The Biggest Unknowns in Functional MRI

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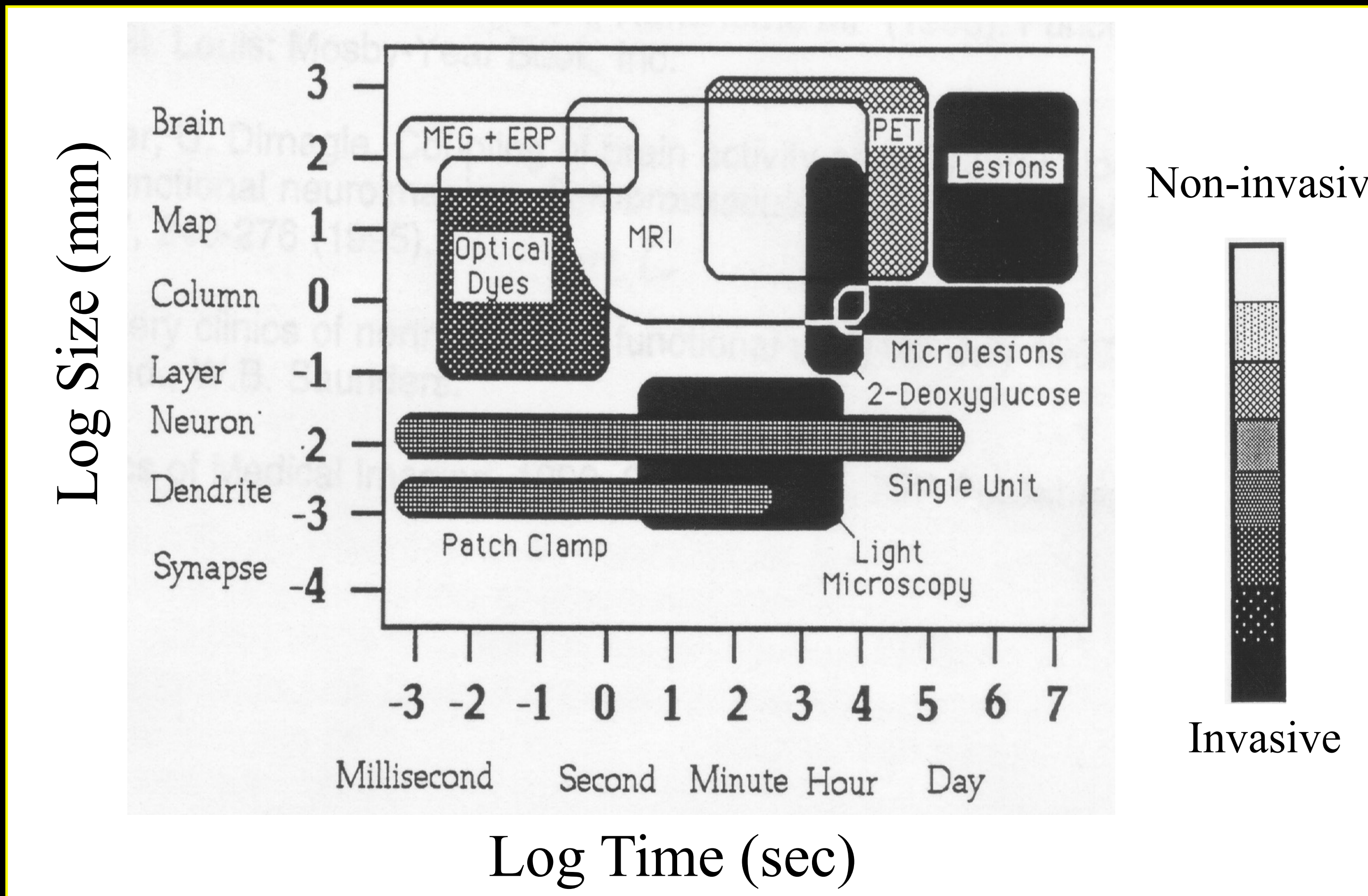
Functional Neuroimaging Techniques



Uses

Understanding normal brain organization and changes

- -networks involved with specific tasks (low to high level processing)
- -changes over time (seconds to years)
- -correlates of behavior (response accuracy, performance changes...)

Clinical research

- -correlates of specifically activated networks to clinical populations
- -presurgical mapping

Future Uses

Complementary use for clinical diagnosis

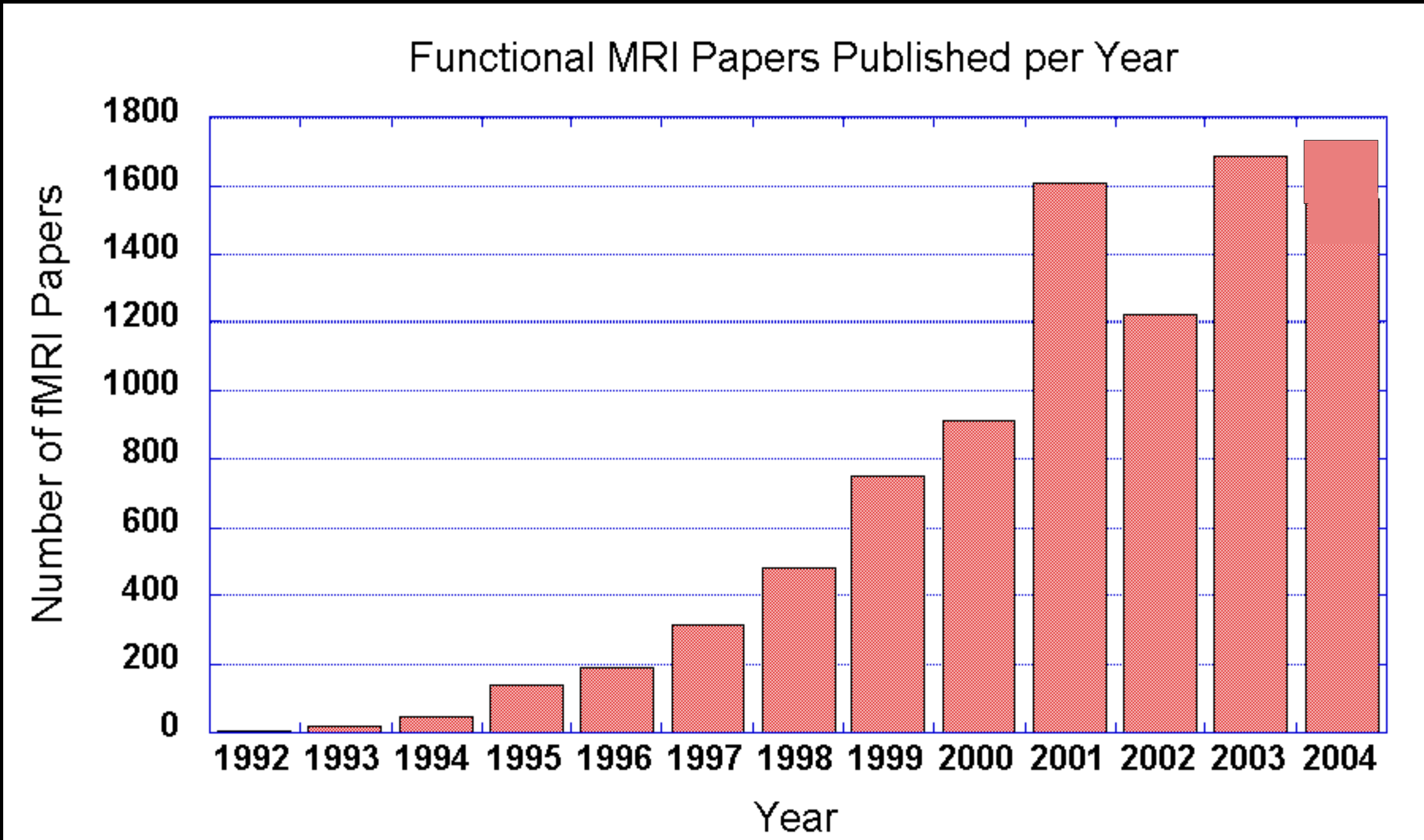
- -utilization of clinical research results
- -prediction of pathology

Clinical treatment and assessment

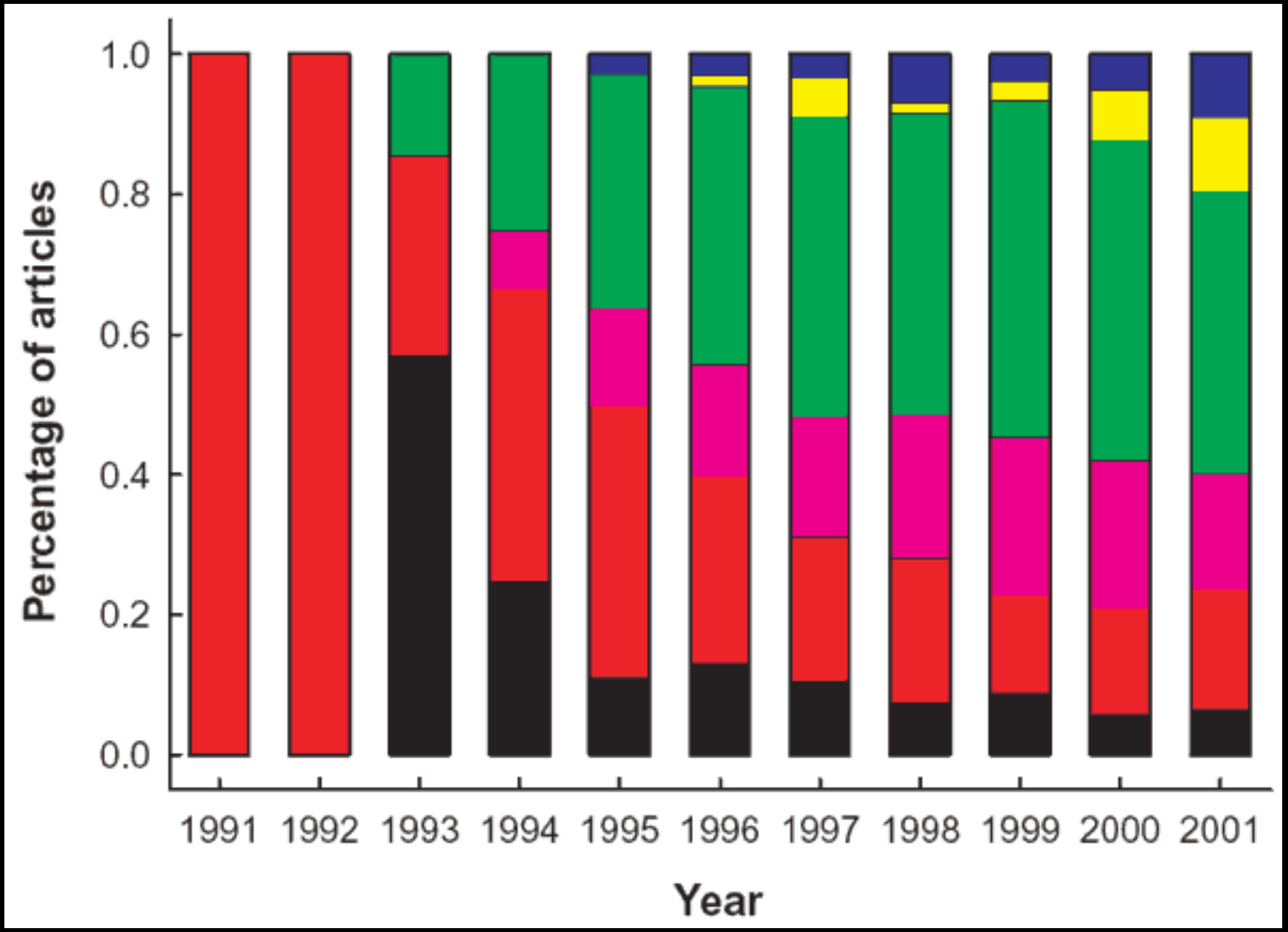
- -drug, therapy, rehabilitation, biofeedback
- -epileptic foci mapping
- -drug effects

Non clinical uses

- -complementary use with behavioral, anatomical, other modality results
- -lie detection
- -prediction of behavior tendencies
- -brain/computer interface

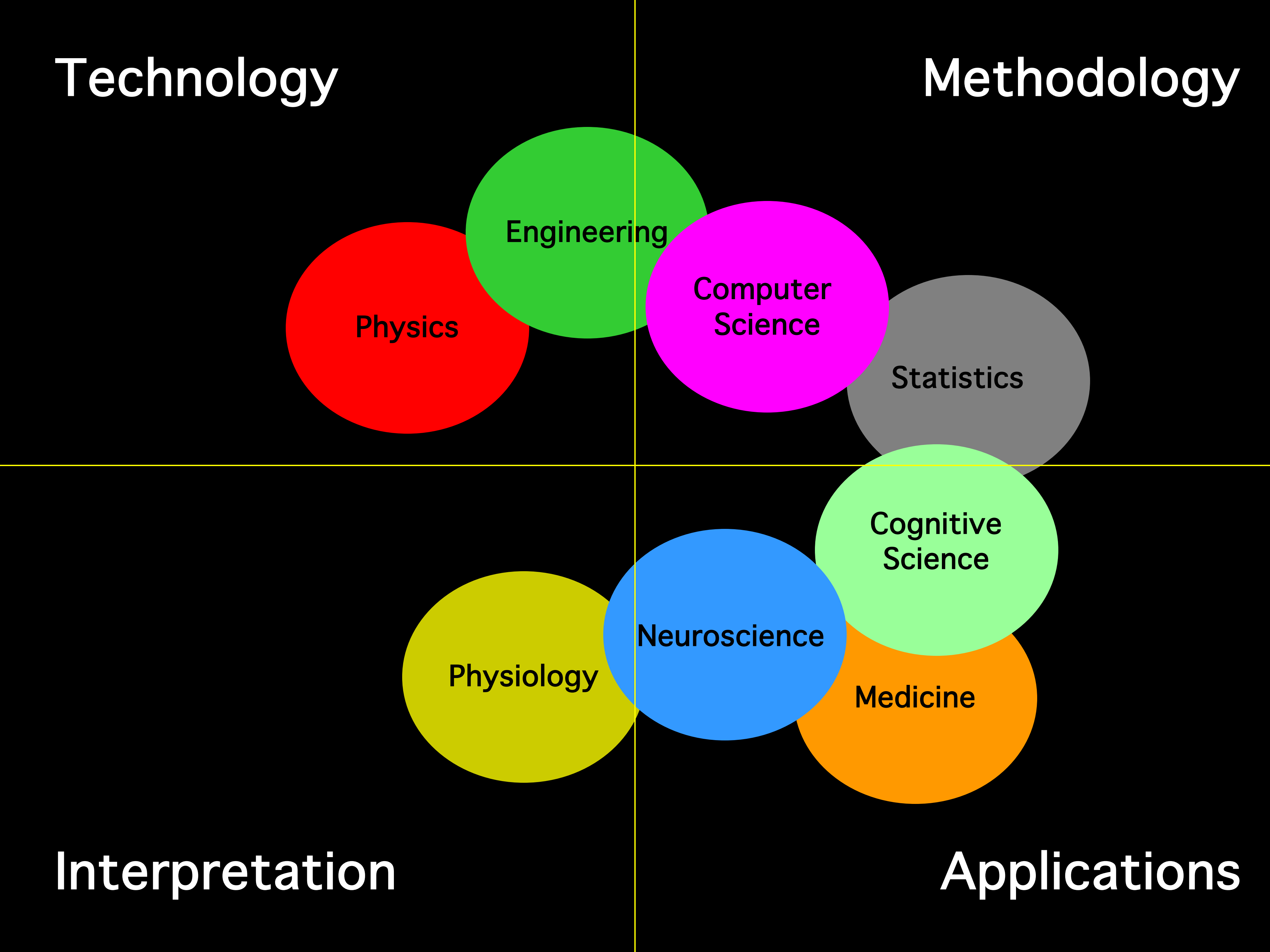

Functional MRI Papers Published per Year
Number of fMRI Papers
0
200
400
600
800
1000
1200
1400
1600
1800
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year

Type of fMRI research performed



Motor (black)
Primary Sensory (red)
Integrative Sensory (violet)
Basic Cognition (green)
High-Order Cognition (yellow)
Emotion (blue)

J. Illes, M. P. Kirschen, J. D. E. Gabrielli, Nature Neuroscience, 6 (3) p.205, 2001


Technology
Methodology
Engineering
Physics
Computer
Science
Statistics
Cognitive
Science
Neuroscience
Physiology
Medicine
Interpretation
Applications

The Biggest Unknowns in Functional MRI

1. Relationship between neuronal activity and fMRI.
2. Sources of fMRI dynamic characteristics.
3. Sources of spatial and temporal 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 processing and display methods?
11. Optimal field strength?

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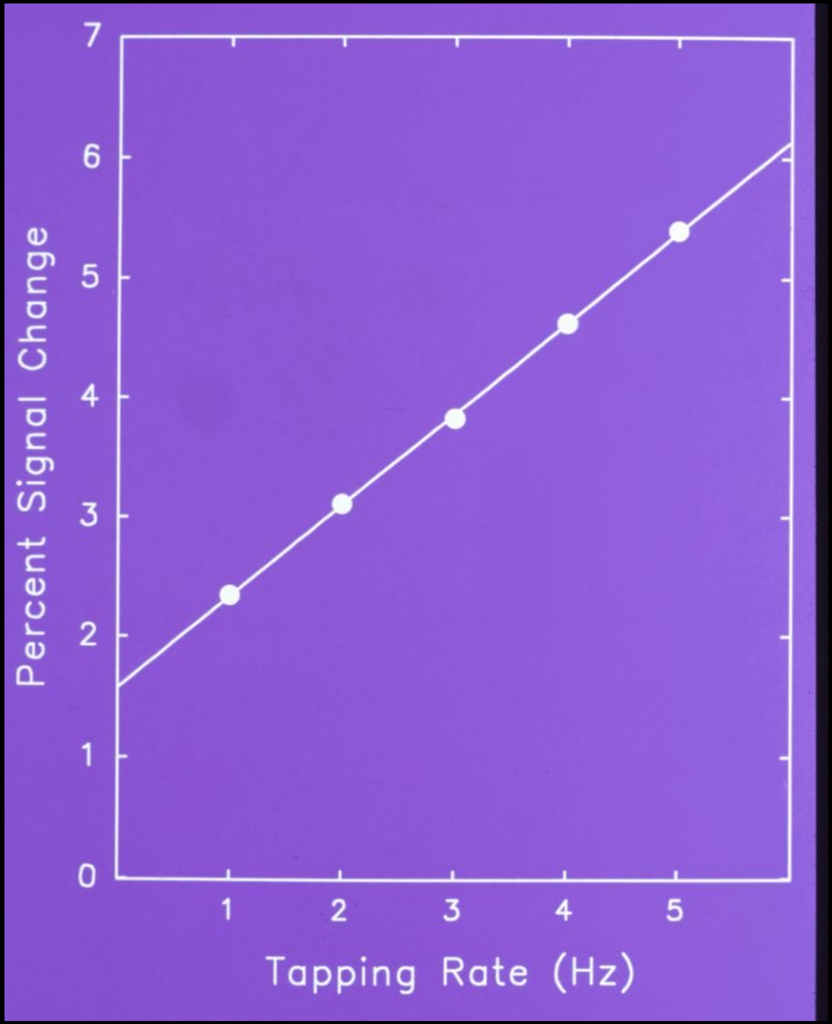
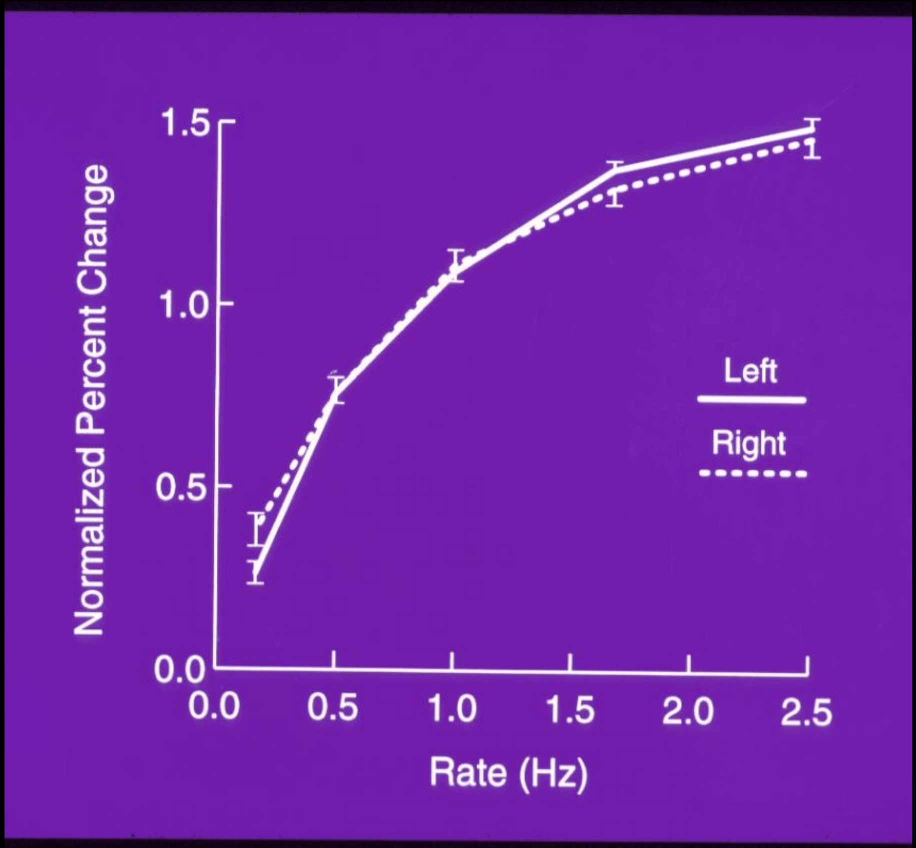
Motor Cortex



S. M. Rao et al, (1996) "Relationship between finger movement rate and functional magnetic resonance signal change in human primary motor cortex." *J. Cereb. Blood Flow and Met.* 16, 1250-1254.

Auditory Cortex



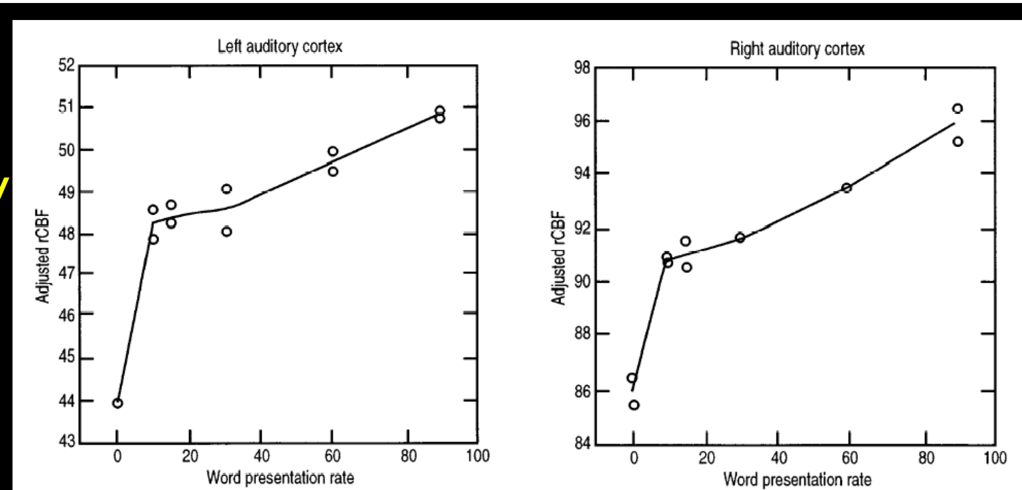
J. R. Binder, et al, (1994). "Effects of stimulus rate on signal response during functional magnetic resonance imaging of auditory cortex." *Cogn. Brain Res.* 2, 31-38

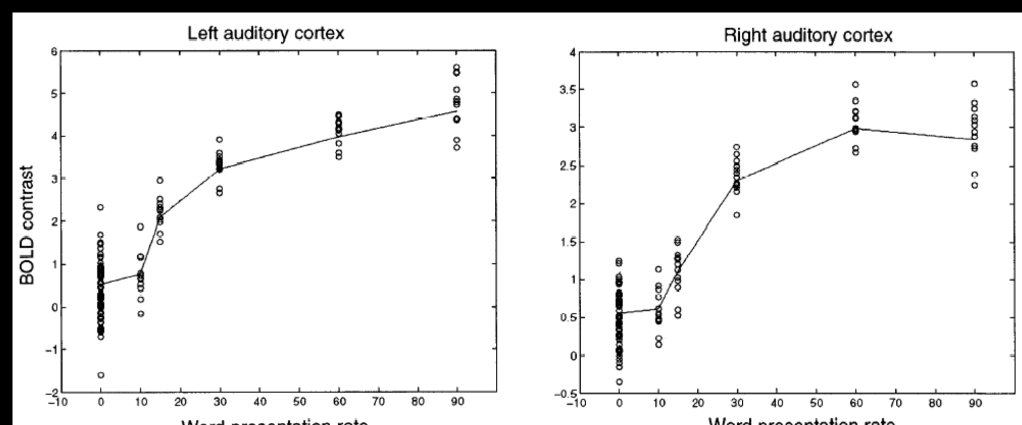
NEUROIMAGE **6**, 270–278 (1997)
ARTICLE NO. NI970300

Characterizing the Relationship between BOLD Contrast and Regional Cerebral Blood Flow Measurements by Varying the Stimulus Presentation Rate

Geraint Rees, A. Howseman, O. Josephs, C. D. Frith, K. J. Friston, R. S. J. Frackowiak, and R. Turner
The Wellcome Department of Cognitive Neurology, Institute of Neurology, Queen Square, London WC1N 3BG, United Kingdom

Flow modulation is not necessarily the same as BOLD modulation





Magnetic Resonance in Medicine 41:469–473 (1999)

Simultaneous Recording of Evoked Potentials and T_2^*-Weighted MR Images During Somatosensory Stimulation of Rat

Gerrit Brinker, Christian Bock, Elmar Busch, Henning Krep, Konstantin-Alexander Hossmann, and Mathias Hoehn-Berlage

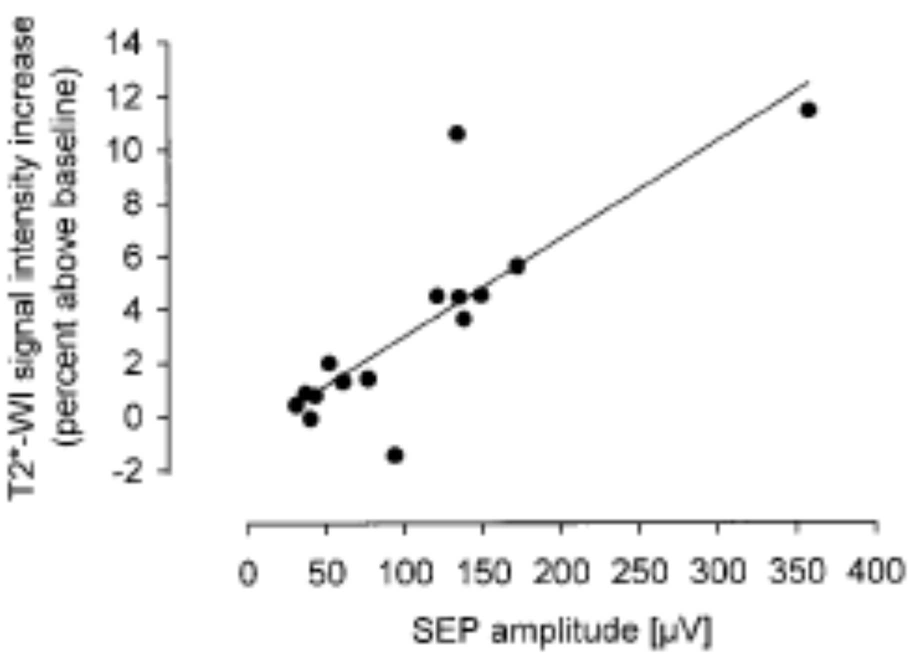
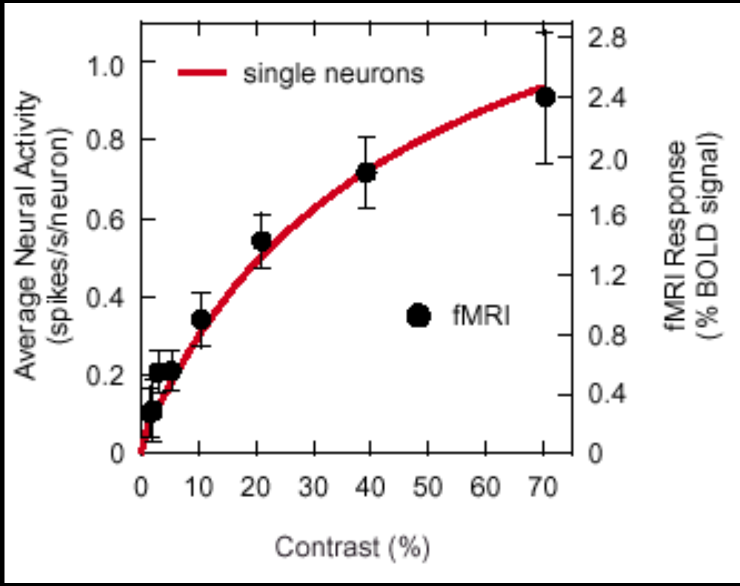


FIG. 3. Correlation of the increase of T_2^*-weighted imaging signal intensity with the peak-to-peak amplitude of the somatosensory evoked potential (SEP) during forepaw stimulation at increasing frequencies (data are from one individual animal; r = 0.82).

fMRI responses in human V1 are proportional to average firing rates in monkey V1?



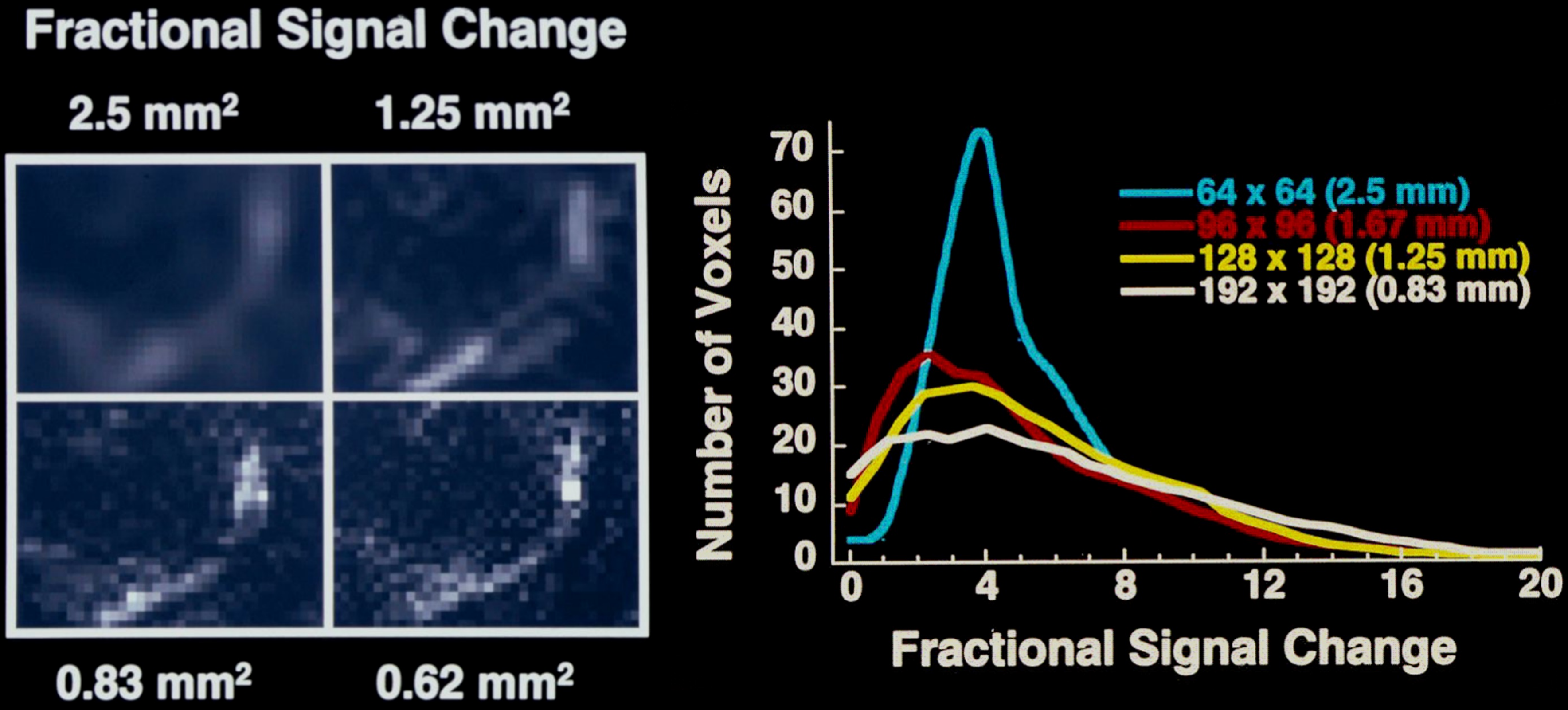
Heeger, D. J., Huk, A. C., Geisler, W. S., and Albrecht, D. G. 2000.Spikes versus BOLD: What does neuroimaging tell us about neuronal activity? *Nat. Neurosci.* **3:** 631–633.

0.4 spikes/sec -> 1% BOLD

Rees, G., Friston, K., and Koch, C. 2000. A direct quantitative relationship between the functional properties of human and macaque V5. *Nat. Neurosci.* **3:** 716–723.

9 spikes/sec -> 1% BOLD

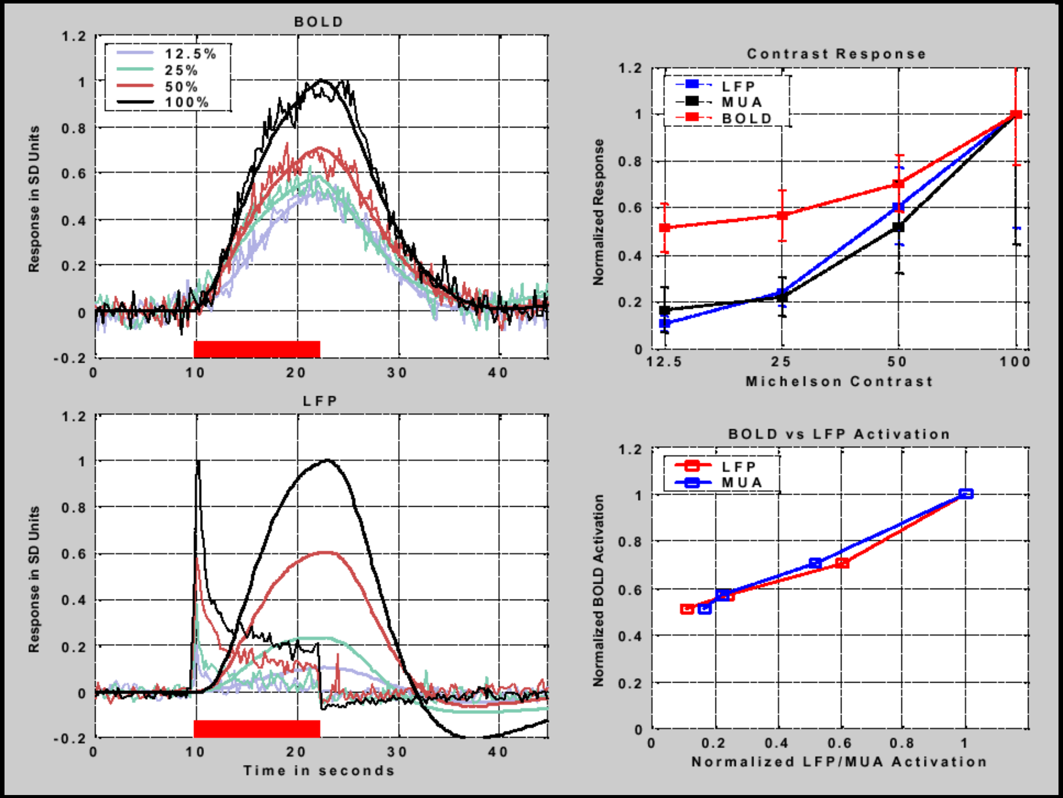
Magnitude



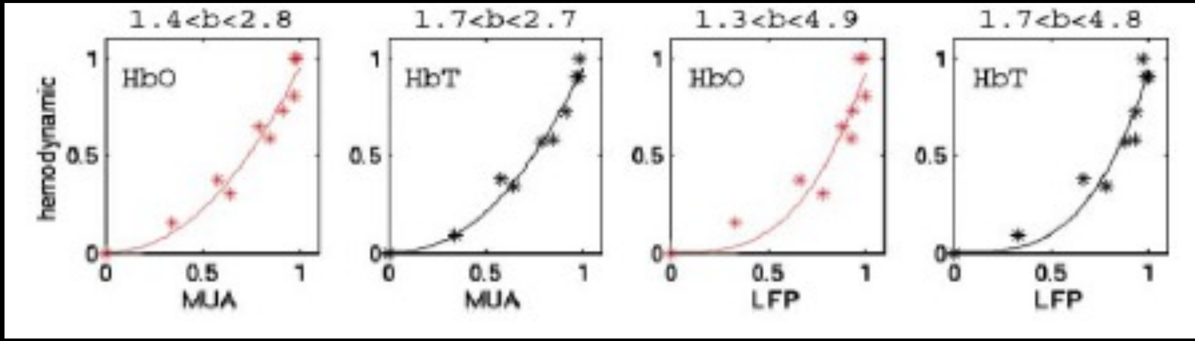
Jesmanowicz, P. A. Bandettini, J. S. Hyde, (1998) “Single shot half k-space high resolution EPI for fMRI at 3T.” *Magn. Reson. Med.* 40, 754-762.

Relationship between neuronal activity and BOLD.

Magnitude



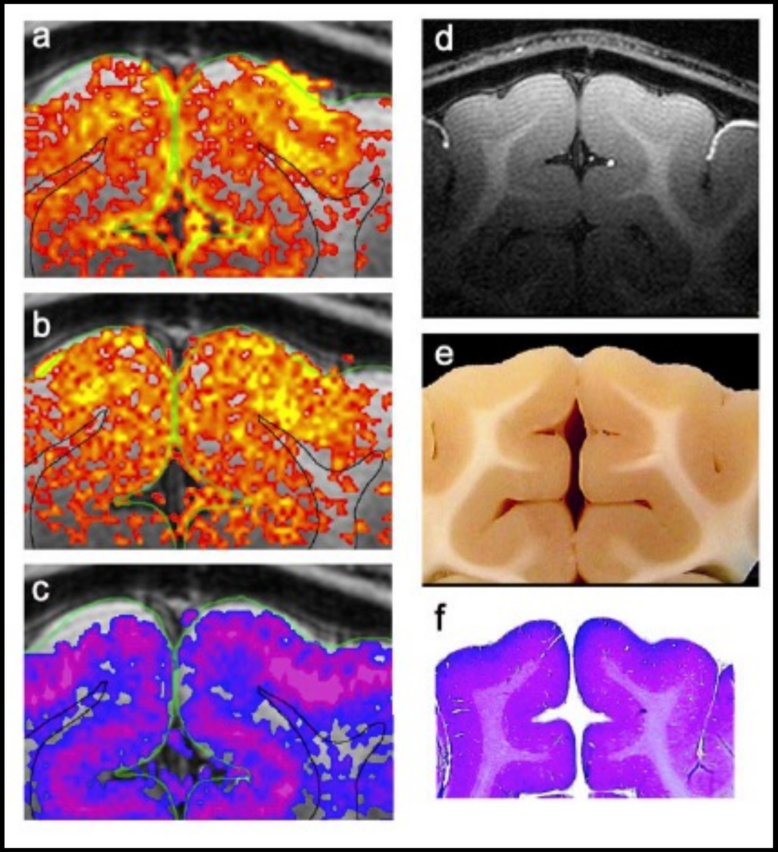
Logothetis et al. (2001) Nature, 412, 150-157



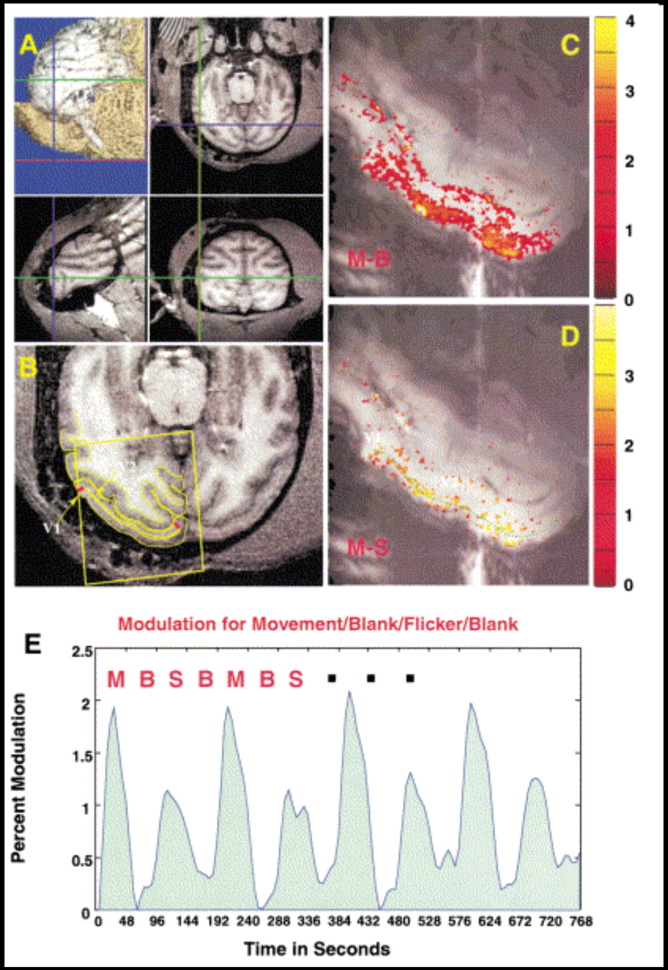
Devor et al. (2001) Neuron, 39, 353-359

Relationship between neuronal activity and BOLD.

Location



Harel et al. (2004) ISMRM, 200



Logothetis et al. (2002) Neuron, 35, 227-242

T1 - weighted

Flow weighted

T2* weighted

BOLD weighted

T1 and T2* weighted

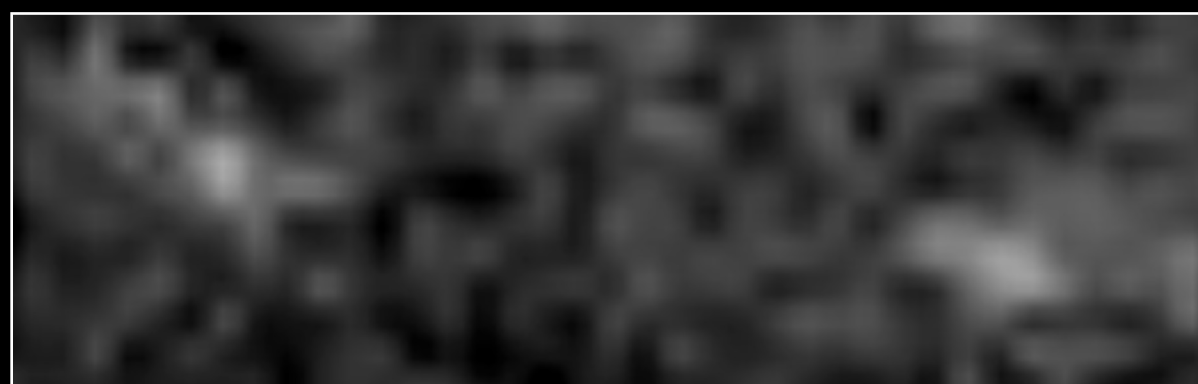
Flow and BOLD weighted

P. A. Bandettini, E. C. Wong, Echo - planar magnetic resonance imaging of human brain activation, *in* "Echo Planar Imaging: Theory, Technique, and Application" (F. Schmitt, M. Stehling, R. Turner, Eds.), p.493-530, Springer - Verlag, Berlin, 1997

Anatomy

BOLD

Perfusion



P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

The spatial extent of the BOLD response

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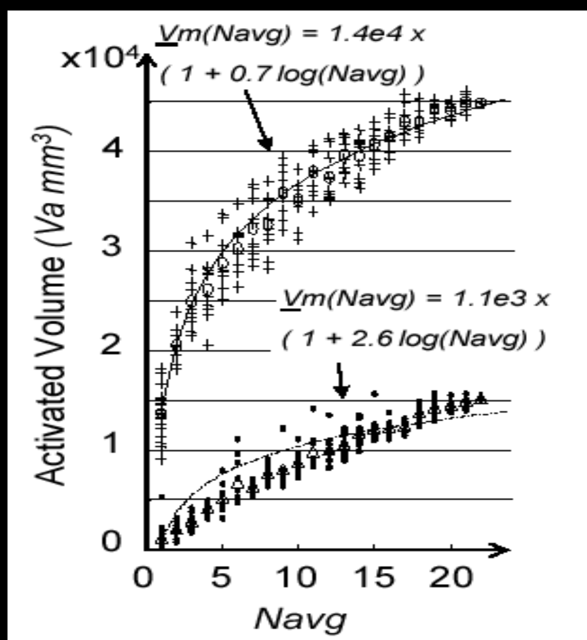
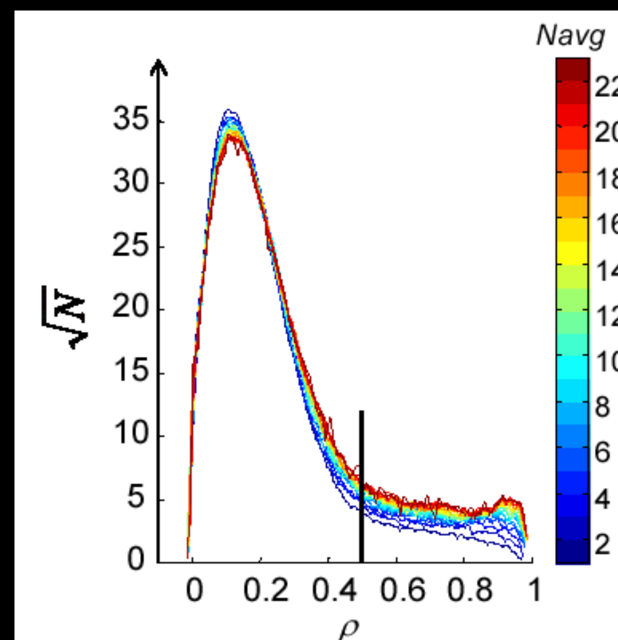
[c] Department of Cell Biology, Neurobiology and Anatomy, Medical College of Wisconsin, Milwaukee, WI 53226, USA

Received 16 August 2002; revised 29 October 2002; accepted 21 November 2002

NeuroImage, **19:** 132-144, (2003).





NeuroImage **16,** 103–114 (2002)
doi:10.1006/nimg.2001.1050, available online at http://www.idealibrary.com on IDEAL®

Task-Related Changes in Cortical Synchronization Are Spatially Coincident with the Hemodynamic Response

Krish D. Singh,*,†,‡ Gareth R. Barnes,* Arjan Hillebrand,* Emer M. E. Forde,* and Adrian L. Williams§

*The Wellcome Trust Laboratory for MEG Studies, Neurosciences Research Institute, Aston University, Birmingham, United Kingdom; †MARIARC, Liverpool University, Liverpool, United Kingdom; ‡Walton Centre for Neurology and Neurosurgery, Liverpool, United Kingdom; and §Department of Psychology, Royal Holloway, University of London, Egham, United Kingdom

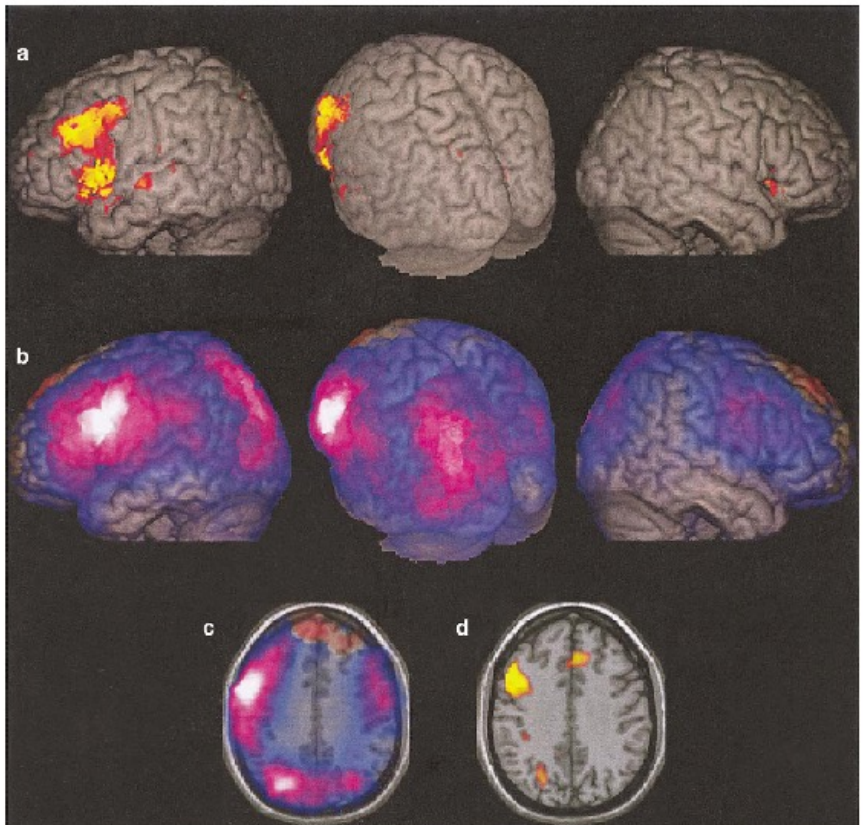


FIG. 2. The results of the group fMRI experiment and the group MEG experiment for the letter fluency task, superimposed on a template brain. The color scales are as described in the legend of Fig. 1. (a) Group fMRI data. Only those clusters significant at $P < 0.05$ (corrected) are shown. (b) The peak group SAM image. This shows the peak power increase or decrease at each voxel in the brain, irrespective of which frequency band the power change occurred in. This image can be thought of as an amalgam of Figs. 1b to 1f. (c) The peak group SAM data superimposed on a slice through the template brain at an MNI Z coordinate of +36. The image shows bilateral, but strongly left biased, activation within the dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex. (d) The group fMRI data superimposed on the $Z = +36$ slice. Note the left DLPFC and left posterior parietal activation which match the group SAM results. However, there is also a small cluster in a more anterior portion of the parietal lobe, and another in the medial frontal gyri, which are visible in the group fMRI data but not in the group MEG data.

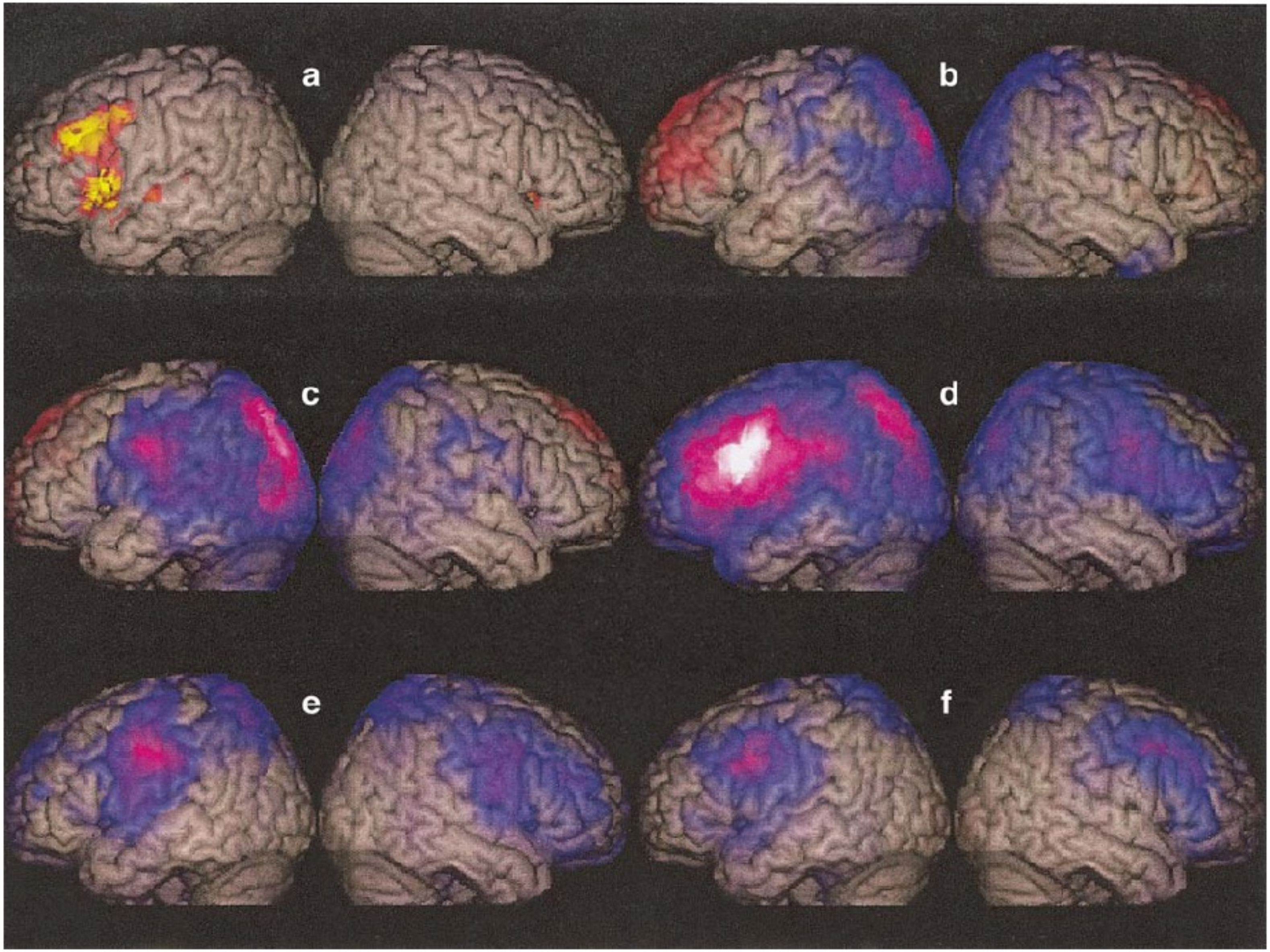
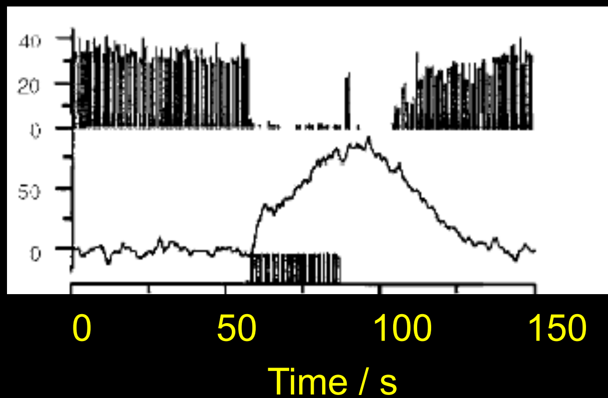


FIG. 1. The results of the group fMRI experiment and the group MEG experiment for the covert letter fluency task, superimposed on a template brain. (a) Group fMRI data. Only those clusters significant at $P < 0.05$ (corrected) are shown. The red–orange–yellow color scale depicts increasing BOLD amplitude. (b–f) The results of the group SAM analysis of the MEG data. Increases in signal power in the Active phase, compared to the Passive baseline are shown using a red–orange–yellow color scale. Decreases in signal power in the Active phase are shown using a blue–purple–white color scale. The power changes are in the following frequency bands (b) 1–10 Hz; (c) 5–15 Hz; (d) 15–25 Hz; (e) 25–35 Hz; and (f) 35–45 Hz.

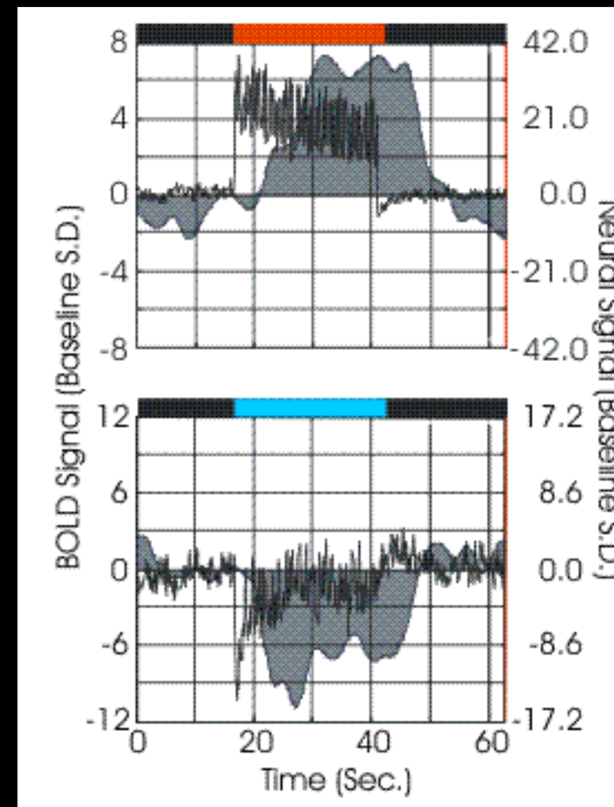
Relationship between neuronal activity and BOLD.

Inhibition



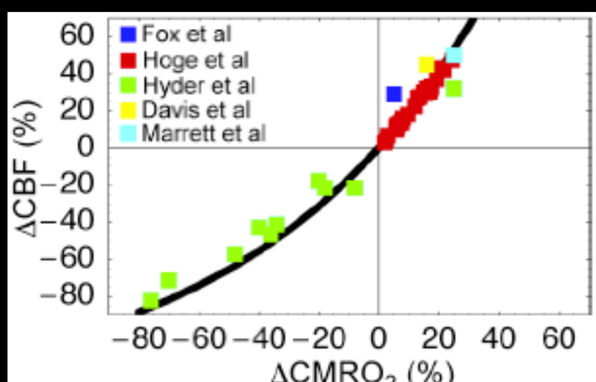
Mathiesen, et al (1998), J Physiol 512.2:555-566

Neg. BOLD



Schmuel et al. (2003) OHBM, 308

Why?



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

Buxton (2004) ISMRM, 273

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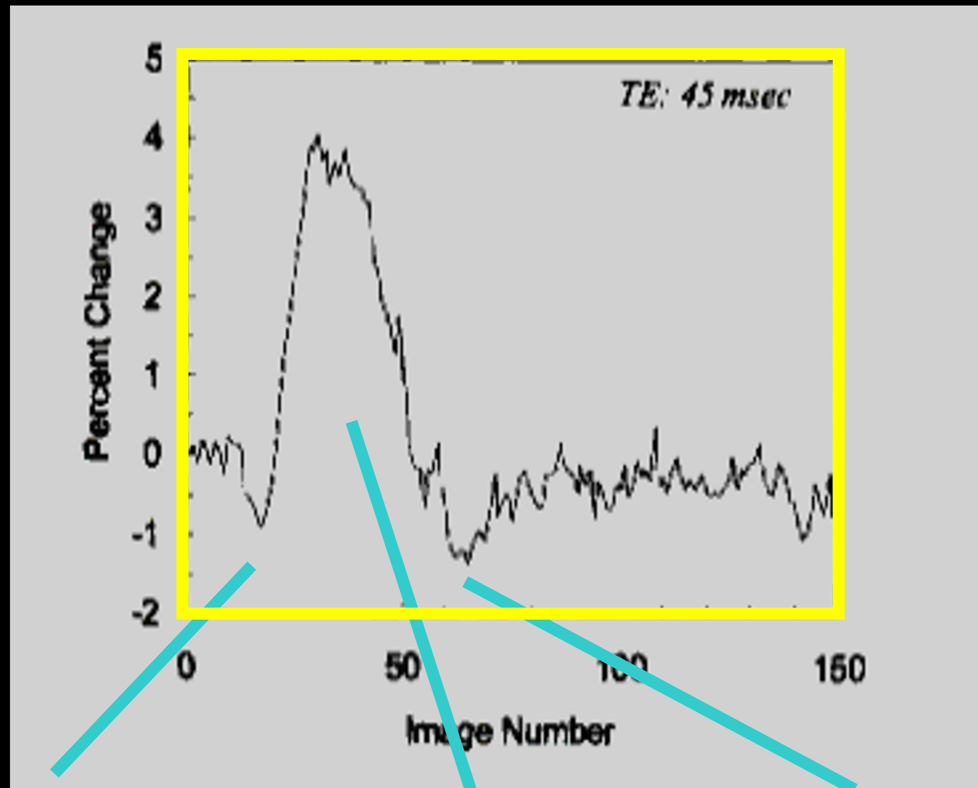
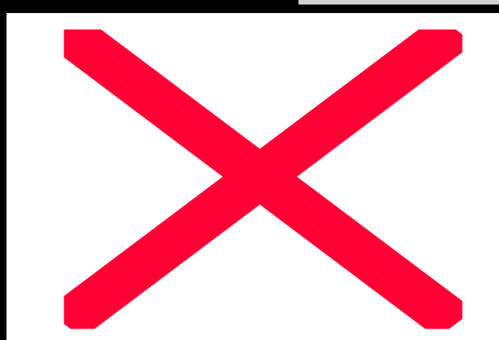
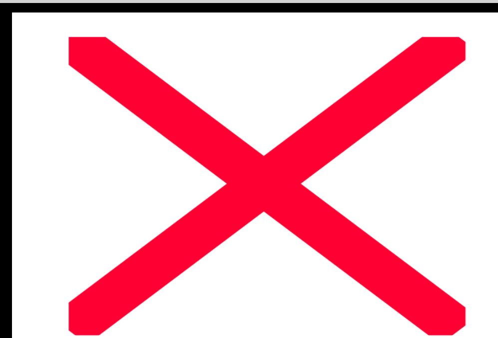
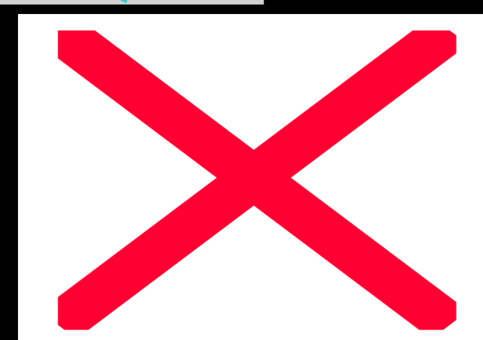
Sources of BOLD dynamic characteristics.



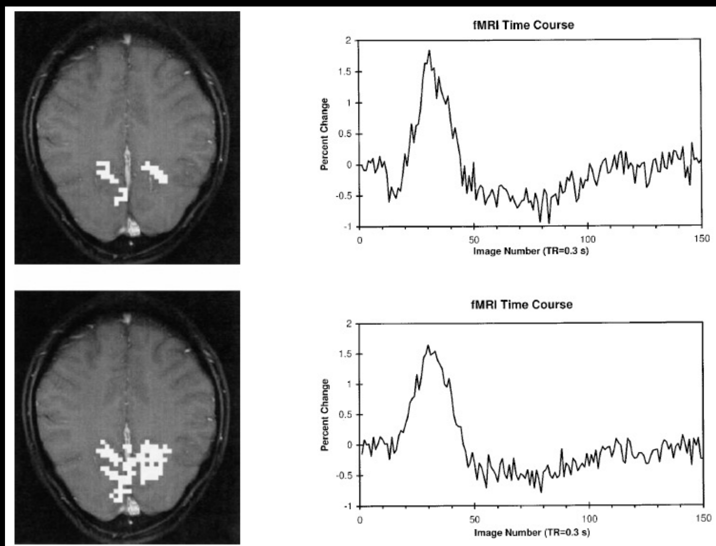
Yacoub E, Le TH, Ugurbil K, Hu X (1999) Magn Res Med 41(3):436-41

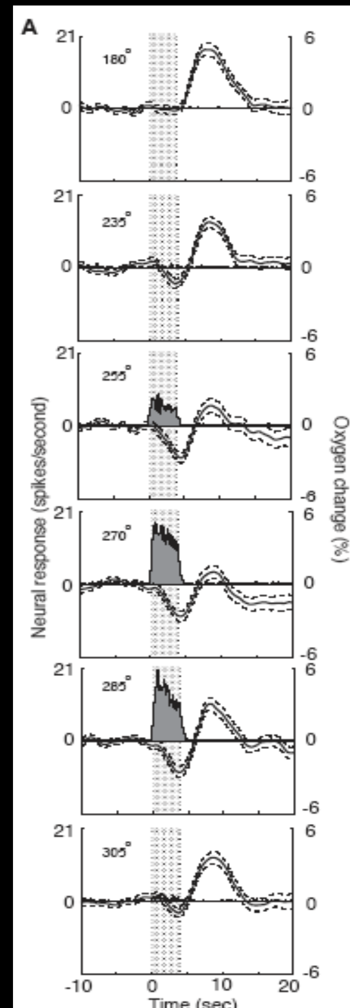
Courtesy of Arno Villringer

Sources of BOLD dynamic characteristics.

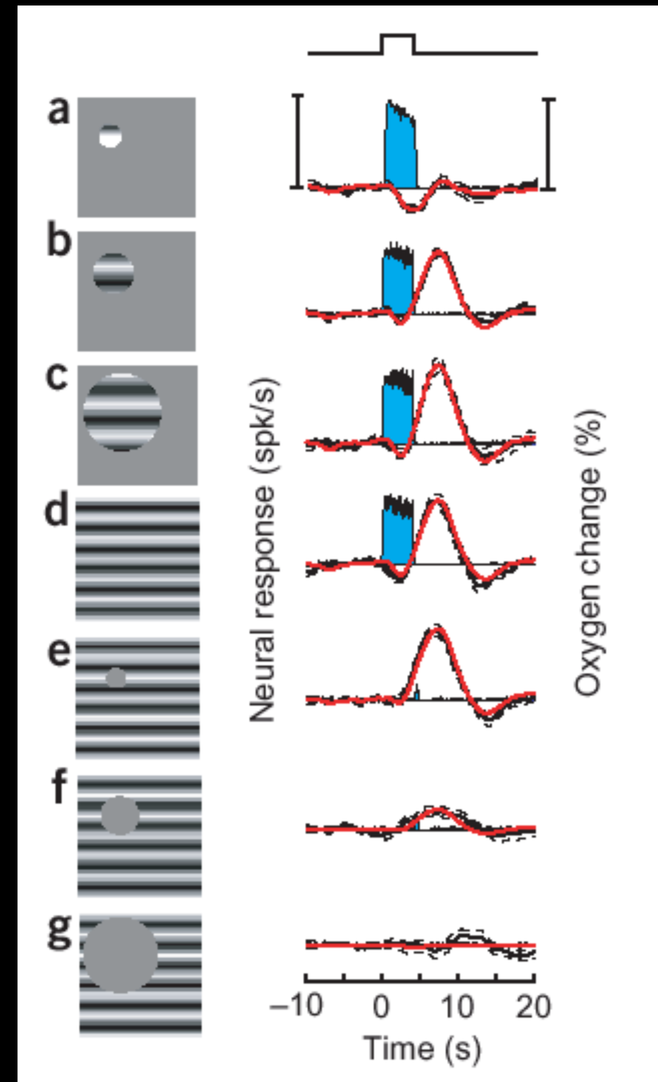
Pre-undershoot



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



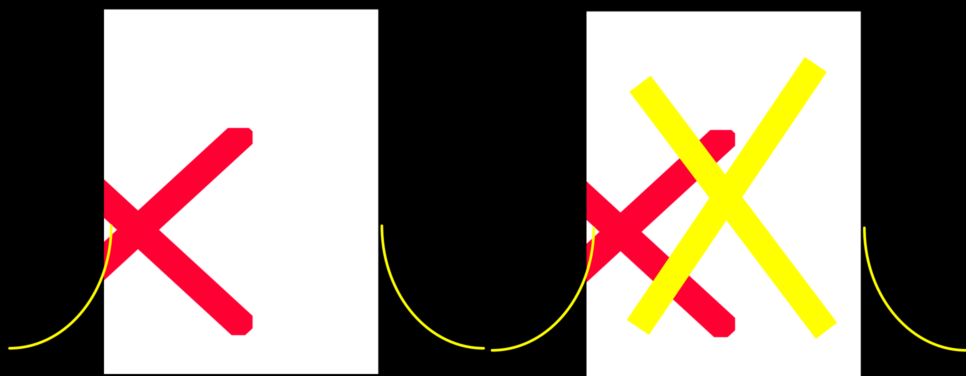
Thompson, et al (2003), Science 299, 1070-1072

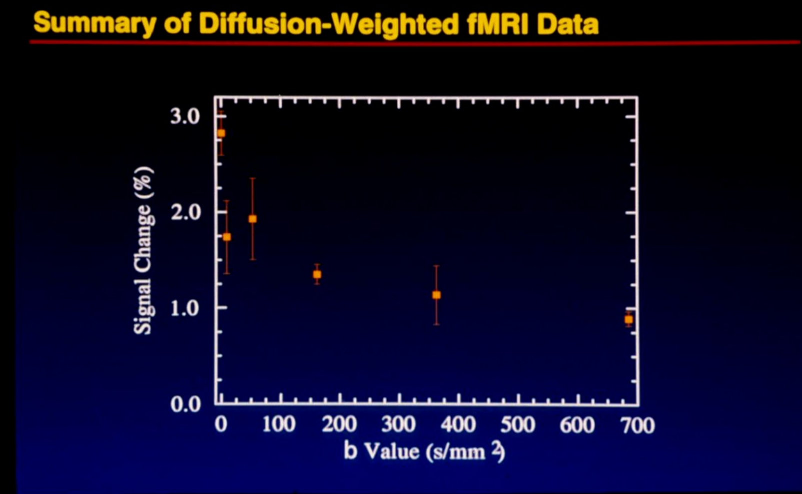


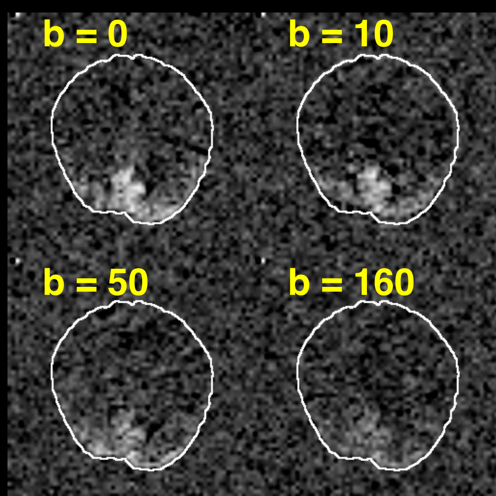
Thompson, et al (2004), Nature Neuroscience 7, 919-920

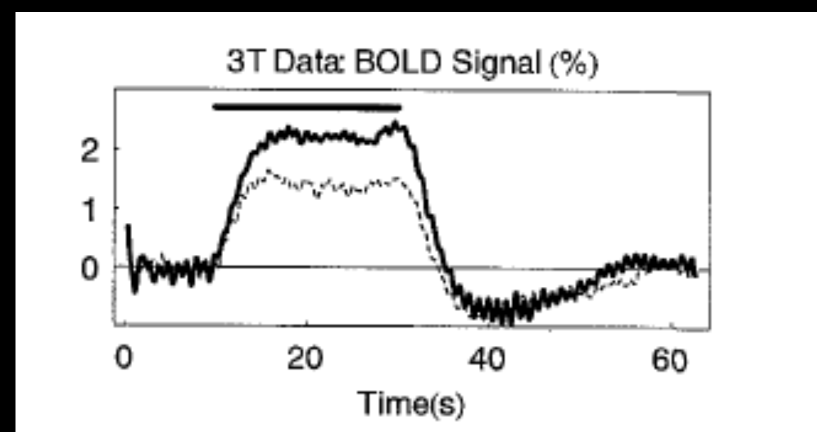
Post-undershoot

no diffusion weighting   diffusion weighting

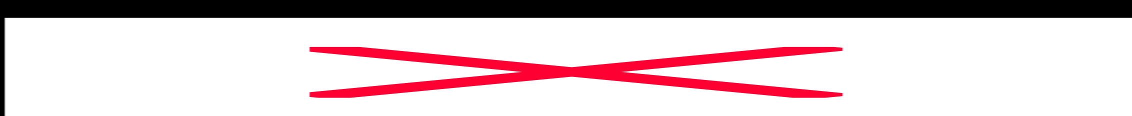




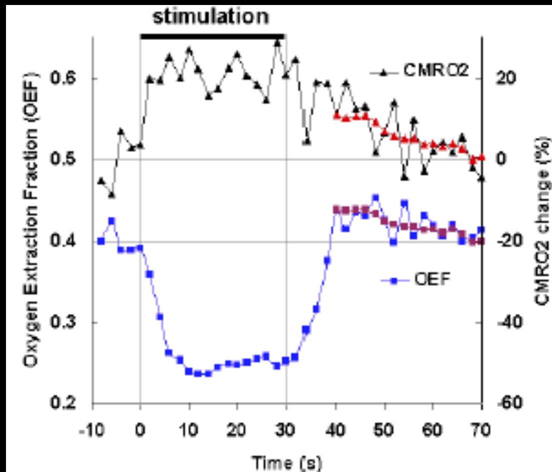


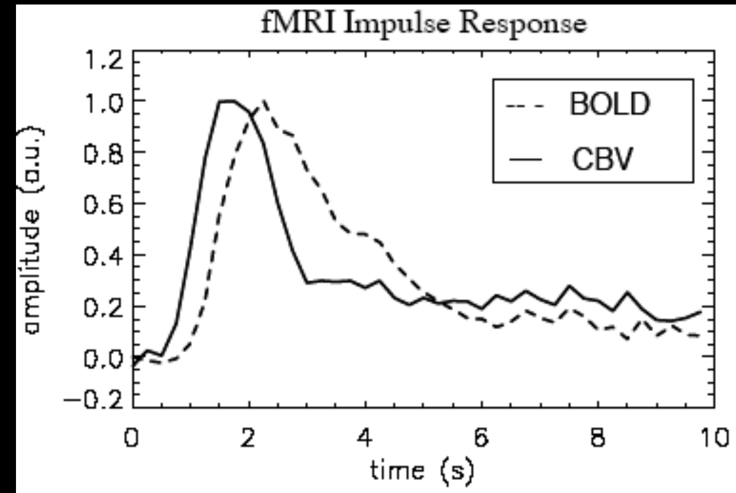


Buxton, et al (1998), ISMRM 7

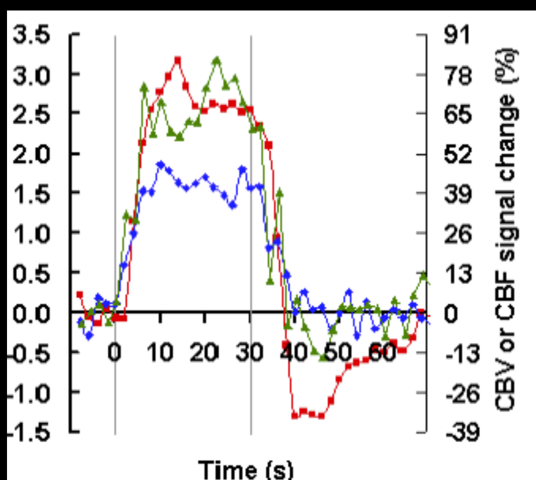


Sources of BOLD dynamic characteristics.

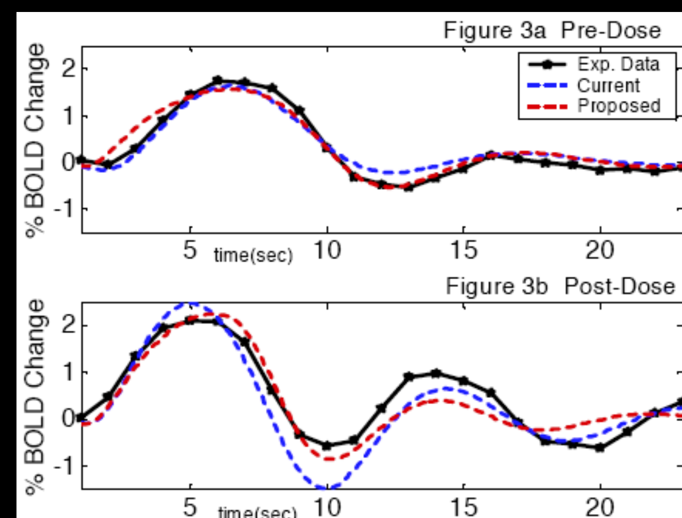




Silva, et al (2004), ISMRM 277



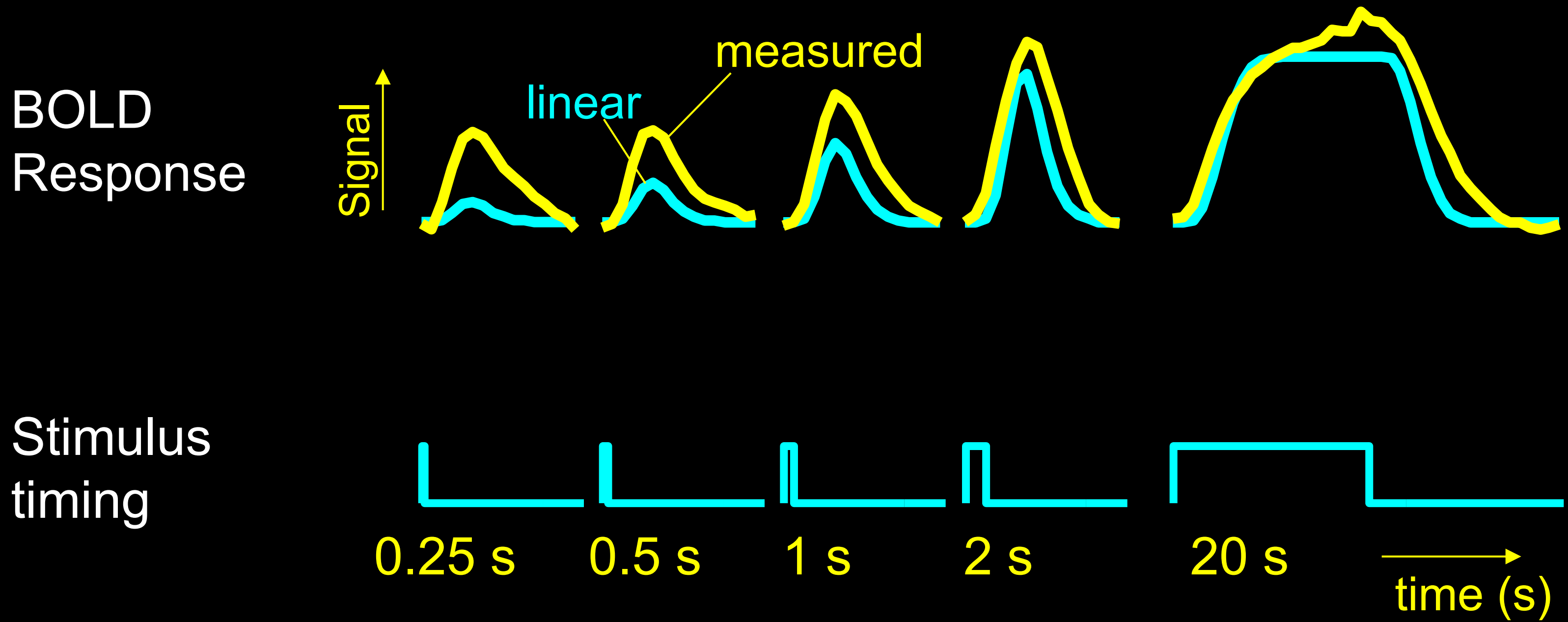
Lu, et al (2004), ISMRM 271



Behzadi, et al (2004), ISMRM 279

Dynamic Nonlinearity Assessment

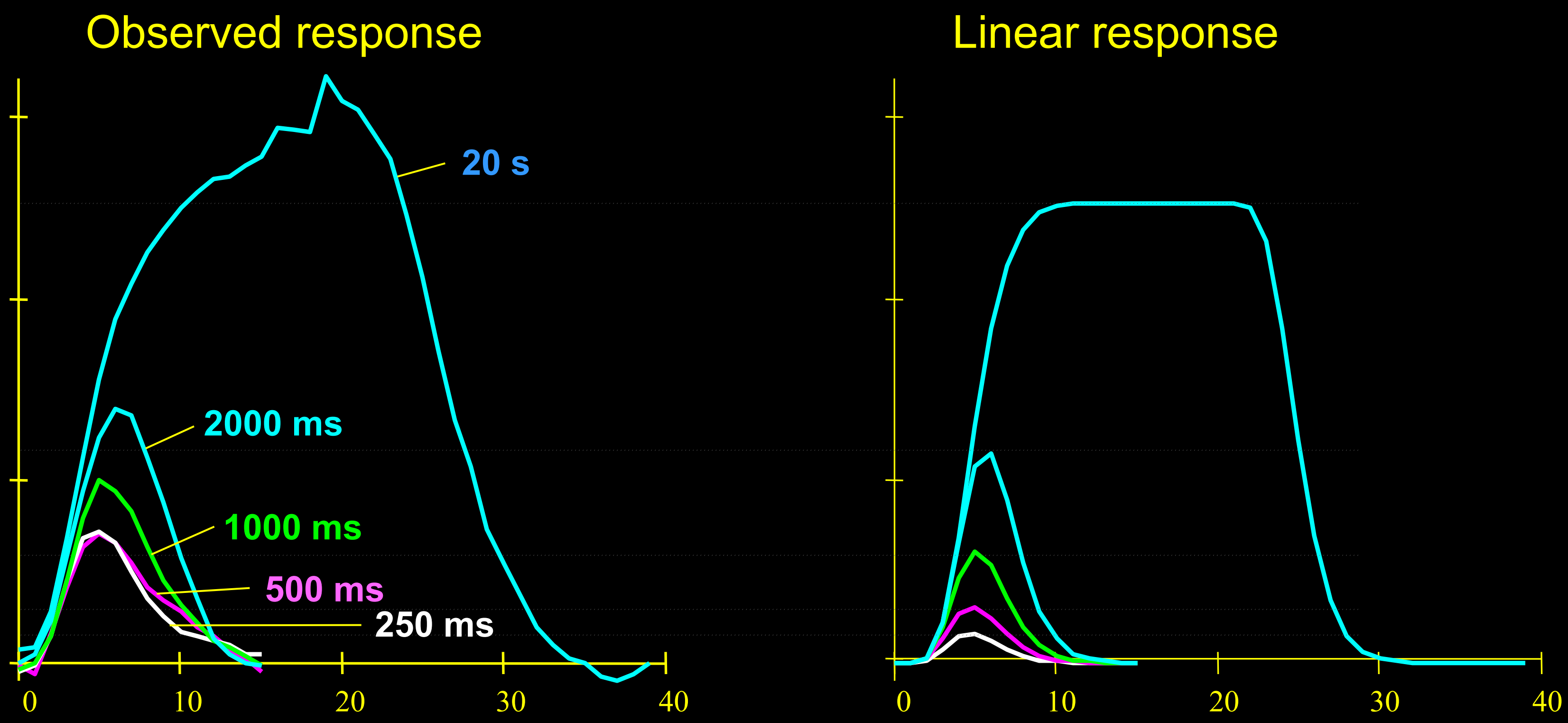
Different stimulus "ON" periods



Brief stimuli produce larger responses than expected

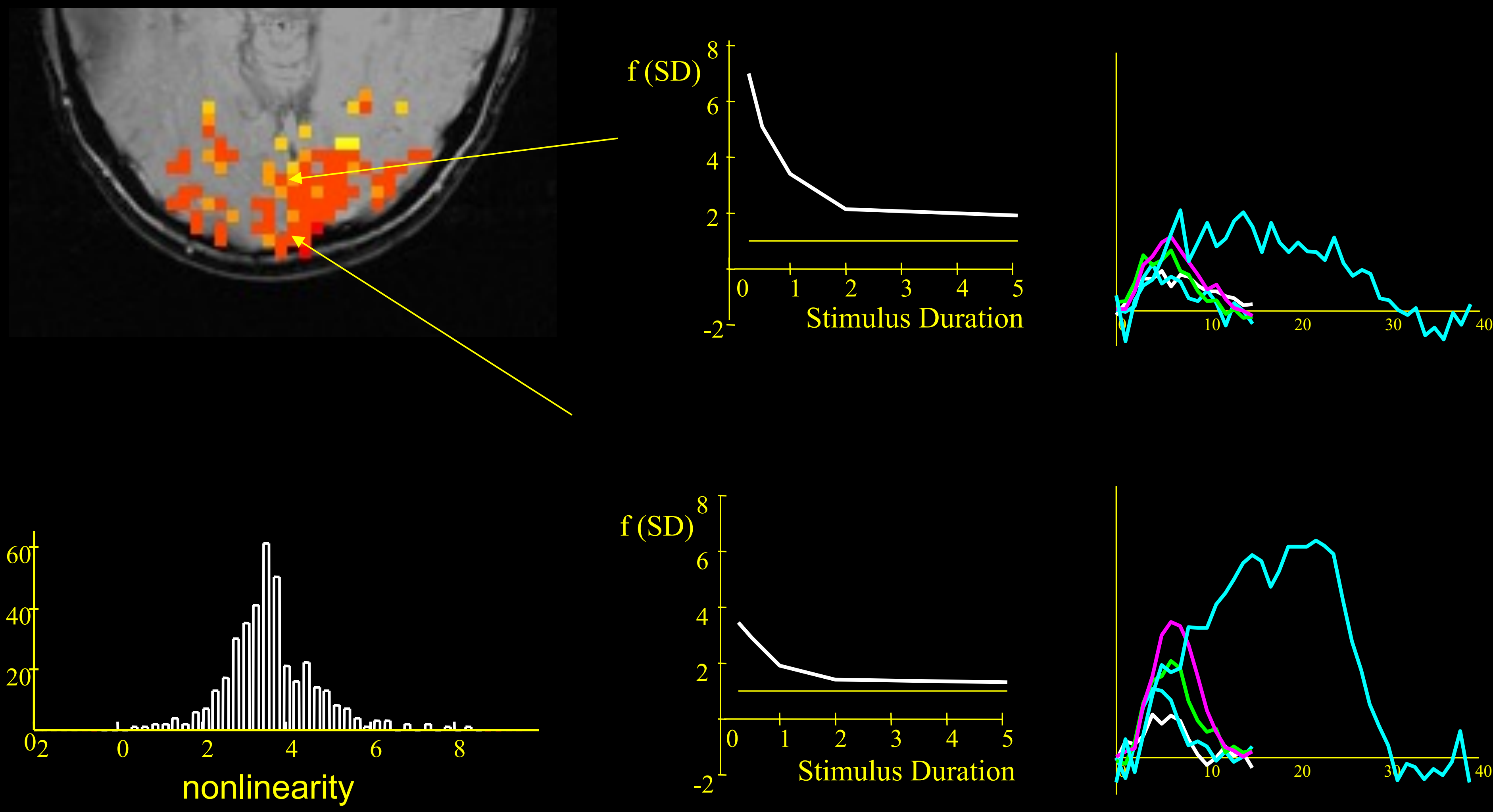
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." ***NeuroImage*****, 14: 817-826.**

BOLD response is nonlinear



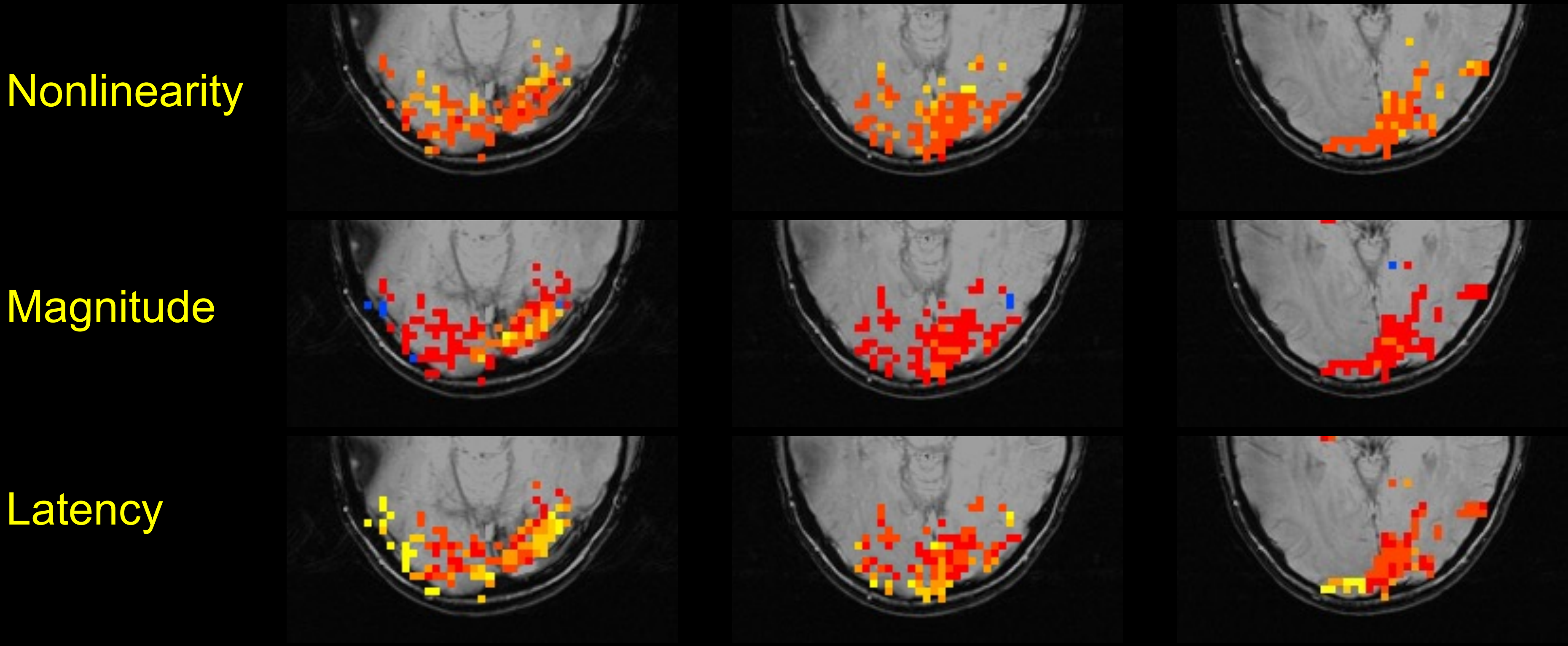
Short duration stimuli produce larger responses than expected

Spatial Heterogeneity of BOLD Nonlinearity



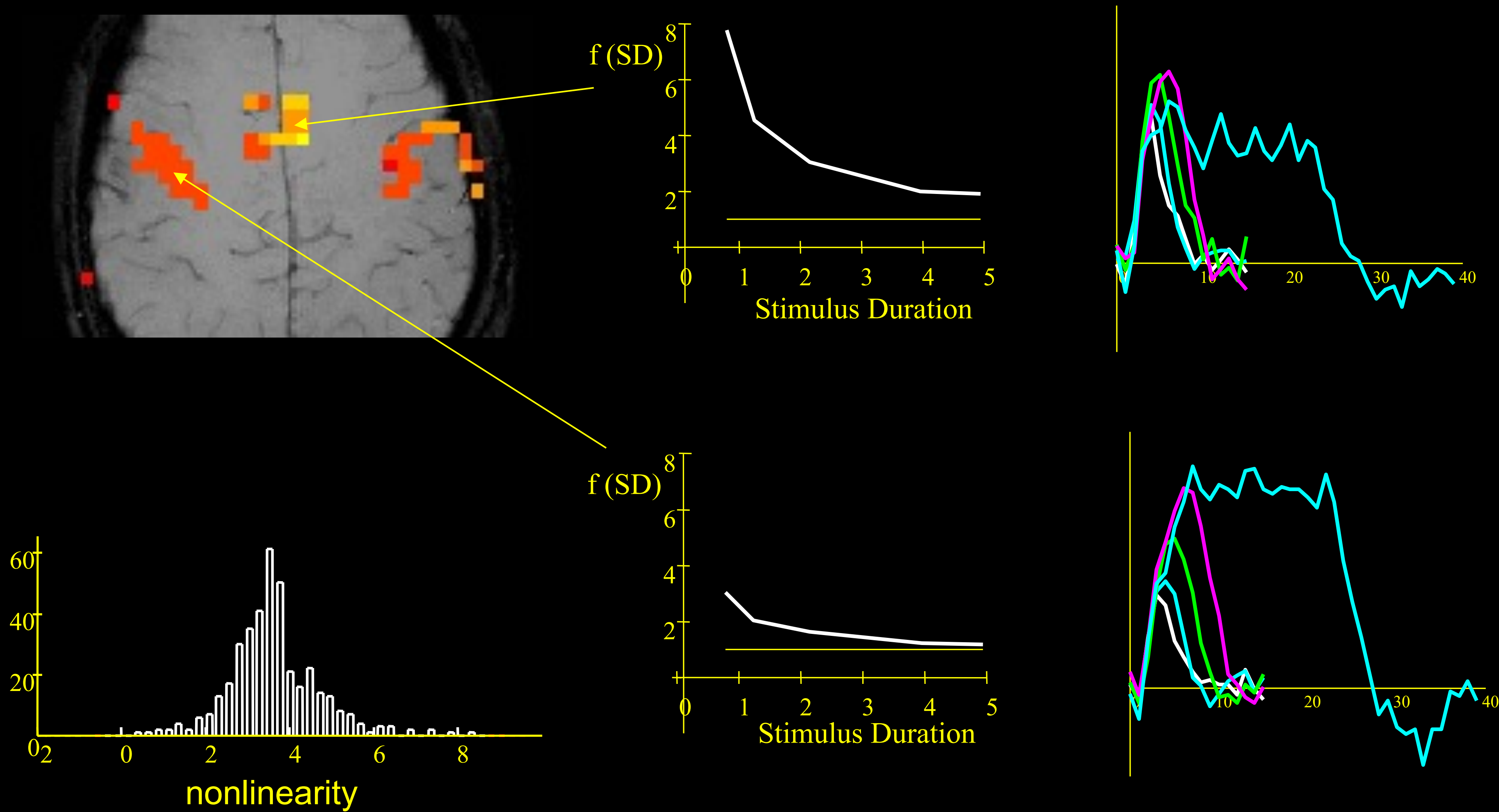
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) “Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response.” *NeuroImage*, 14: 817-826.

Results – visual task



R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." *NeuroImage*, 14: 817-826.

Results – motor task

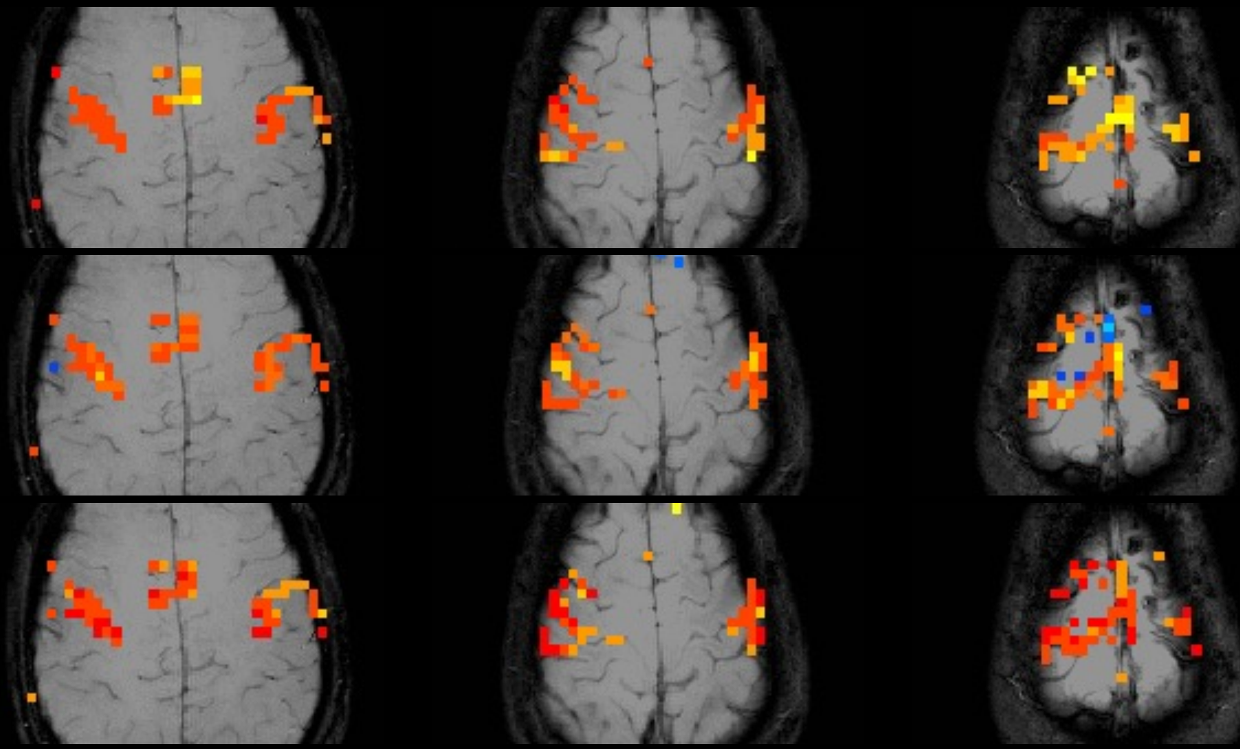


Results – motor task

Nonlinearity

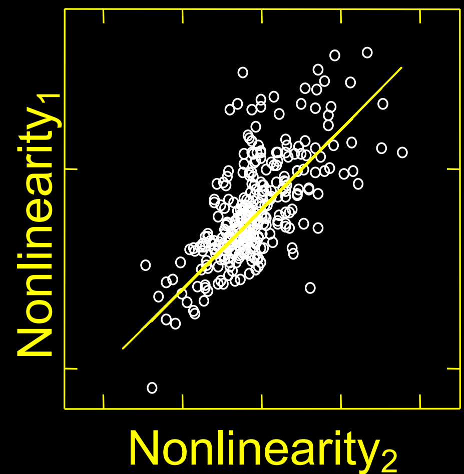
Magnitude

Latency

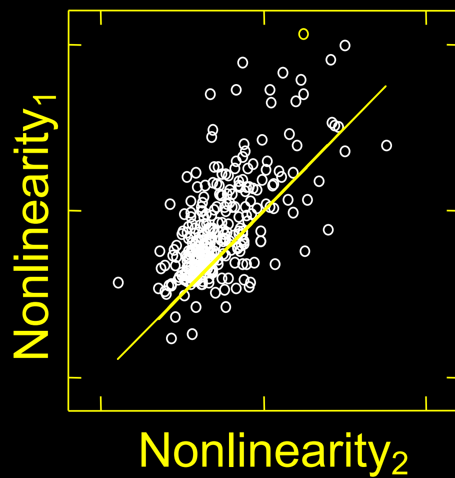


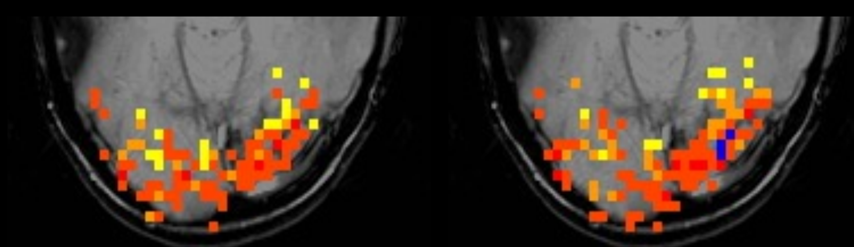
Reproducibility

Visual task

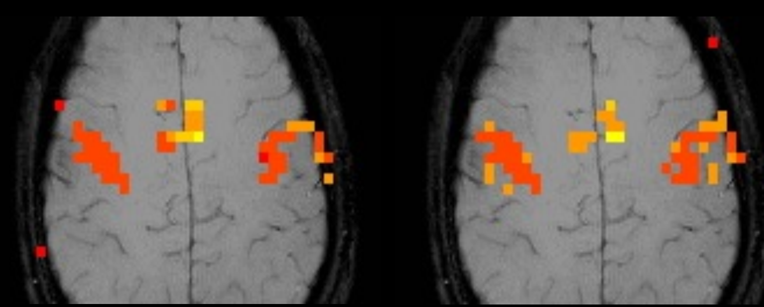


Motor task



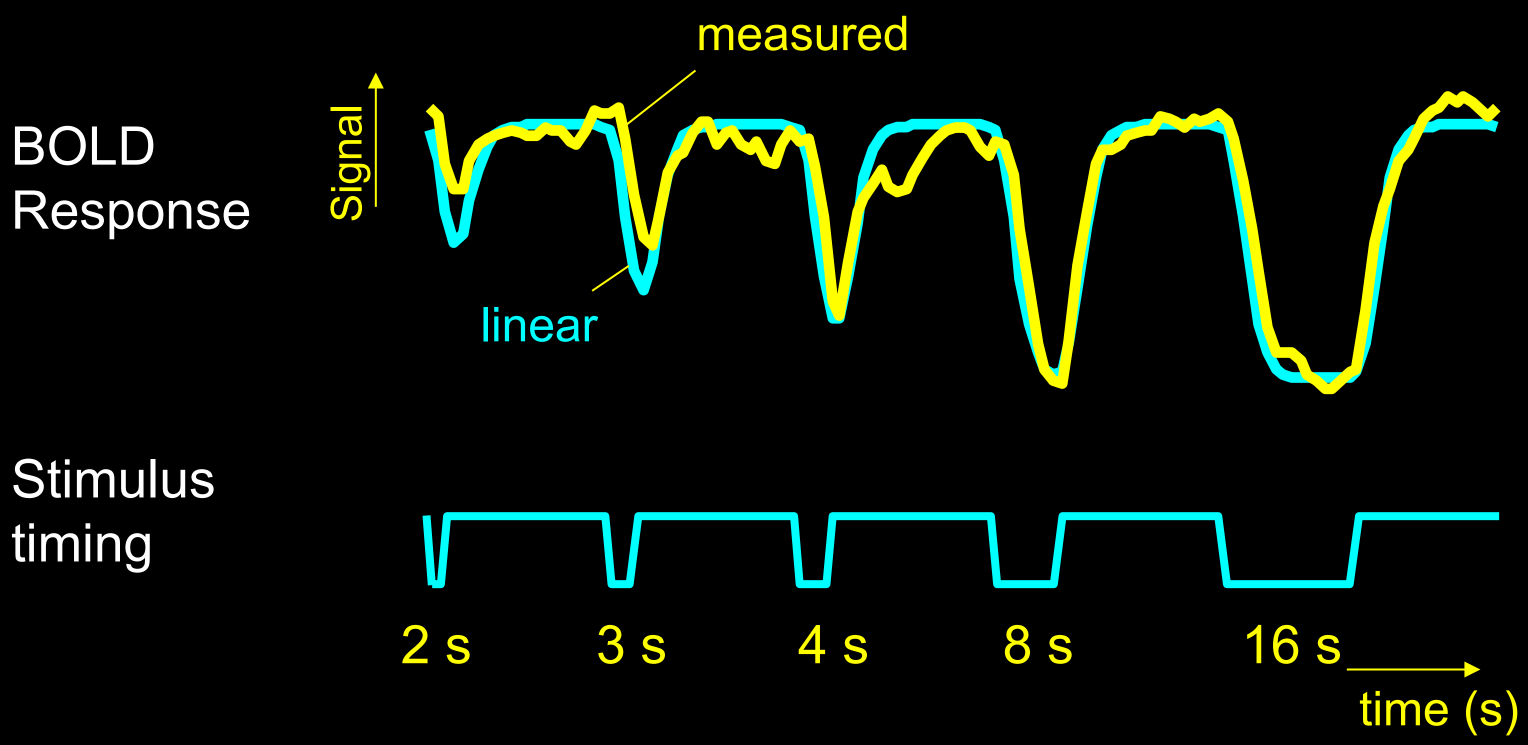


Experiment 1 Experiment 2



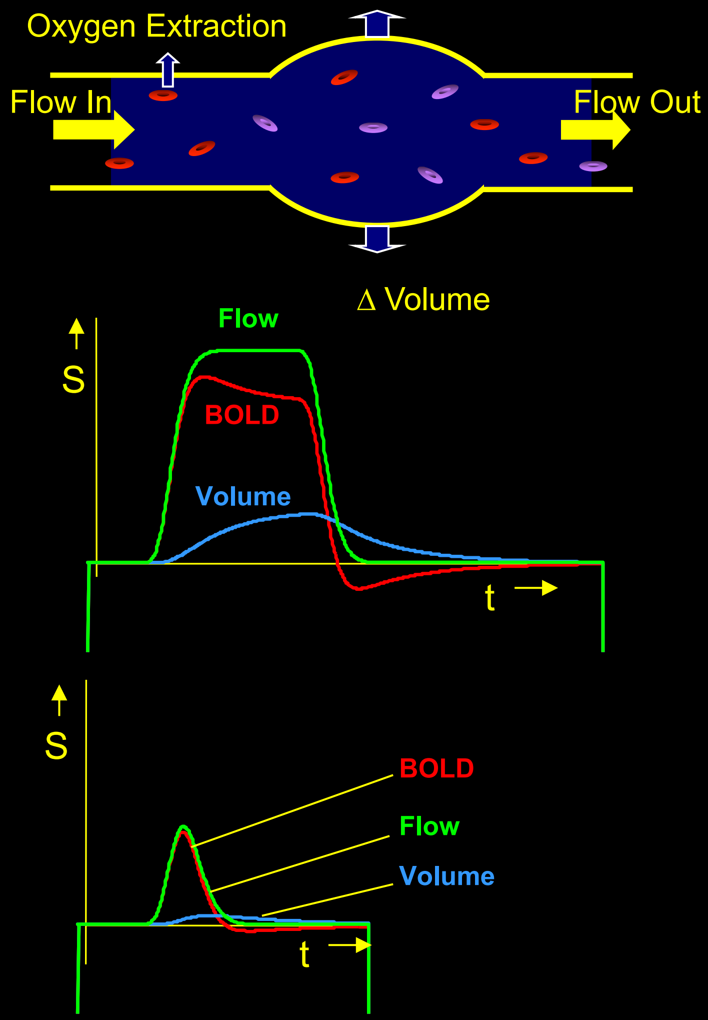
Experiment 1 Experiment 2

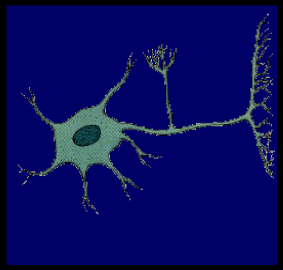
Different stimulus "OFF" periods

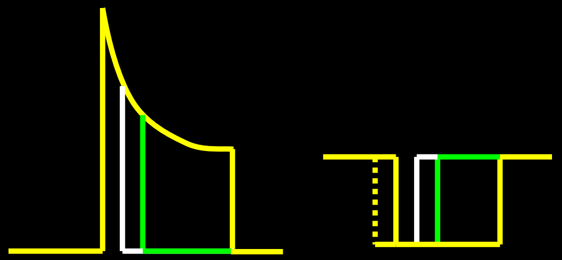


Brief stimulus OFF periods produce smaller decreases than expected

Sources of this Nonlinearity



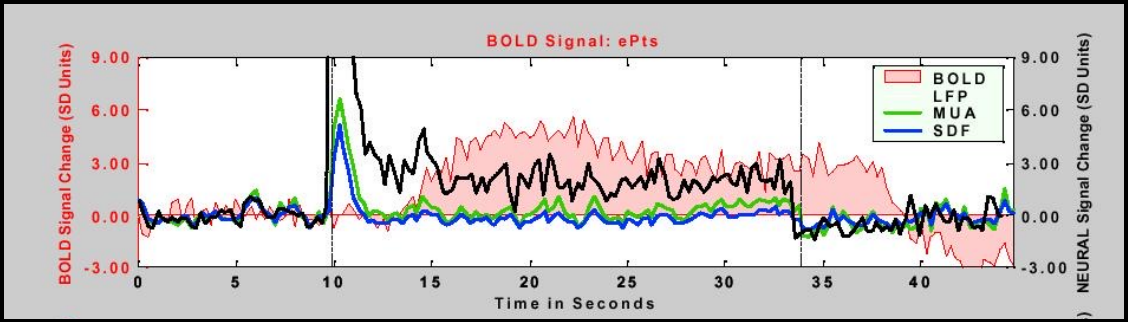




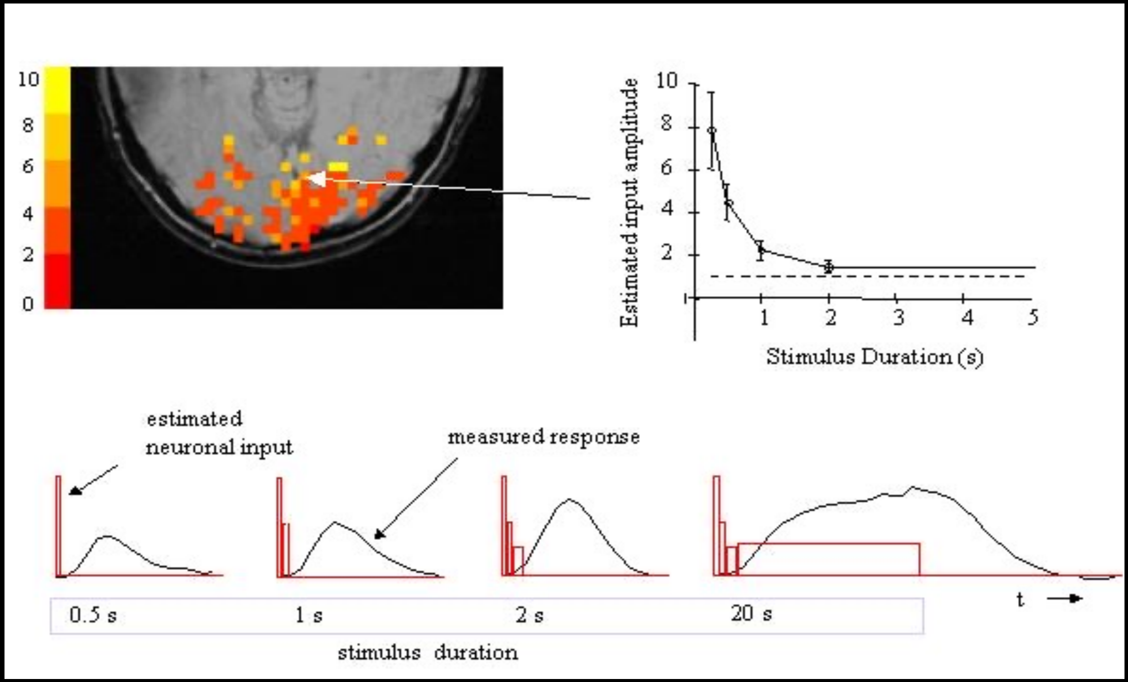
Vasquez et al. (1998) NeuroImage, 7, 108-118

BOLD Correlation with Neuronal Activity

Logothetis et al. (2001) "Neurophysiological investigation of the basis of the fMRI signal" Nature, 412, 150-157.



P. A. Bandettini and L. G. Ungerleider, (2001) "From neuron to BOLD: new connections." Nature Neuroscience, 4: 864-866.



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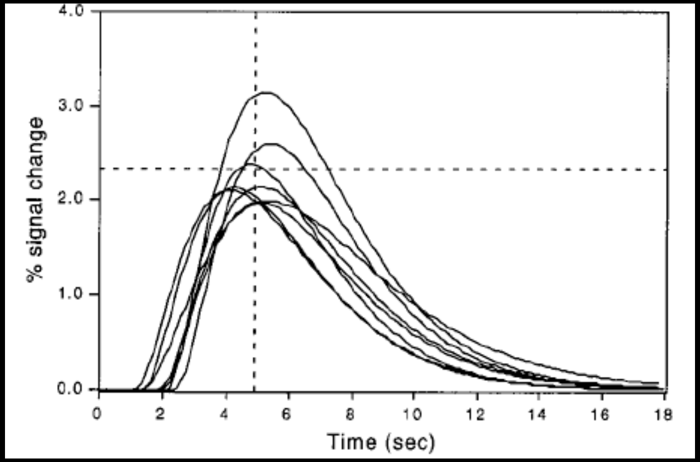
Sources of spatial and temporal variability.

Latency and Magnitude

From Subject to Voxel….

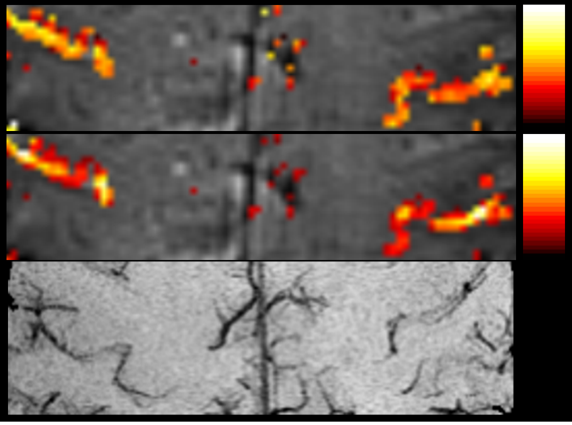


Miezin, et al (2000), NeuroImage 11, 735-759

Latency

Magnitude

Venogram

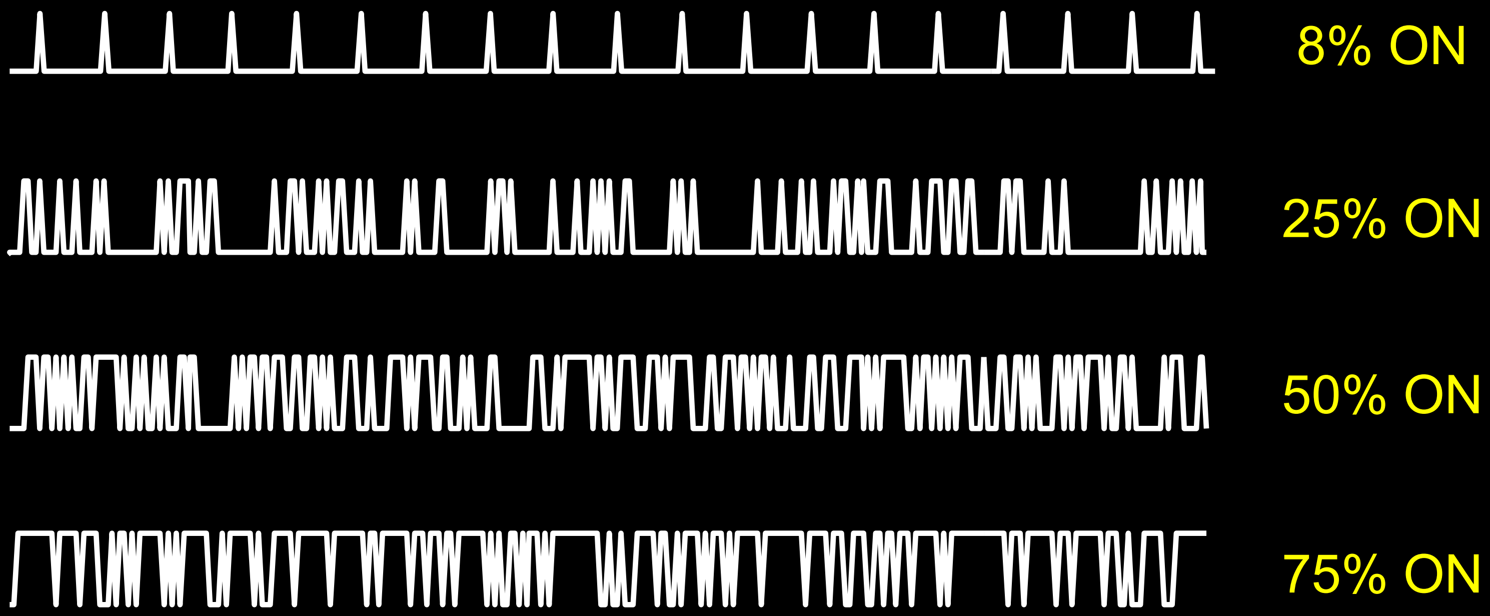


+ 2 sec

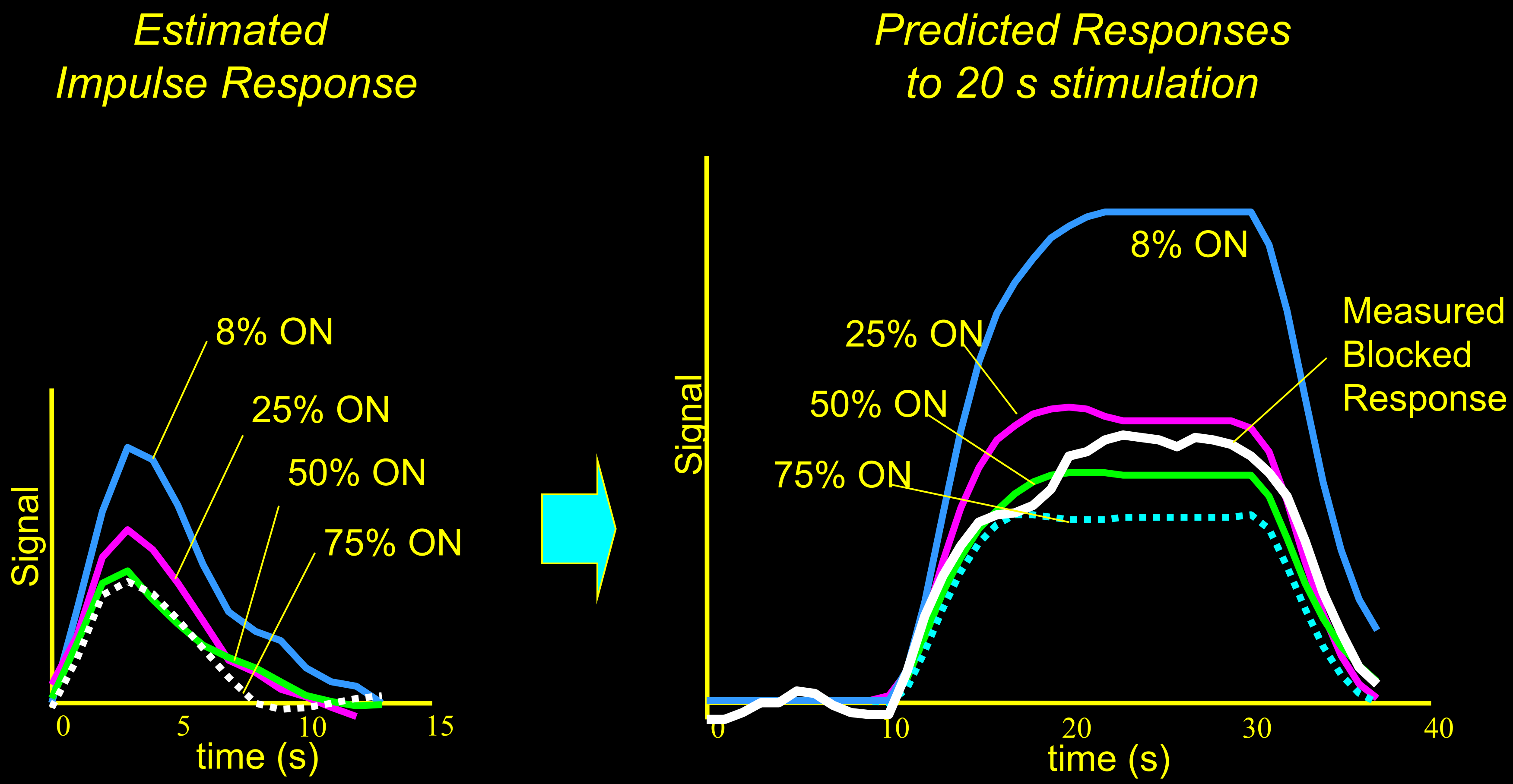
- 2 sec

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

Rapid event-related design with varying ISI



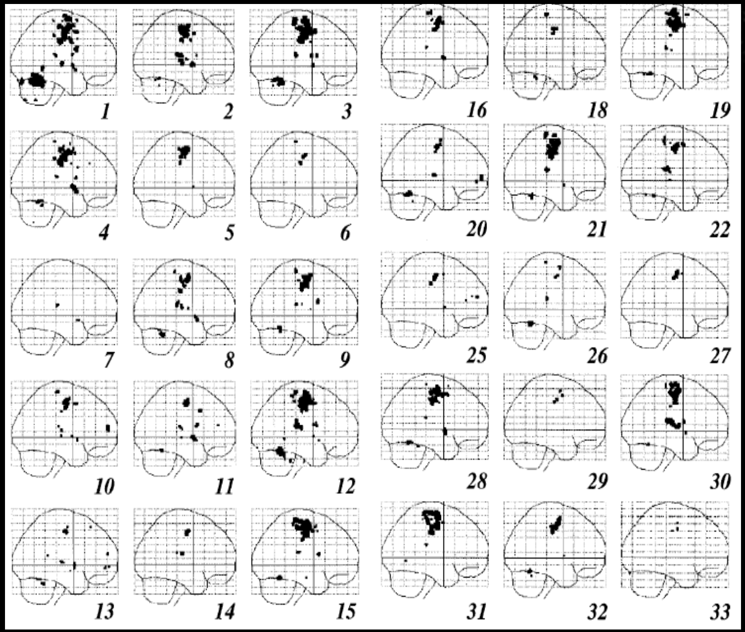
R. Birn, et al (2001), OHBM 971



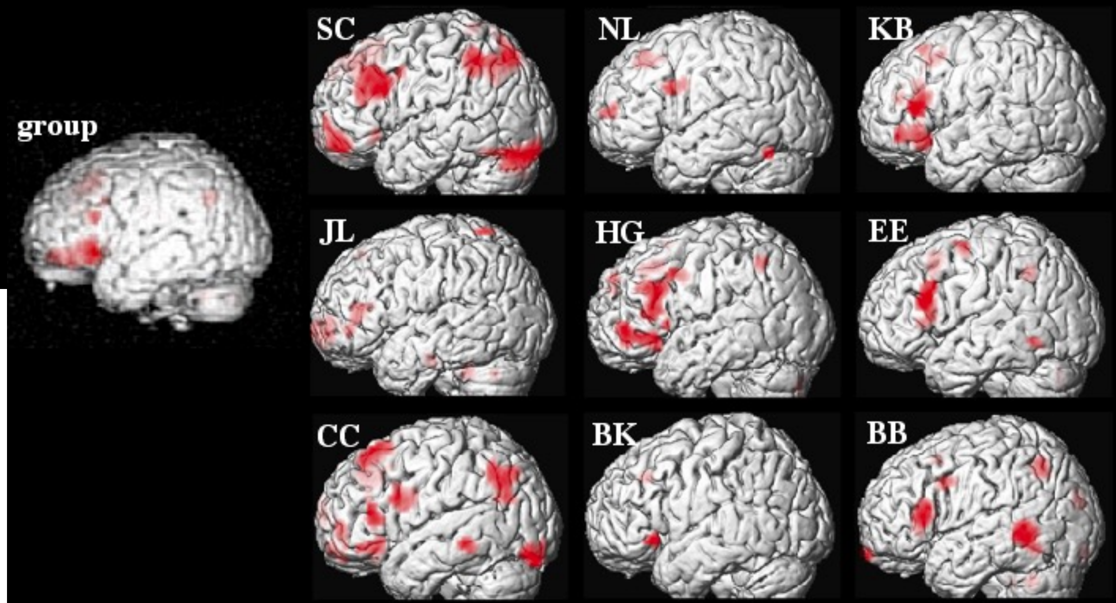
R. Birn, et al (2001), OHBM 971

Sources of spatial and temporal variability.

Spatial Variation

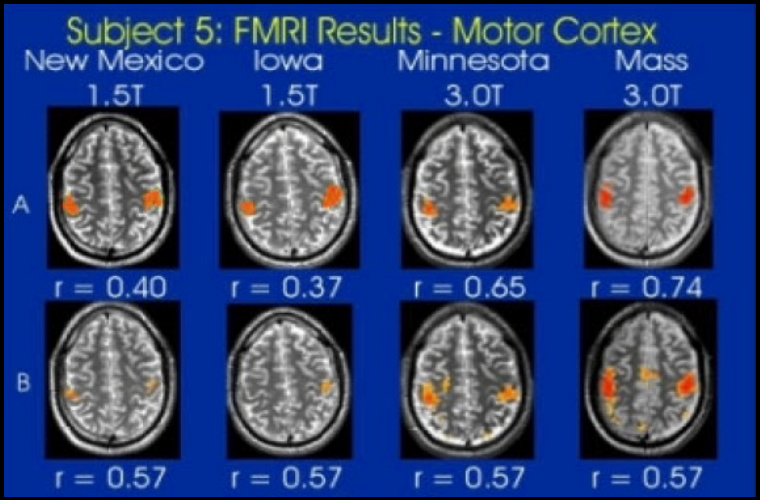


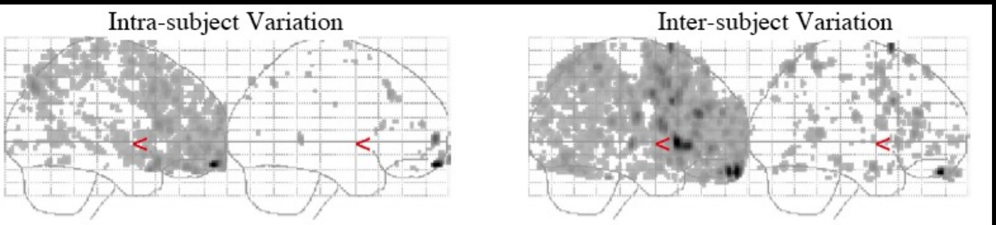
McGonigle, et al (2000), NeuroImage 11, 708-734



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

F. BIRN Biomedical Informatics Research Network





T.E. Lund, et al (2004), ISMRM 497å

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

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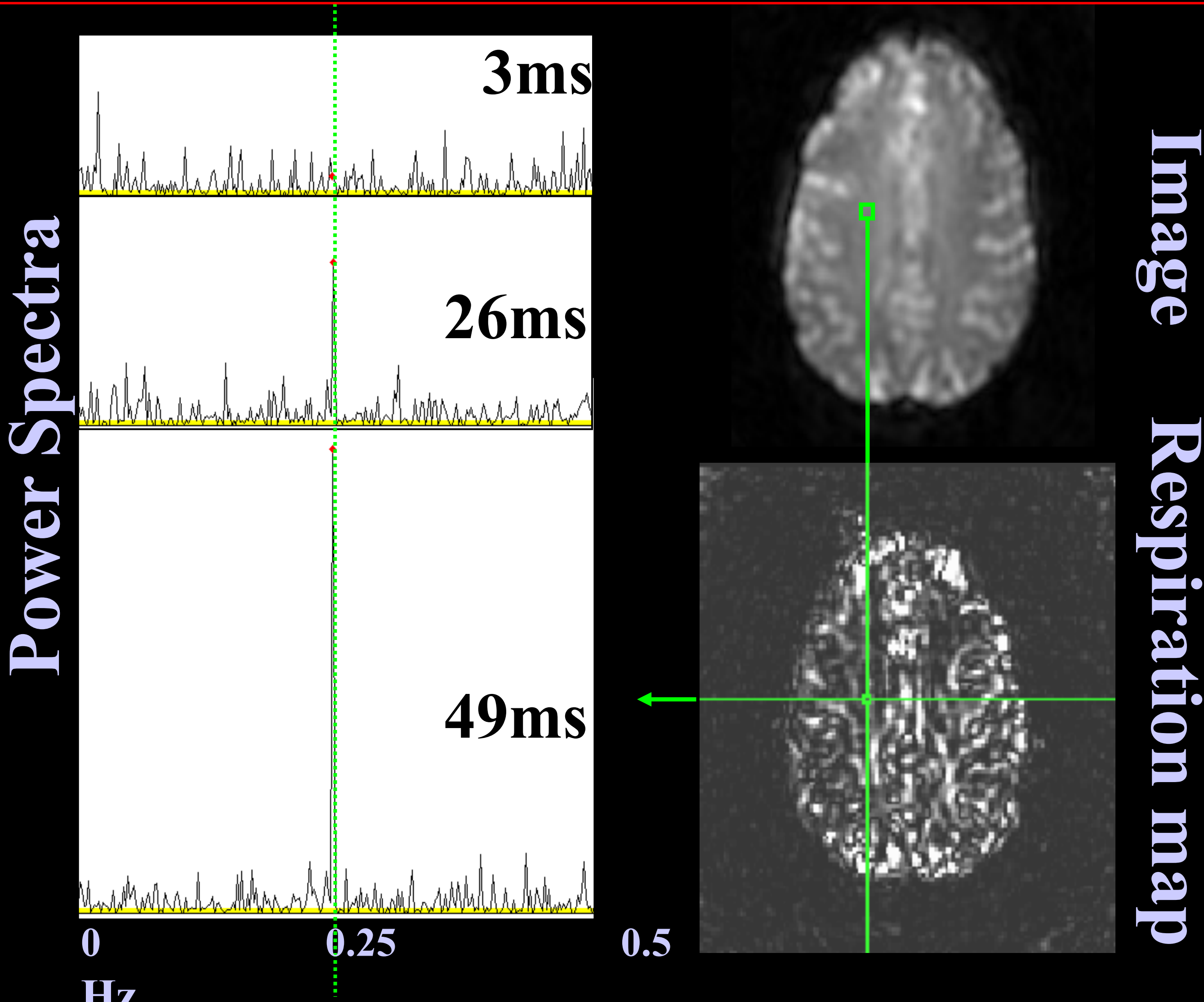
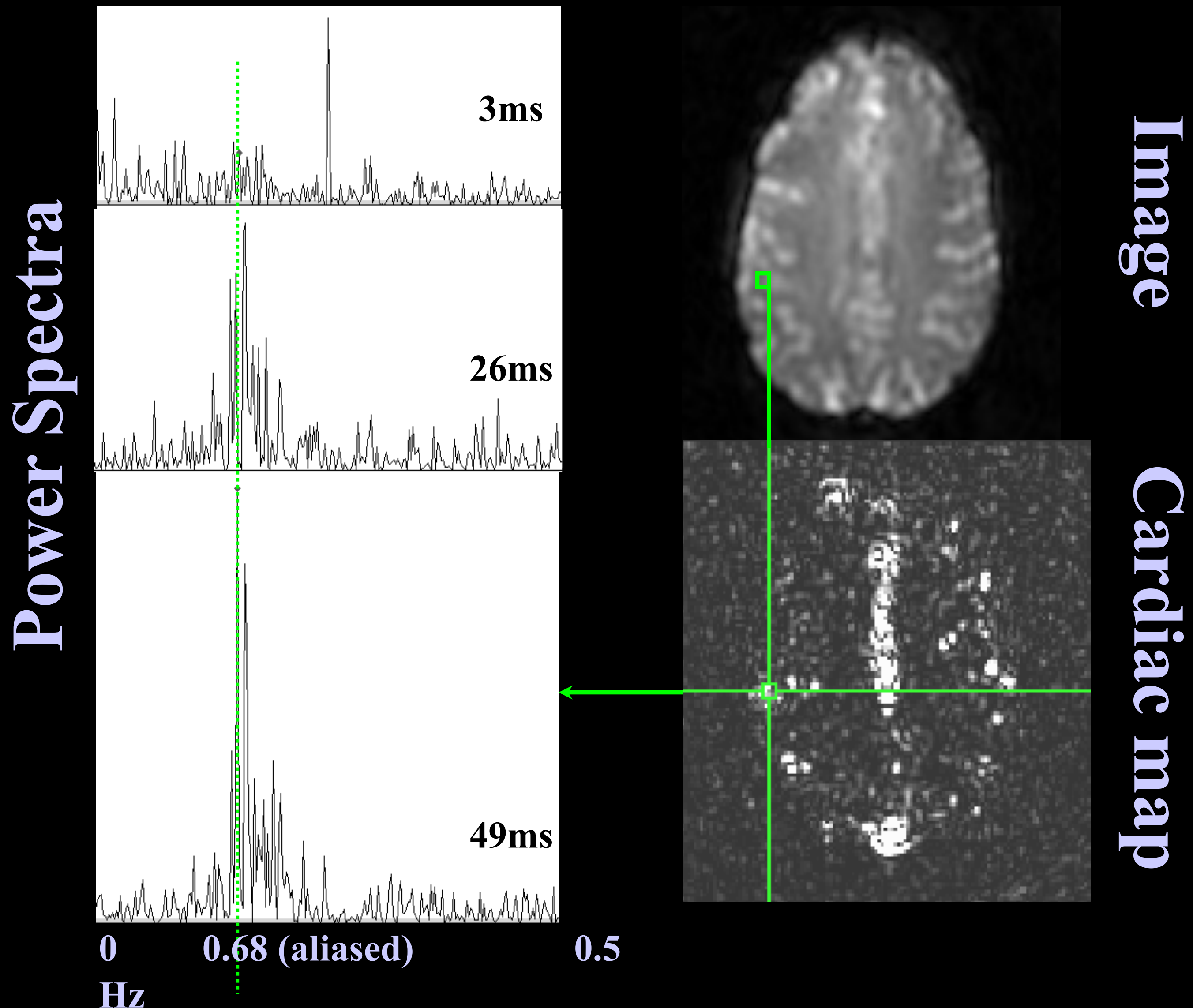
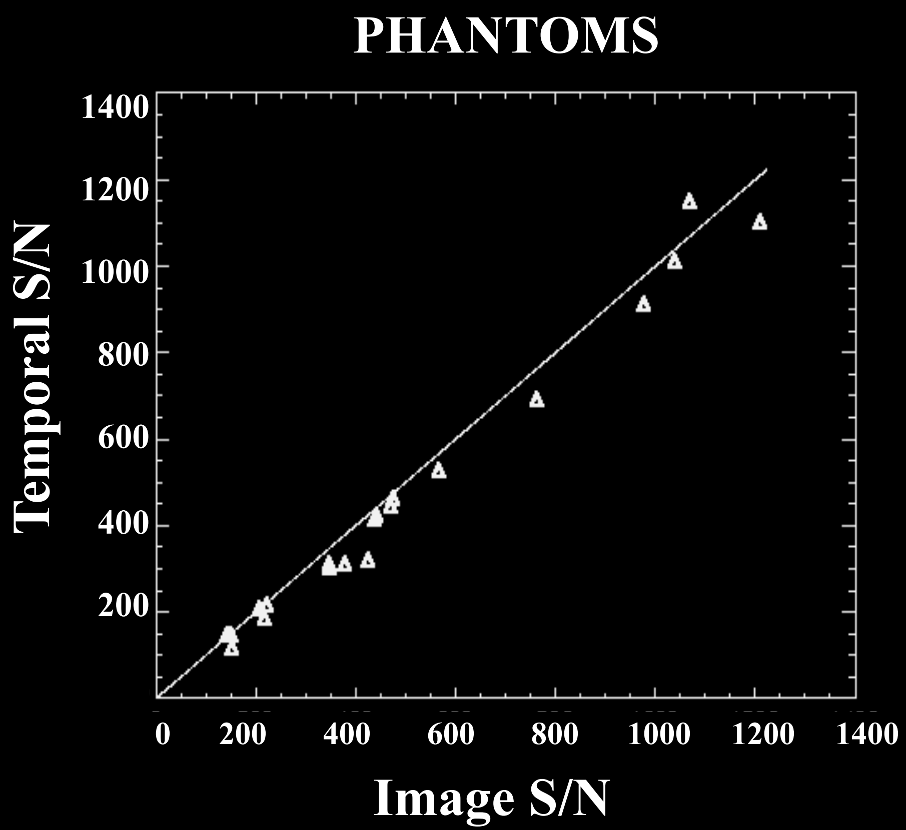
0.25 Hz Breathing at 3T

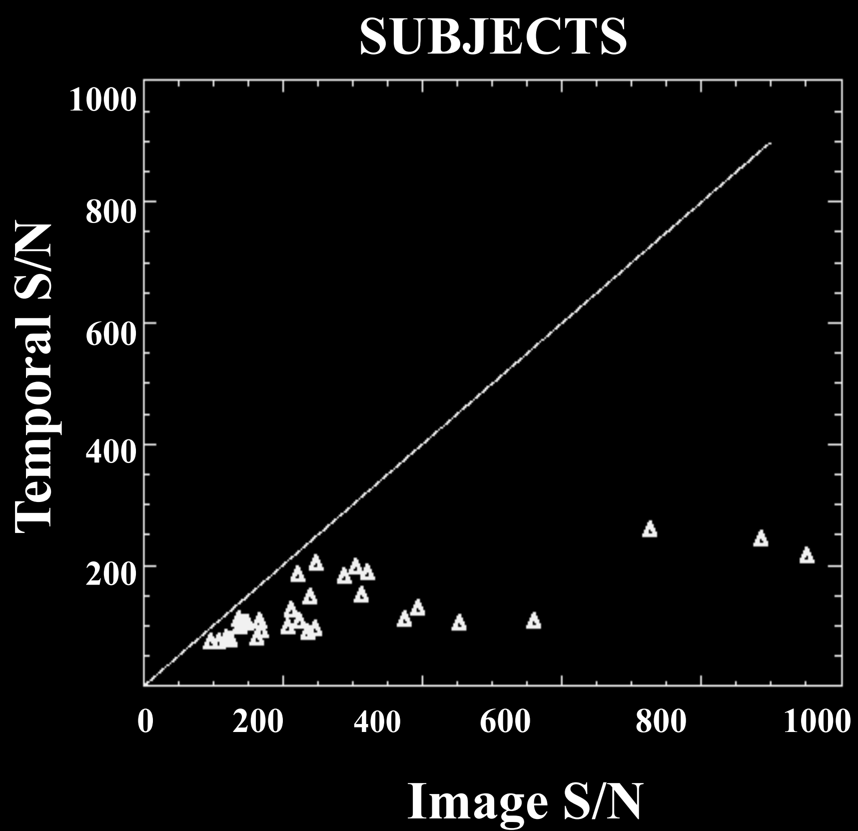


0.68 Hz Cardiac rate at 3T

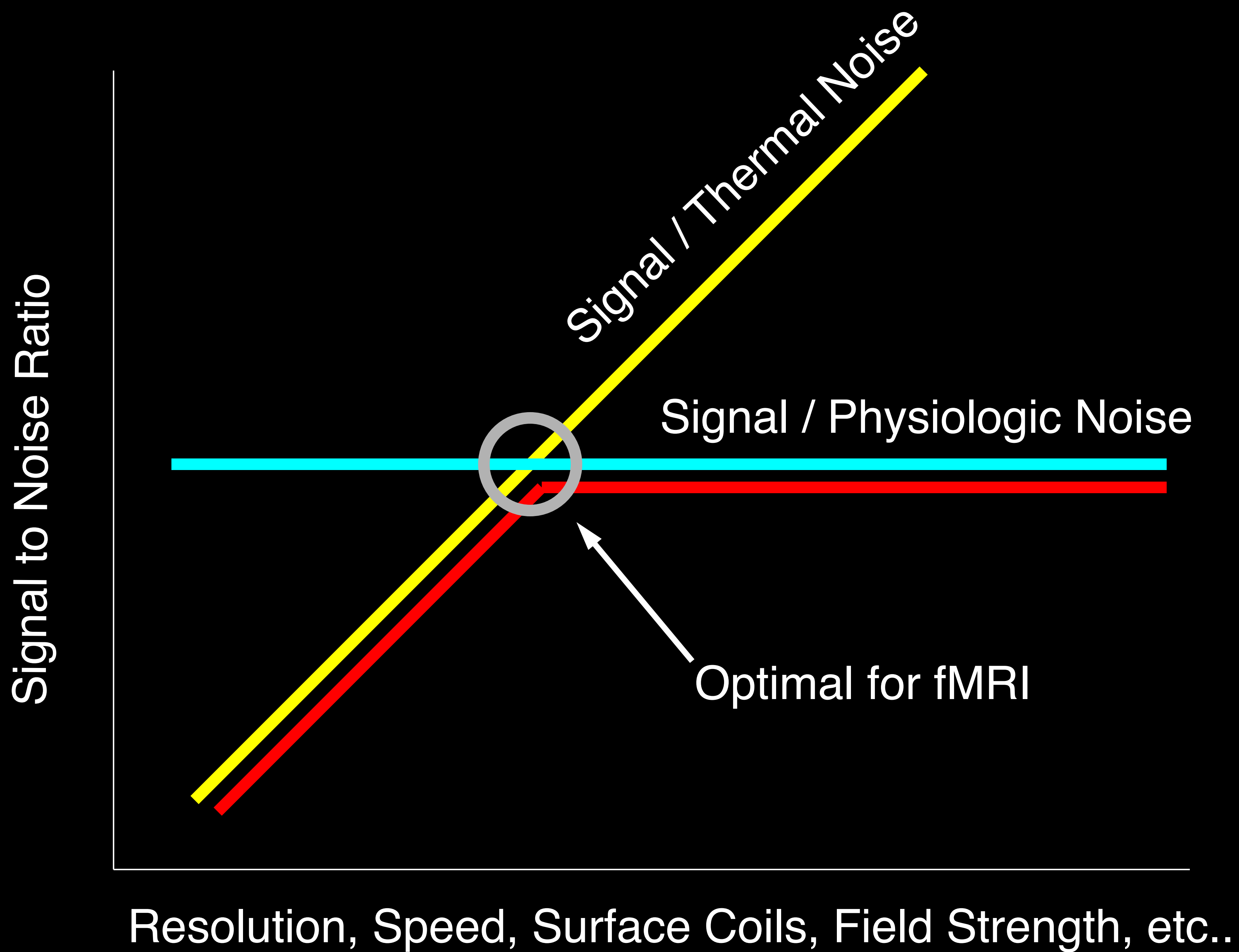


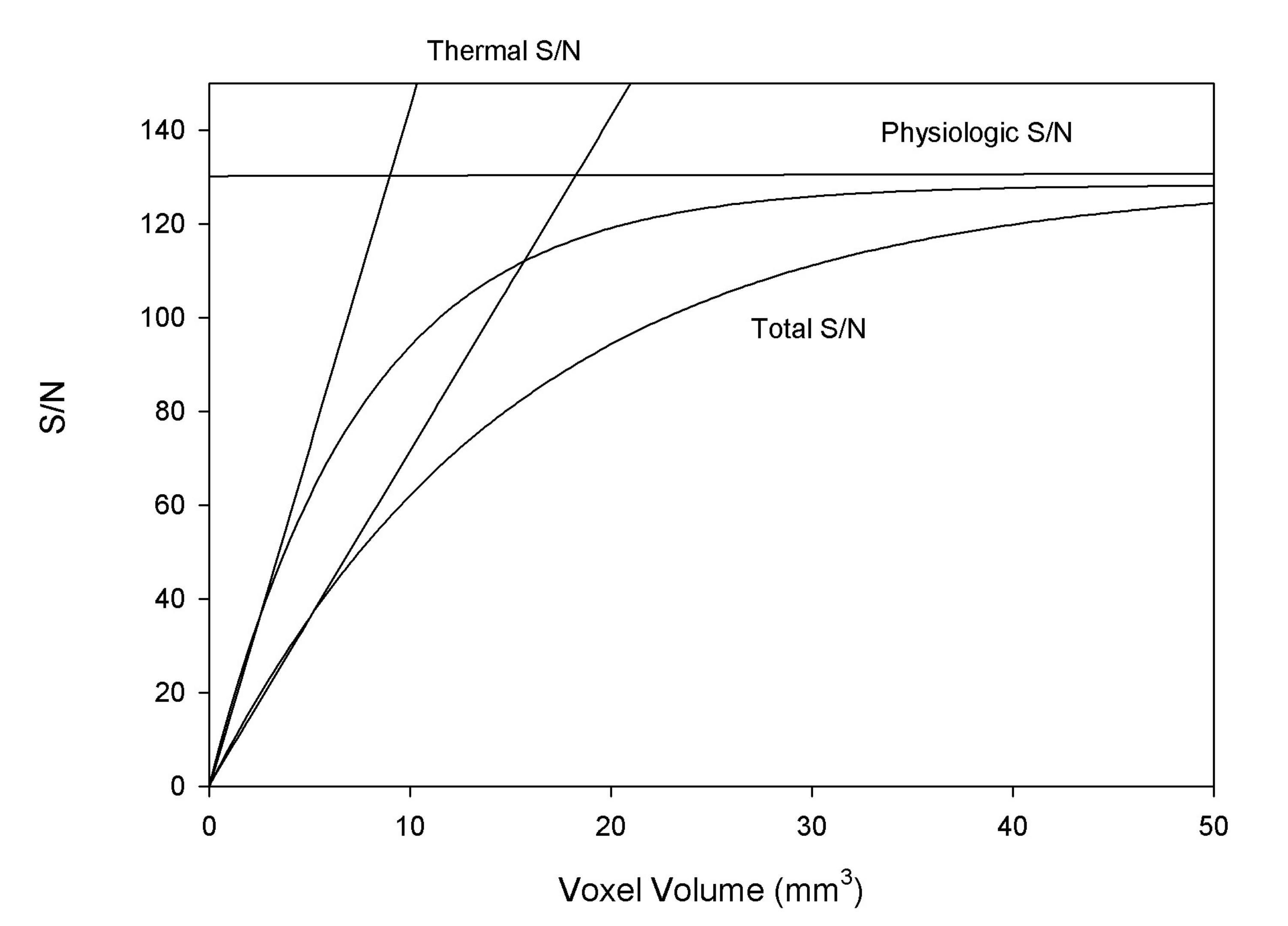
Temporal S/N vs. Image S/N



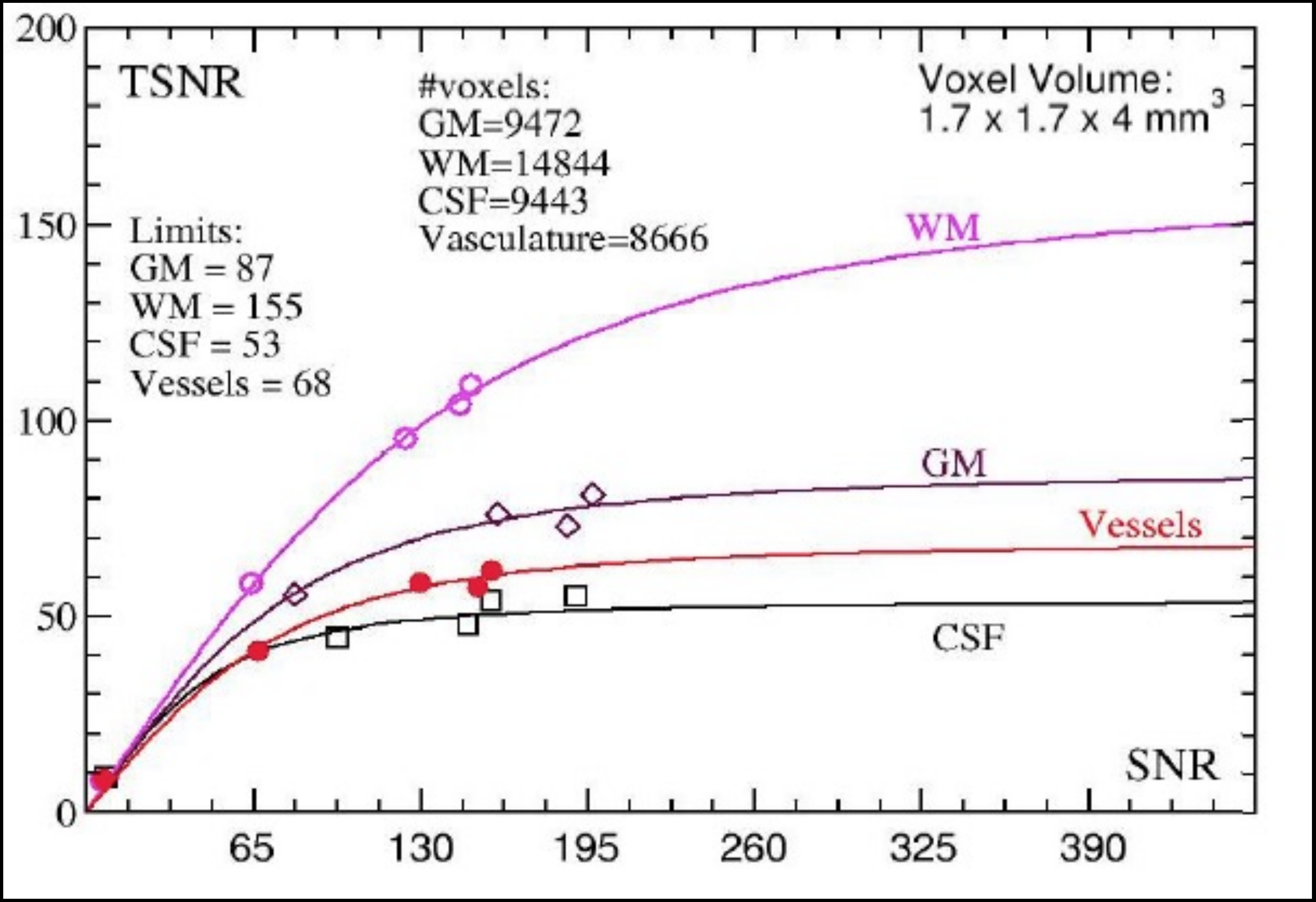


N. Petridou


Signal / Thermal Noise
Signal / Physiologic Noise
Optimal for fMRI
Signal to Noise Ratio
Resolution, Speed, Surface Coils, Field Strength, etc..



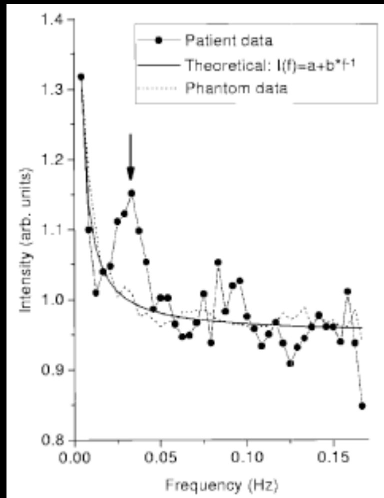
Thermal S/N
Physiologic S/N
Total S/N
S/N
140
120
100
80
60
40
20
0
0
10
20
30
40
50
Voxel Volume (mm3)

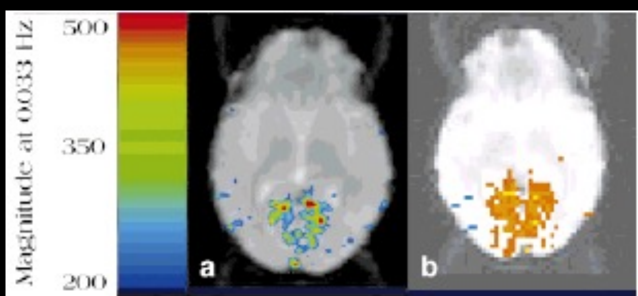


TSNR
#voxels:
GM=9472
WM=14844
CSF=9443
Vasculature=8666
Voxel Volume:
1.7 x 1.7 x 4 mm3
Limits:
GM = 87
WM = 155
CSF = 53
Vessels = 68
WM
GM
Vessels
CSF
SNR
0
50
100
150
200
65
130
195
260
325
390

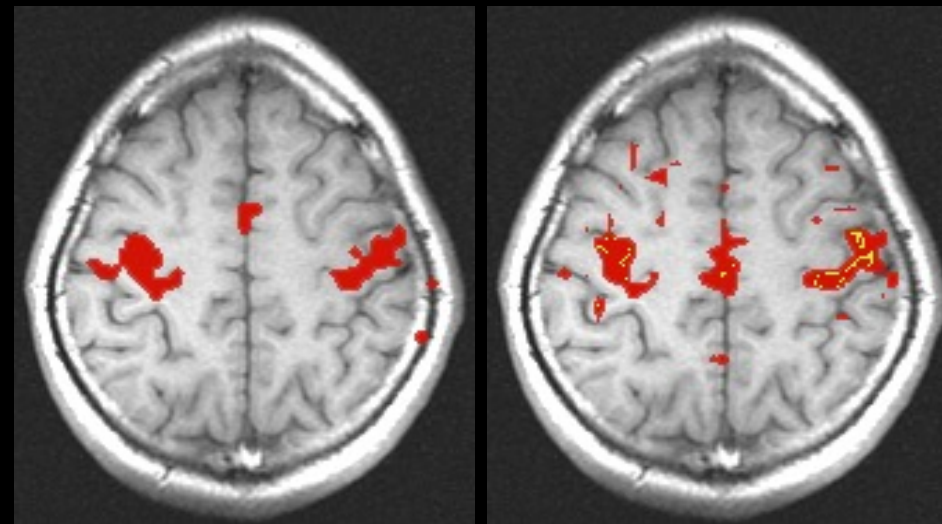
What’s really in the noise?

Spontaneous Fluctuation Correlation

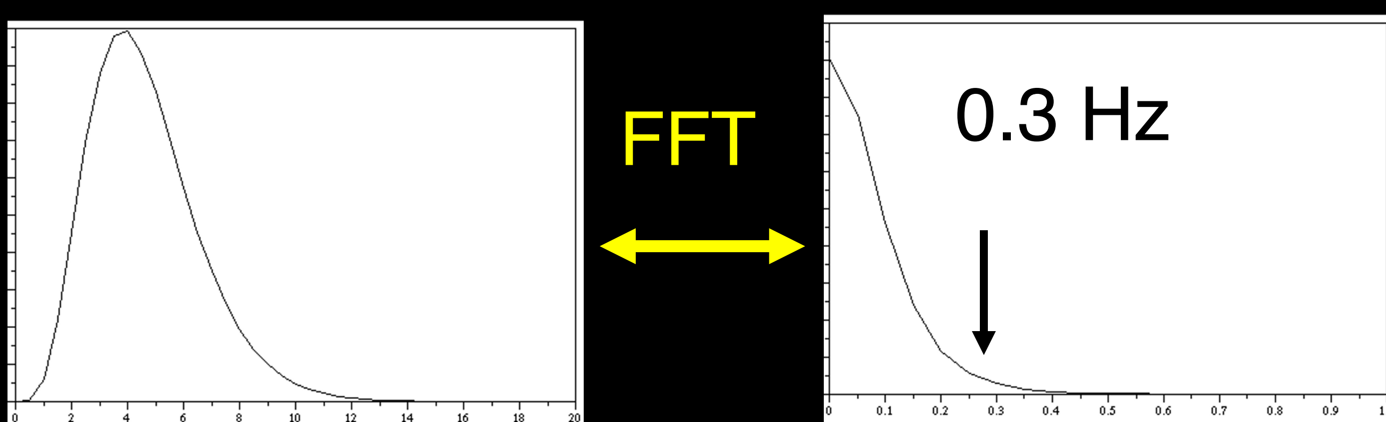




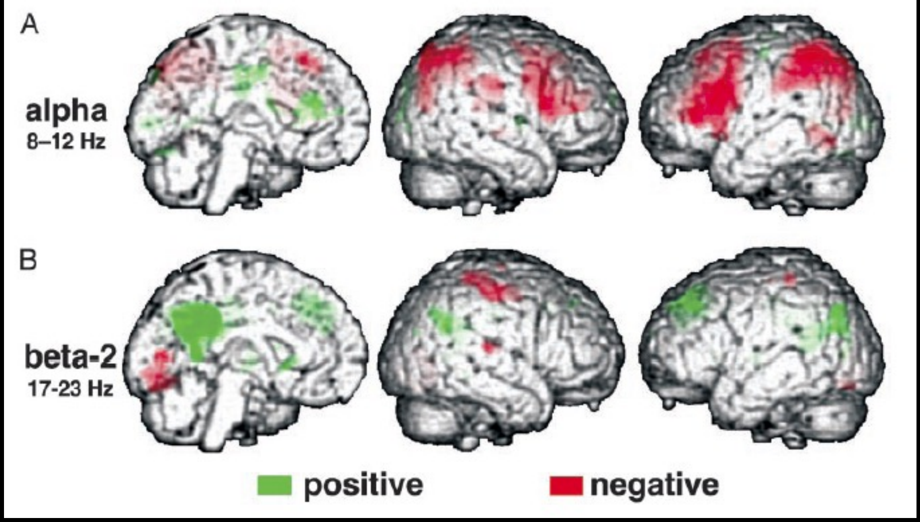
Kiviniemi, et al (2000), MRM 44, 373-378



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

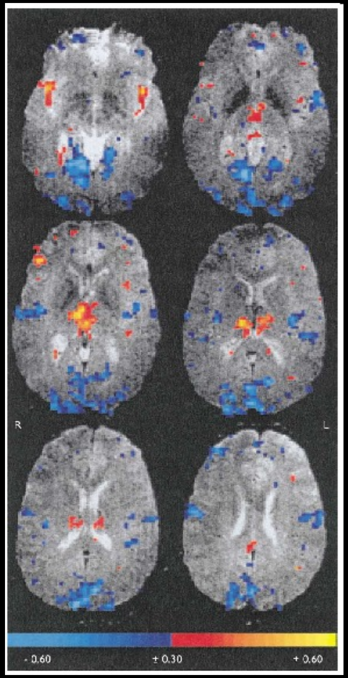


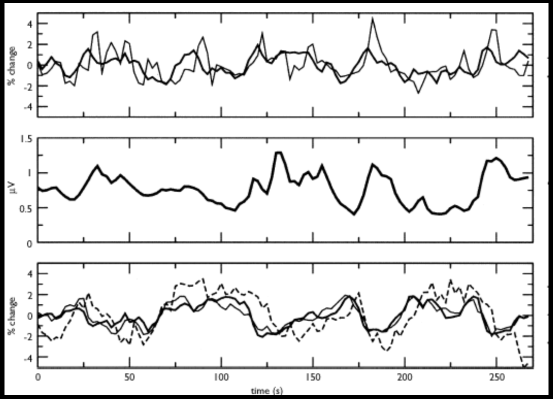
What's really in the noise?

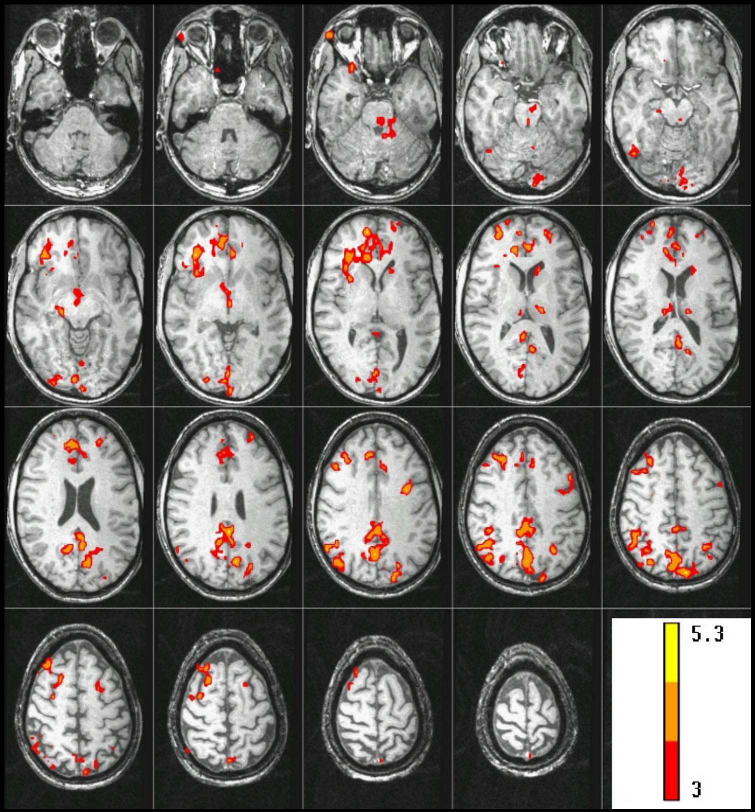


Laufs, et al (2003), PNAS 100 (19), 11053-11058

Correlation with External Measures







Goldman, et al (2002), Neuroreport

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

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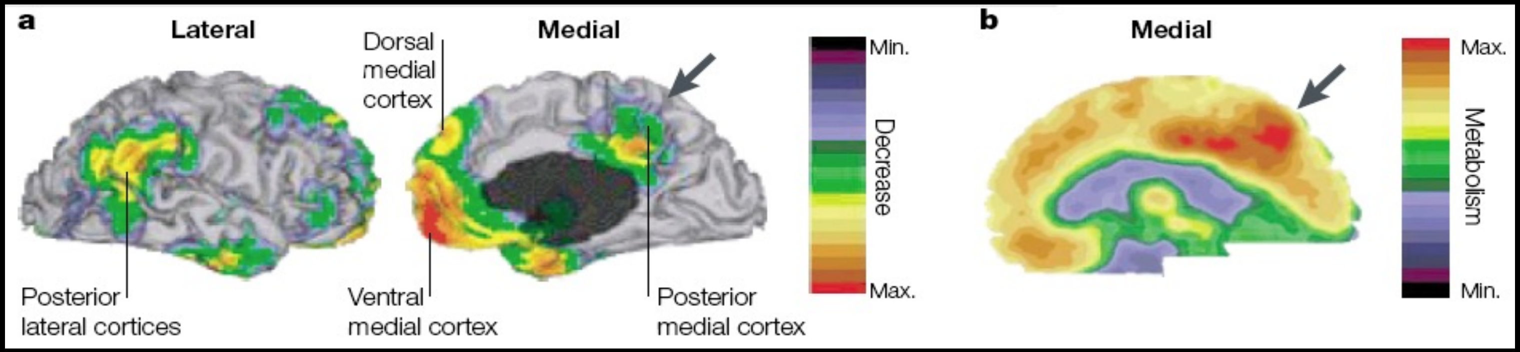
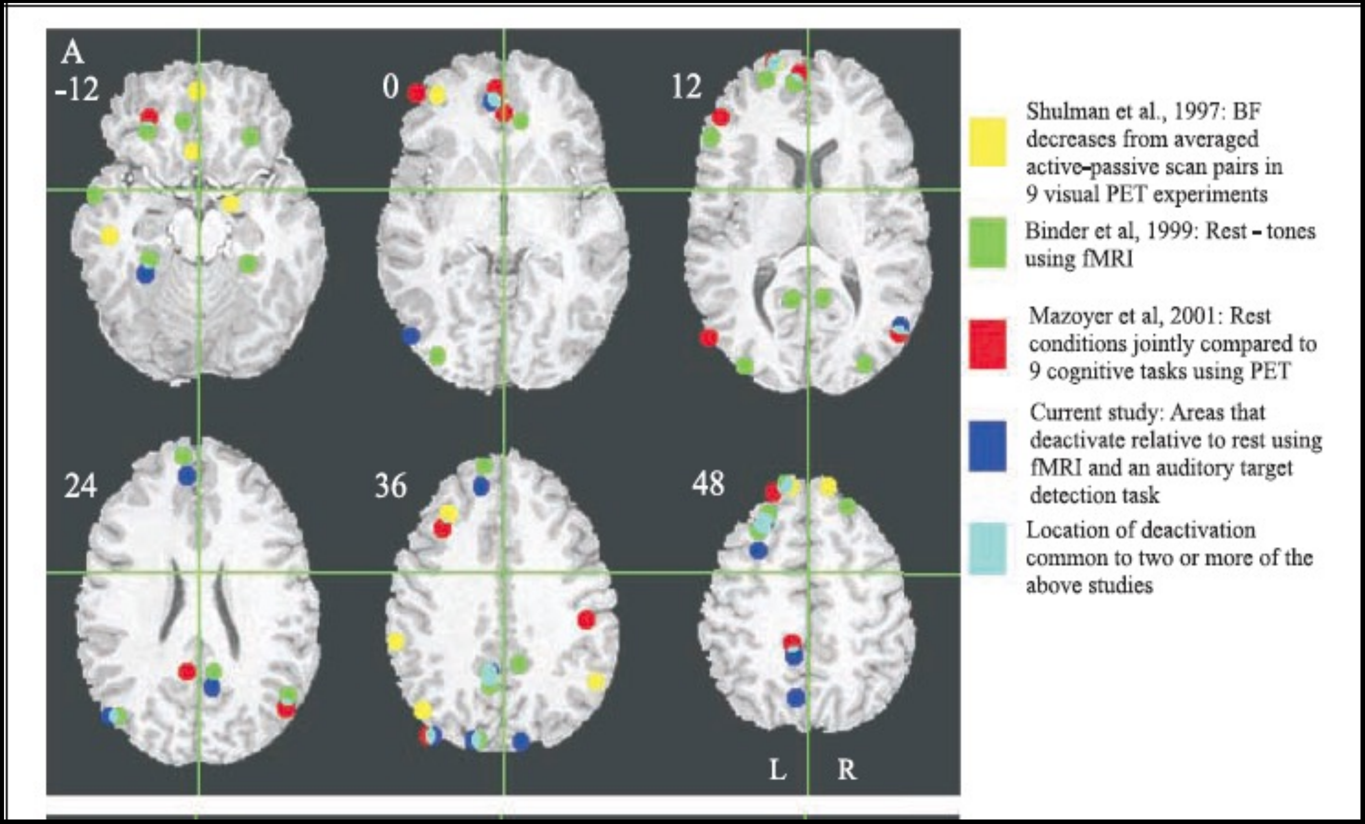
What is “resting” state?



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

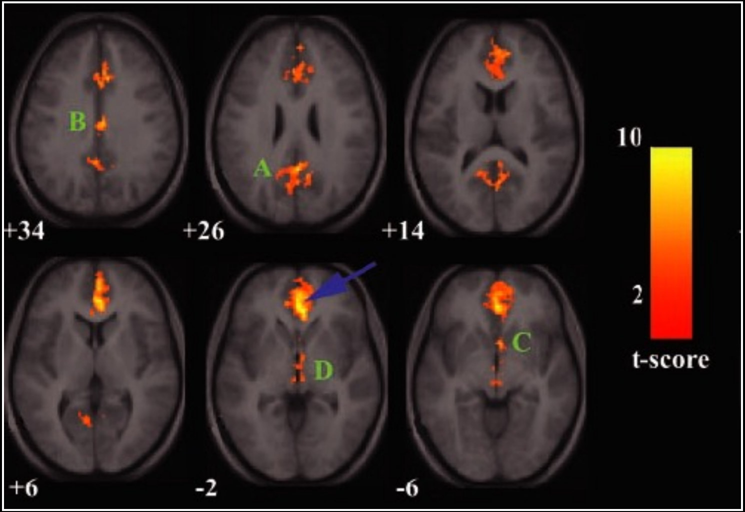
Decreases during activation

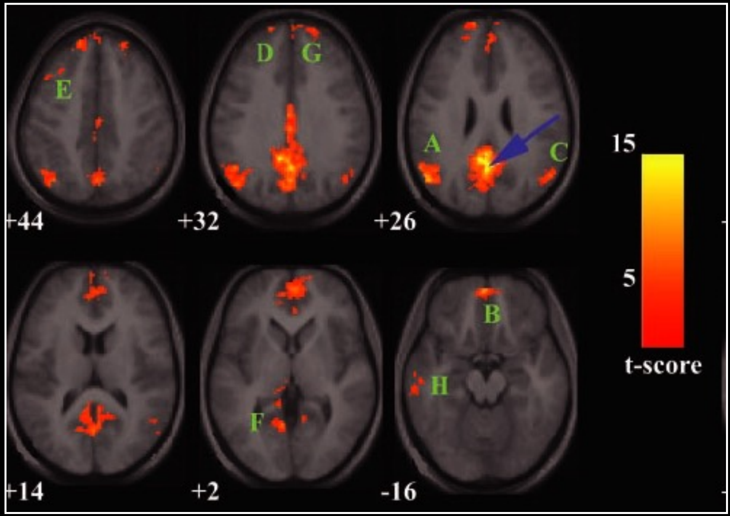


McKiernan, et al (2003), Journ. of Cog. Neurosci. 15 (3), 394-408

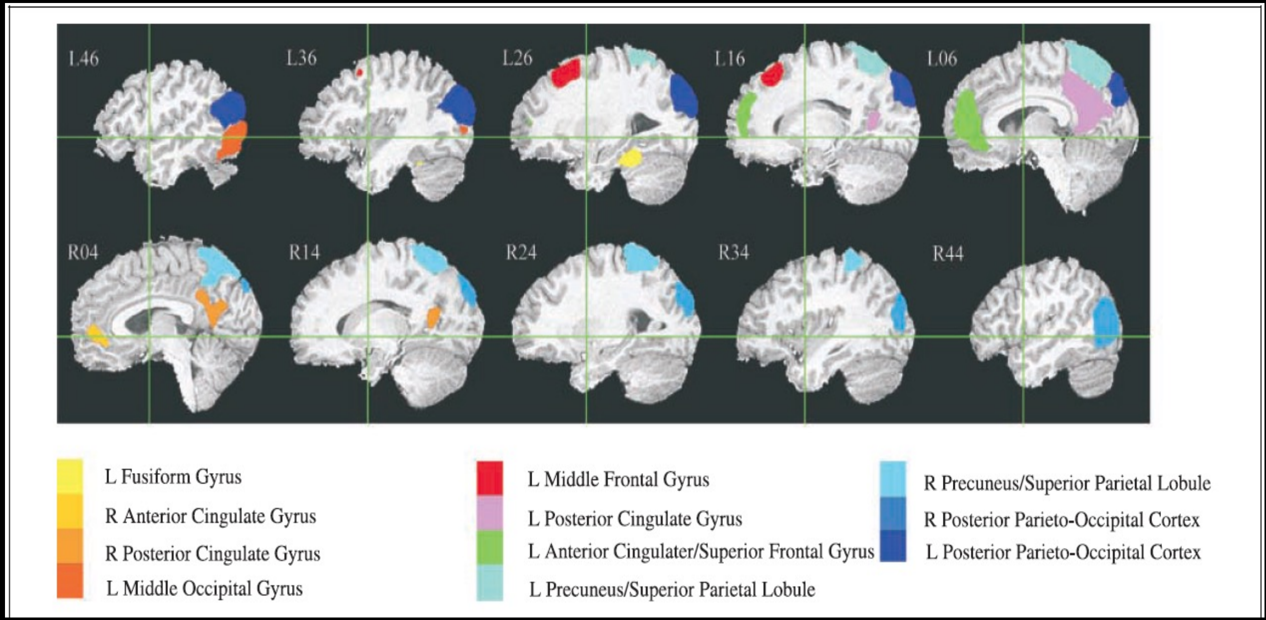
What is “resting” state?

Are decreases related to resting correlations?





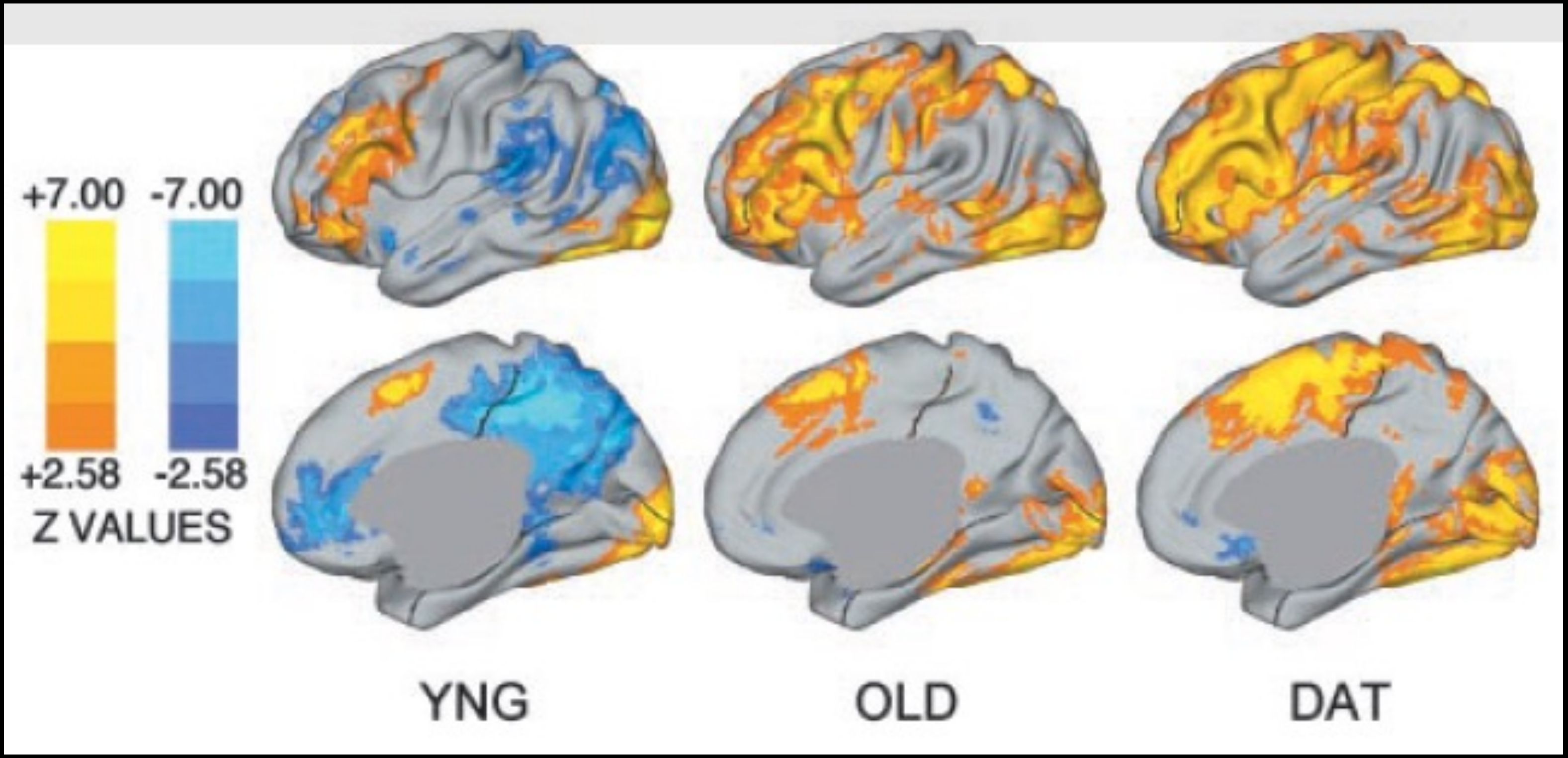
Greicius, et al (2003), PNAS 100 (1), 253-258



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

What is "resting" state?

Clinical applications?



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

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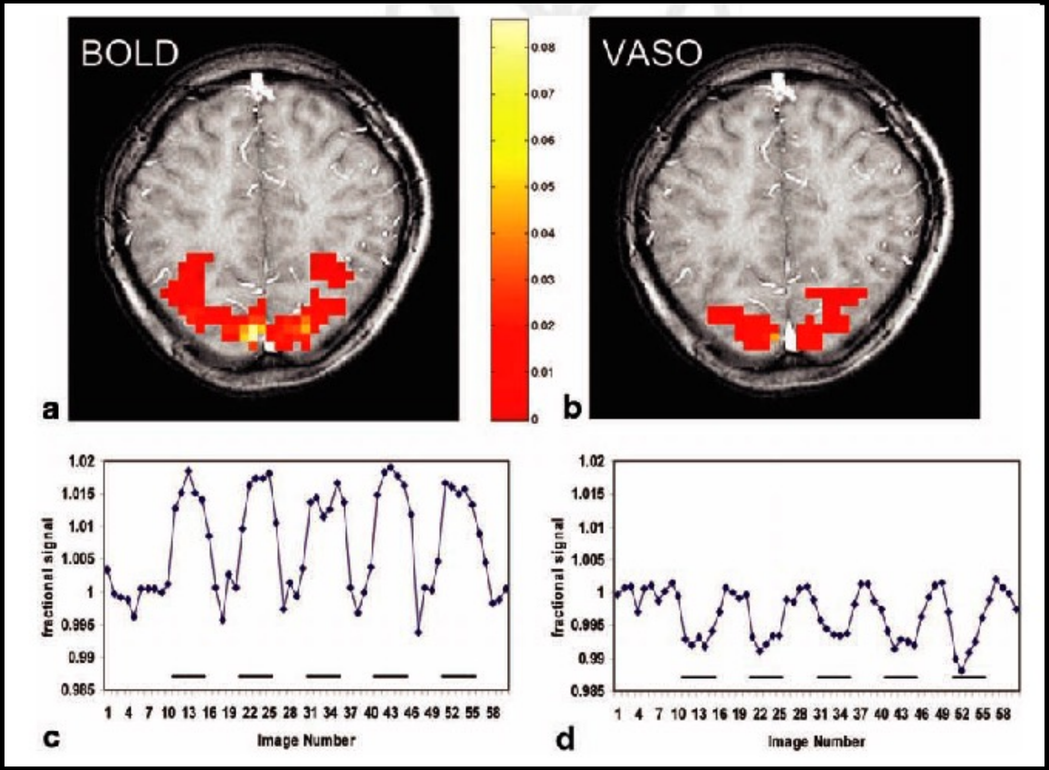
Other sources of functional contrast?

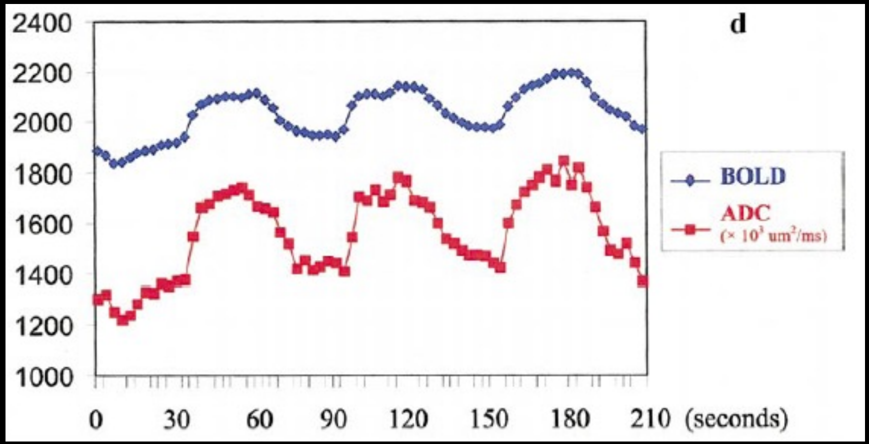
Blood Volume



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

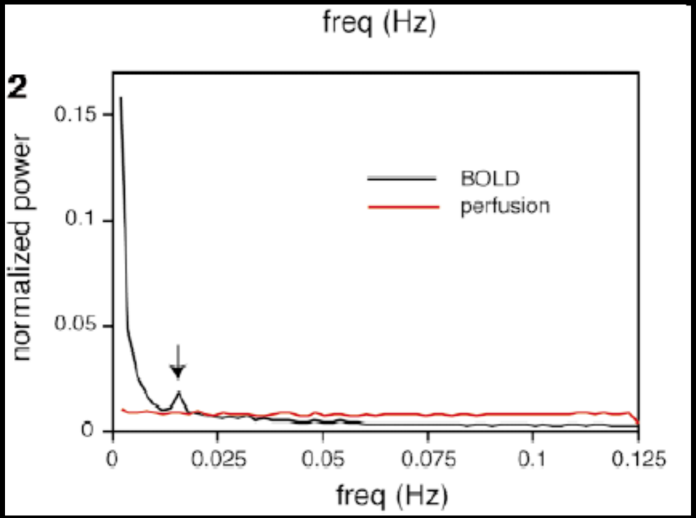
Other sources of functional contrast?

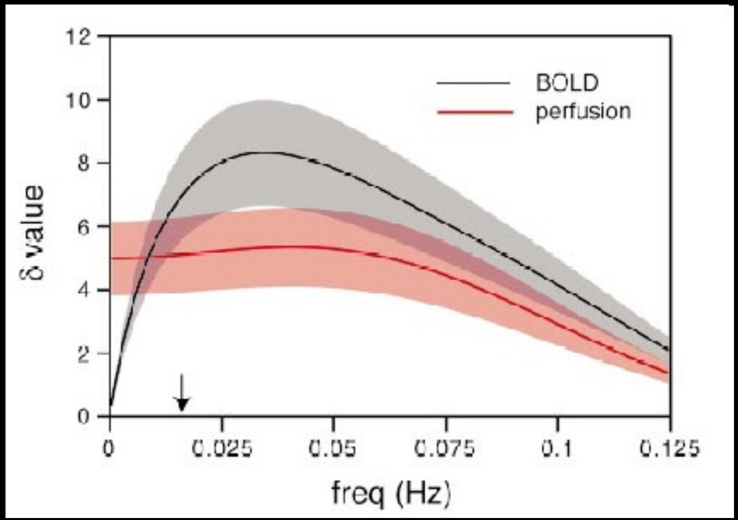
Non-ASL Perfusion



Perfusion Application

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





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

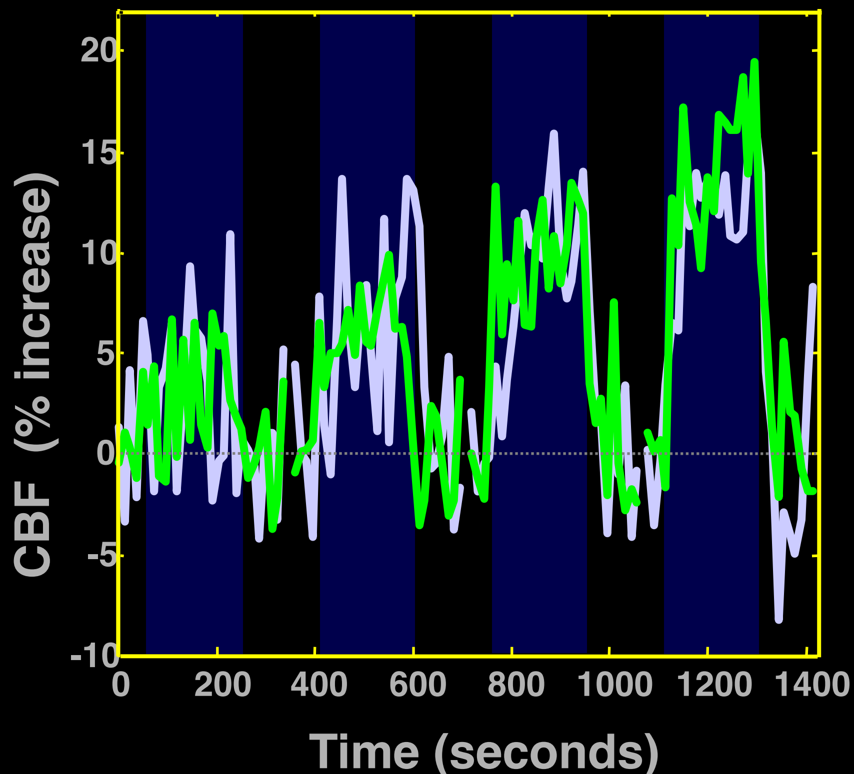
Proc. Natl. Acad. Sci. USA
Vol. 96, pp. 9403–9408, August 1999
Neurobiology

Linear coupling between cerebral blood flow and oxygen consumption in activated human cortex

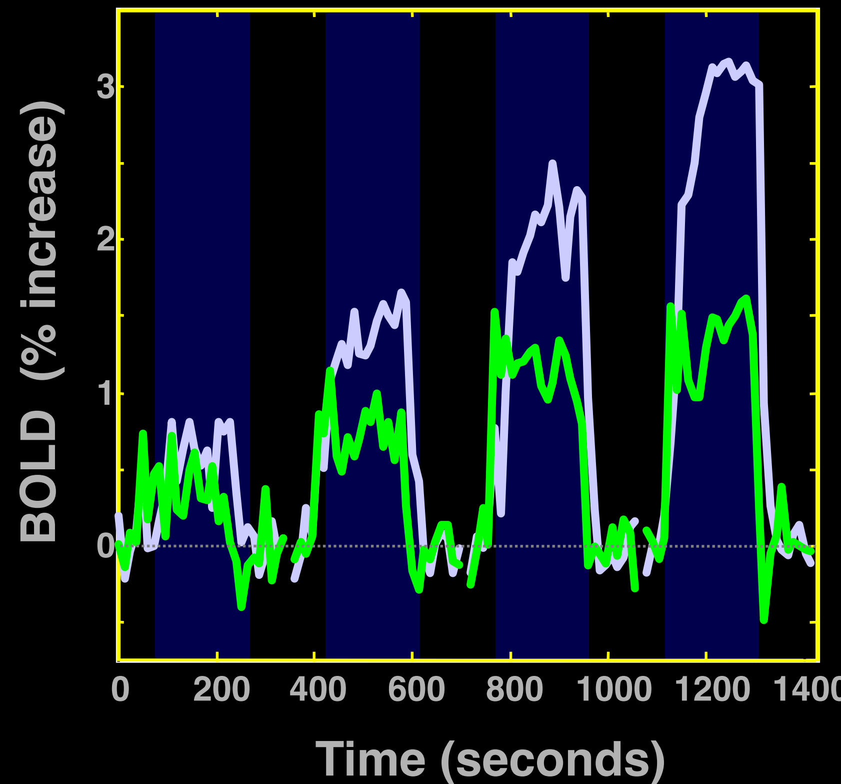
Richard D. Hoge*†, Jeff Atkinson*, Brad Gill*, Gérard R. Crelier*, Sean Marrett‡, and G. Bruce Pike*

*Room WB325, McConnell Brain Imaging Centre, Montreal Neurological Institute, Quebec, Canada H3A 2B4; and ‡Nuclear Magnetic Resonance Center, Massachusetts General Hospital, Building 149, 13th Street, Charlestown, MA 02129

CBF



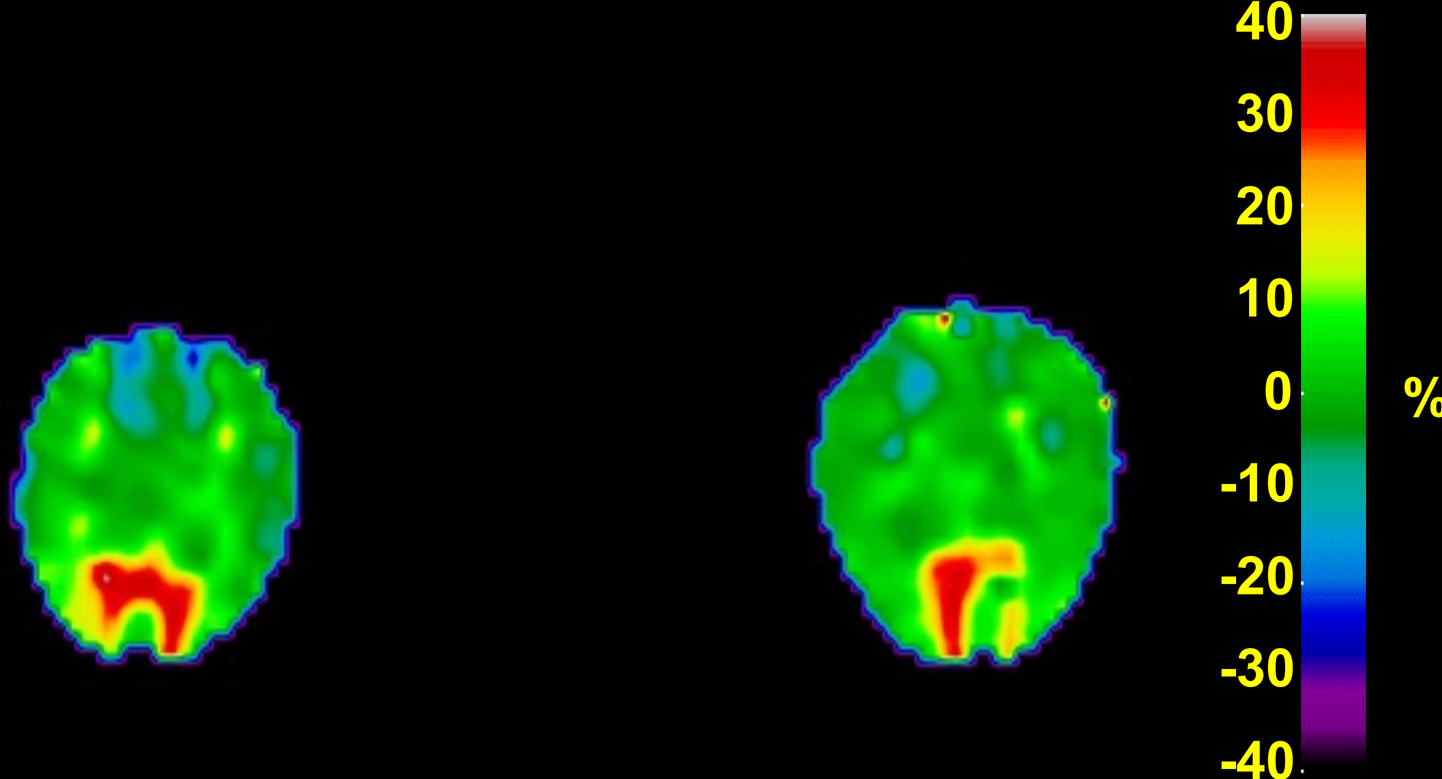
BOLD



Simultaneous Perfusion and BOLD imaging during graded visual activation and hypercapnia

N=12

Computed $CMRO_2$ Changes



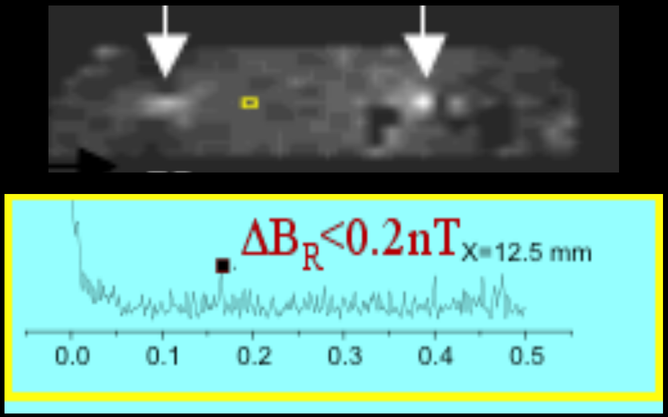
Subject 1

Subject 2

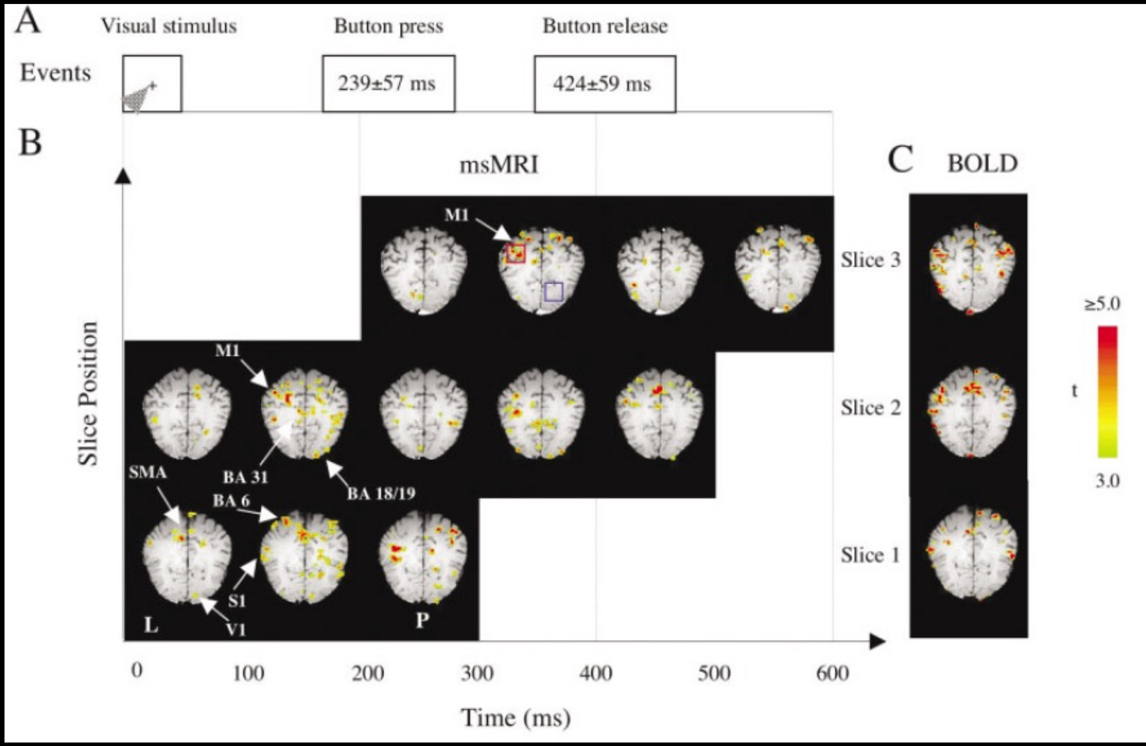
R. Hoge et al.

Other sources of functional contrast?

Direct Neuronal Current Imaging

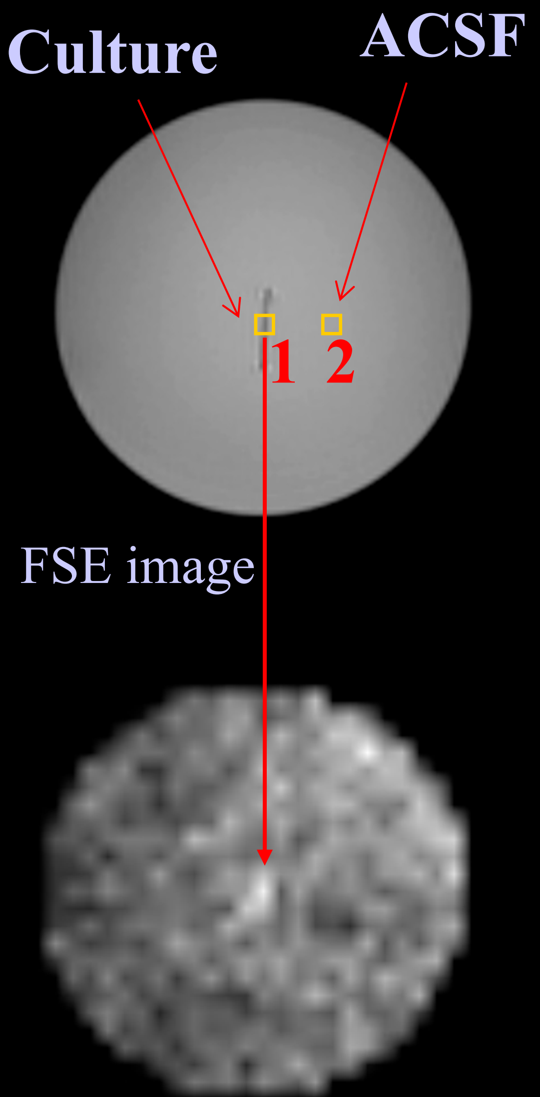


J. Bodurka, et al (2002). MRM 47: 1052-1058.

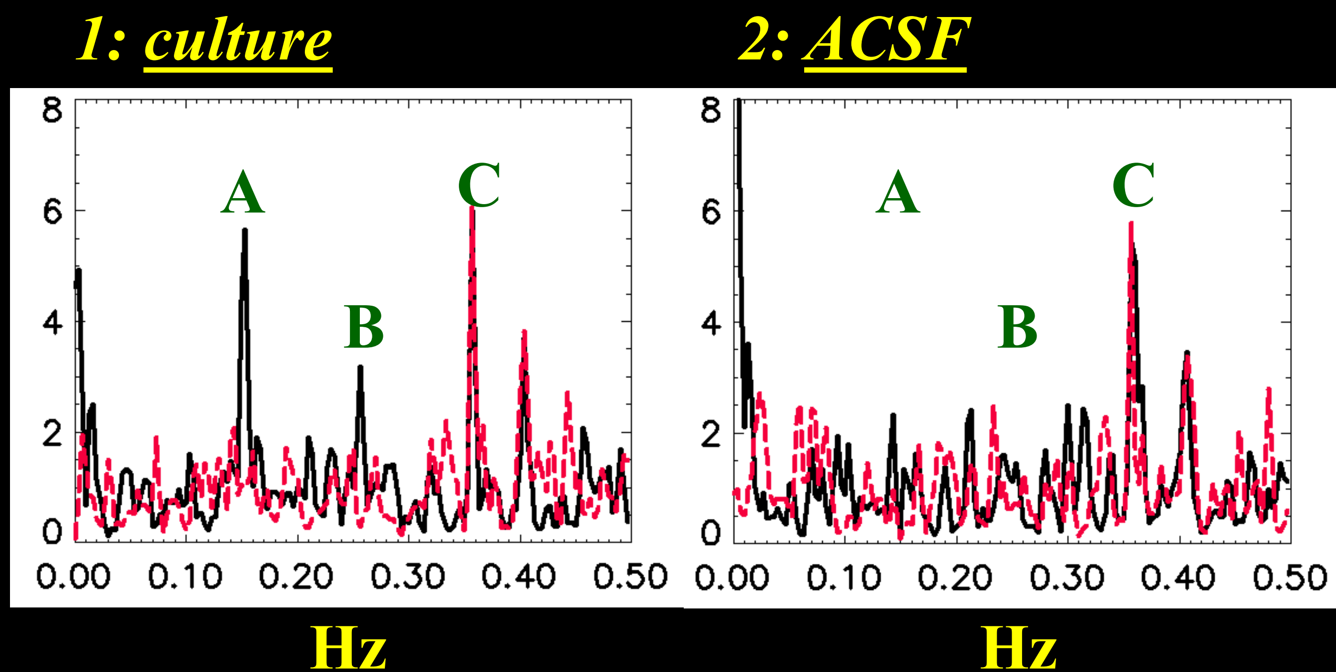


J. Xiong, et al. (2003) HBM, 20: 41-49.

In Vitro Results — Other sources of functional contrast?



0.15Hz map



Active condition: black line

Inactive condition: red line

A: 0.15 Hz activity, on/off frequency

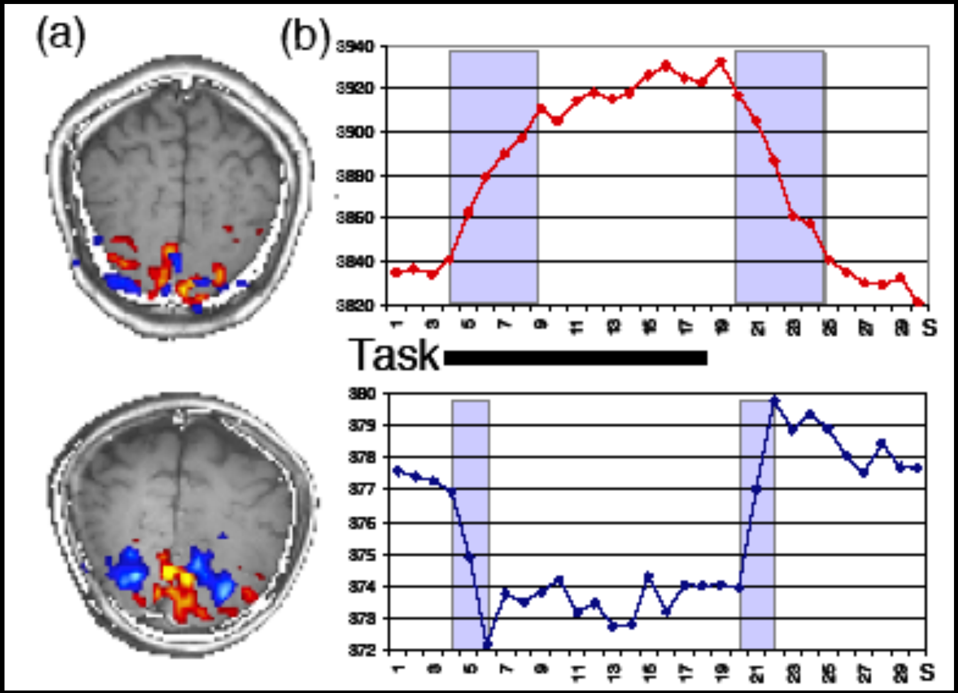
B: activity

C: scanner noise (cooling-pump)

Petridou, et al (2003), HBM

Other sources of functional contrast?

Diffusion coefficient (high b-factor)



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

Temperature:

Yablonskiy, D. A., J. J. H. Ackerman, et al. (2000). "Coupling between changes in human brain temperature and oxidative metabolism during prolonged visual stimulation." Proceedings of the National Academy of Sciences of the United States of America **97**(13): 7603-7608.

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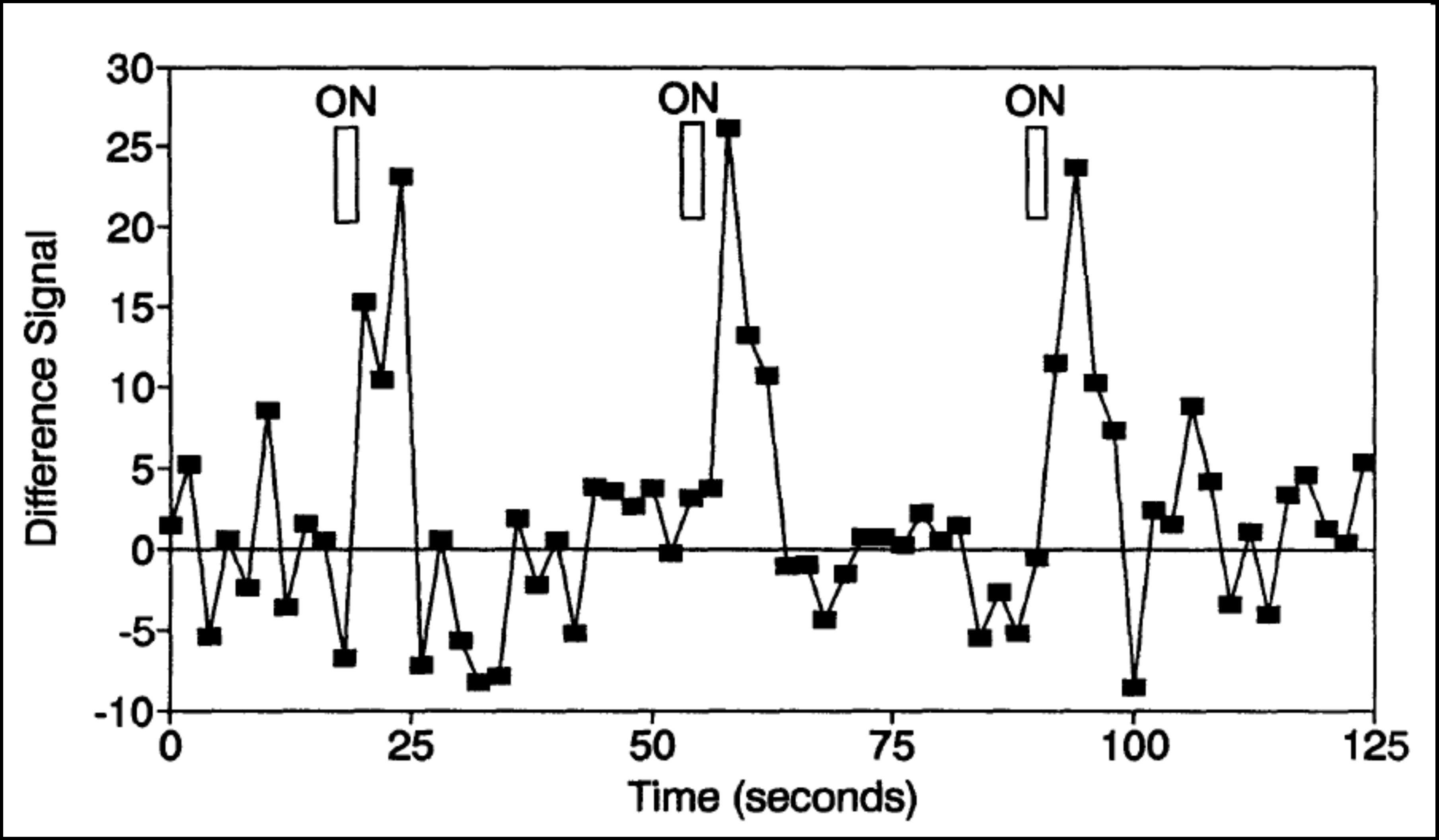
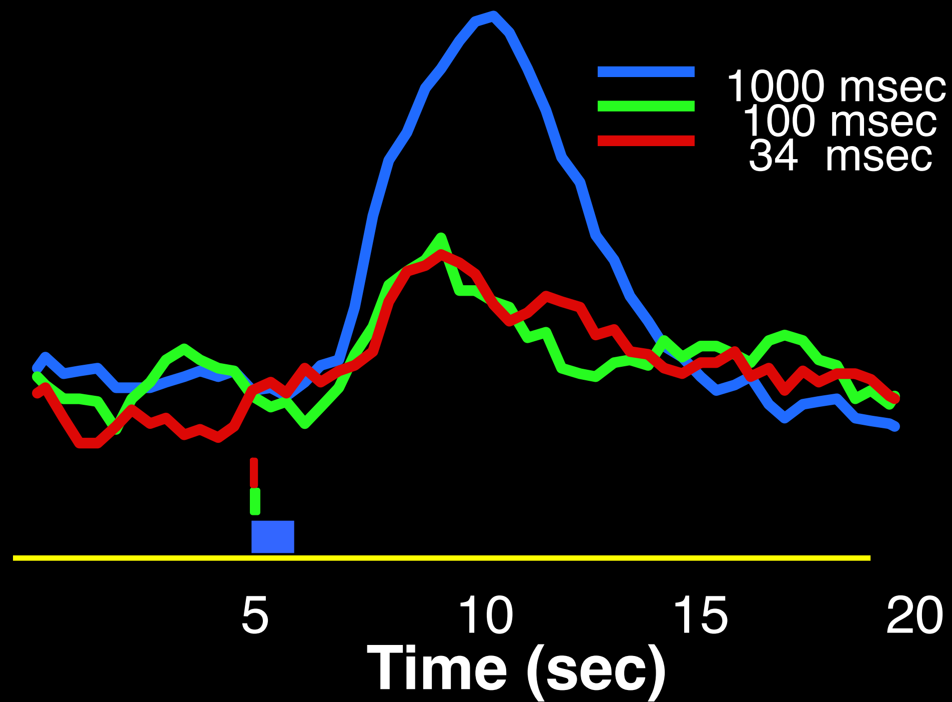
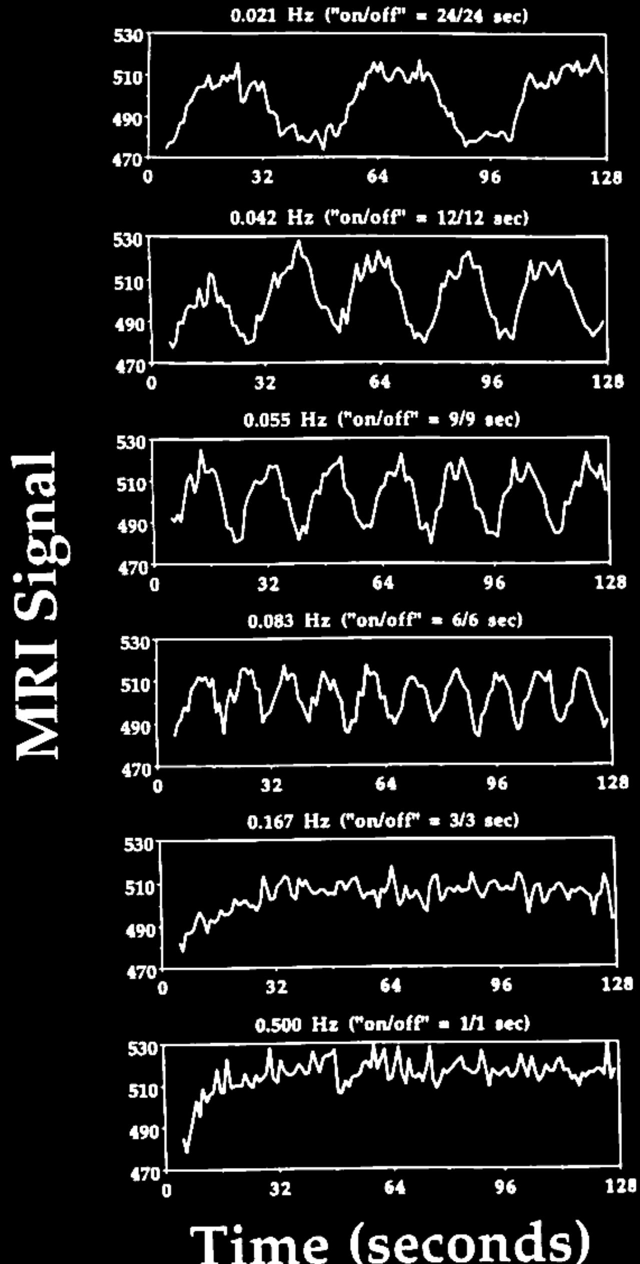
First Event-related fMRI Results

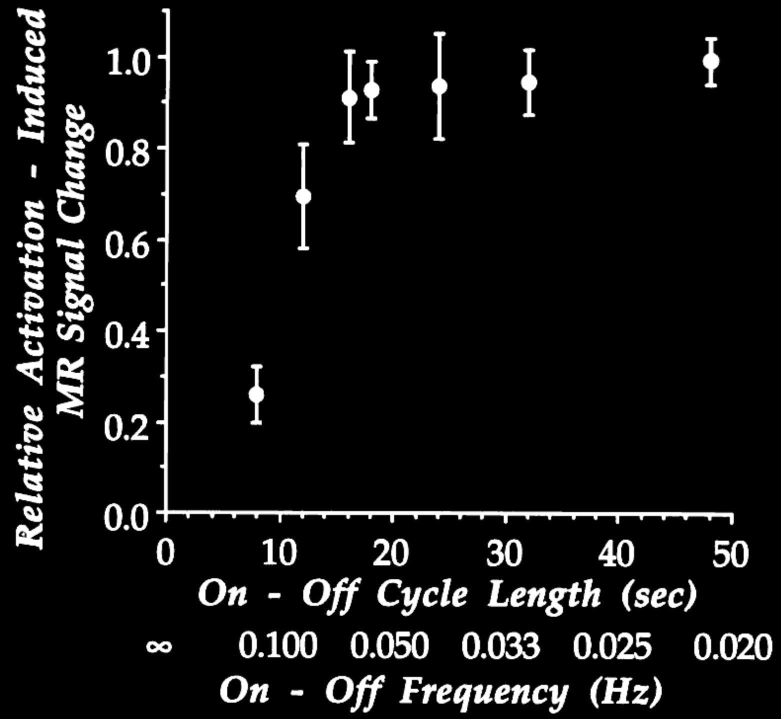


Blamire, A. M., et al. (1992). "Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging." Proc. Natl. Acad. Sci. USA 89: 11069-11073.



R. L. Savoy, et al., Pushing the temporal resolution of fMRI: studies of very brief visual stimuli, onset variability and asynchrony, and stimulus-correlated changes in noise [oral], 3'rd Proc. Soc. Magn. Reson., Nice, p. 450. (1995).



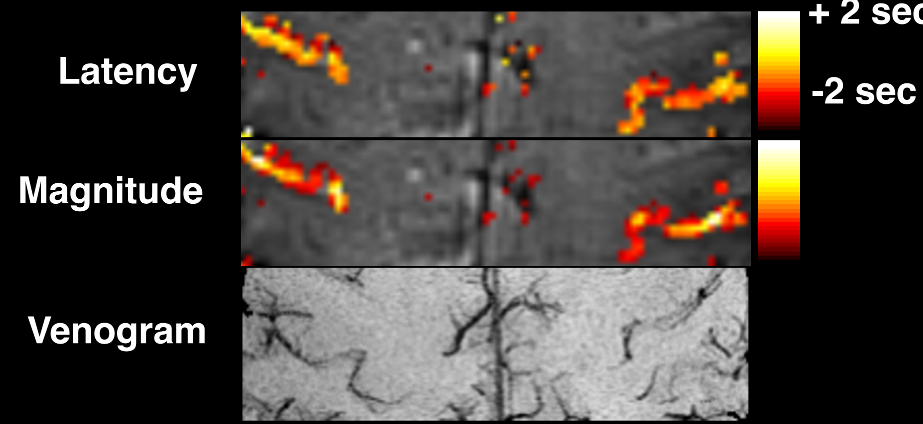


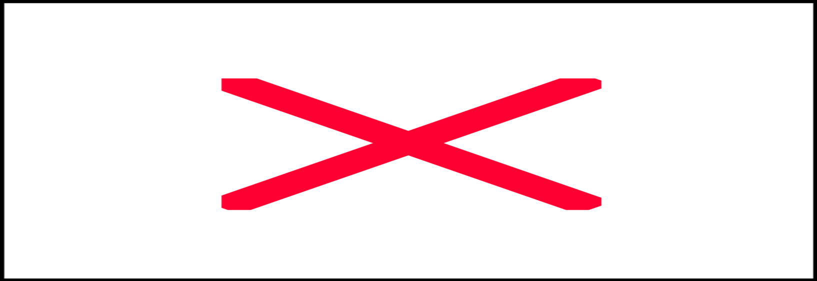
P. A. Bandettini, Functional MRI temporal resolution *in* "Functional MRI" (C. Moonen, and P. Bandettini., Eds.), p. 205-220, Springer - Verlag,. 1999.

Ultimate temporal resolution?

Voxel-wise hemodynamic variation

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	≈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.

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

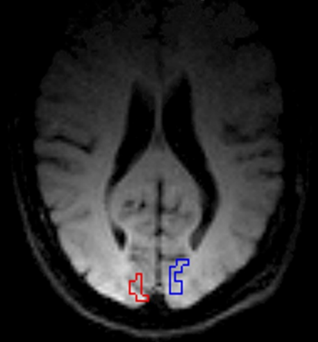
Relative dynamics obtained by precise activation timing modulation

Preliminary results:

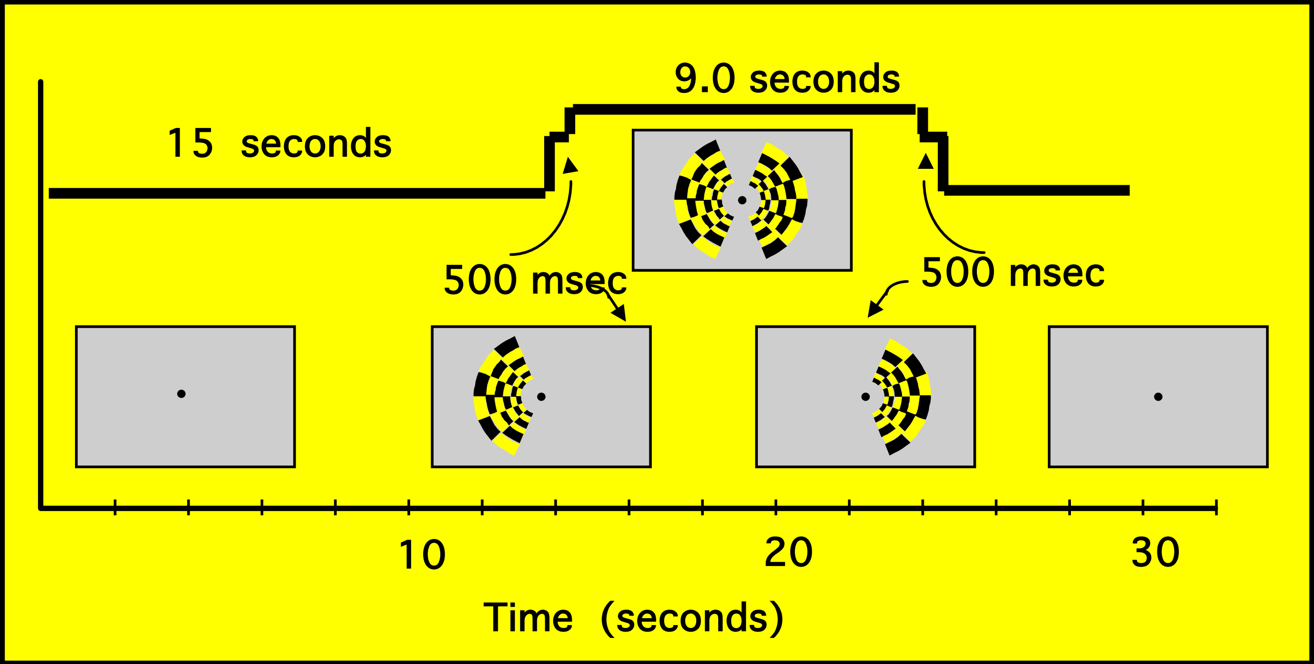
(with Savoy et al. ~ 1995)

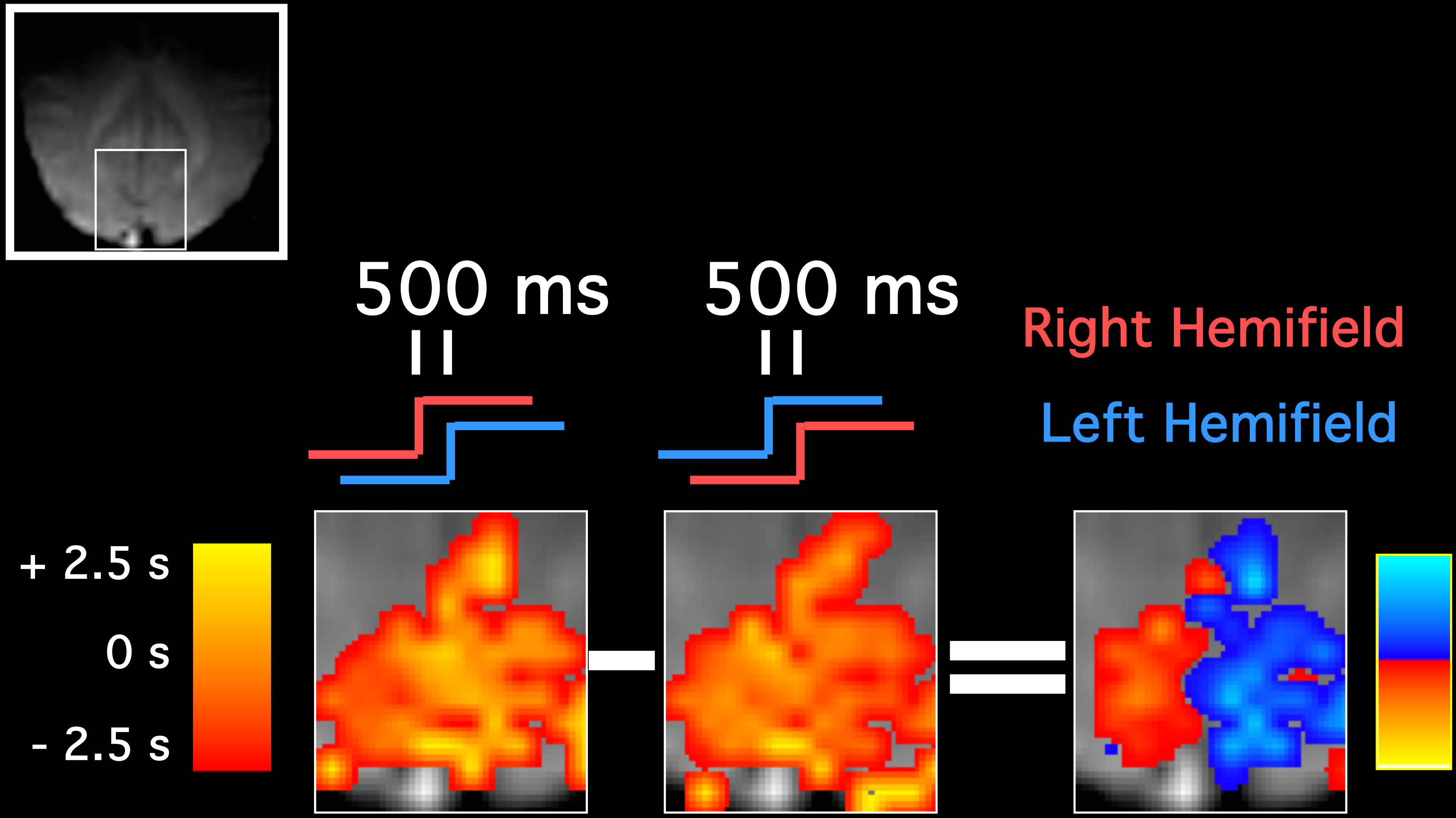
Hemi-Field Experiment

Left Hemisphere



Right Hemisphere



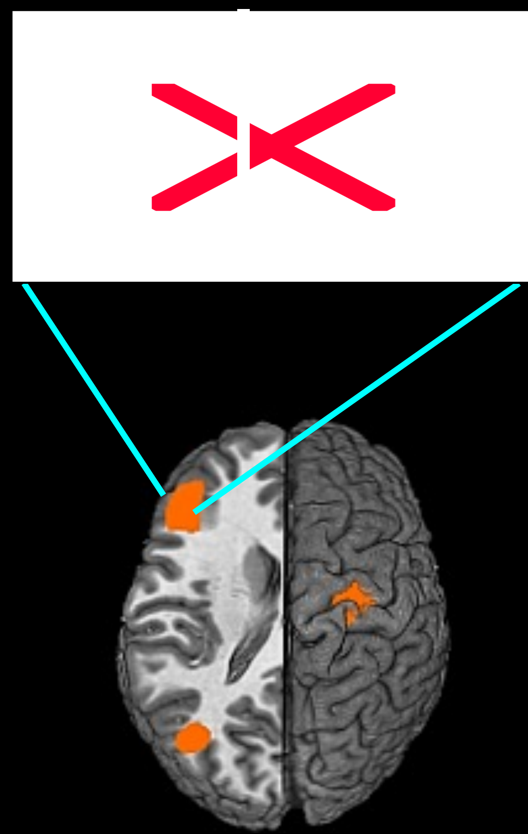

500 ms
500 ms
Right Hemifield
Left Hemifield
+ 2.5 s
0 s
- 2.5 s

Ultimate temporal resolution?

Task Timing Modulation

Word vs. Non-word

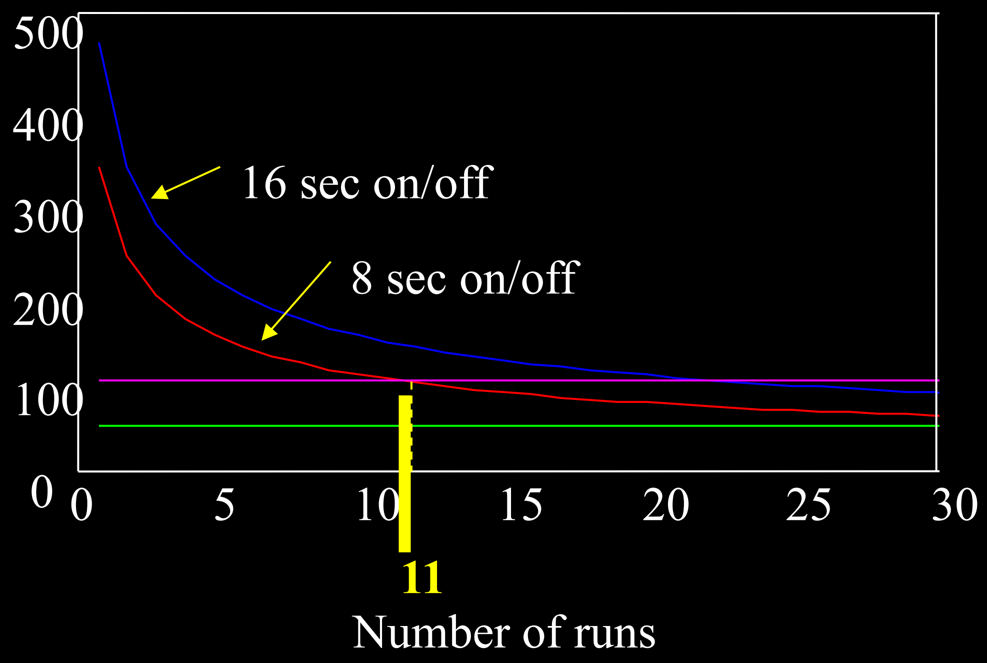
0°, 60°, 120° Rotation



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

Ultimate temporal resolution?

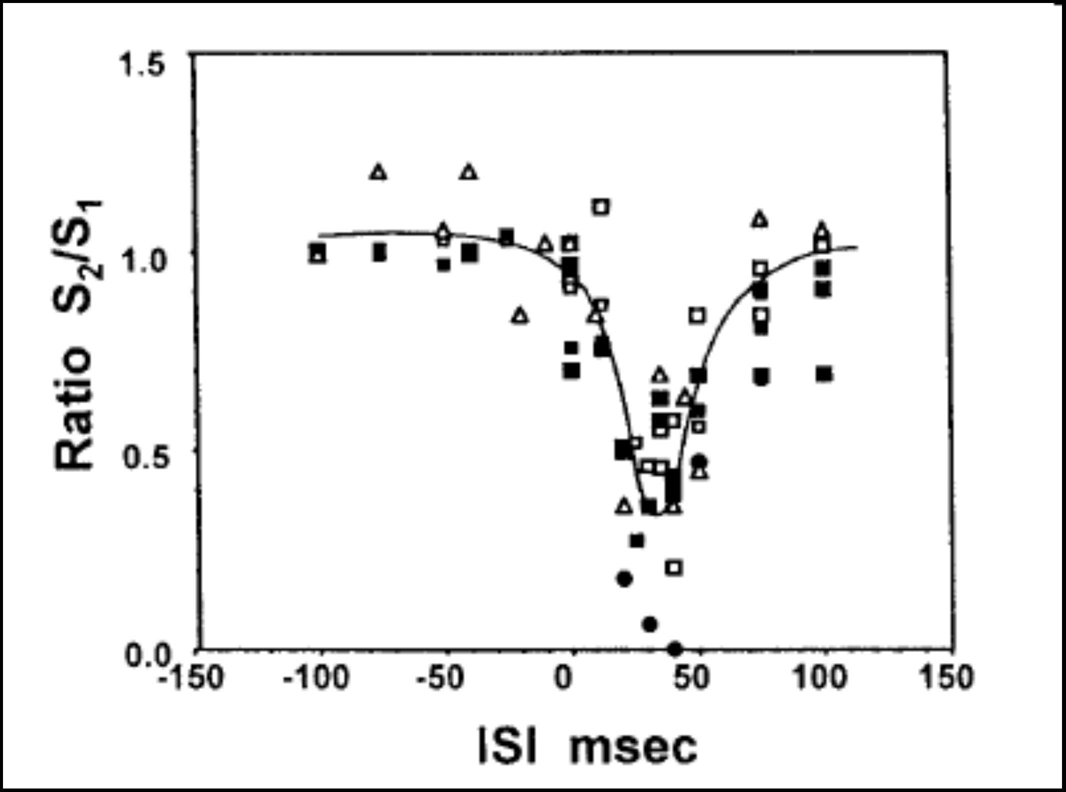
In an ideal world…no hemodynamic variation over space.



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

Ultimate temporal resolution?

Neuronal Communication Timing



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

The Biggest Unknowns in Functional MRI

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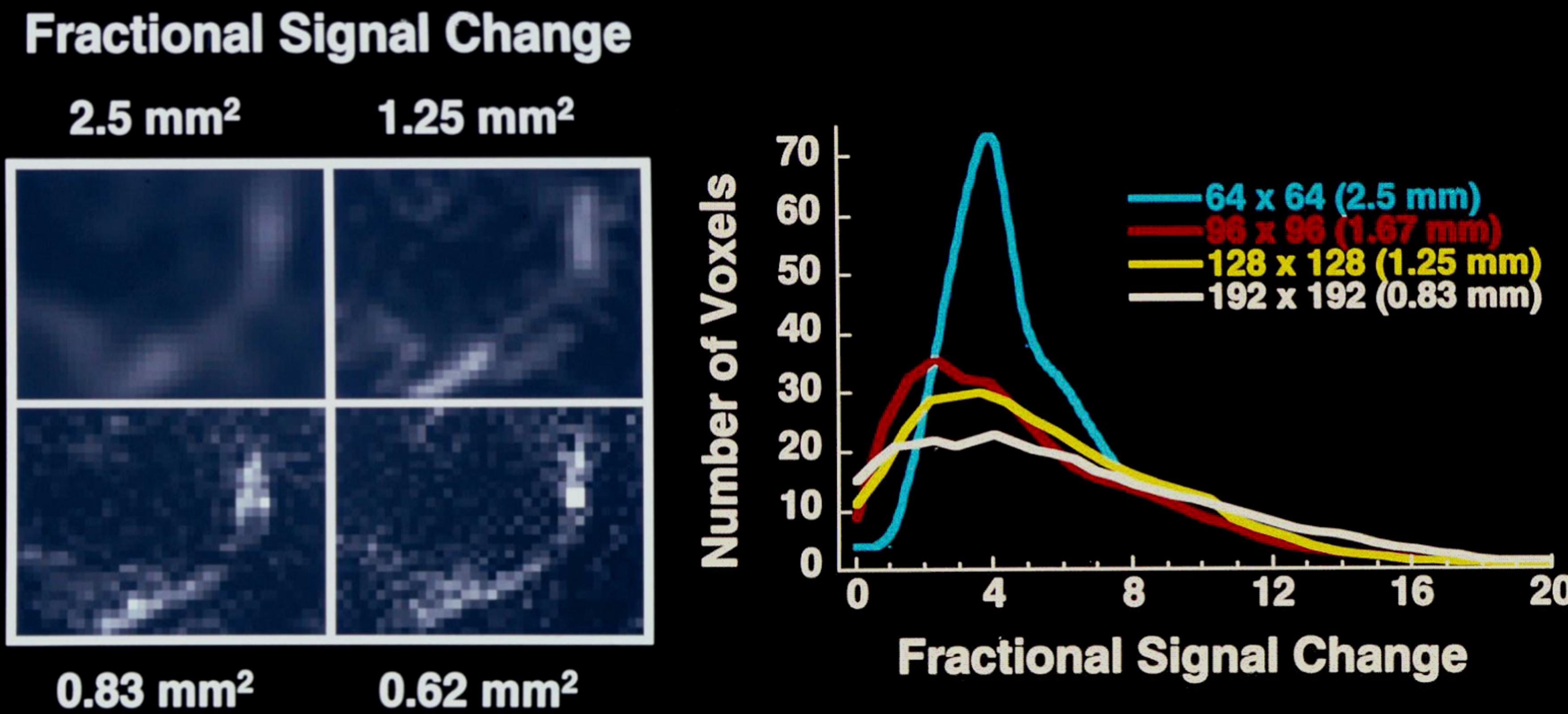
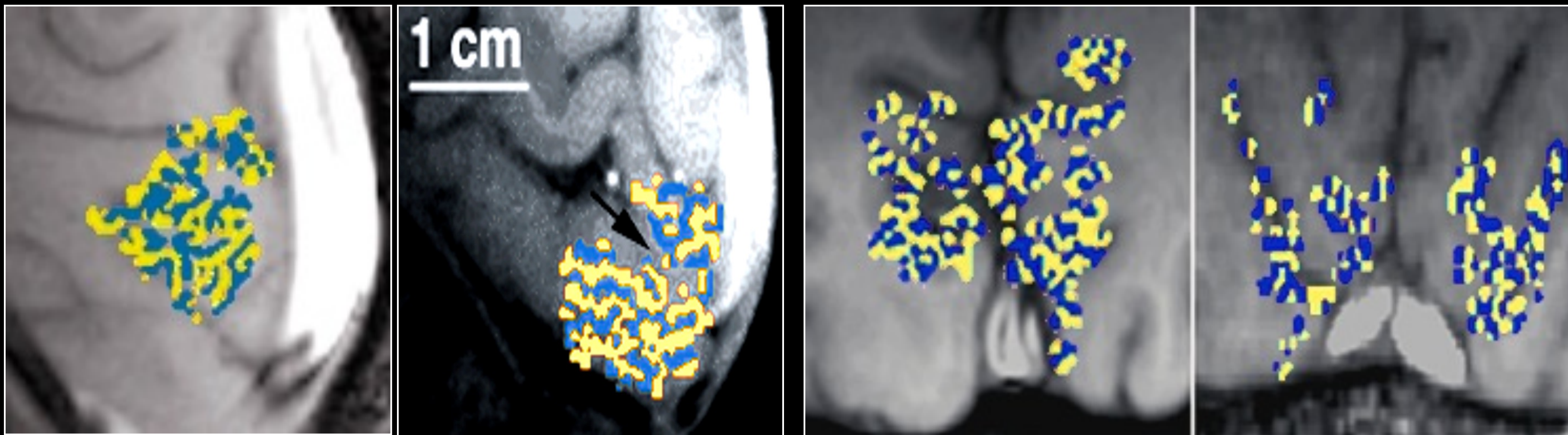
Magnitude

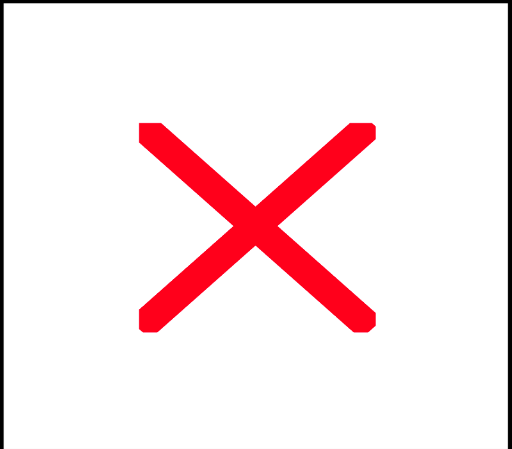


Jesmanowicz, P. A. Bandettini, J. S. Hyde, (1998) “Single shot half k-space high resolution EPI for fMRI at 3T.” *Magn. Reson. Med.* 40, 754-762.

Ocular Dominance Column Mapping using fMRI



Menon, R. S., S. Ogawa, et al. (1997). "Ocular dominance in human V1 demonstrated by functional magnetic resonance imaging." J Neurophysiol 77(5): 2780-7.



Optical Imaging

R. D. Frostig et. al, PNAS 87: 6082-6086, (1990).

Neuron, Vol. 32, 359–374, October 25, 2001, Copyright ©2001 by Cell Press

Human Ocular Dominance Columns as Revealed by High-Field Functional Magnetic Resonance Imaging

Kang Cheng,[1] R. Allen Waggoner, and Keiji Tanaka
Laboratory for Cognitive Brain Mapping
RIKEN Brain Science Institute and
CREST
Japan Science and Technology Corporation
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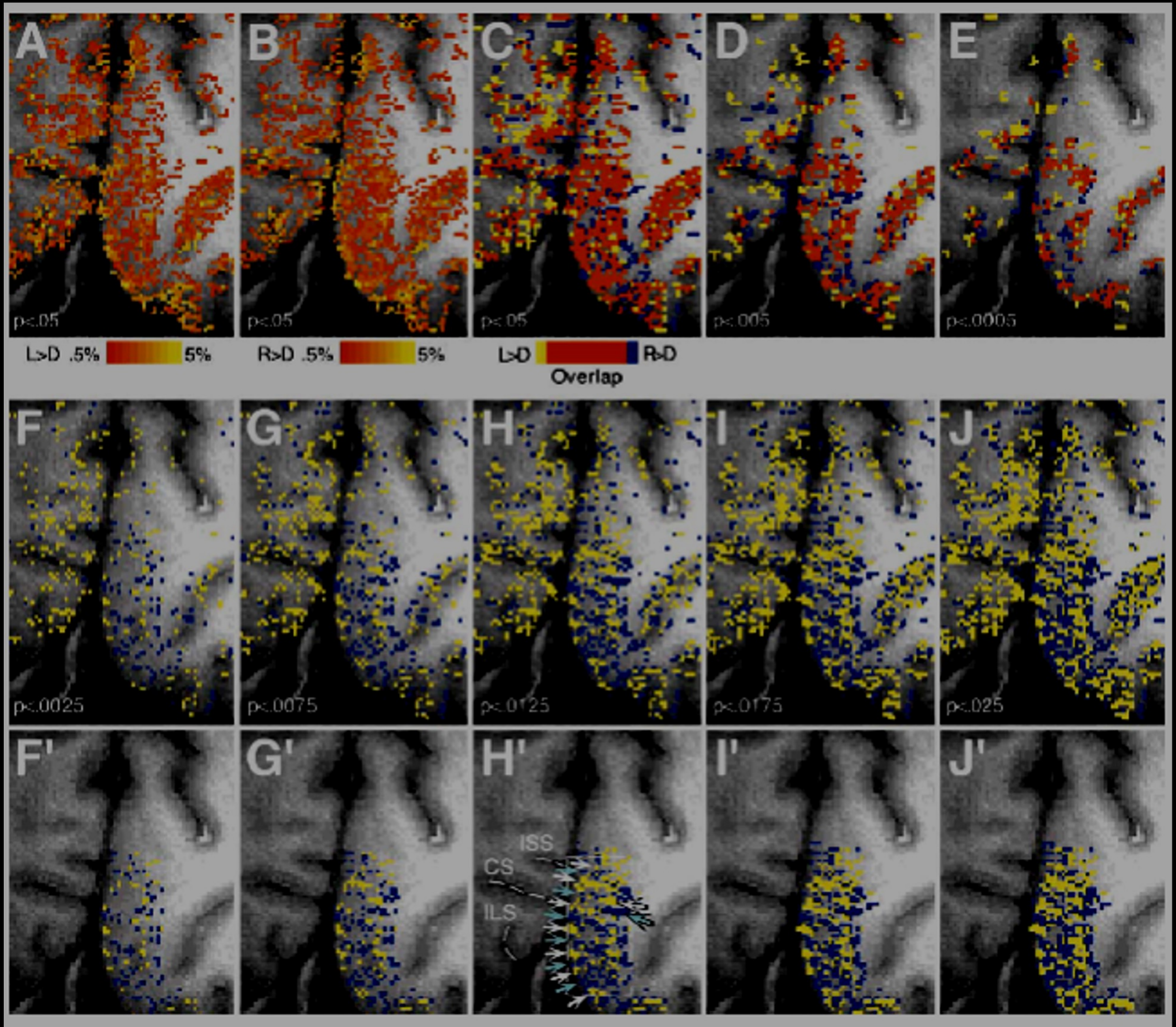
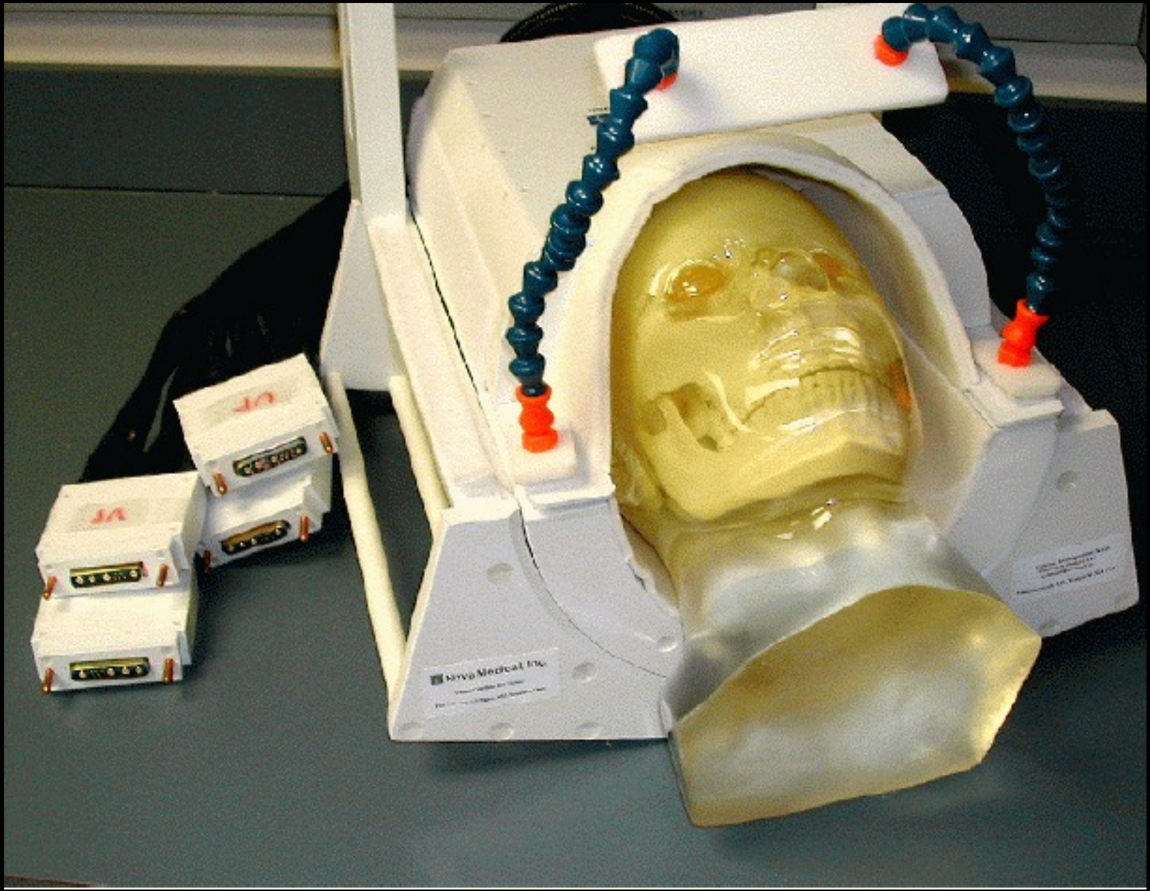
Japan



Parallel acquisition (16 radio frequency channels)

Custom-built
Radio-frequency
(RF) coil

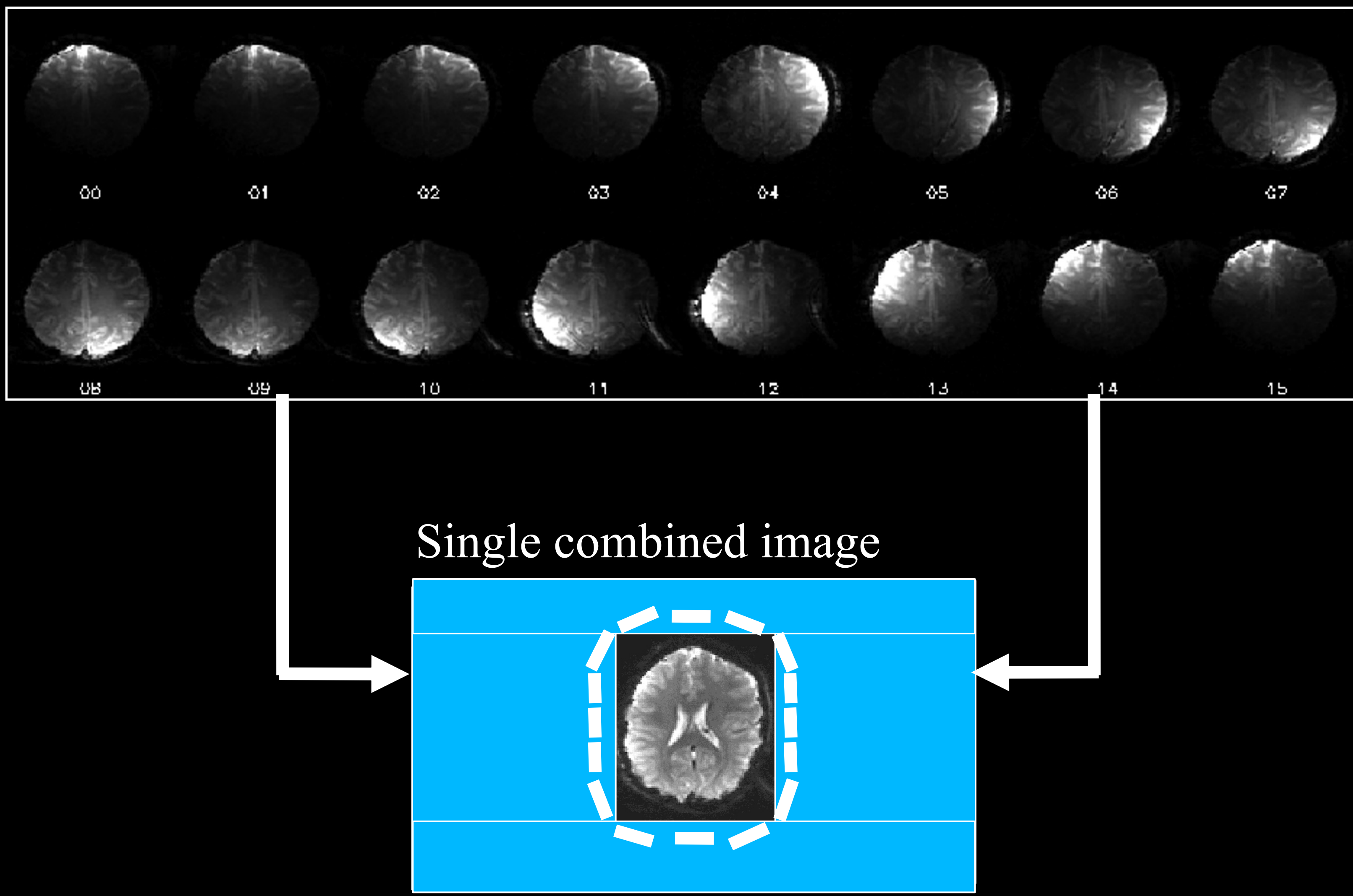


Nova Medical, Inc.

Parallel acquisition (16 radio frequency channels)

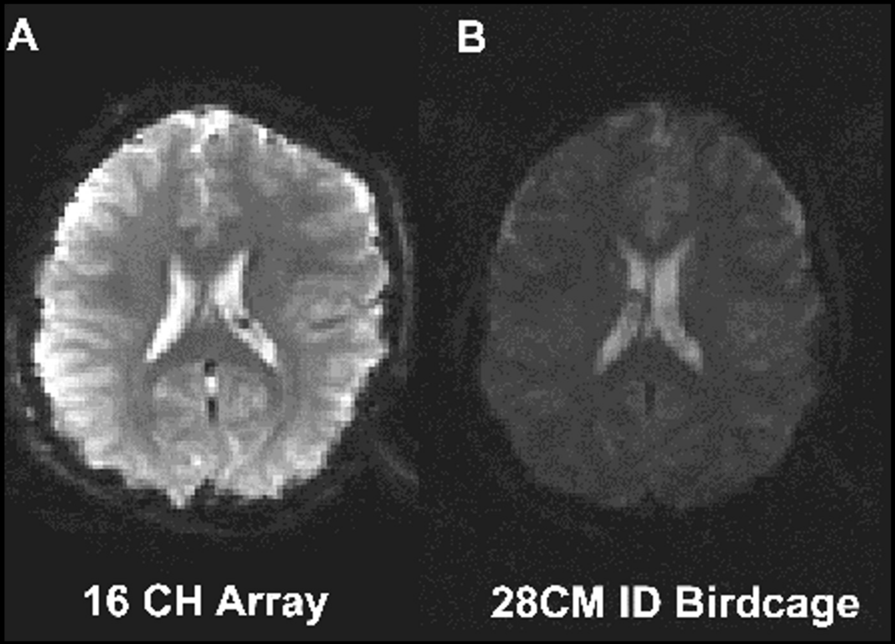
Receiver
Hardware

Individual coil images



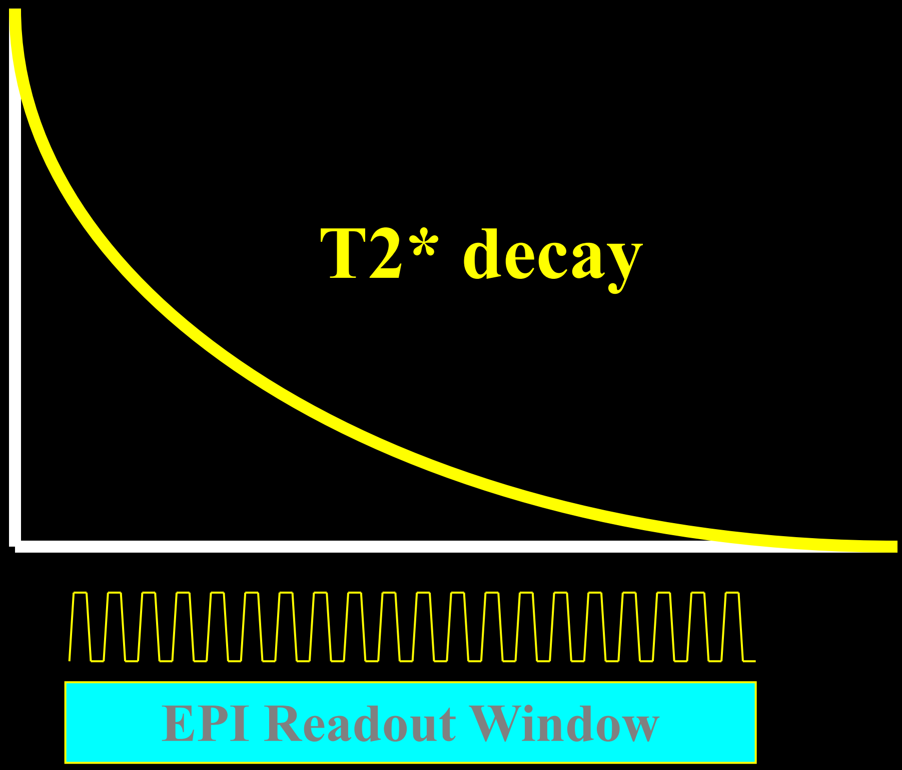
Parallel acquisition (16 radio frequency channels)

Large improvement in signal-to-noise ratio (SNR)

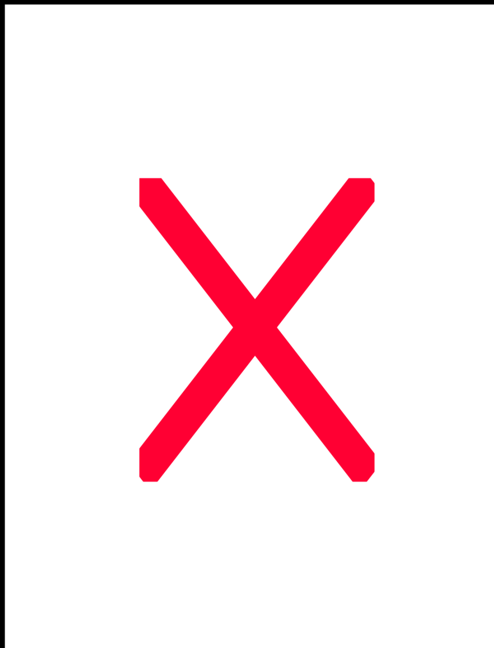


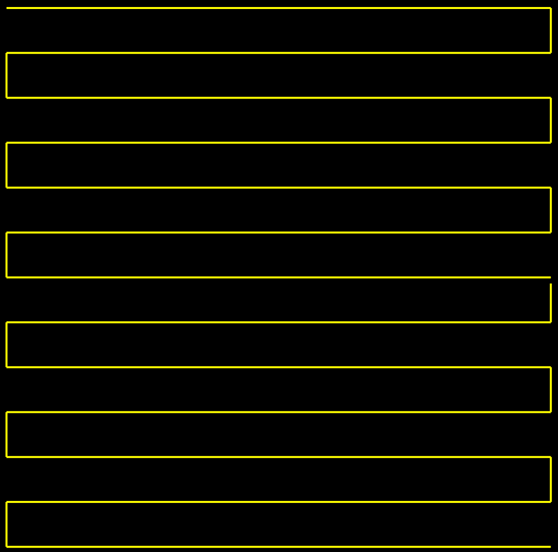
- Increased resolution
- Increased imaging speed
- Increased sensitivity

Single Shot EPI

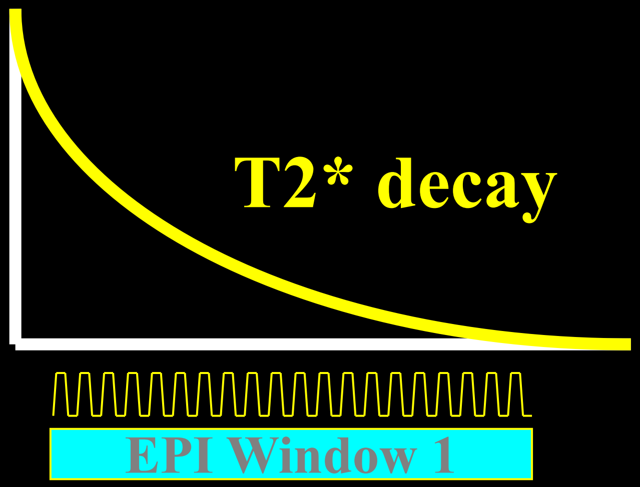


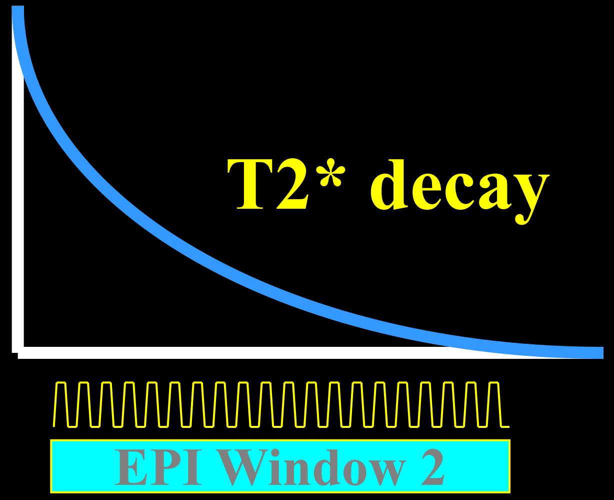
≈ 20 to 40 ms

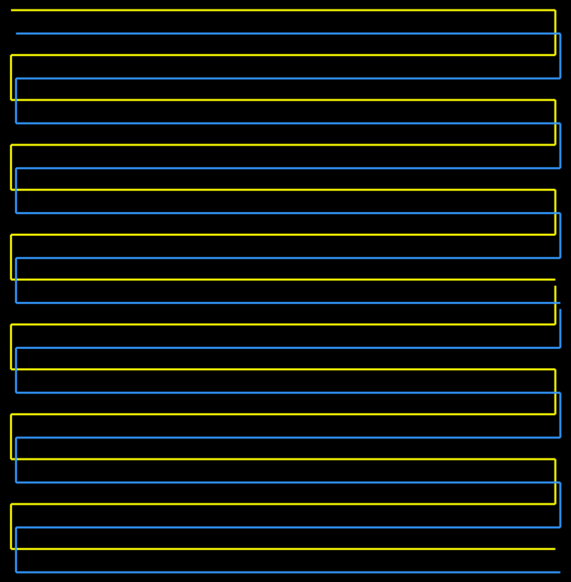




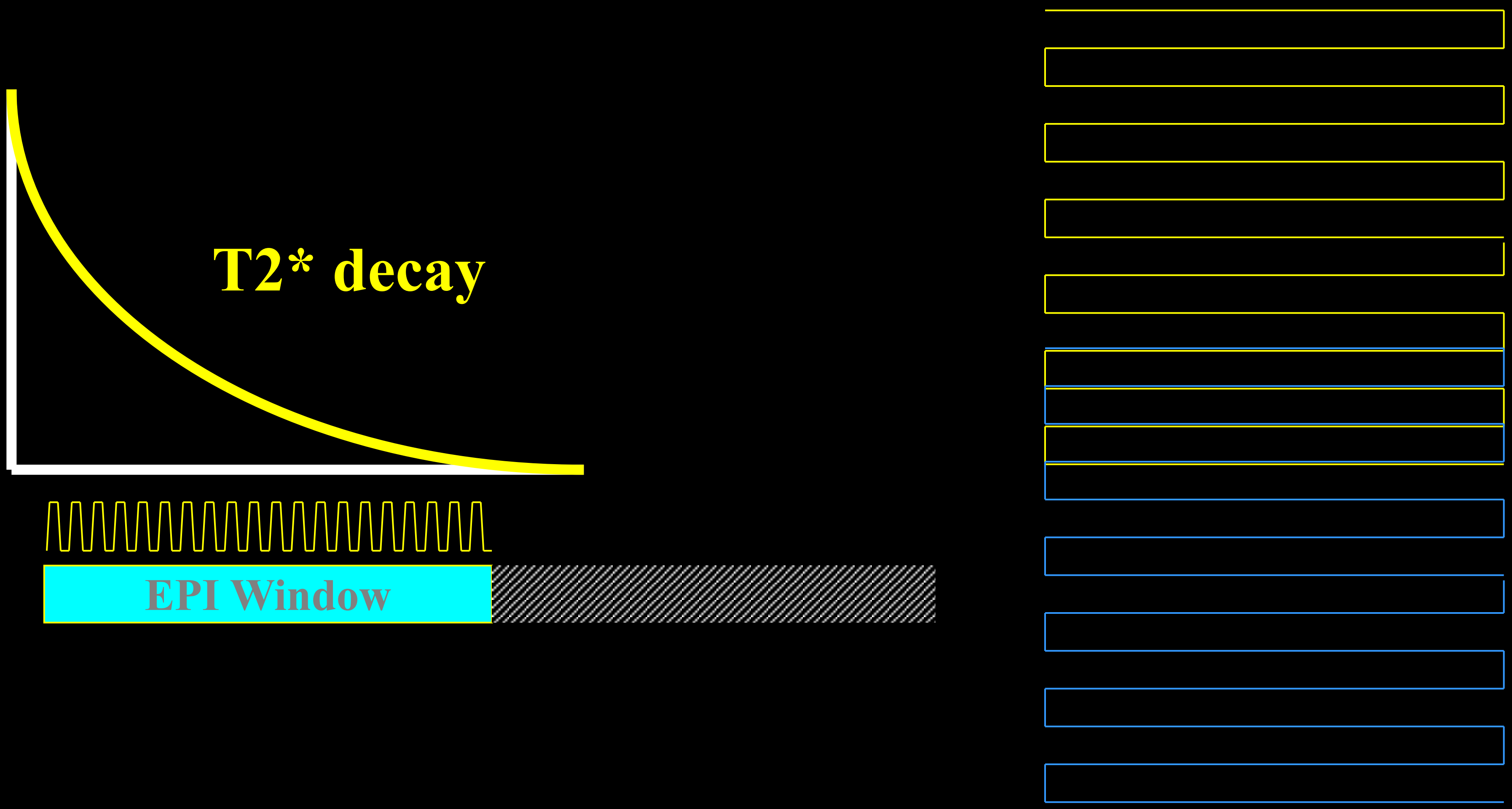
Multishot Imaging



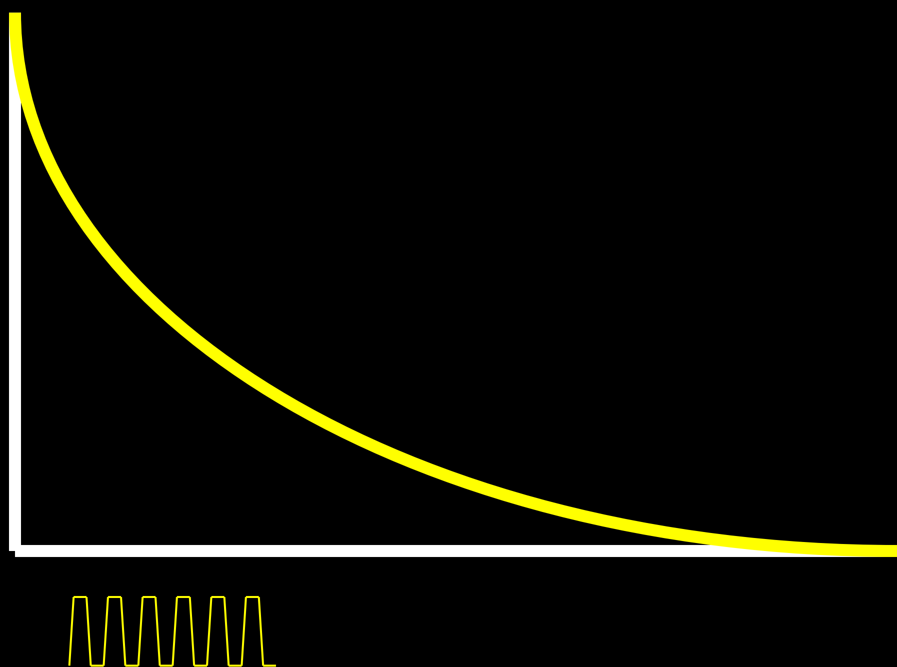




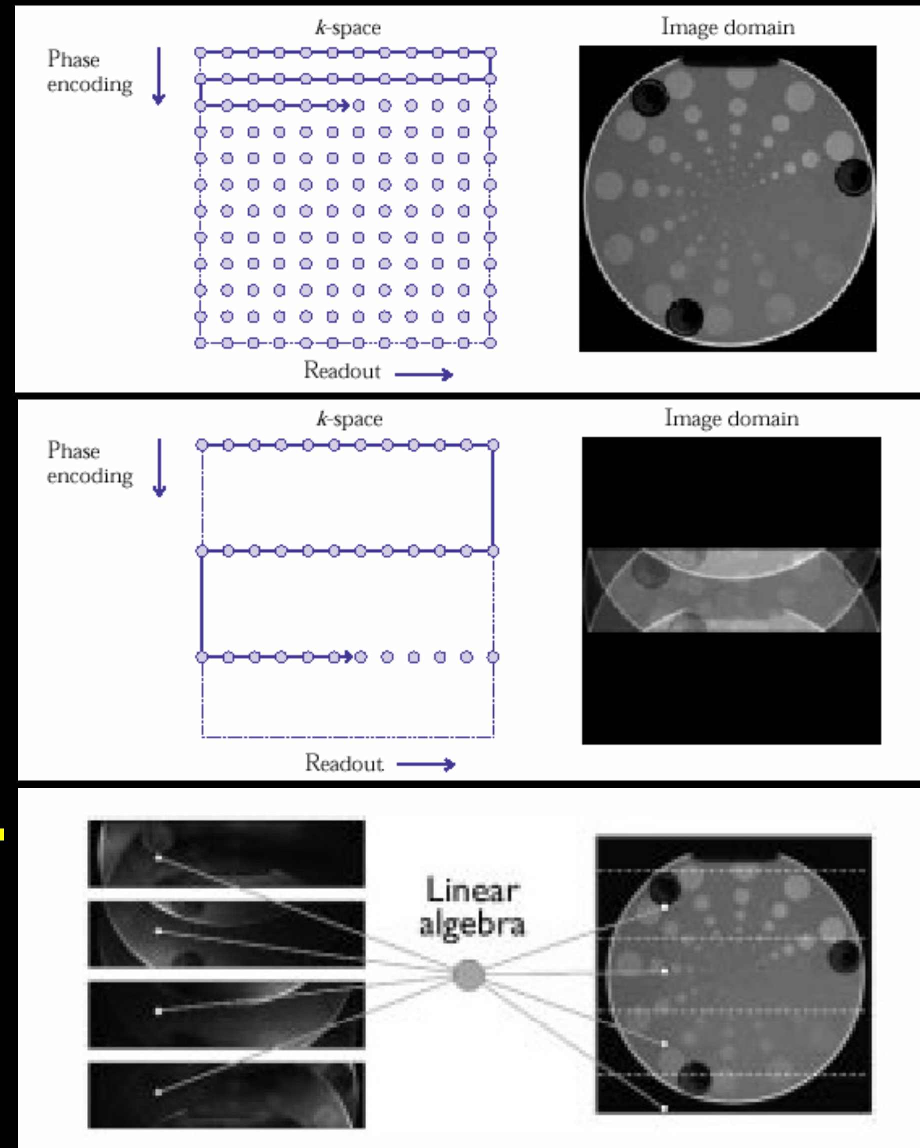
Partial k-space imaging



SENSE Imaging



≈ 5 to 30 ms

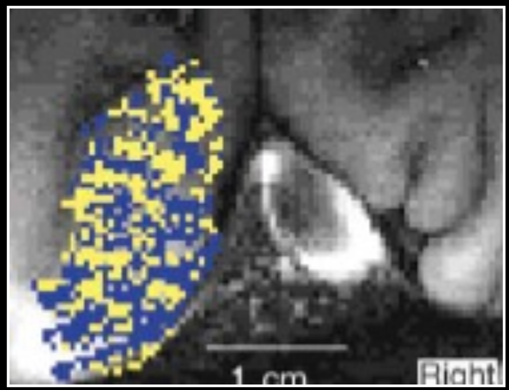


Pruessmann, et al.

Ultimate spatial resolution?

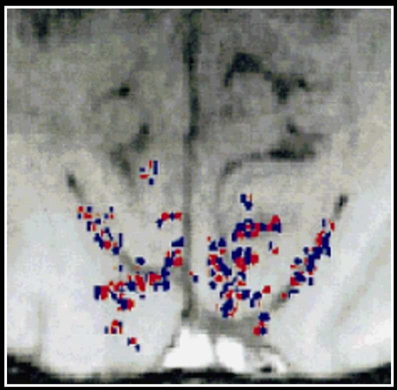
Resolving columns with single shot EPI is a goal..

0.47 x 0.47 in plane resolution



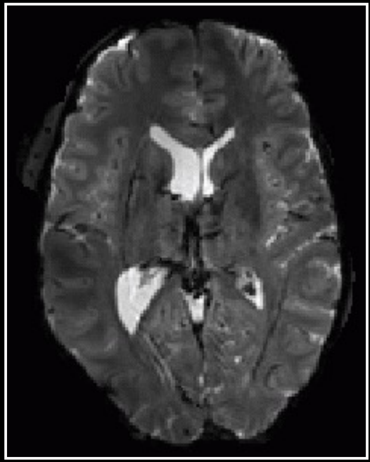
Cheng, et al. (2001) Neuron,32:359-374

0.54 x 0.54 in plane resolution



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

Multi-shot with navigator pulse



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

…using SENSE, 32 channels, 7T,
and perhaps partial k-space we might get to 0.5 mm^3

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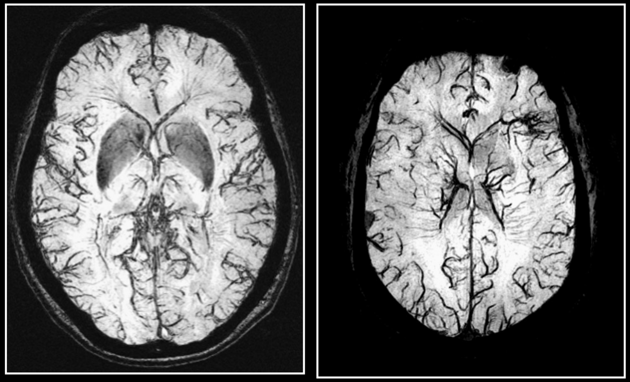
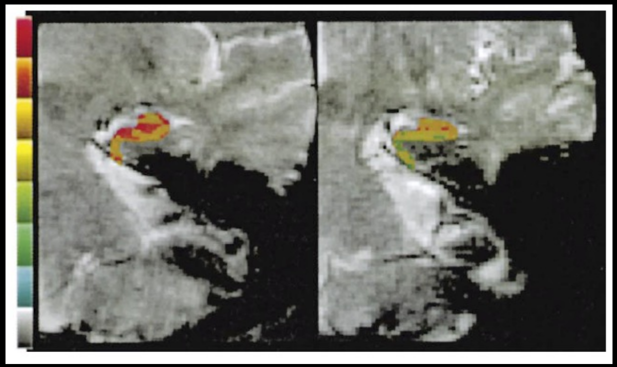
Ultimate clinical utility?

Needs:

- Real time feedback
- Characterization of confounding effects
- Robust yet incisive set of probe tasks
- Baseline information?

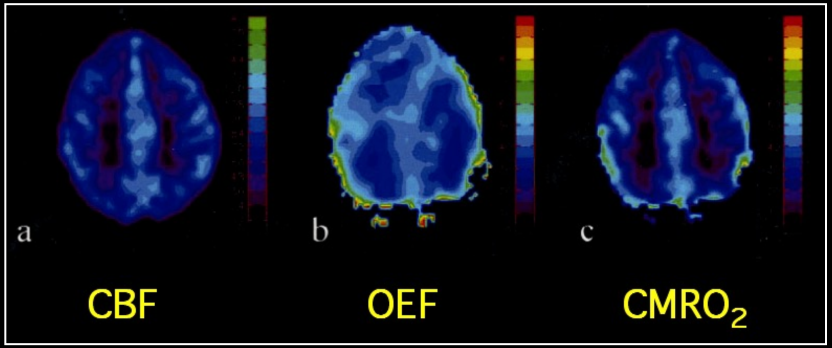


Bove-Bettis, et al (2004), SMRT



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

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Best processing and display methods?

Processing

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 processing and display methods?

Display

To convey:

-collapsed multidimensional data

-sense of data quality

Surface

Glass brain

ROI

Time courses

Example slices

Connectivity maps?

“Quality” index?

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Optimal Field Strength?

Utility vs. Difficulty

Difficulty:

Shimming (generally lower T2 and T2*)
RF penetration effects
Stability

Utility:

Higher SNR
Better susceptibility contrast
Better ASL perfusion contrast (longer T1)

Functional Imaging Methods Unit
&
Functional MRI Facility

fim.nimh.nih.gov

fmrif.nimh.nih.gov

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Adam Thomas

Staff Scientists:
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Wen-Ming Luh
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Post Docs:
Hauke Heekeren
David Knight
Anthony Boemio
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Scanning Technologists:
Karen Bove-Bettis
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Ellen Condon

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Kay Kuhns

Graduate Student:
Natalia Petridou

Unit on Functional Imaging & FMRI Core Facility

http://sodium.nimh.nih.gov/upload

T165.ppt