

The Biggest Unknowns in Functional MRI

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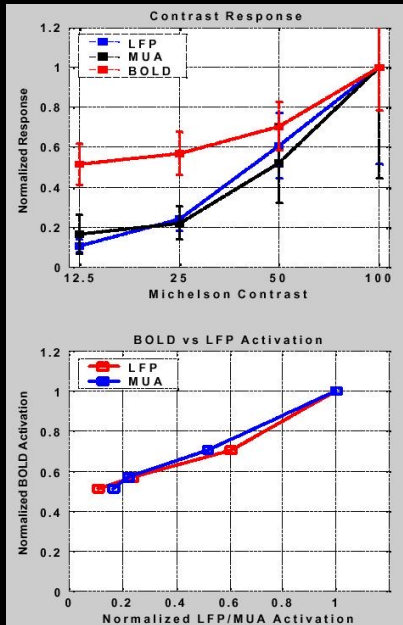


The Biggest Unknowns in Functional MRI

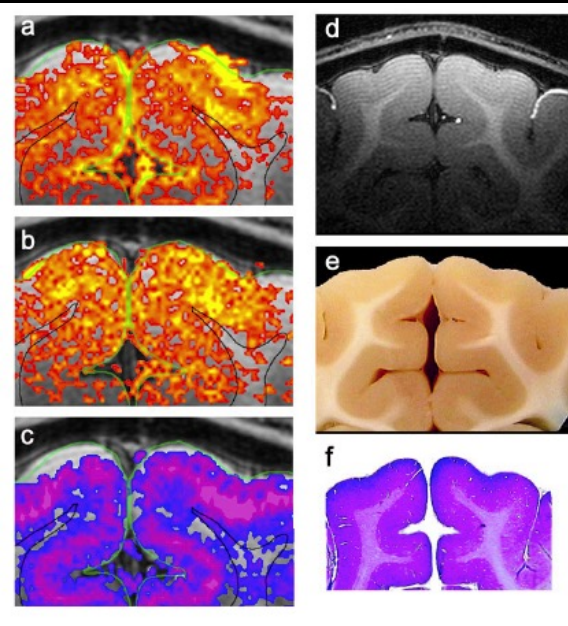
1. Relationship between neuronal activity and BOLD contrast?
2. Source of BOLD dynamic characteristics?
3. Sources of variability?
4. What's really in the noise?
5. What's "resting" state?
6. Other sources of functional contrast?
7. Ultimate temporal resolution?
8. Ultimate spatial resolution?
9. Ultimate clinical utility?
10. Best display methods?
11. Best processing methods?
12. Optimal Field Strength?

Relationship between neuronal activity and BOLD contrast?

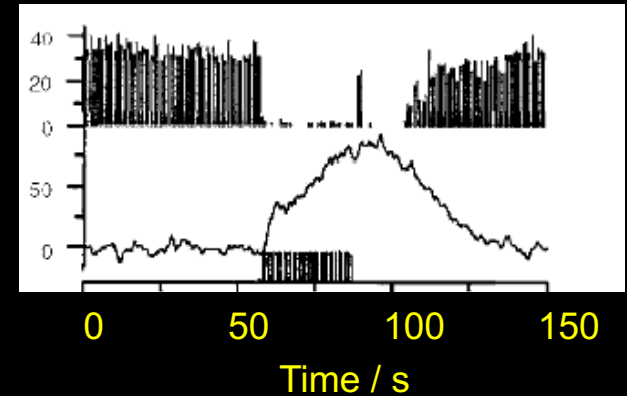
Magnitude



Location



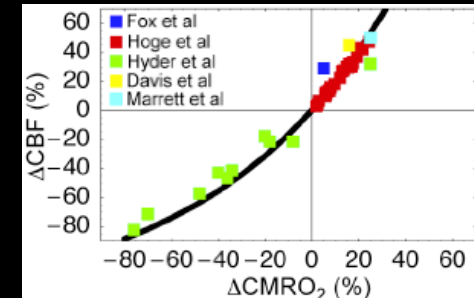
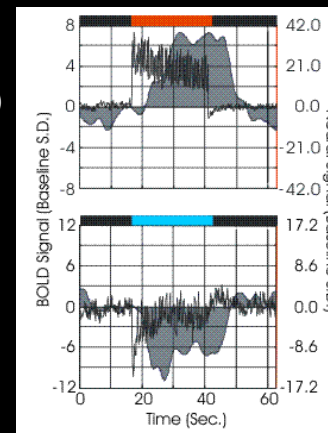
Inhibition



Mathiesen, et al (1998), J Physiol 512.2:555-566

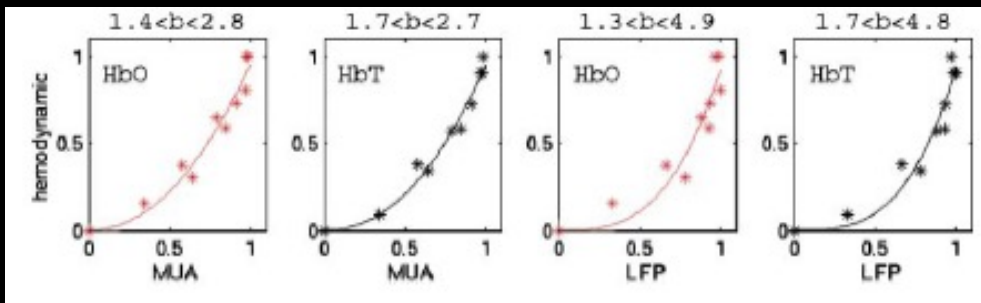
Neg. BOLD

Why?



to preserve $[O_2]/[CO_2]$ at mitochondria

Logothetis et al. (2001) Nature, 412, 150-157 Harel et al. (2004) ISMRM, 200

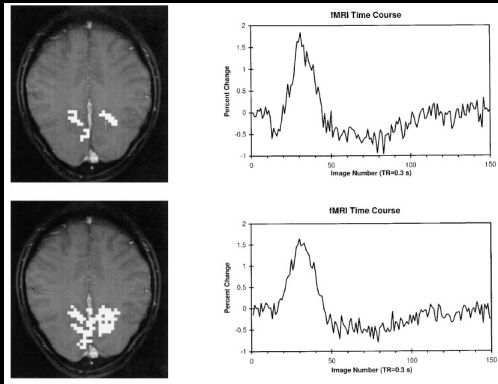
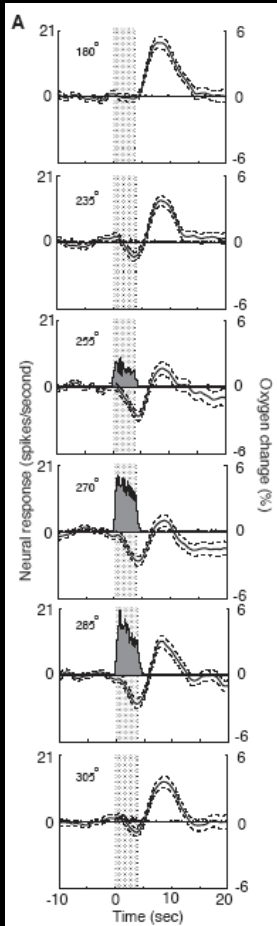


Devor et al. (2001) Neuron, 39, 353-359

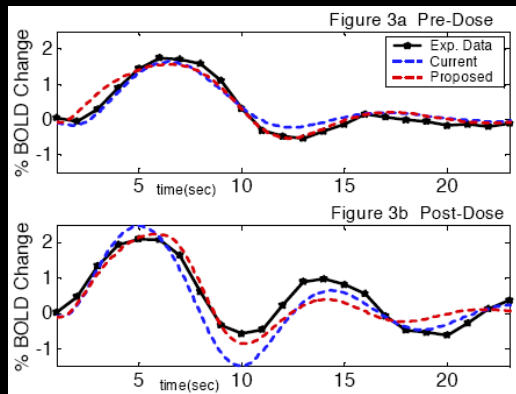
Schmuel et al. (2003) OHBM, 308

Buxton (2004) ISMRM, 273

Source of BOLD Characteristics?

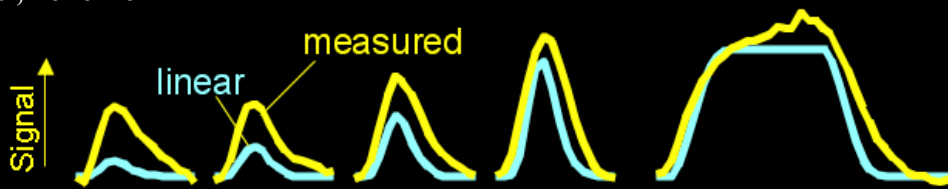


Yacoub, et al (1999), MRM 41, 1088-1092

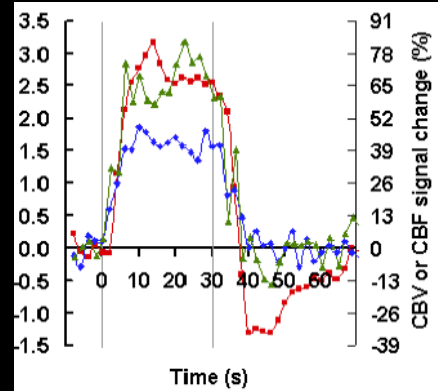


Behzadi, et al (2004), ISMRM 279

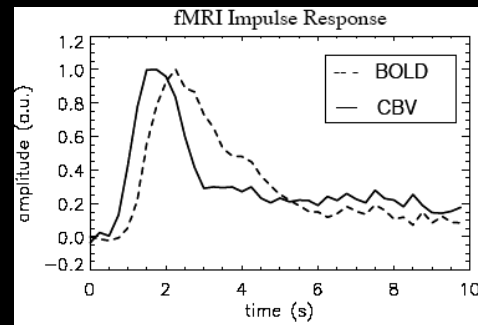
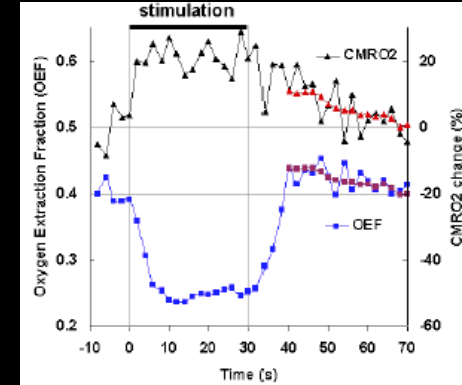
Thompson, et al (2003), Science 299, 1070-1072



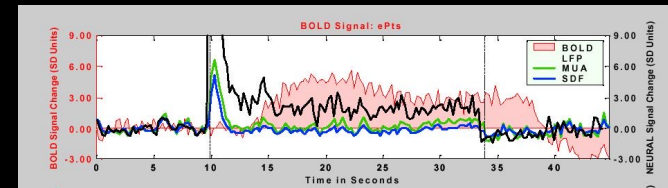
R. M. Birn, (2001) NeuroImage, 14: 817-826.



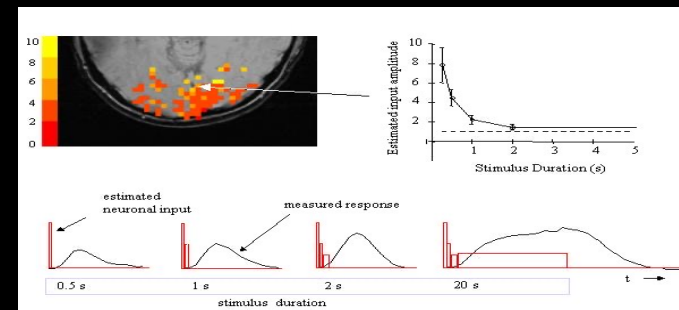
Lu, et al (2004), ISMRM 271



Silva, et al (2004), ISMRM 277

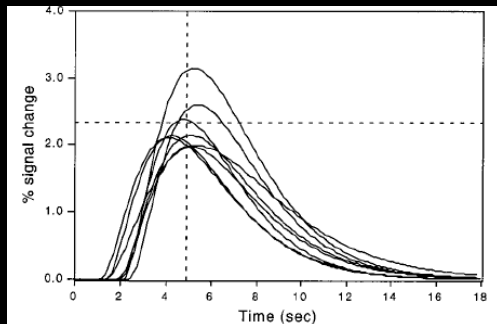


Logothetis et al. (2001) Nature, 412, 150-157.



P. A. Bandettini et al, (2001) Nature Neuroscience, 4: 864-866.

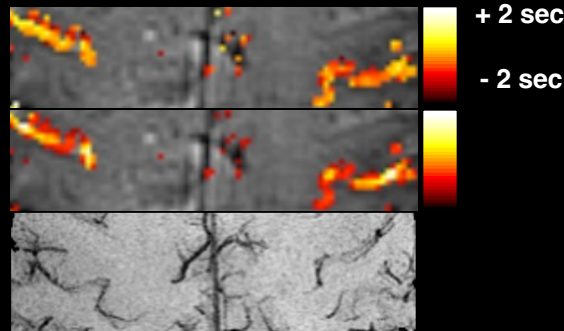
Sources of variability?



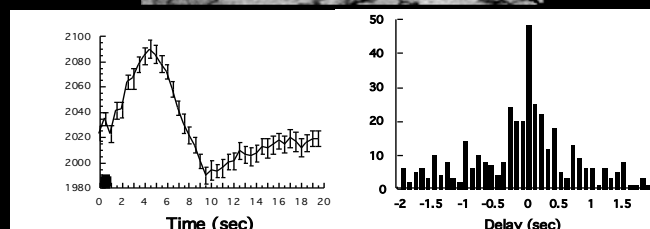
Latency

Magnitude

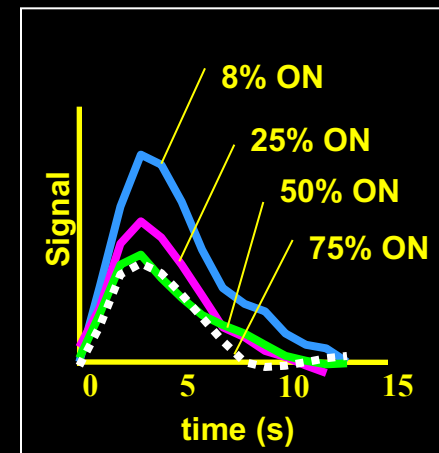
Venogram



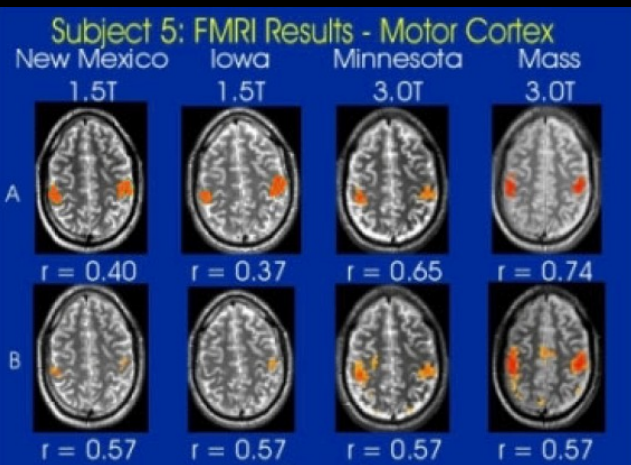
Miezin, et al (2000), NeuroImage 11, 735-759



P. A. Bandettini, (1999) "Functional MRI" 205-220.

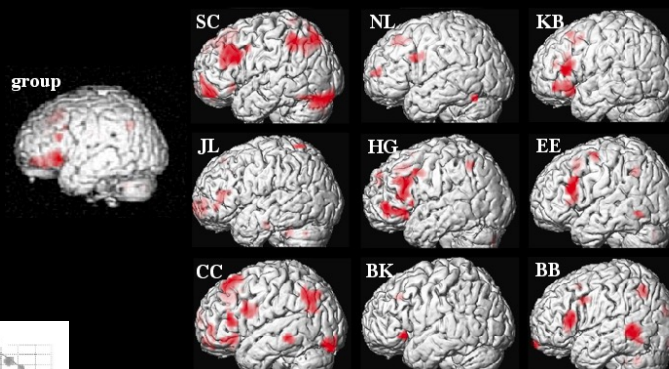


R. Birn, et al (2001), OHBM 971

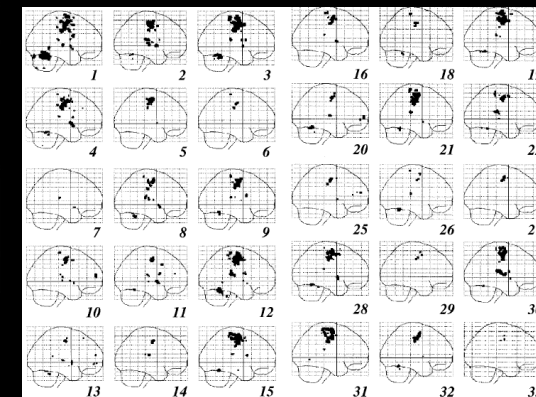


F. BIRN project

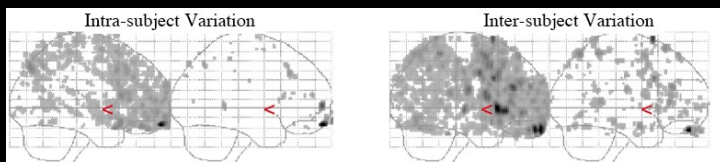
L. Friedman, et al (2004), ISMRM 489



Courtesy, Mike Miller, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth

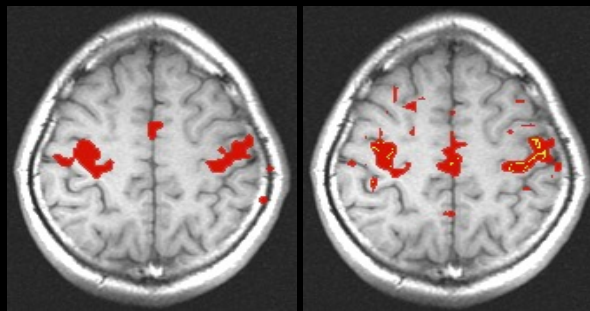
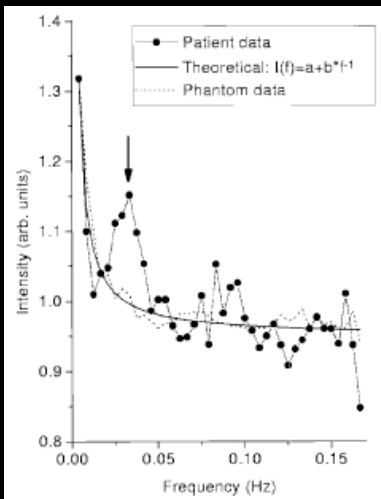


McGonigle, et al (2000), NeuroImage 11, 708-734

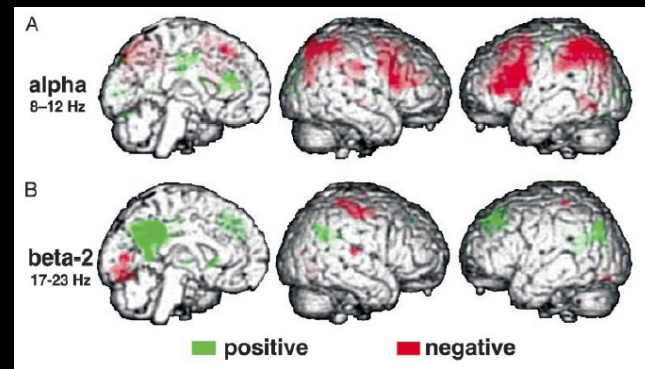
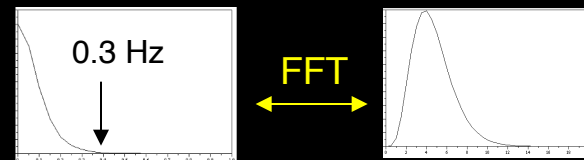


T.E. Lund, et al (2004), ISMRM 497a

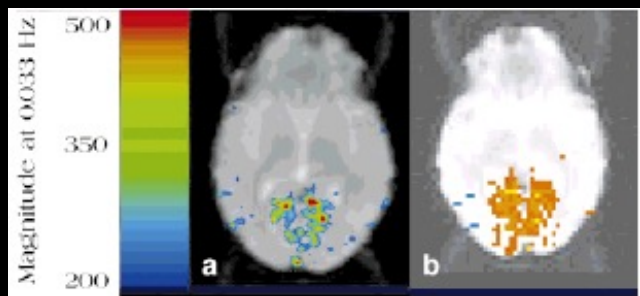
What's really in the noise?



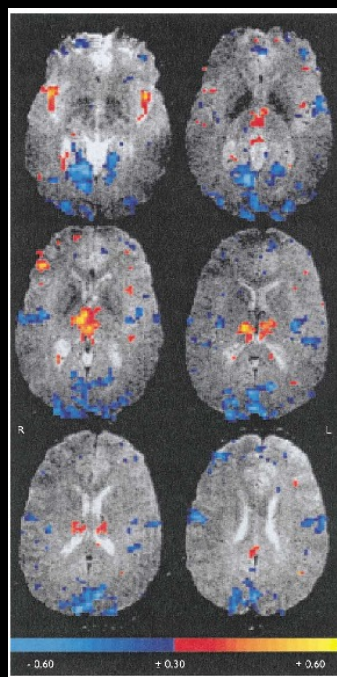
Biswal, et al (1995), MRM 34, 537-541



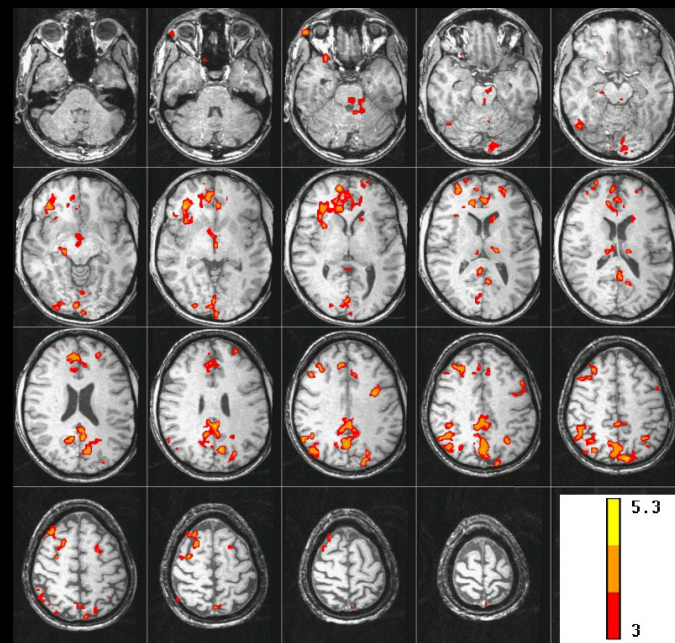
Laufs, et al (1995), PNAS 100 (19), 11053-11058



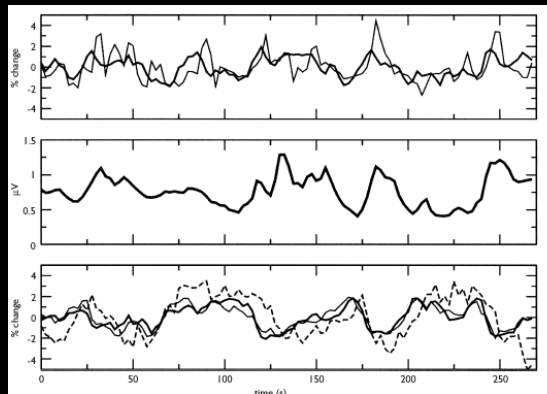
Kiviniemi, et al (2000), MRM 44, 373-378



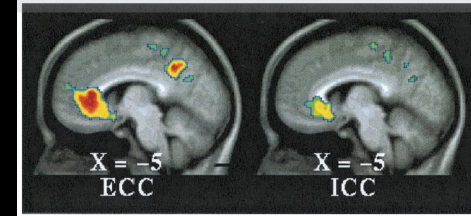
Goldman, et al (2002), Neuroreport



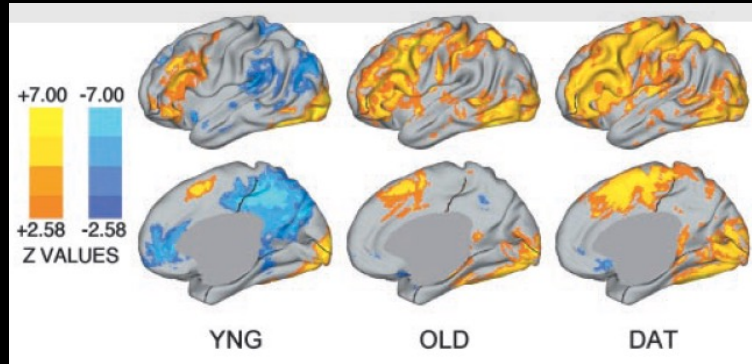
Patterson, et al (2002), NeuroImage 17, 1787-1806



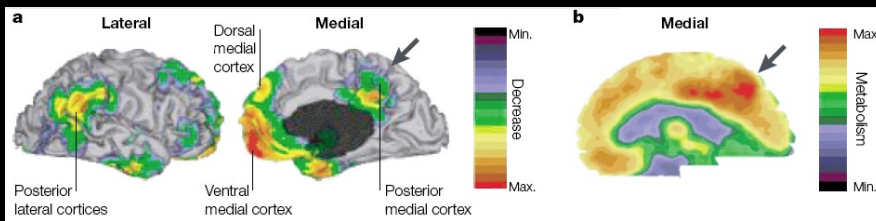
What is "resting" state?



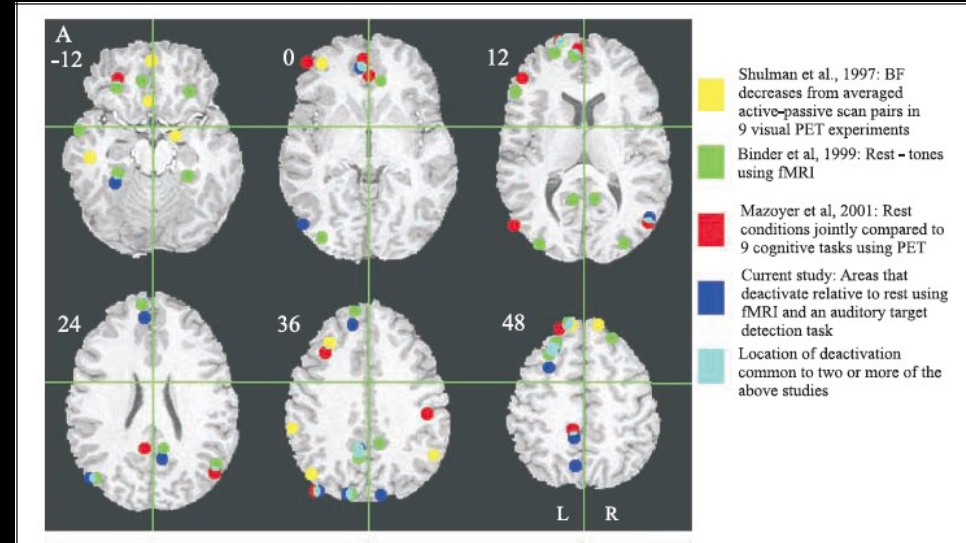
Gusnard, et al (2001), PNAS 98 (7), 4259-4264



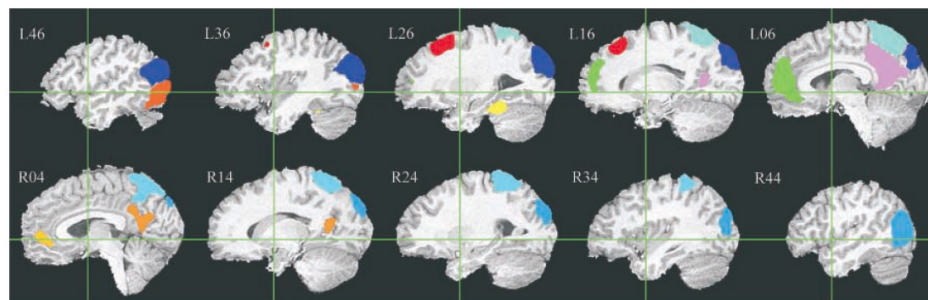
Lustig, et al (2003), PNAS 100 (19), 14504-14509



Gusnard, et al (2001), Nature Reviews Neuroscience (2), 685-694

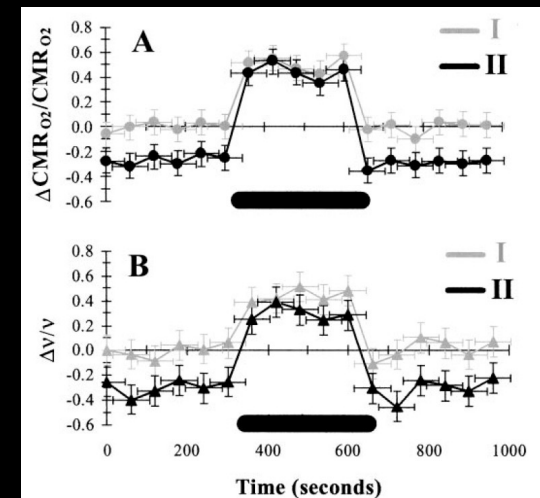


McKiernan, et al (2003), Journ. of Cog. Neurosci. 15 (3), 394-408



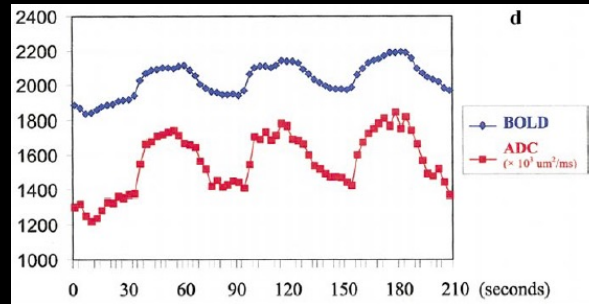
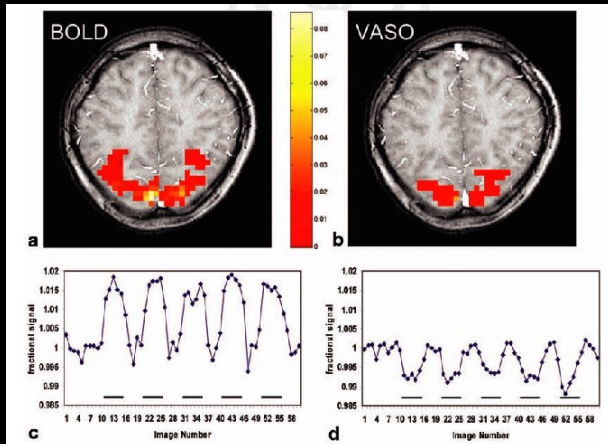
- L Fusiform Gyrus
- R Anterior Cingulate Gyrus
- R Posterior Cingulate Gyrus
- L Middle Occipital Gyrus
- L Middle Frontal Gyrus
- L Posterior Cingulate Gyrus
- L Anterior Cingulate/Superior Frontal Gyrus
- L Precuneus/Superior Parietal Lobule
- R Precuneus/Superior Parietal Lobule
- R Posterior Parieto-Occipital Cortex
- L Posterior Parieto-Occipital Cortex

McKiernan, et al (2003), Journ. of Cog. Neurosci. 15 (3), 394-408

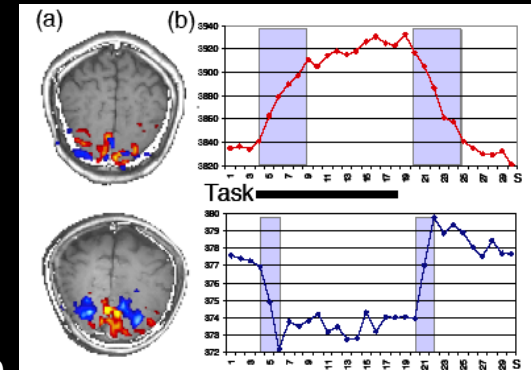


Hyder, et al (2002), PNAS 99 (16), 10771-10776

Other sources of functional contrast?

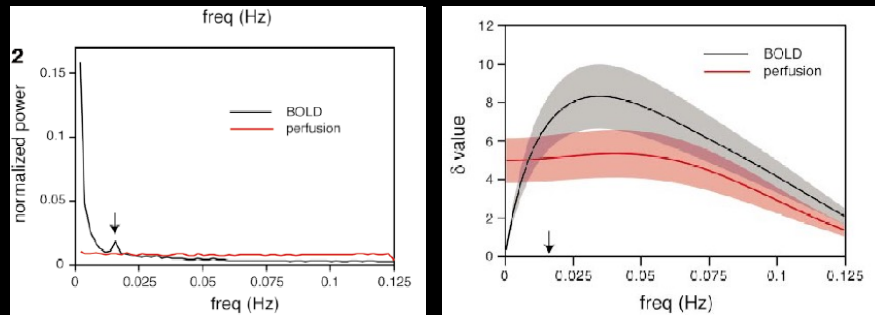


A. Song, et al (2002), NeuroImage 17, 742-750

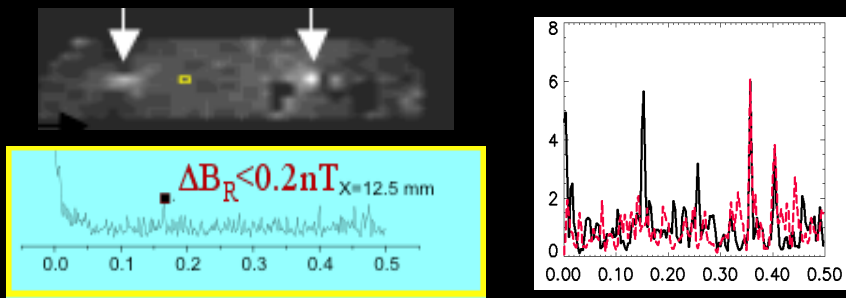


A. Song, et al (2004), ISMRM 1063

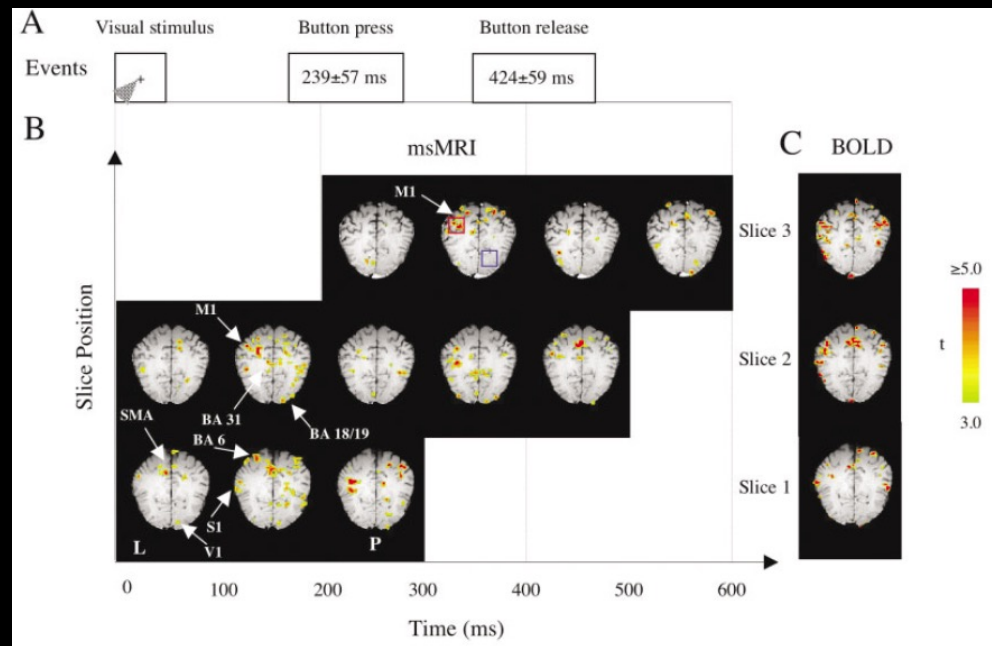
Lu, et al (2003) MRM 50 (2): 263-274



GK Aguirre et al, (2002) NeuroImage 15 (3): 488-500

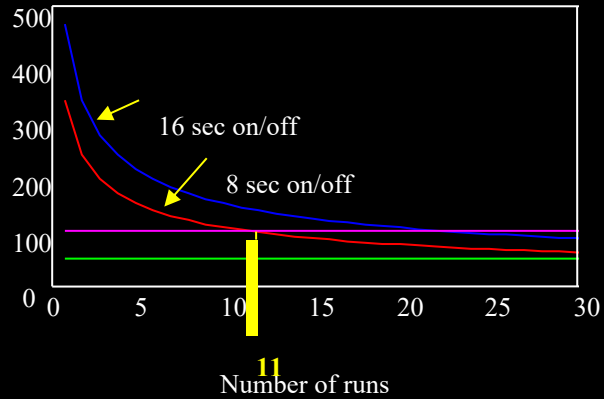


J. Bodurka, et al (2002). MRM 47: 1052-1058. Petridou, et al (2003), OHBM

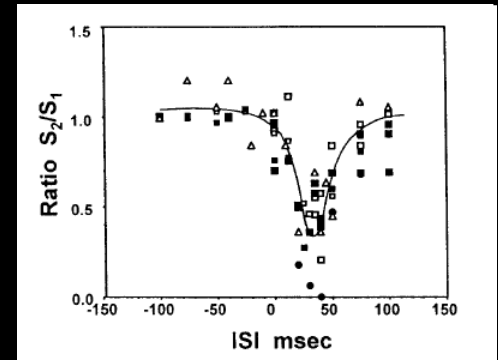


J. Xiong, et al. (2003) HBM, 20: 41-49.

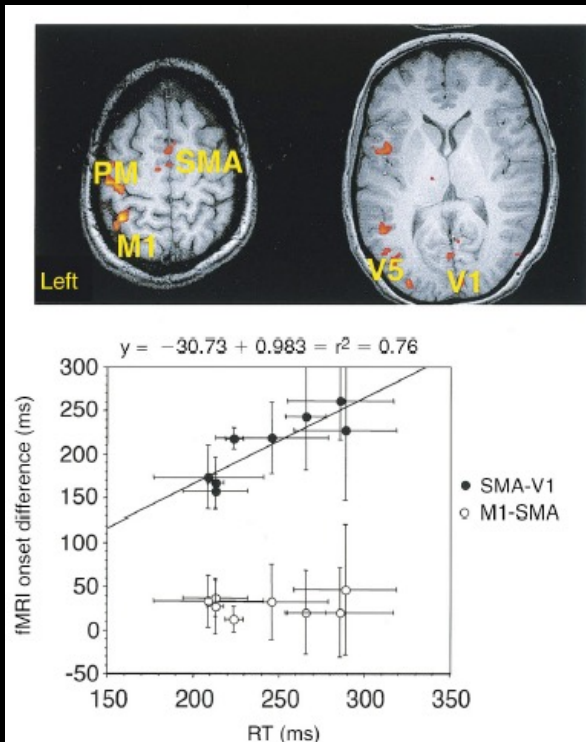
Ultimate temporal resolution?



Smallest latency
Variation Detectable
(ms) ($p < 0.001$)



Ogawa, et al (2000), PNAS 97 (20)11026–11031

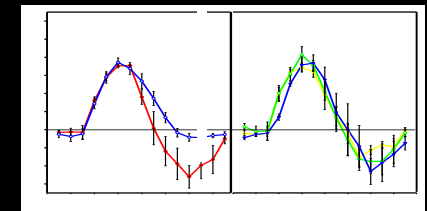


Menon, et al (2000), TICS 3 (6) 207-215

Temporal resolution factors	Values for each factor
Fastest image acquisition rate	≈ 64 images/s
Minimum time for signal to significantly deviate from baseline	≈ 3 s
Fastest on-off rate in which amplitude-is not compromised	≈ 8 s on, 8 s off
Fastest on-off rate in which hemodynamic response keeps up	≈ 2 s on, 2 s off
Minimum activation duration	≈ 30 ms (no limit determined yet, but the response behaves similarly below 500 ms)
Standard deviation of baseline signal	$\approx 1\%$ (less if physiological fluctuations and system instabilities are filtered out)
Standard deviation of onset time estimation	≈ 450 ms
Standard deviation of return to baseline time estimation	≈ 1250 ms
Standard deviation of entire on-off response time estimation	≈ 650 ms
Range of latencies over space	± 2.5 s

P. A. Bandettini, (1999) "Functional MRI" 205-220.

Word vs. Non-word
0°, 60°, 120° Rotation

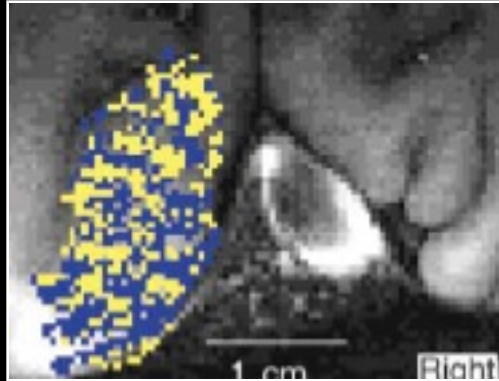


Bellgowan, et al (2003), PNAS 100, 15820–15283

Ultimate spatial resolution?

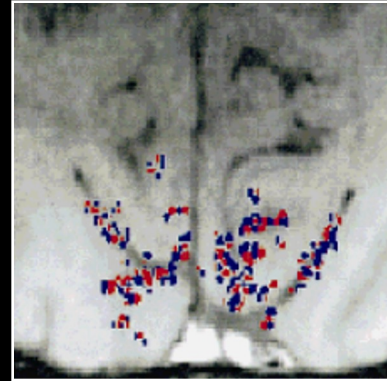
Resolving columns with single shot EPI is a goal..

0.47 x 0.47 in plane resolution



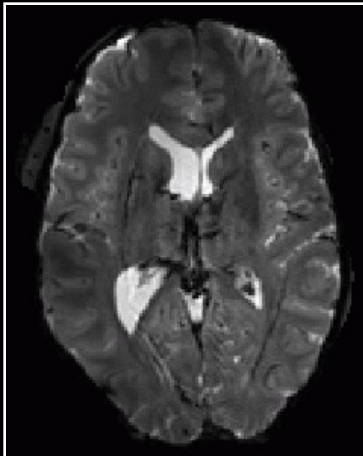
Cheng, et al. (2001) Neuron,32:359-374

0.54 x 0.54 in plane resolution



Menon et al, (1999) MRM 41 (2): 230-235

Multi-shot with
navigator pulse



...using SENSE, 32 channels, 7T,
and perhaps partial k-space we might get to 0.5 mm³

3T single-shot SENSE EPI using 16-
channels: 1.25x1.25x2mm

Ultimate clinical utility?

Needs:

Real time feedback

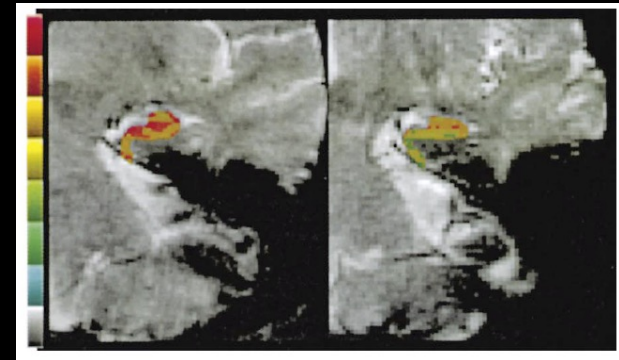
Characterization of confounding effects

Robust yet incisive set of probe tasks

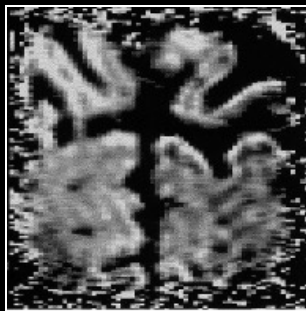
Baseline information?



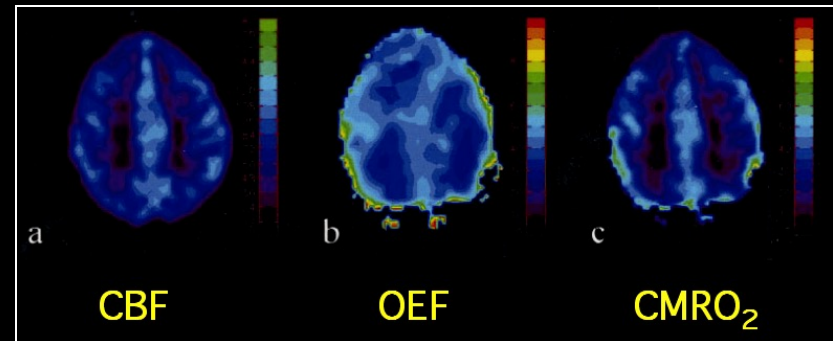
Bove-Bettis, et al (2004), SMRT



Small, et al (2001), Neuron 28:853-664



Bartha, et al (2002), MRM 47:742-750



An, et al (2001), NMR in Biomedicine 14:441-447

Best processing methods?

fMRI data, and noise is time and space varying in predictable and unpredictable ways over several temporal and spatial scales...

Signal and noise models...

Model free, open ended, methods?

Classification methods?

Multivariate methods?

Connectivity (across time and space scales?)

Best display methods?

To convey:

-collapsed multidimensional data

-sense of data quality

Surface

Glass brain

ROI

Time courses

Example slices

Connectivity maps?

“Quality” index?

Optimal Field Strength?

Utility vs. Difficulty

Both depend on the specific needs

...needs tend to increase with better technology



Functional Imaging Methods Unit &



Functional MRI Facility

Computer Specialist:

Adam Thomas

Staff Scientists:

Sean Marrett

Jerzy Bodurka

Frank Ye

Wen-Ming Luh

Rasmus Birn

Post Docs:

Hauke Heekeren

David Knight

Anthony Boemio

Niko Kriegeskorte

Scanning Technologists:

Karen Bove-Bettis

Paula Rowser

Alda Ottley

Ellen Condon

Program Assistant:

Kay Kuhns

Graduate Student:

Natalia Petridou