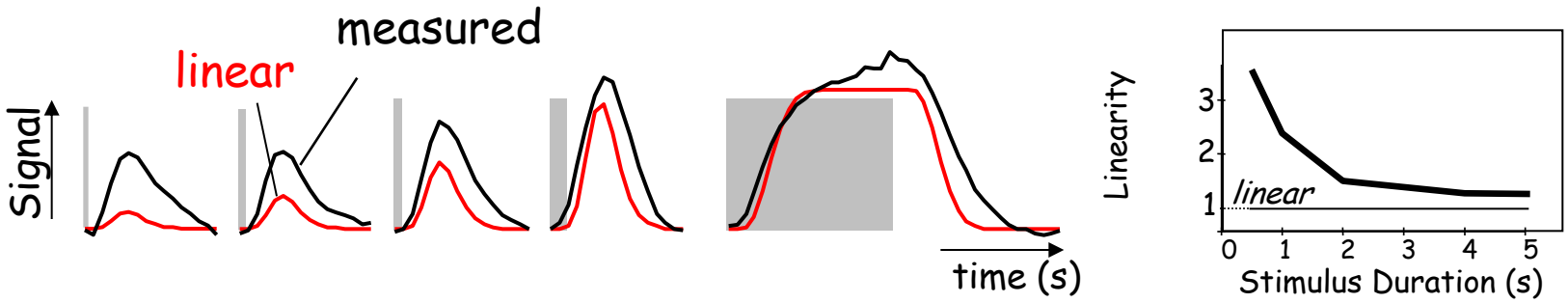
task





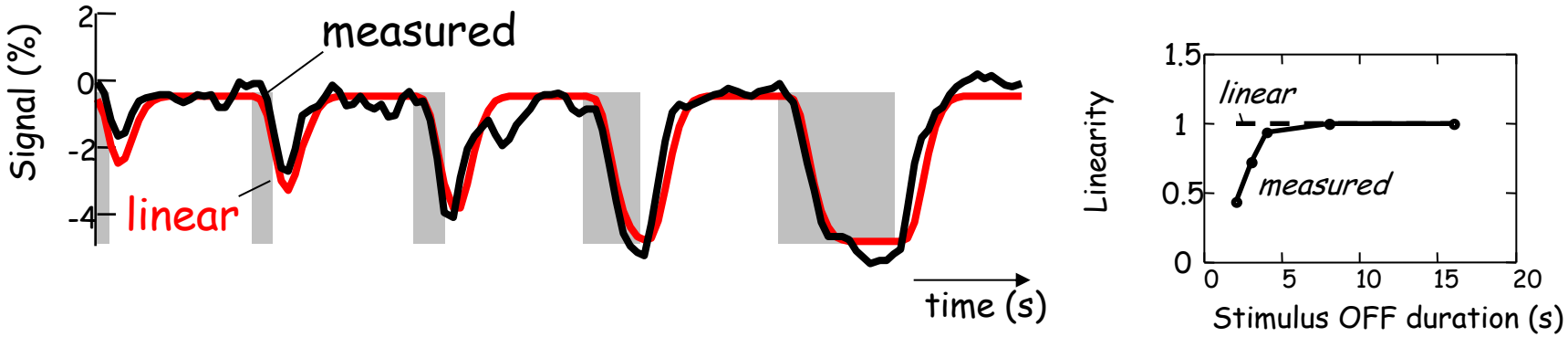
task

Brief "on" periods produce larger increases than expected.



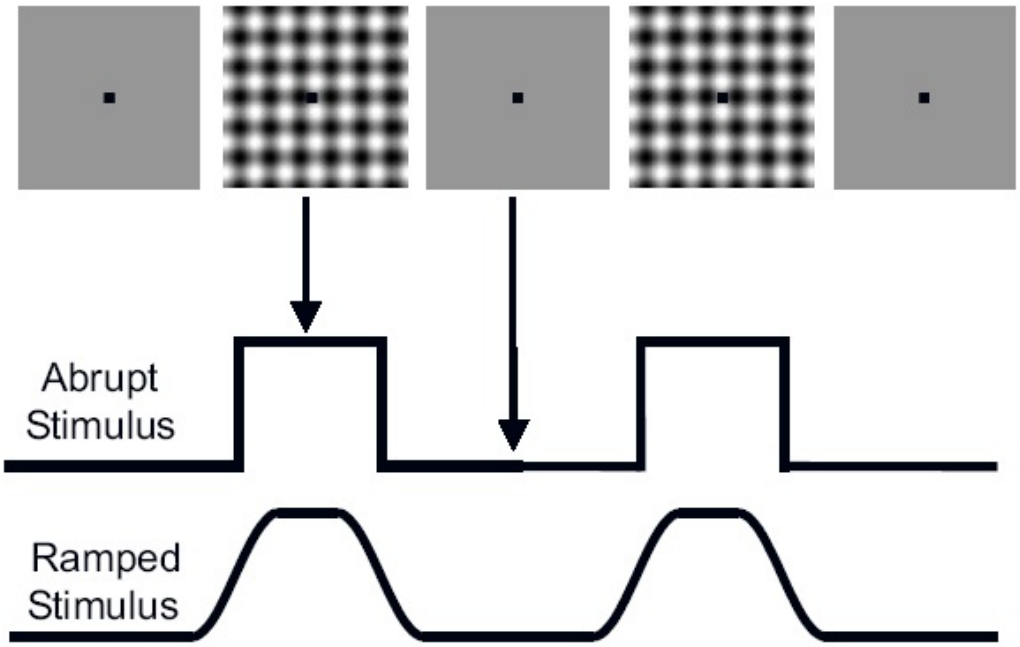
R. M. Birn, Z. Saad, P. A. Bandettini, NeuroImage, 14: 817-826, (2001)

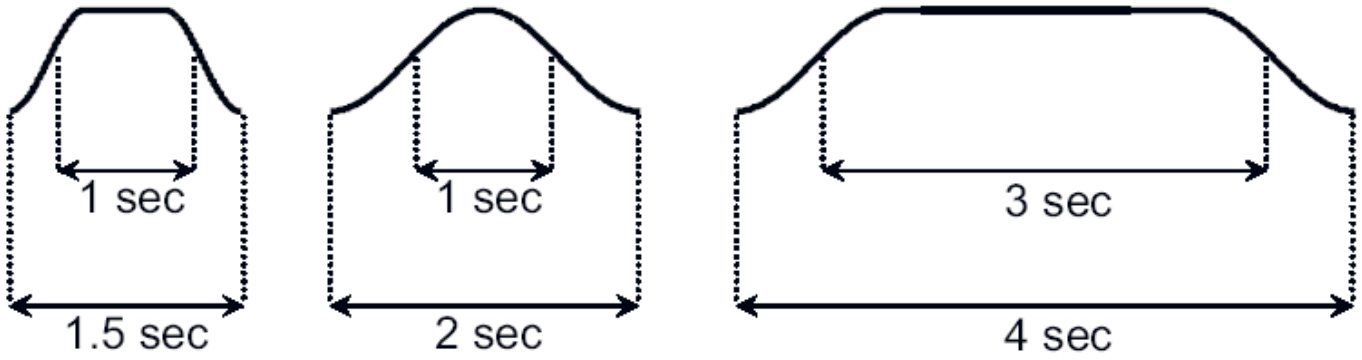
Brief "off" periods produce smaller decreases than expected.



R.M. Birn, P. A. Bandettini, NeuroImage, 27, 70-82 (2005)

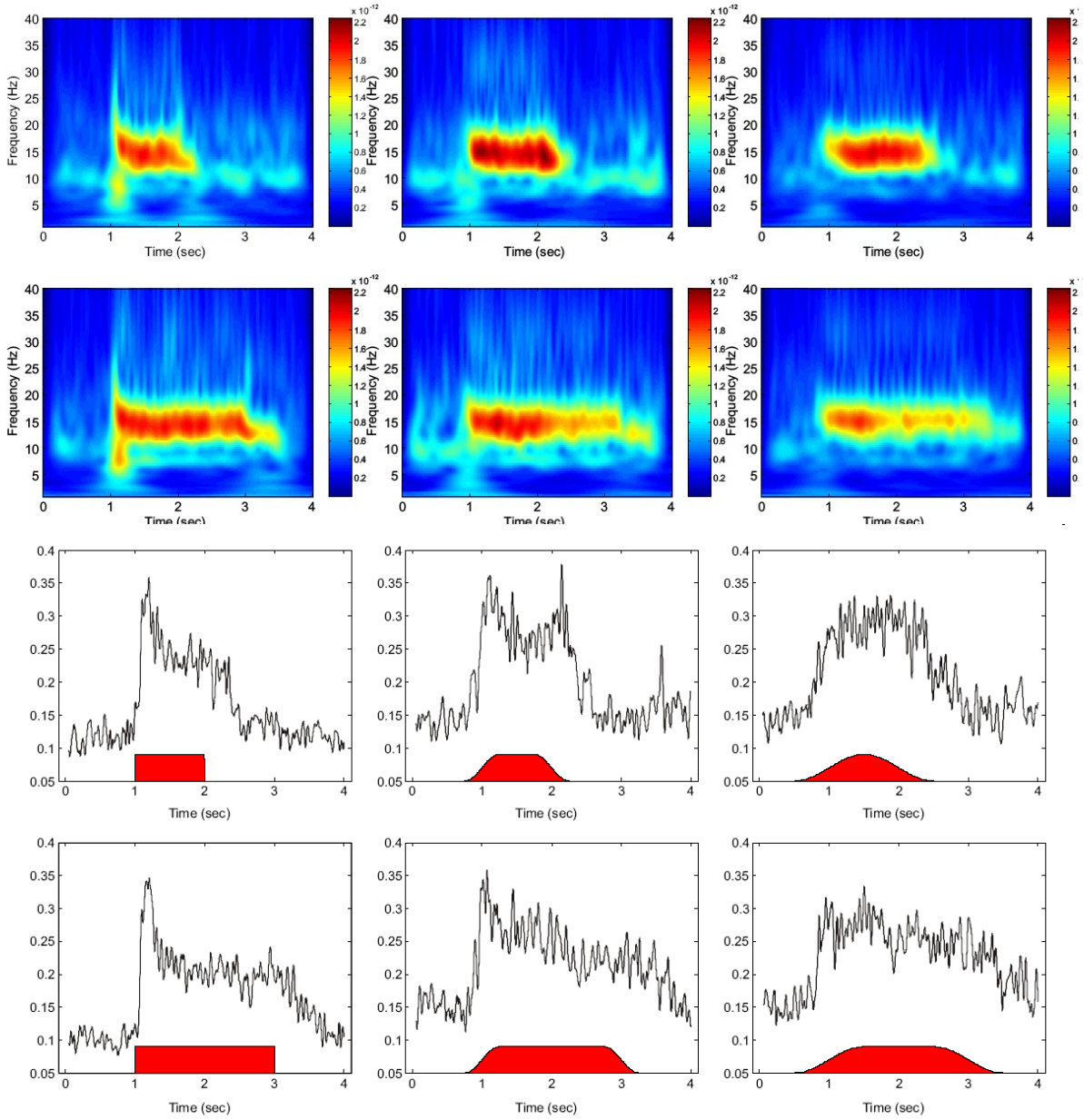
MEG & fMRI Linearity Comparison





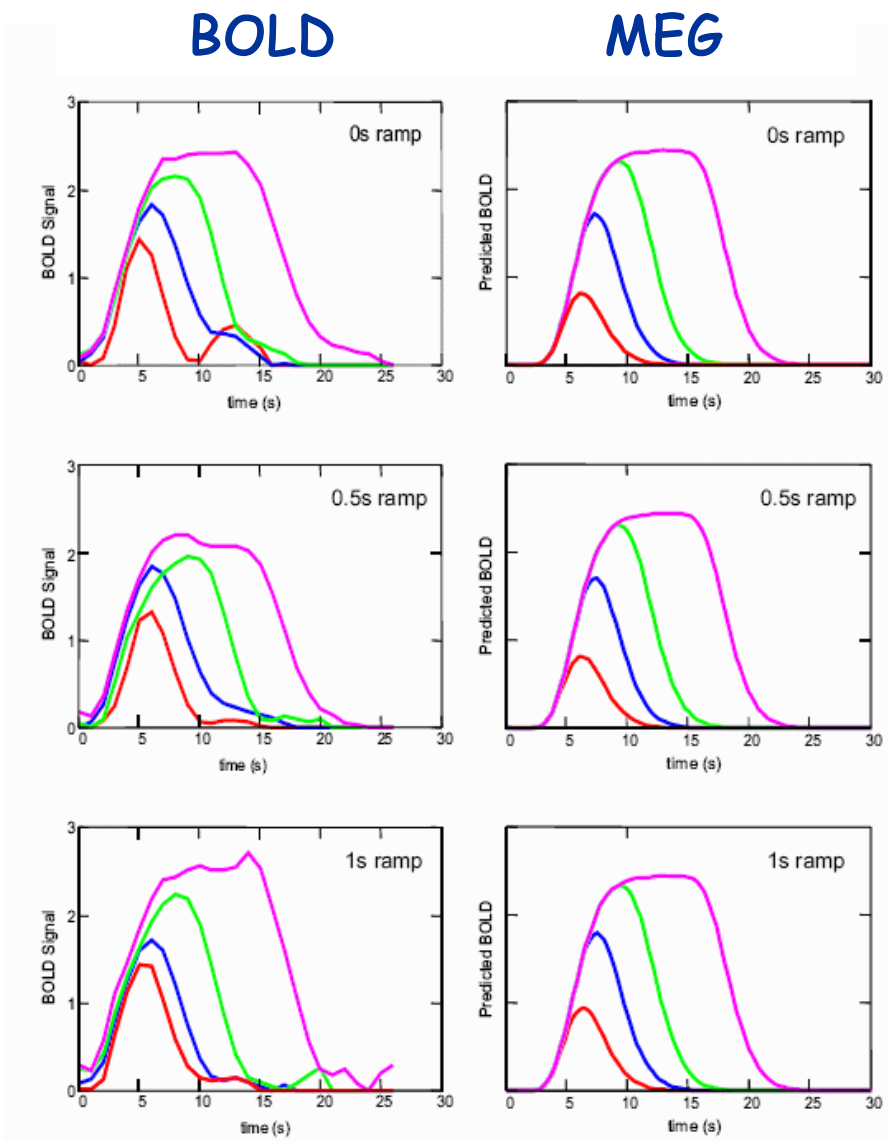
A. Tuan, R. M. Birn, P. A. Bandettini, G. M. Boynton, (submitted)

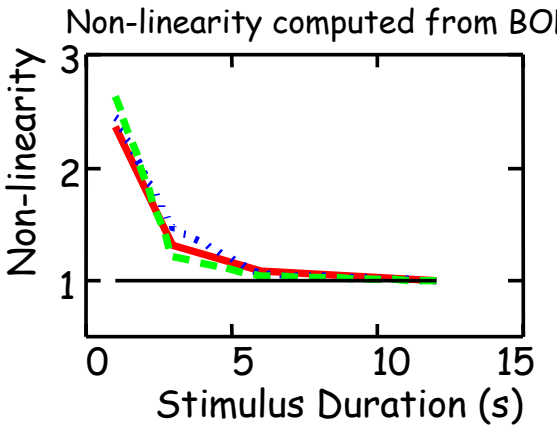
MEG Results

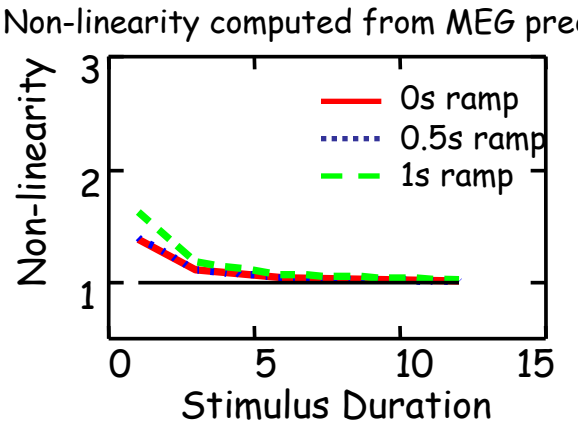


A. Tuan, R. M. Birn, P. A. Bandettini, G. M. Boynton,
International Journal of Imaging Systems and Technology 18, 17-28 (2008)

Measured and Predicted BOLD responses







A. Tuan, R. M. Birn, P. A. Bandettini, G. M. Boynton,
International Journal of Imaging Systems and Technology 18, 17-28 (2008)

1. Dynamics

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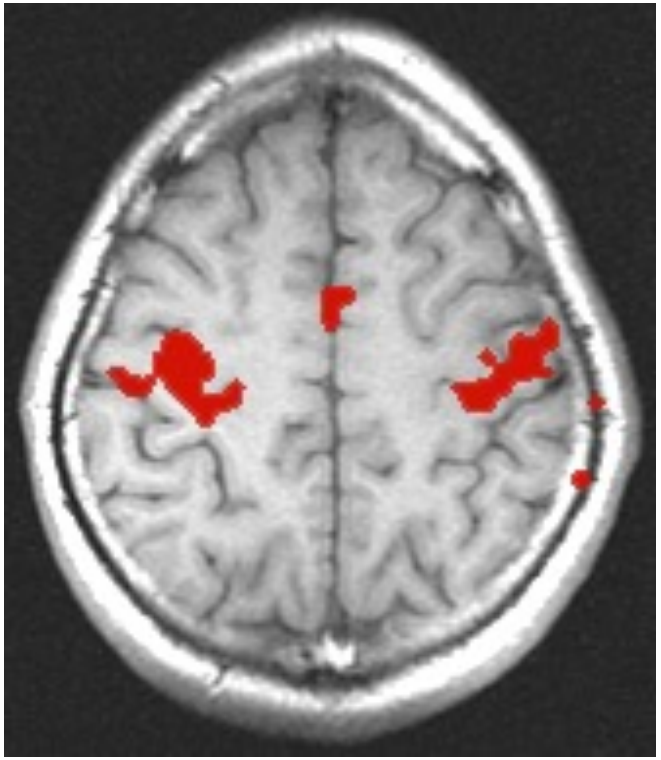
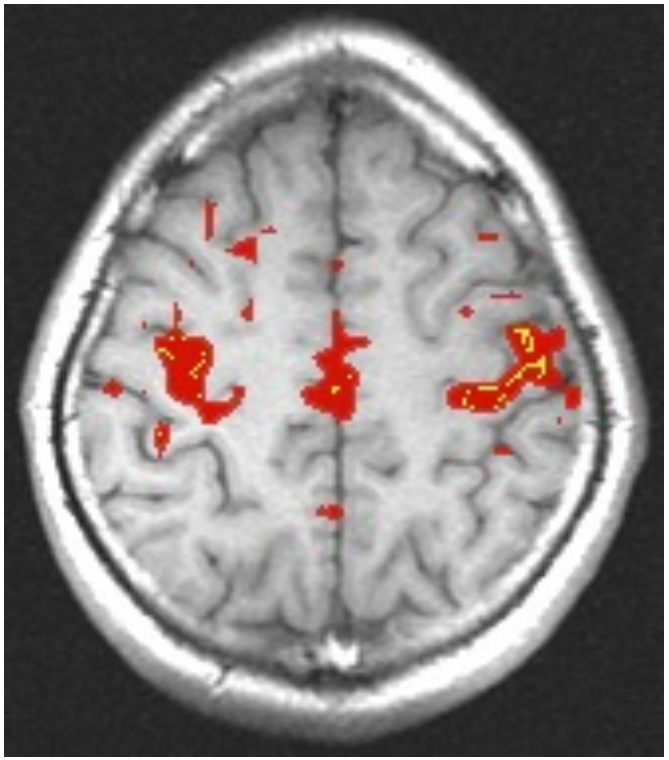
4. Neuronal Current MRI

Resting State Correlations



Activation:
correlation with reference function



Rest:
seed voxel in motor cortex

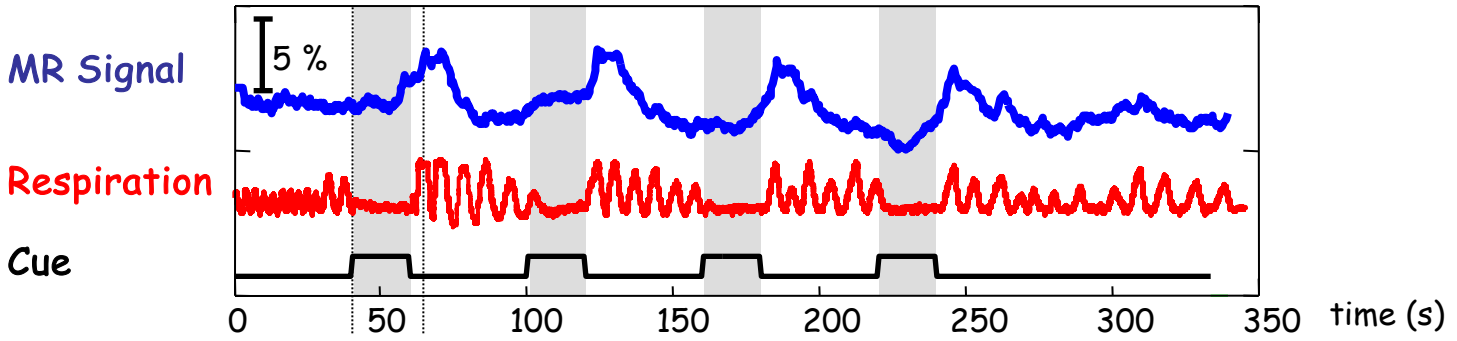
B. Biswal *et al.*, MRM, 34:537 (1995)

Sources of time series fluctuations:

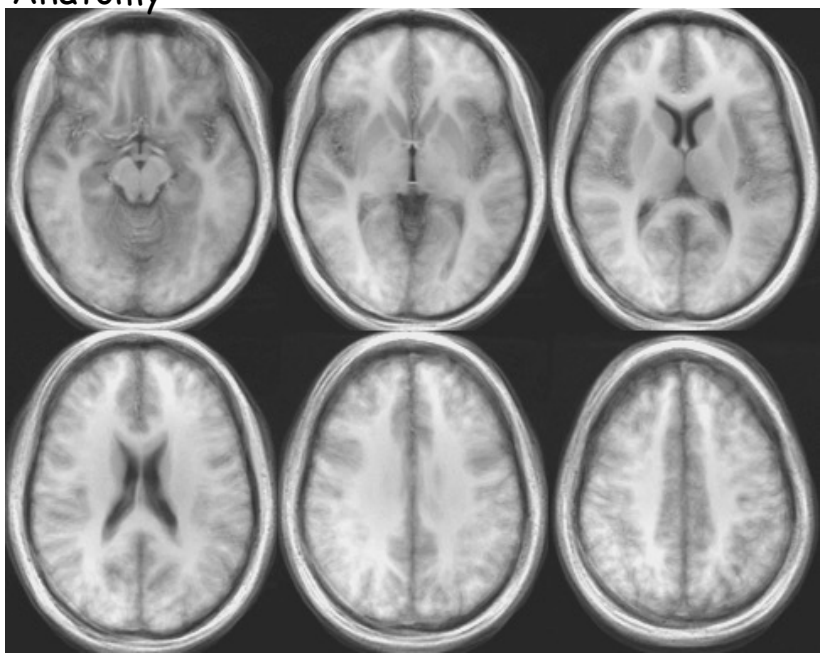
- Blood, brain and CSF pulsation
- Vasomotion
- Breathing cycle (B_0 shifts with lung expansion)
- Bulk motion
- Scanner instabilities
- Changes in blood CO_2 (changes in breathing)
- Spontaneous neuronal activity

Breath-holding

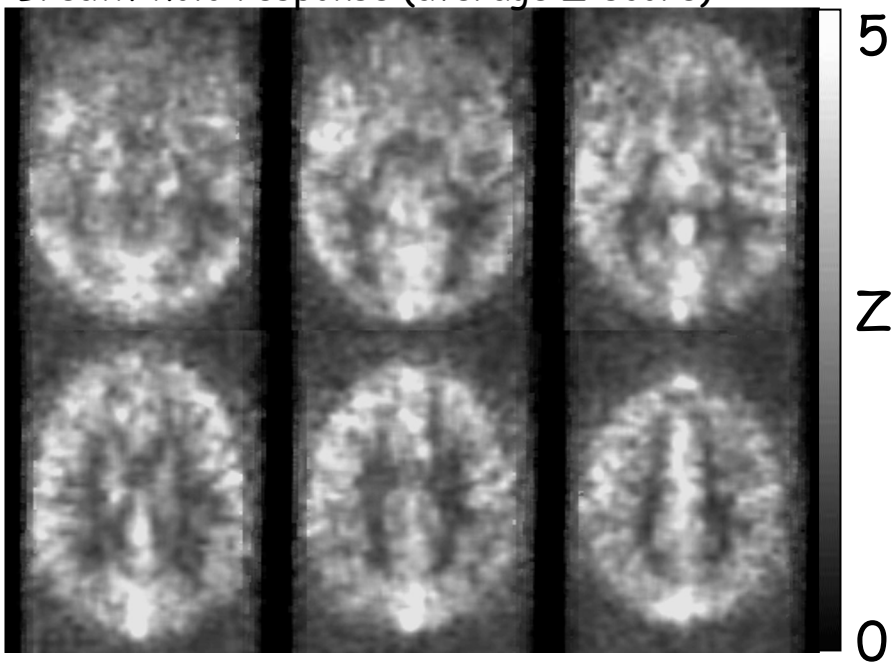
Group Maps (N = 7)



Anatomy

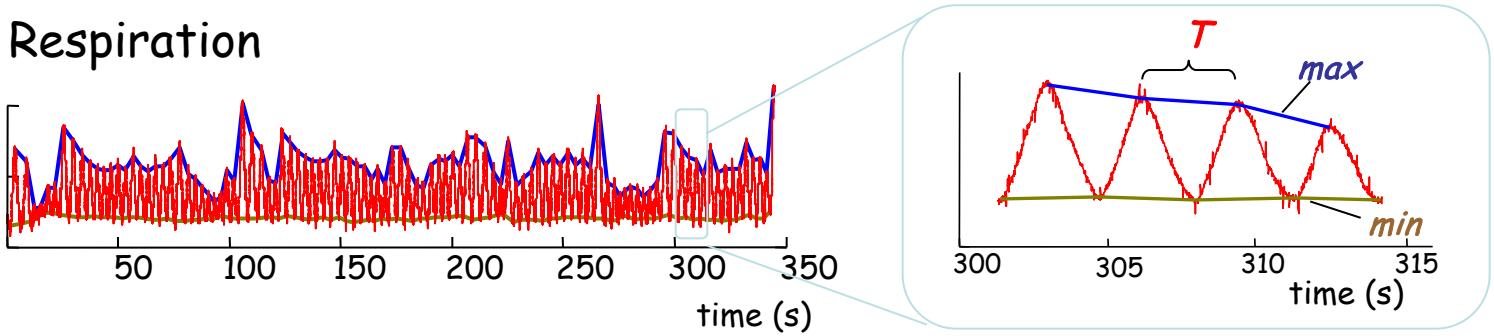


Breath-hold response (average Z-score)

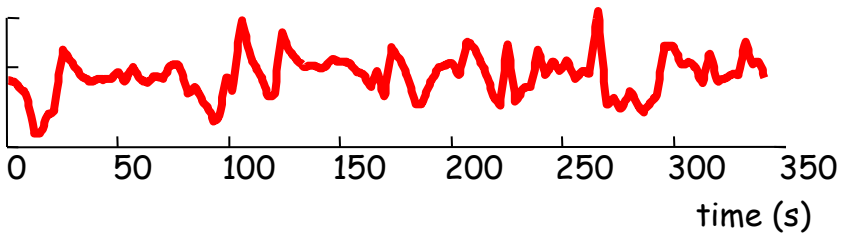


R.M. Birn, J. A. Diamond, M. A. Smith, P. A. Bandettini, *NeuroImage*, 31, 1536-1548

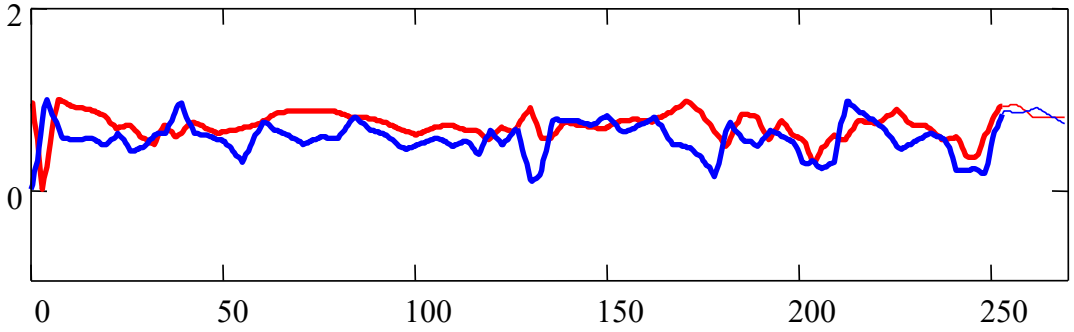
Estimating respiration volume changes

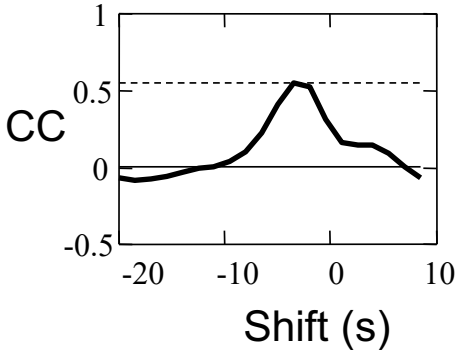


Respiration Volume / Time (RVT)



$$RVT = \frac{max - min}{T}$$

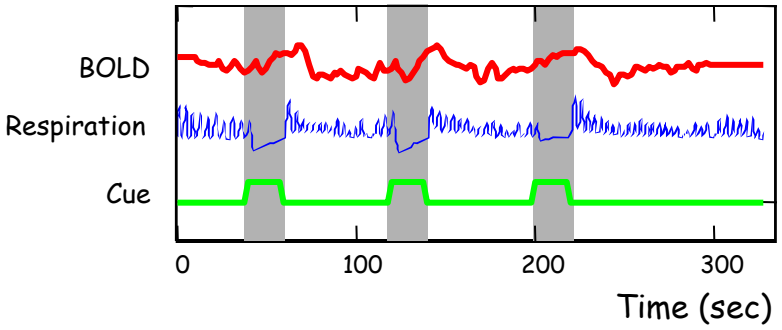




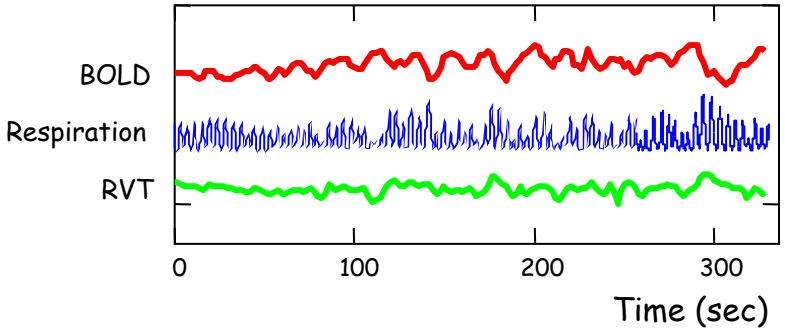
RVT precedes end tidal CO_2 by 5 sec.

Respiration induced signal changes

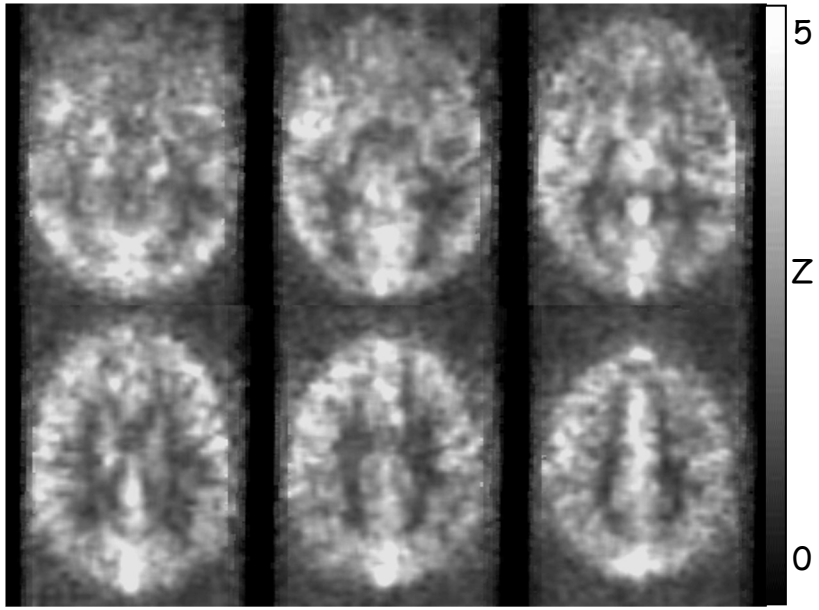
Breath-holding

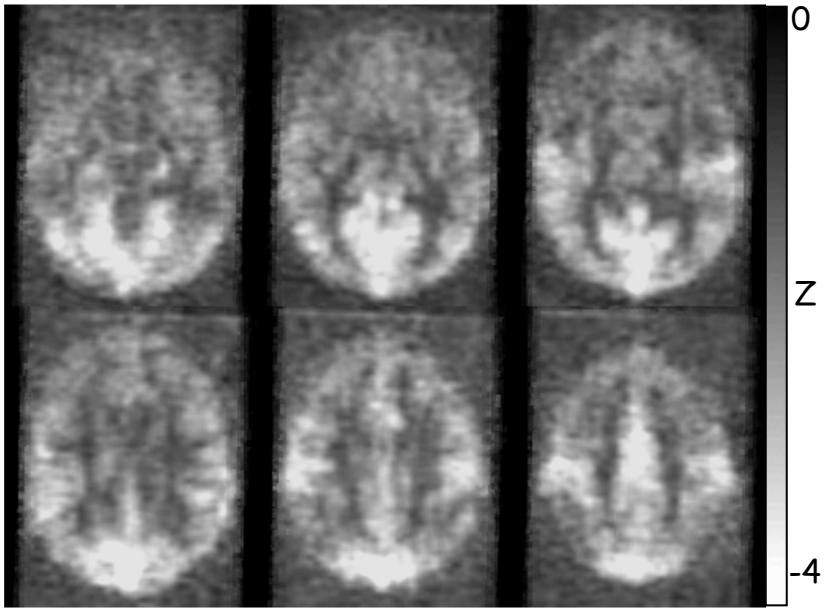


Rest



(N=7)

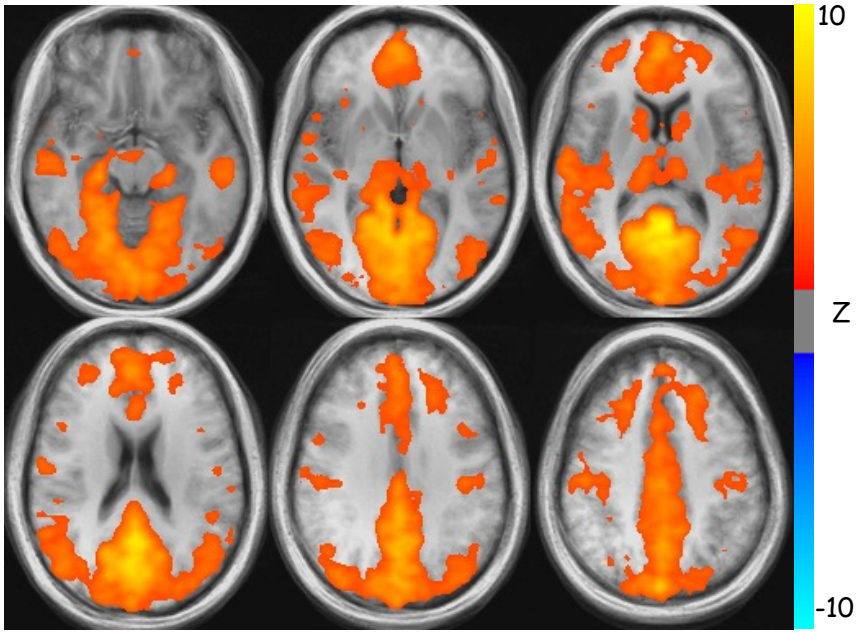




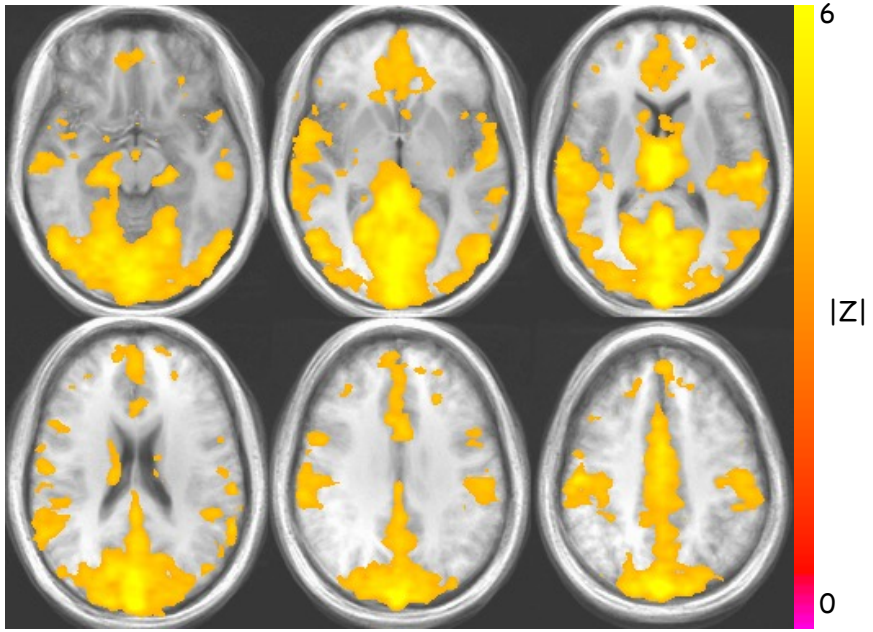
R.M. Birn, J. A. Diamond, M. A. Smith, P. A. Bandettini, *NeuroImage*, 31, 1536-1548 (2006)

RVT Correlation Maps & Functional Connectivity Maps

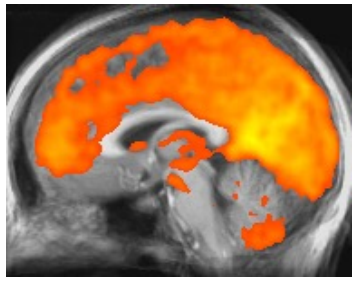
Resting state correlation with signal from posterior cingulate



Resting state correlation with RVT signal



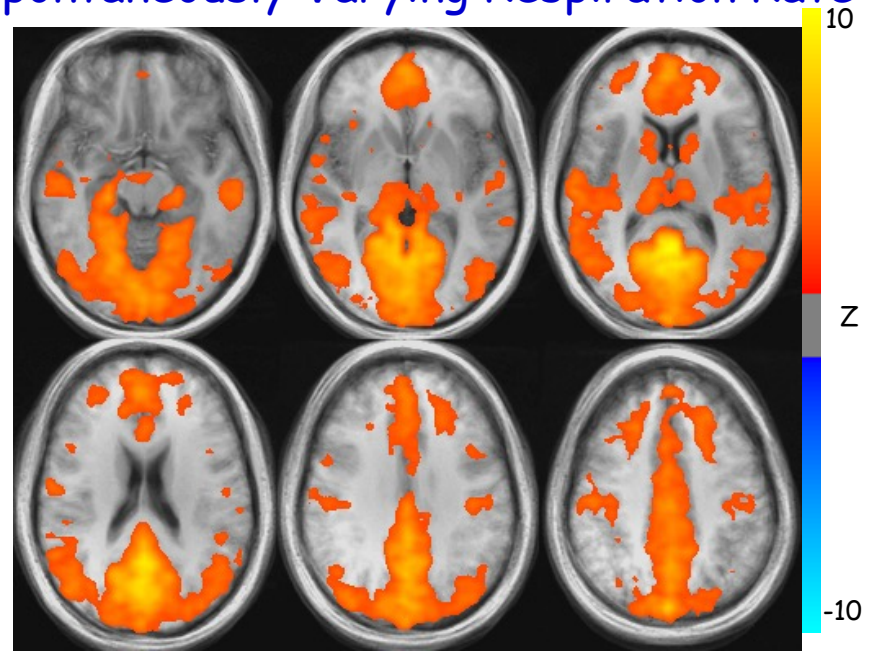
Group (n=10)



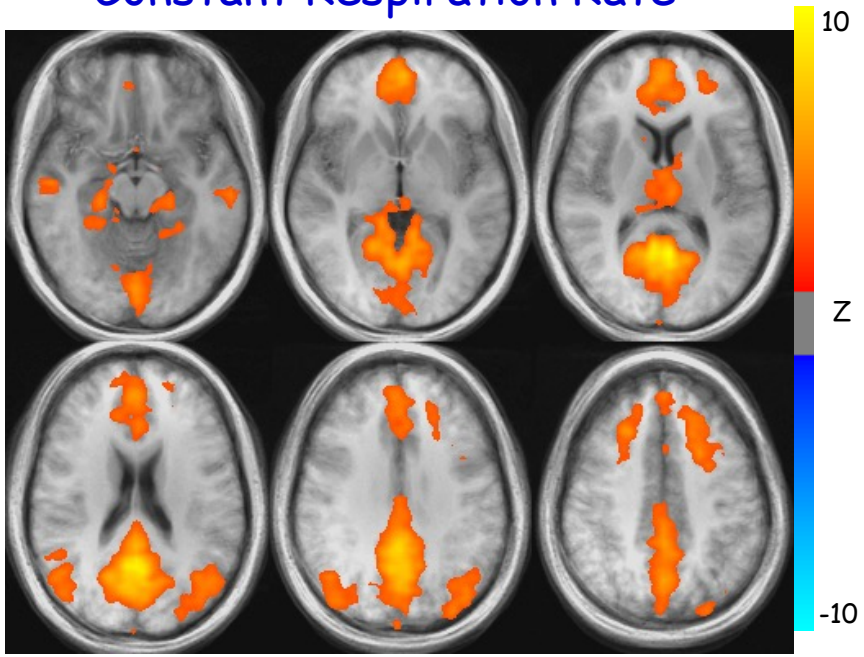
R.M. Birn, J. A. Diamond, M. A. Smith, P. A. Bandettini, *NeuroImage*, 31, 1536-1548 (2006)

Effect of Respiration Rate Consistency on Resting Correlation Maps

Spontaneously Varying Respiration Rate



Constant Respiration Rate

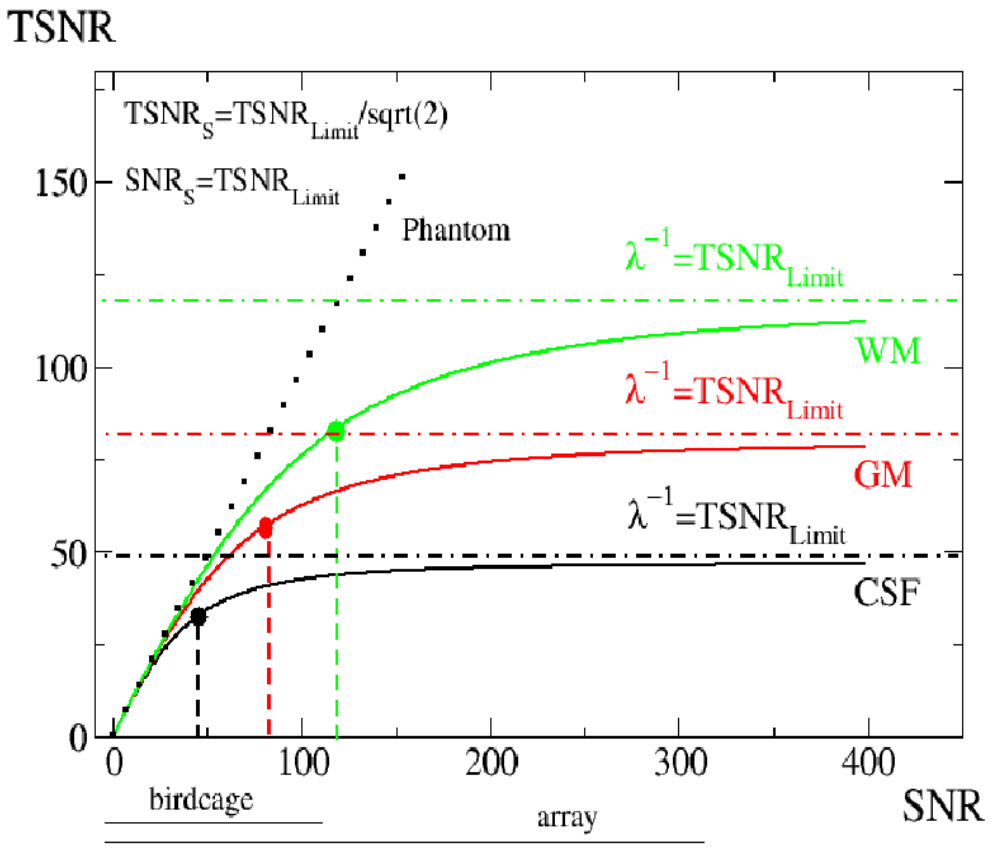


Group (n=10)

R.M. Birn, J. A. Diamond, M. A. Smith, P. A. Bandettini, *NeuroImage*, 31, 1536-1548 (2006)

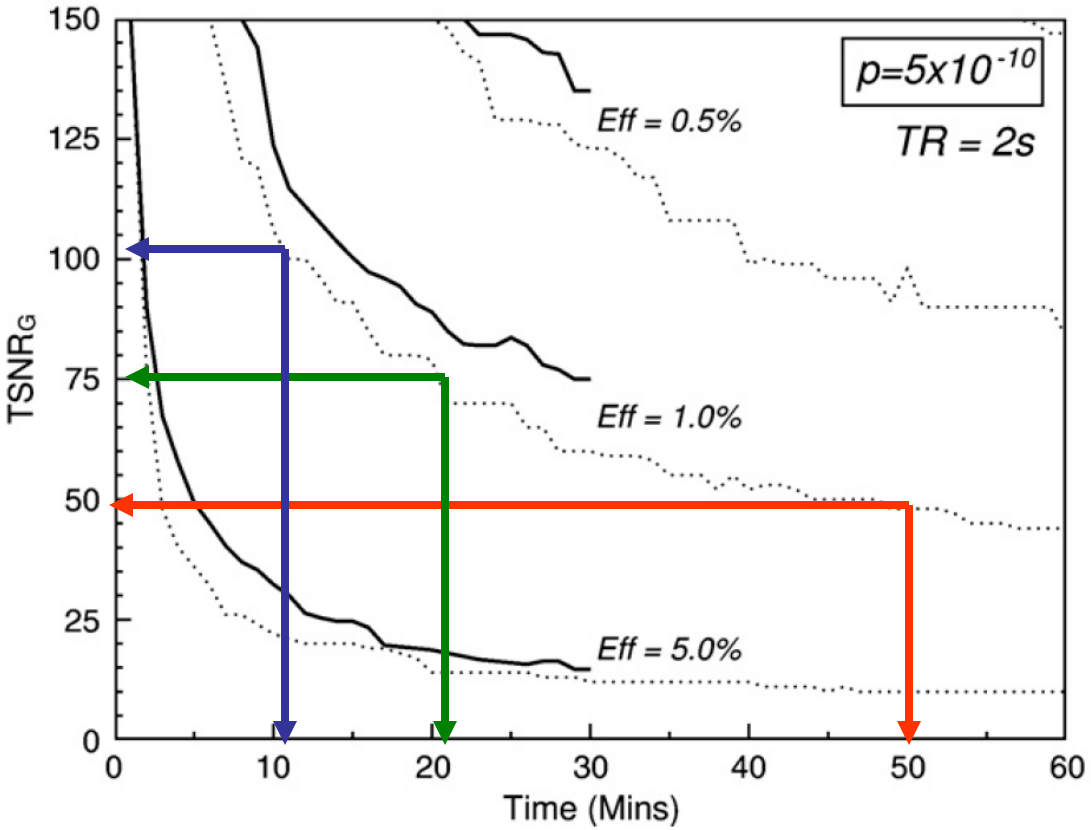
…Tangent on Signal to Noise

Temporal Signal to Noise Ratio (TSNR) vs. Signal to Noise Ratio (SNR)



J. Bodurka, F. Ye, N Petridou, K. Murphy, P. A. Bandettini, *NeuroImage,* 34, 542-549 (2007)

Sensitivity, Scan Time, and Temporal Signal to Noise

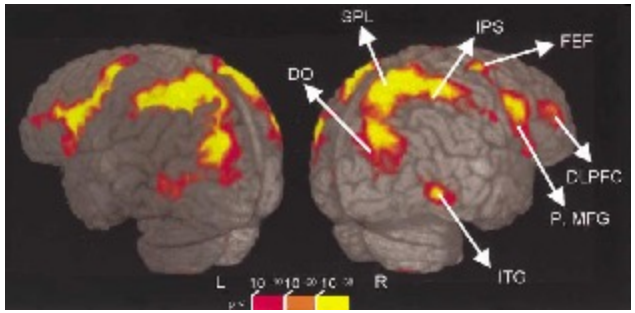


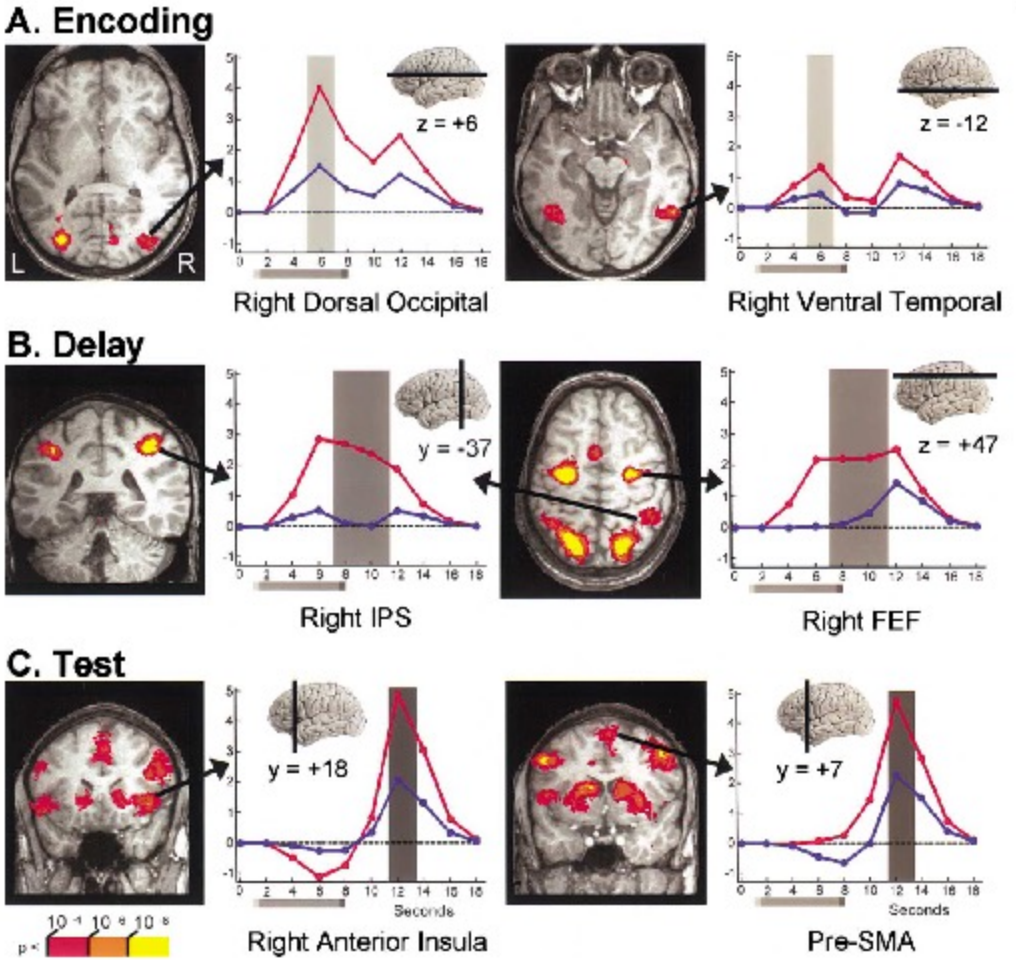
K. Murphy, J. Bodurka, P. A. Bandettini, *NeuroImage*, 34, 565-574 (2007)

Neuron, Vol. 35, 975–987, August 29, 2002, Copyright ©2002 by Cell Press

Neural Correlates of Visual Working Memory: fMRI Amplitude Predicts Task Performance

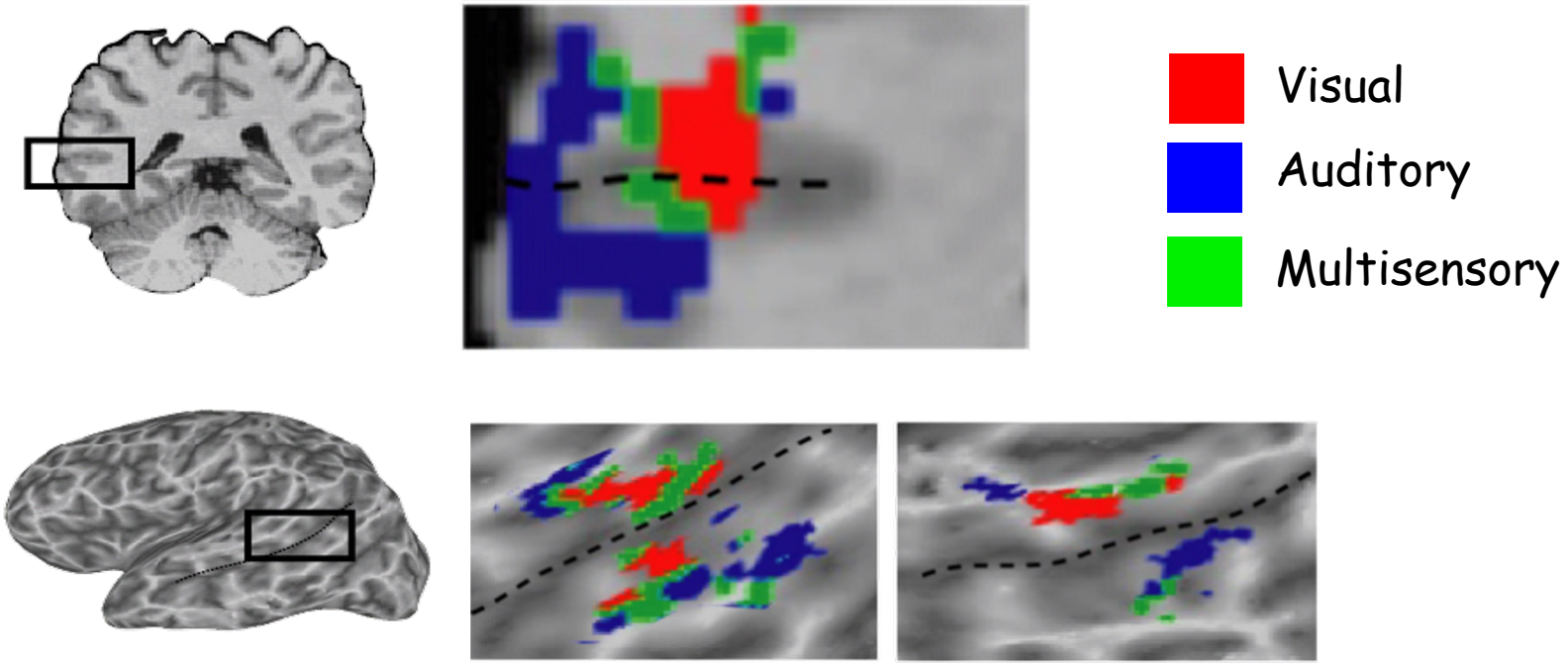
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892





Multi-sensory integration

M.S. Beauchamp et al.,



1. Dynamics

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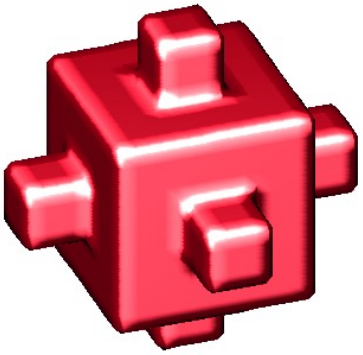
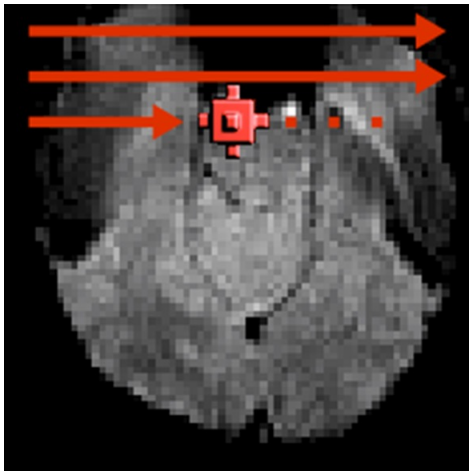
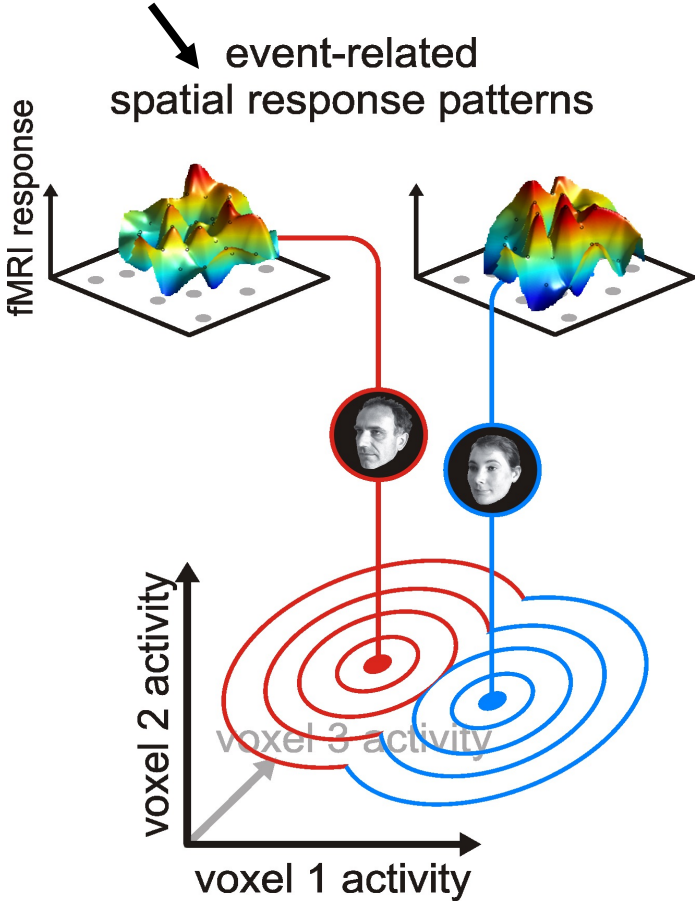
Pattern Information Mapping

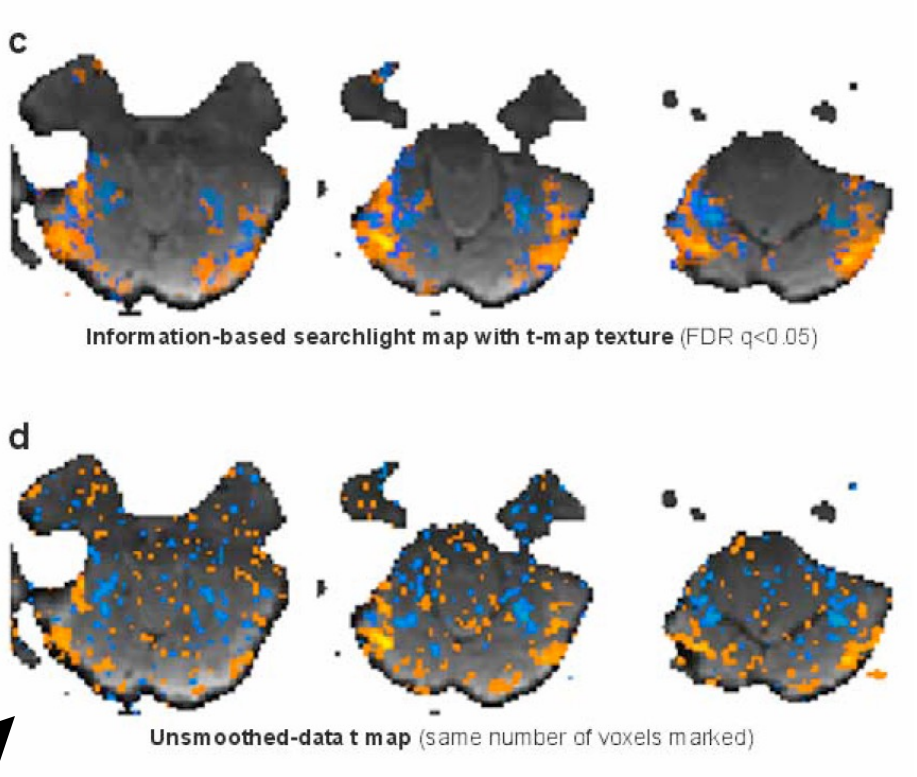
"searchlight" ROI →





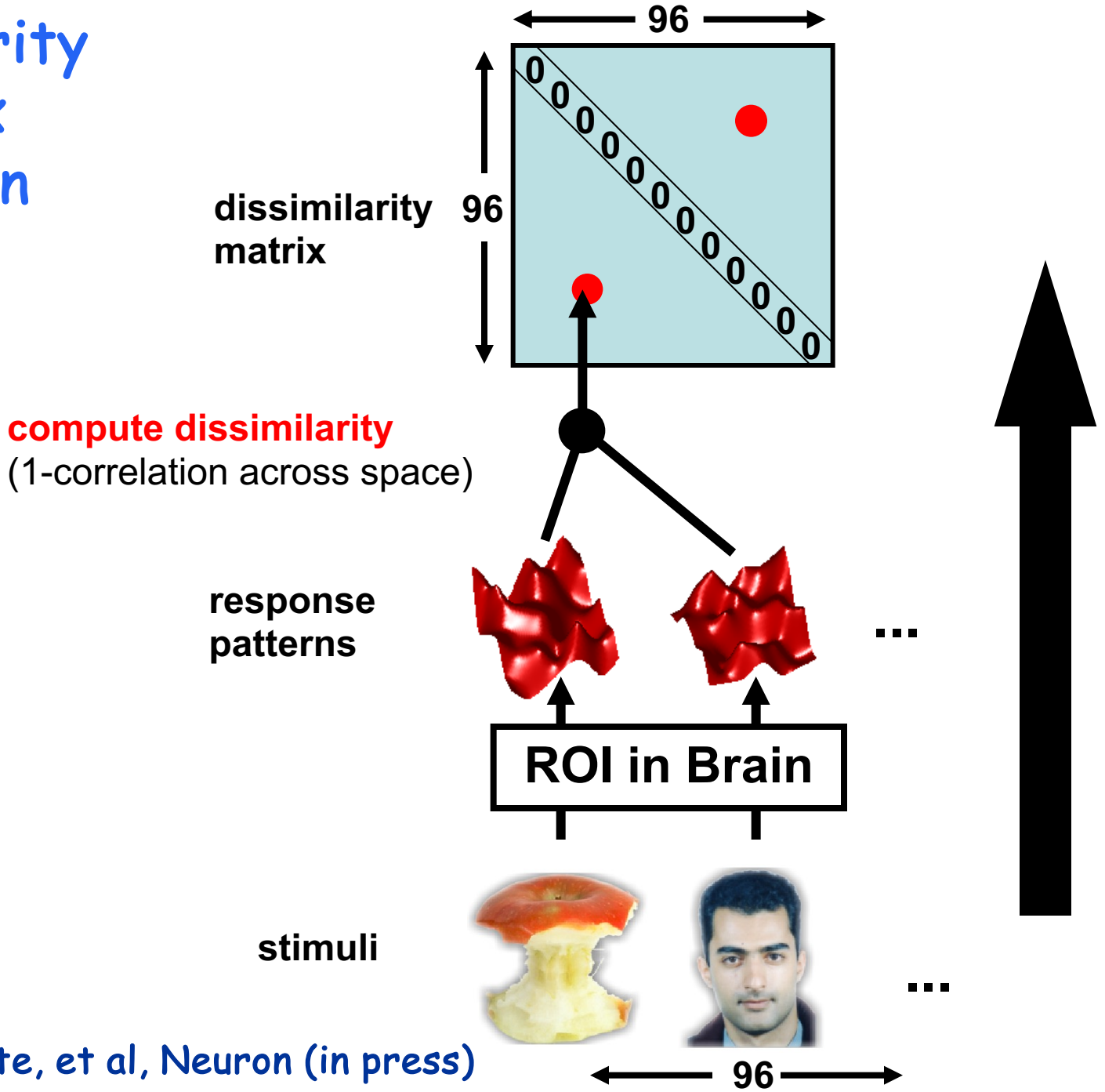
From fixed ROI





N. Kriegeskorte, R. Goebel, P. Bandettini, *Proc. Nat'l. Acad. Sci. USA*, 103, 3863-3868 (2006)

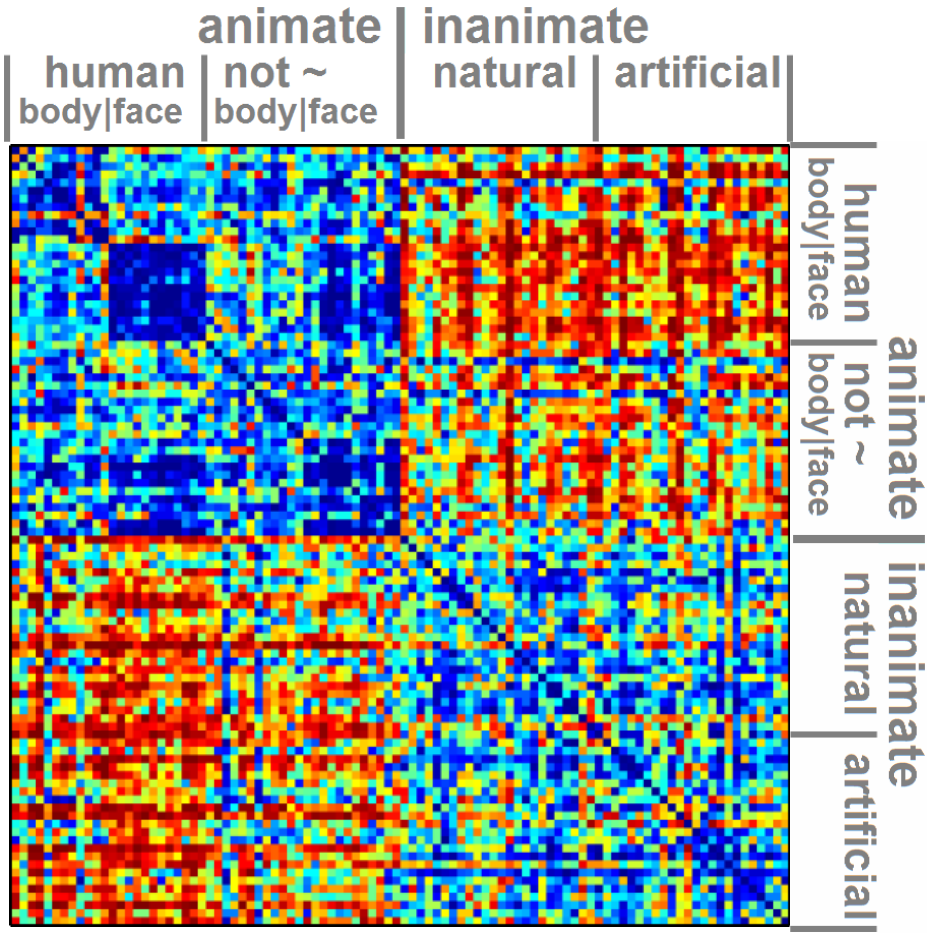
Dissimilarity Matrix Creation

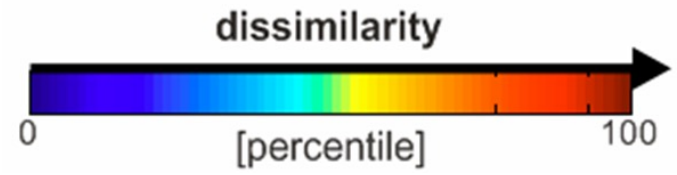


N. Kriegeskorte, et al, Neuron (in press)

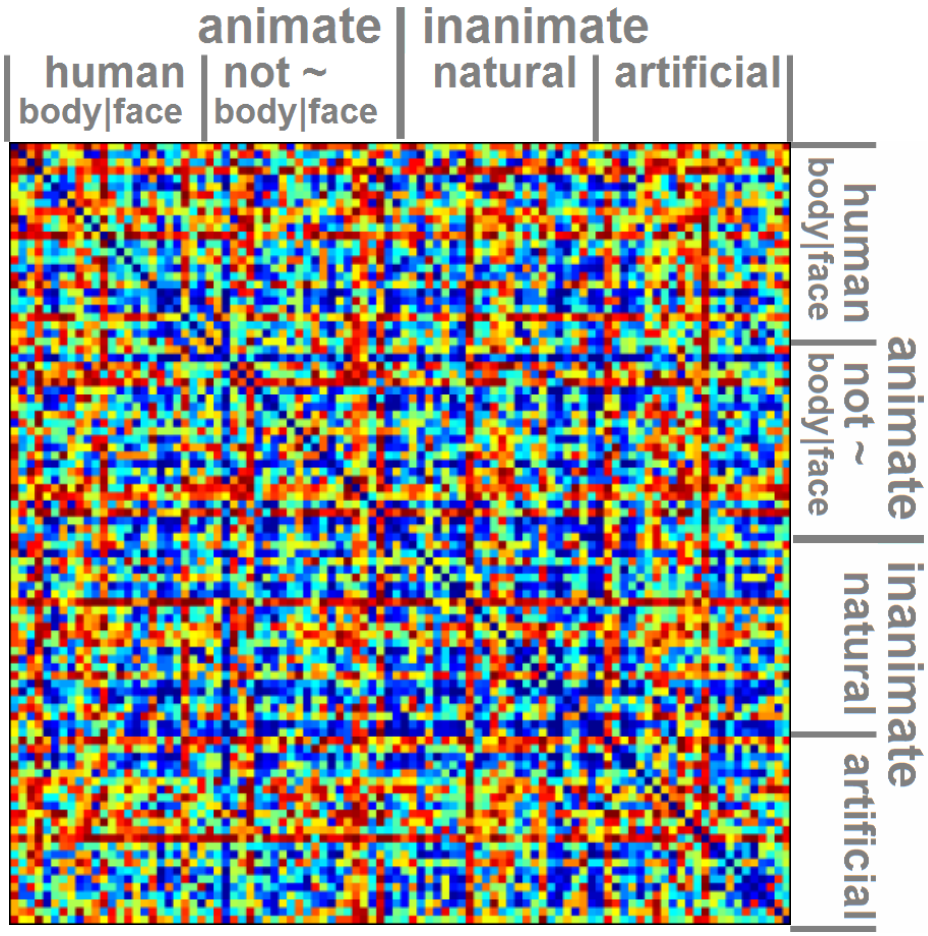
Visual Stimuli

Human IT
(1000 visually most responsive voxels)





Human Early Visual Cortex
(1057 visually most responsive voxels)



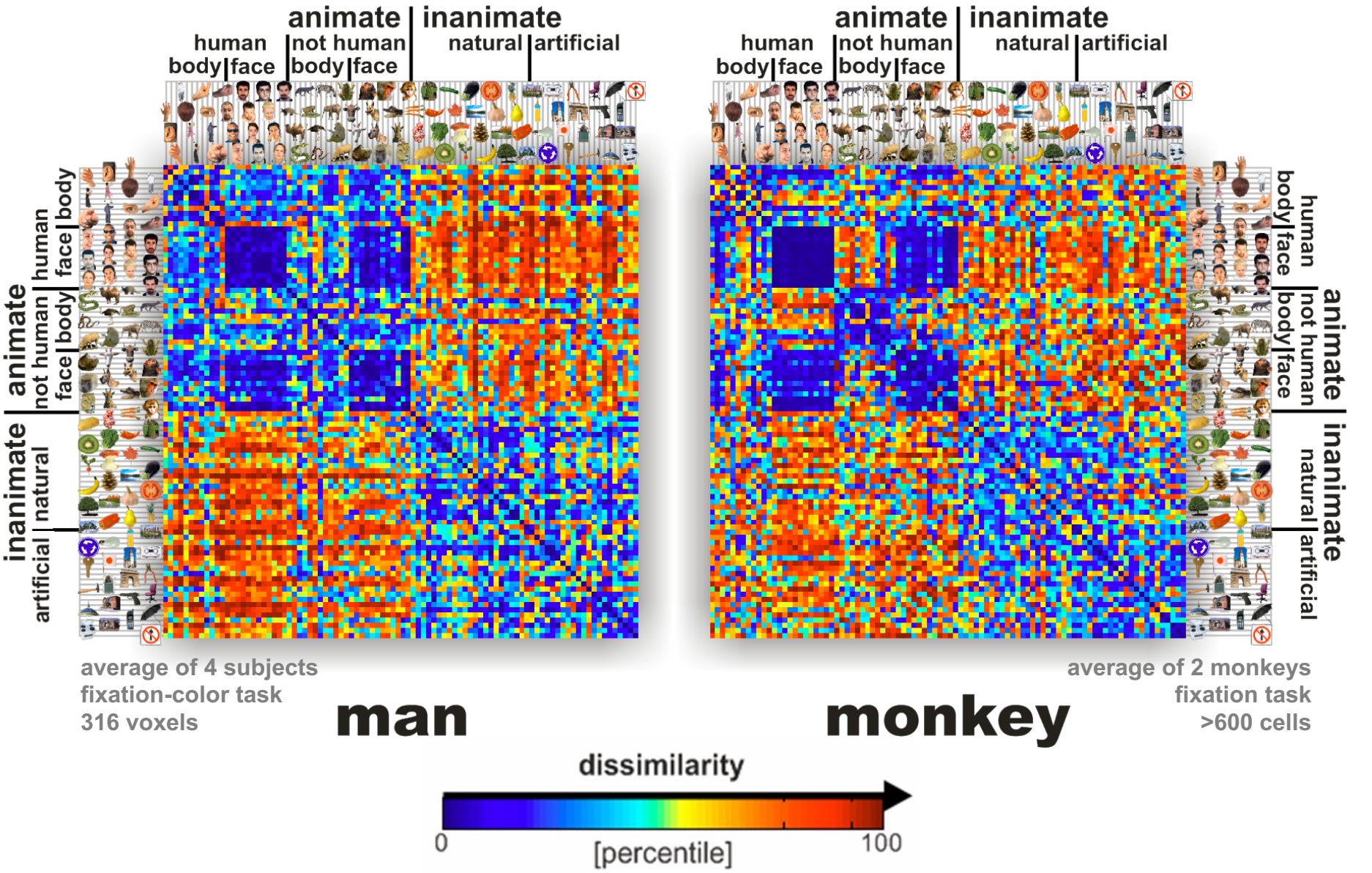
Monkey-Human Comparison Procedure

Human

- fMRI in four subjects
  (repeated sessions,
  >12 runs per subject)
- "quick" event-related design
  (stimulus duration: 300ms,
  stimulus onset asynchrony: 4s)
- fixation task
  (with discrimination of fixation-point color changes)
- occipitotemporal measurement slab
  (5-cm thick)
- small voxels ($1.95 \times 1.95 \times 2 mm^3$)
- 3T magnet, 16-channel coil
  (SENSE, acc. fac. 2)

Monkey (Kiani et al. 2007)

- single-cell recordings in two monkeys
- rapid serial presentation
  (stimulus duration: 105ms)
- fixation task
- electrodes in anterior IT
  (left in monkey 1, right in monkey 2)
- 674 cells total
- windowed spike count
  (140-ms window starting 71ms after stimulus onset)



N. Kriegeskorte, et al Neuron (in press)

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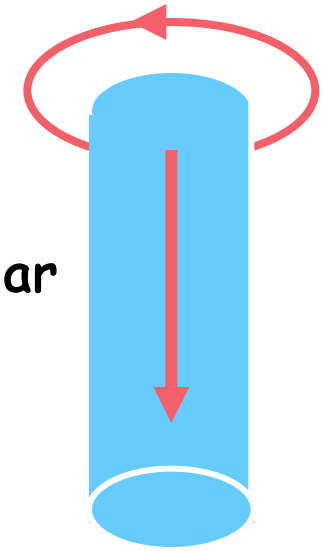
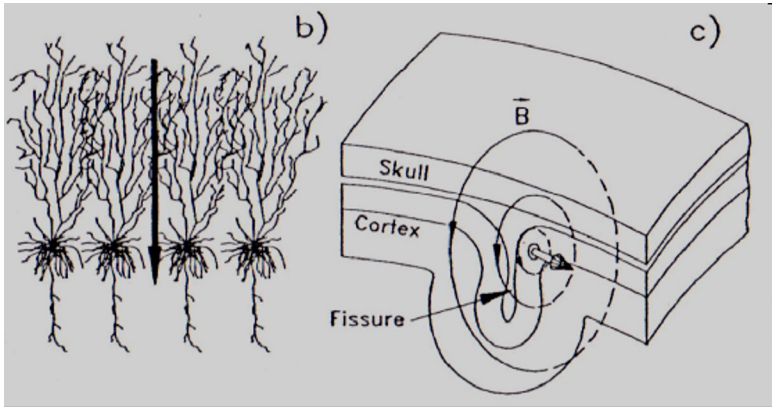
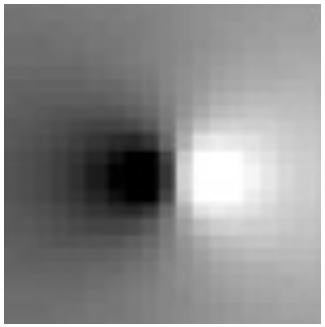
Magnetic Field

Intracellular Current





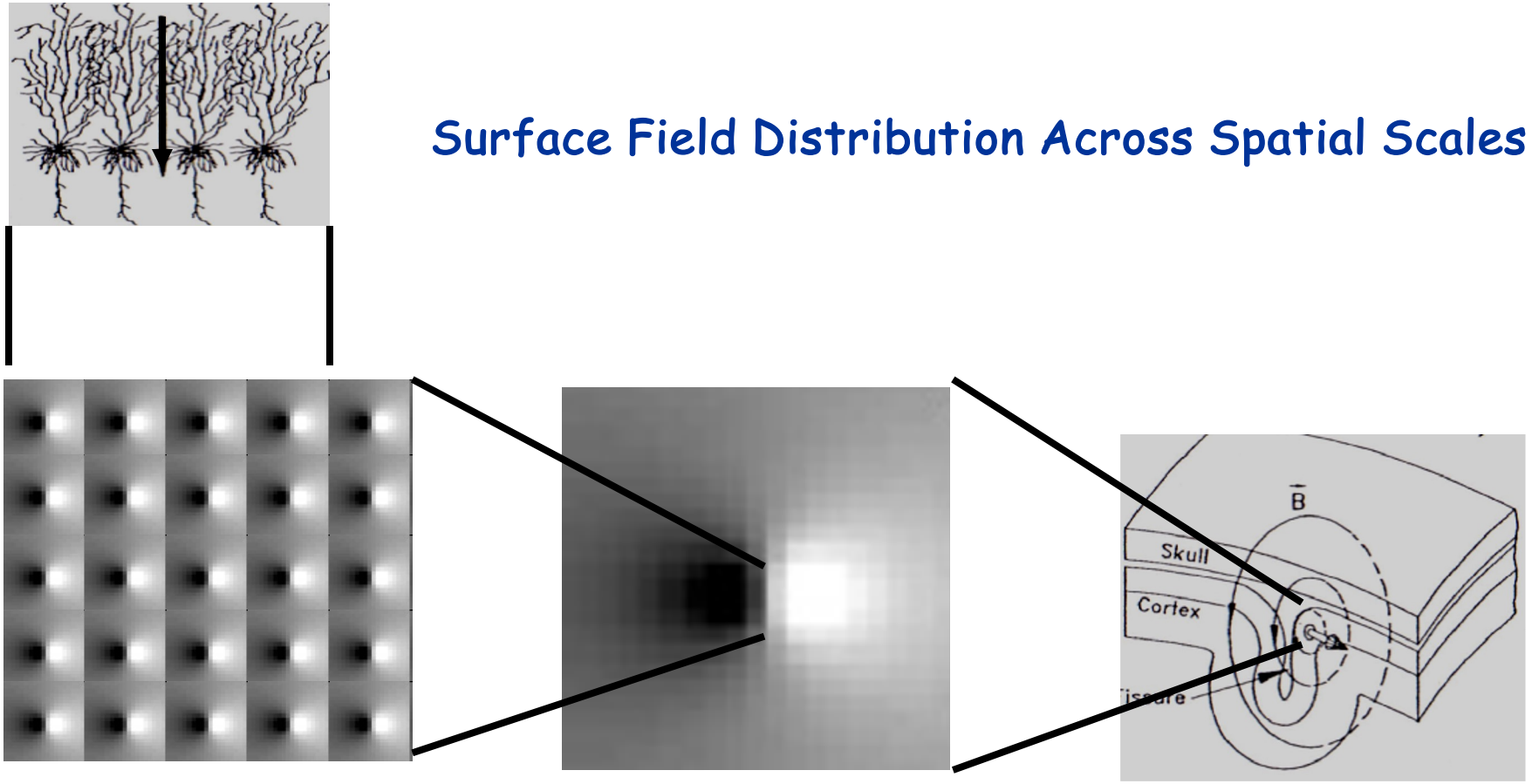
Surface Fields



100 fT at on the scalp

J.P. Wikswo Jr et al. *J Clin Neuronphy* 8(2): 170-188, 1991

Surface Field Distribution Across Spatial Scales

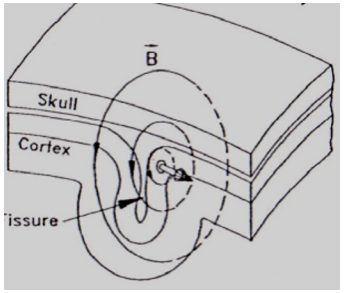


Adapted from: J.P. Wikswo Jr et al.

J Clin Neurophy 8(2): 170-188, 1991

Magnetic field associated with a bundle of dendrites

Because B_{MEG}=100fT is measured by MEG on the scalp

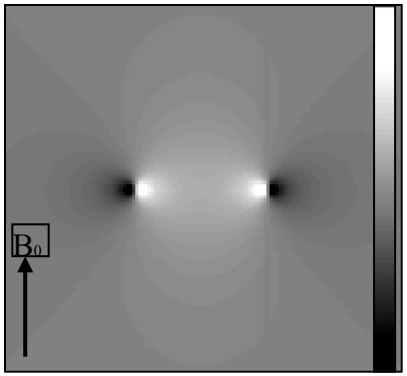


at least 50,000 neurons (0.002 fT (per dendrite) x 50,000 = 100 fT), must coherently act to generate such field. These bundles of neurons produce, within a typical voxel, 1 mm x 1 mm x 1 mm, a field of order:

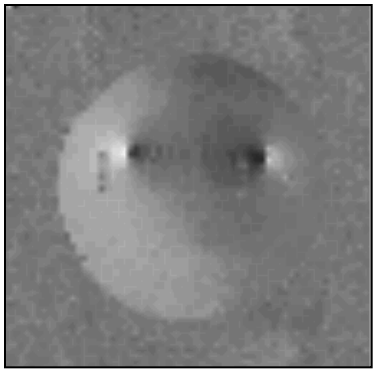
$$B_{MRI} = B_{MEG}\left(\frac{r_{MEG}}{r_{MRI}}\right)^2 = B_{MEG}\left(\frac{4\,cm}{0.1\,cm}\right)^2 = 1600\,B_{MEG}$$

$B_{MRI} \approx 0.2nT$

calculated B_c || B_0

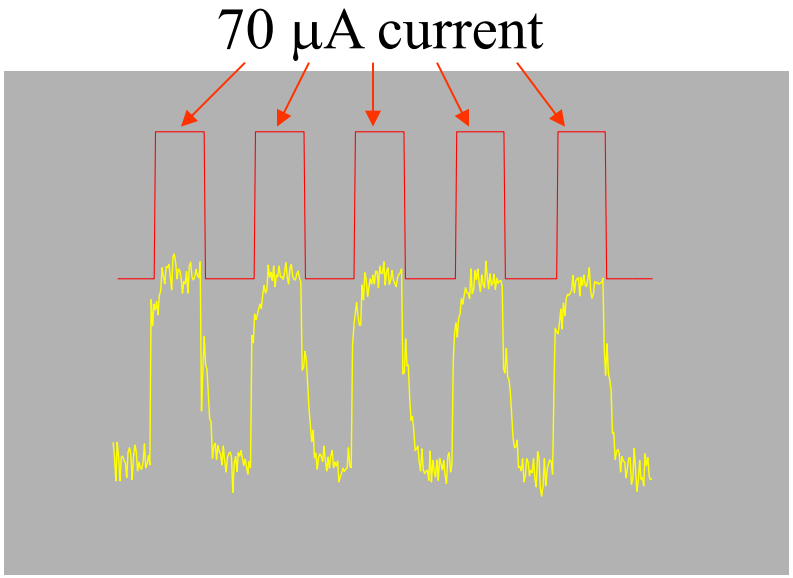


$\Delta\phi \cong 20^0$



Correlation image

Measurement

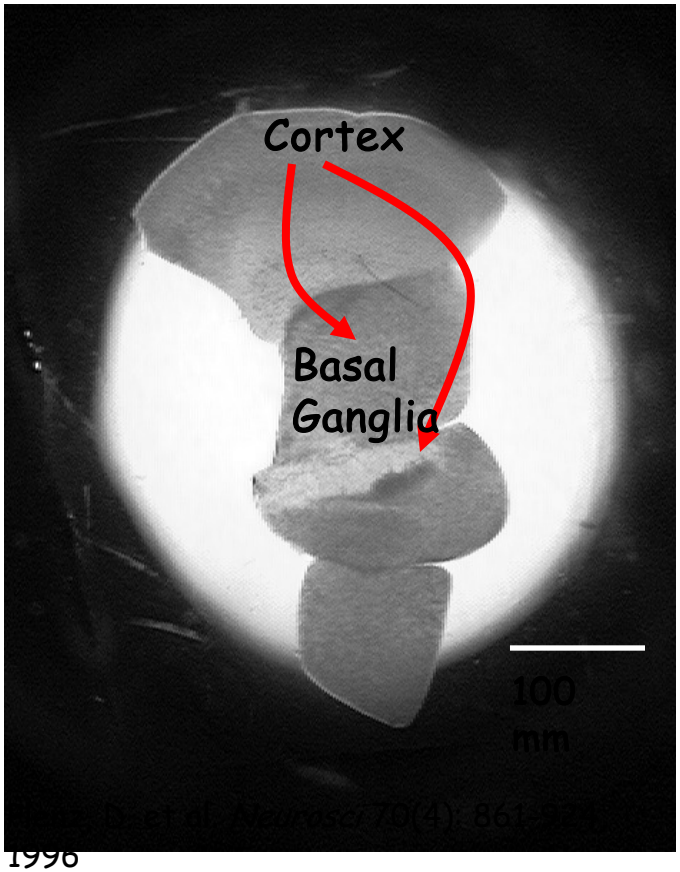


Single shot GE EPI

J. Bodurka, P. A. Bandettini. Magn. Reson. Med. 47: 1052-1058, (2002).

in vitro model

Organotypic (*no blood supply or hemoglobin traces*) sections of newborn-rat somato-sensory Cortex &Basal Ganglia

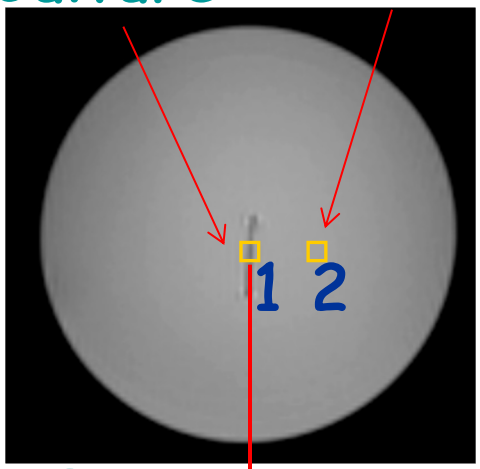


- Size: in-plane:~1-2mm^2, thickness: 60-100μm
- Neuronal Population: 10,000-100,000
- Spontaneous synchronized activity < 2Hz
- Epileptiform activity
- Spontaneous beta freq. activity (20-30Hz)
- Network Activity Range: ~ 0.5-15μV

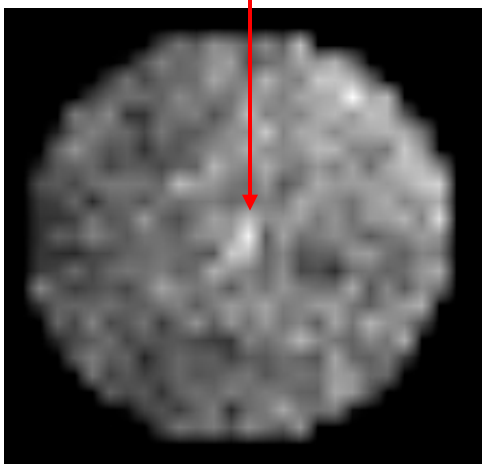
1998

3 Tesla data

Culture ACSF

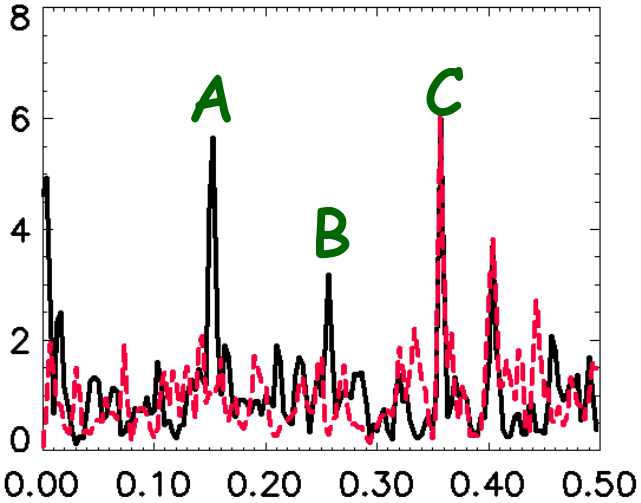


FSE image

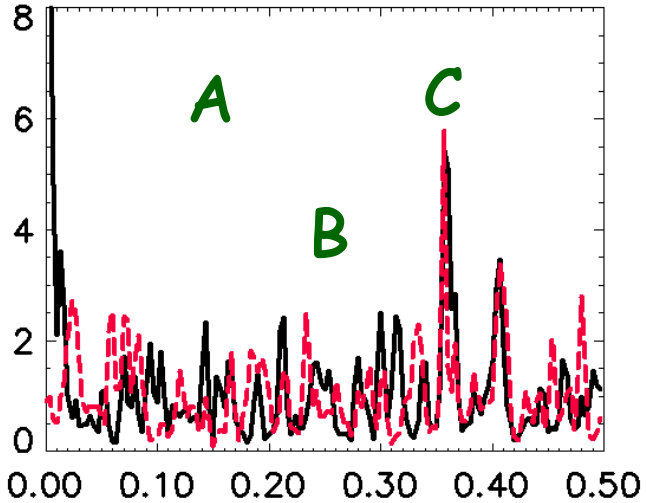


0.15Hz map

1: culture



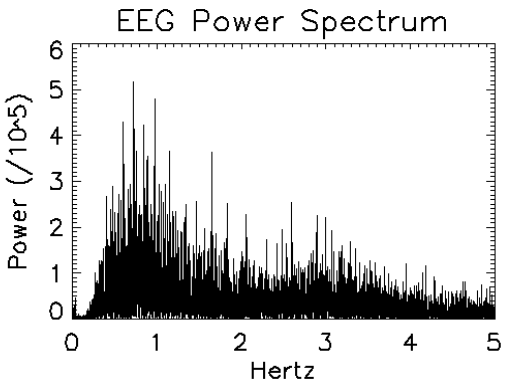
2: ACSF

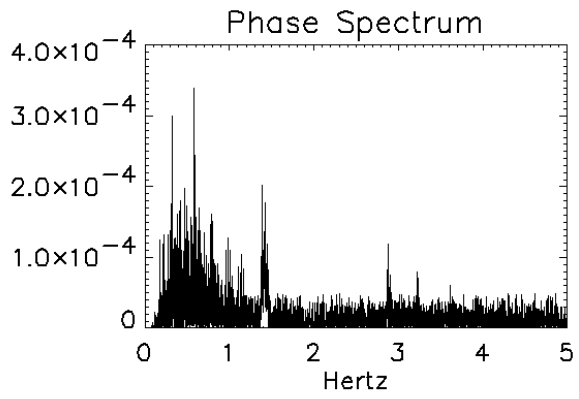


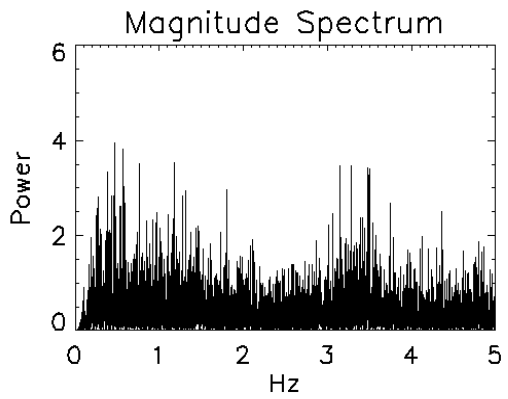
Active condition: black line
Inactive condition: red line

A: 0.15 Hz activity, on/off frequency
B: activity
C: scanner noise (cooling-pump)

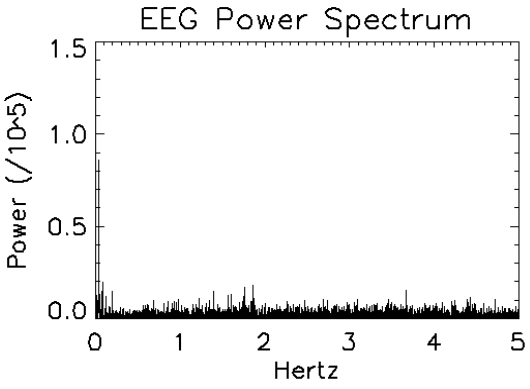
7 Tesla data

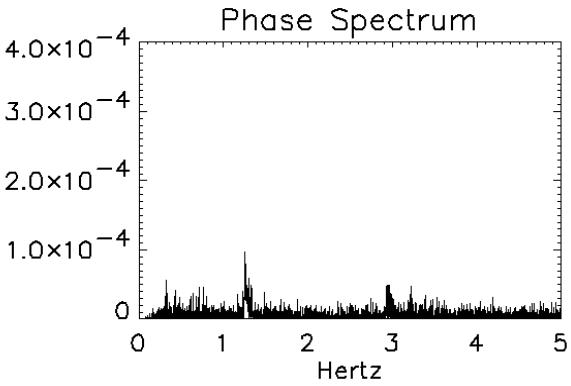


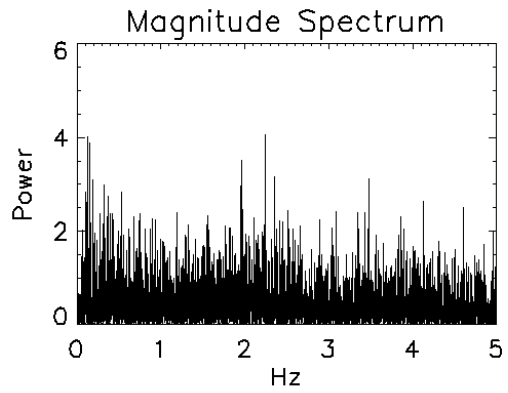




TTX







Power decrease between PRE & TTX EEG : ~ 81%

Decrease between PRE & TTX MR phase: ~ 70%

Decrease between PRE & TTX MR magnitude: ~ 8%

N. Petridou, D. Plenz, A. C. Silva, J. Bodurka, M. Loew, P. A. Bandettini, *Proc. Nat'l. Acad. Sci. USA*. 103, 16015-16020 (2006).