Functional MRI

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Unit on Functional Imaging Methods
&
3T Neuroimaging Core Facility

Laboratory of Brain and Cognition
National Institute of Mental Health

Alternating Left and Right Finger Tapping

~ 1992

A short background..

L. Pauling, C. D. Coryell, (1936) “The magnetic properties and structure of hemoglobin, oxyhemoglobin, and carbonmonoxyhemoglobin.” Proc.Natl. Acad. Sci. USA 22, 210-216.

Thulborn, K. R., J. C. Waterton, et al. (1982).“Oxygenation dependence of the transverse relaxation time of water protons in whole blood at high field.” Biochim. Biophys. Acta. 714: 265-270.

S. Ogawa, T. M. Lee, A. R. Kay, D. W. Tank, (1990) “Brain magnetic resonance imaging with contrast dependent on blood oxygenation.” Proc. Natl. Acad. Sci. USA 87, 9868-9872.

R. Turner, D. LeBihan, C. T. W. Moonen, D. Despres, J. Frank, (1991). Echo-planar time course MRI of cat brain oxygenation changes. Magn. Reson. Med. 27, 159-166.

Functional MRI Methods

Blood Volume Imaging

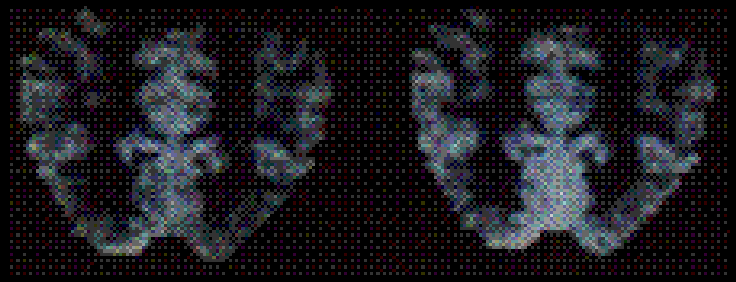
BOLD Contrast

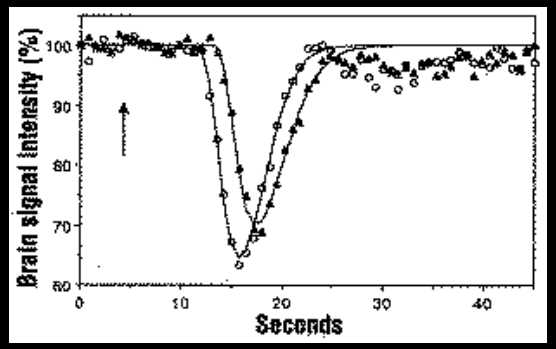
Arterial Spin Labeling

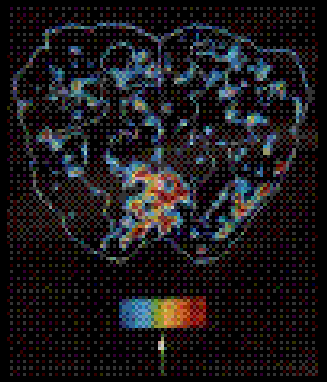
Blood Volume Imaging

Susceptibility Contrast agent bolus injection and time series collection of T2* or T2 - weighted images

Resting Active

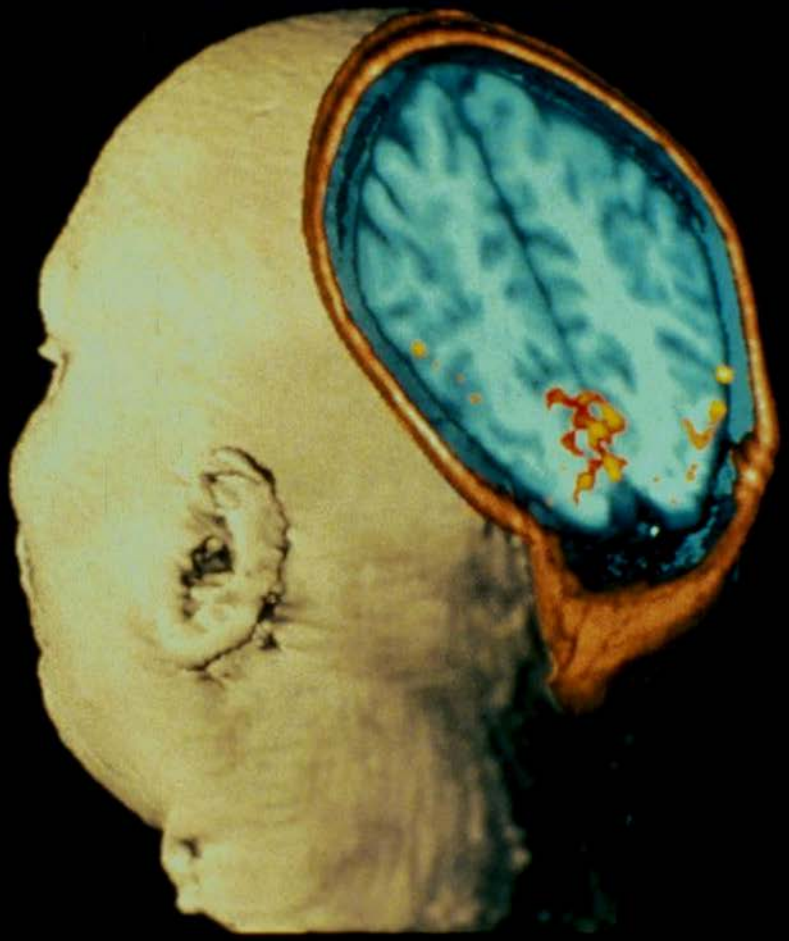






Blood Volume

Photic Stimulation



MRI Image showing activation of the Visual Cortex

From Belliveau, et al. Science Nov 1991

BOLD Contrast in the Detection of Neuronal Activity

Cerebral Tissue Activation

↓

Local Vasodilation

↓

Increase in Cerebral Blood Flow and Volume → Oxygen Delivery Exceeds Metabolic Need

↓

Increase in Capillary and Venous Blood Oxygenation

↓

Decrease in Deoxy-hemoglobin

Deoxy-hemoglobin: paramagnetic
Oxy-hemoglobin: diamagnetic

↓

Decrease in susceptibility-related intravoxel dephasing → Increase in T2 and T2*

↓

Local Signal Increase in T2 and T2* - weighted sequences

Alternating Left and Right Finger Tapping

~ 1992

K. K. Kwong, et al, (1992) "Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation." Proc. Natl. Acad. Sci. USA. 89, 5675-5679.

S. Ogawa, et al., (1992) "Intrinsic signal changes accompanying sensory stimulation: functional brain mapping with magnetic resonance imaging. Proc. Natl. Acad. Sci. USA." 89, 5951-5955.

P. A. Bandettini, et al., (1992) "Time course EPI of human brain function during task activation." Magn. Reson. Med 25, 390-397.

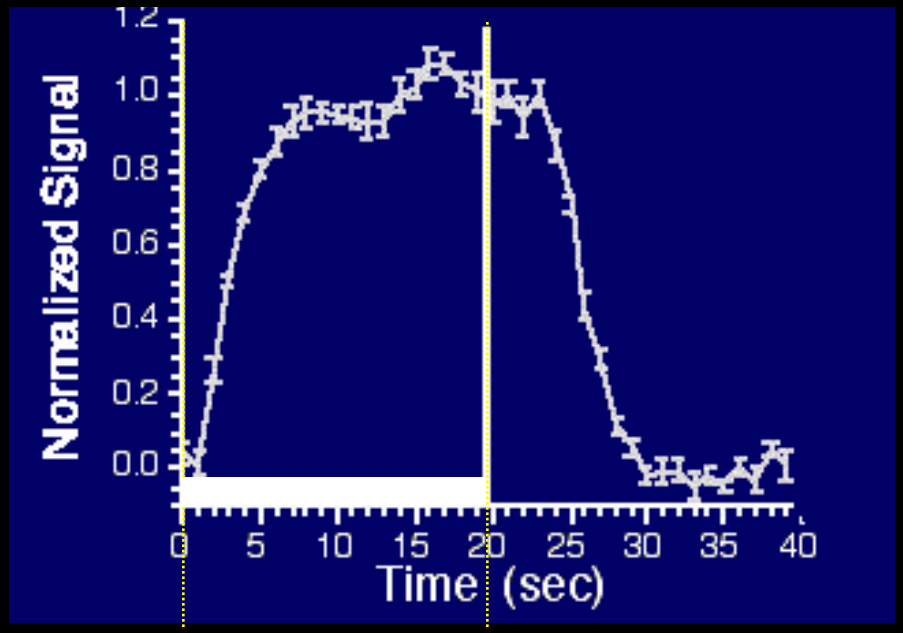
Blamire, A. M., et al. (1992). "Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging." Proc. Natl. Acad. Sci. USA 89: 11069-11073.

Correlation analysis, Fourier analysis, t-test, f-test...
SPM, AFNI, brain voyager, FIASCO, FSL, free surfer...

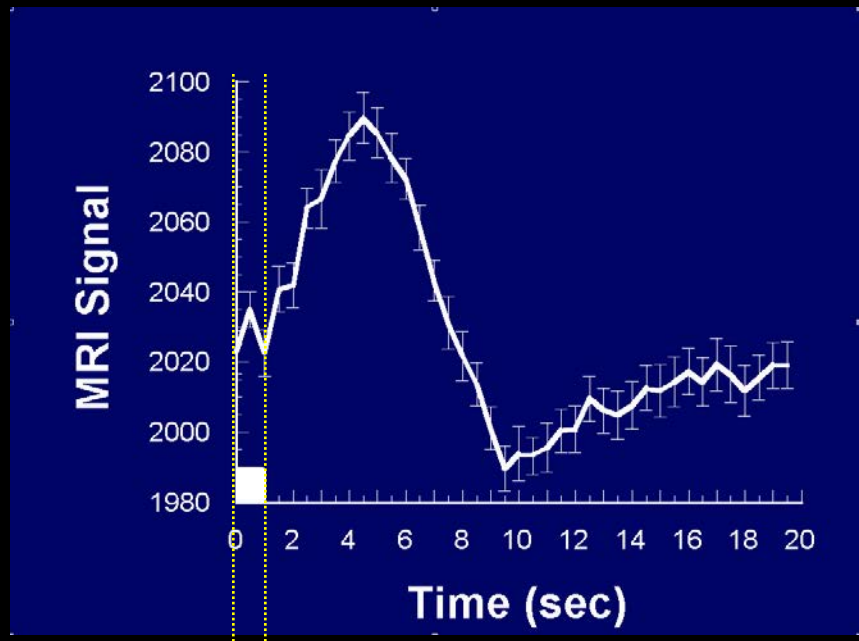
Quality of results and importance of the findings depends on type of question asked, experimental method, and analysis method...

The BOLD Signal

Blood Oxygenation Level Dependent (BOLD) signal changes

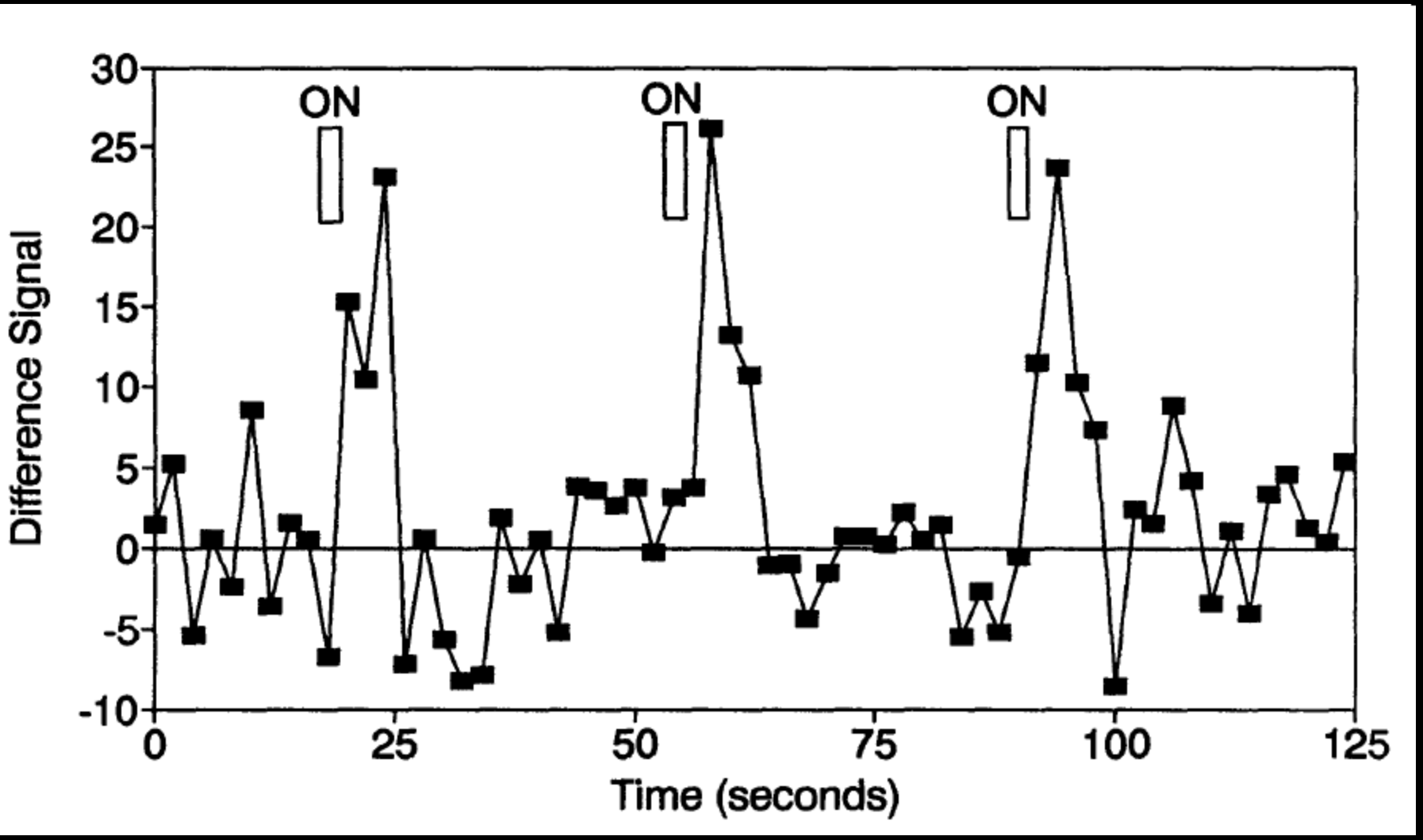


task

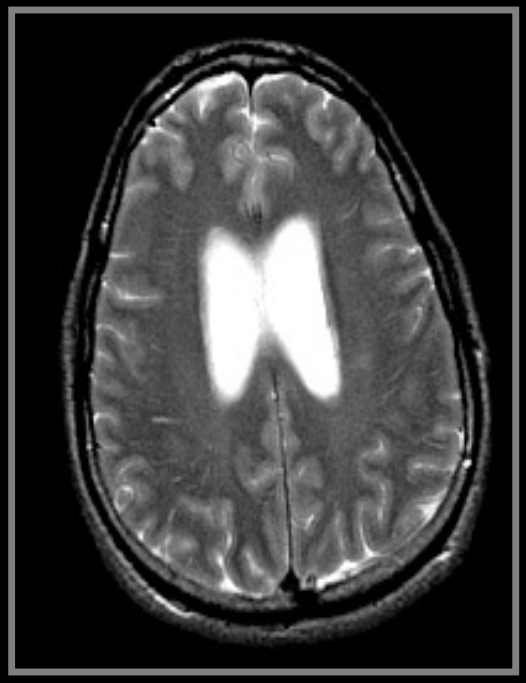


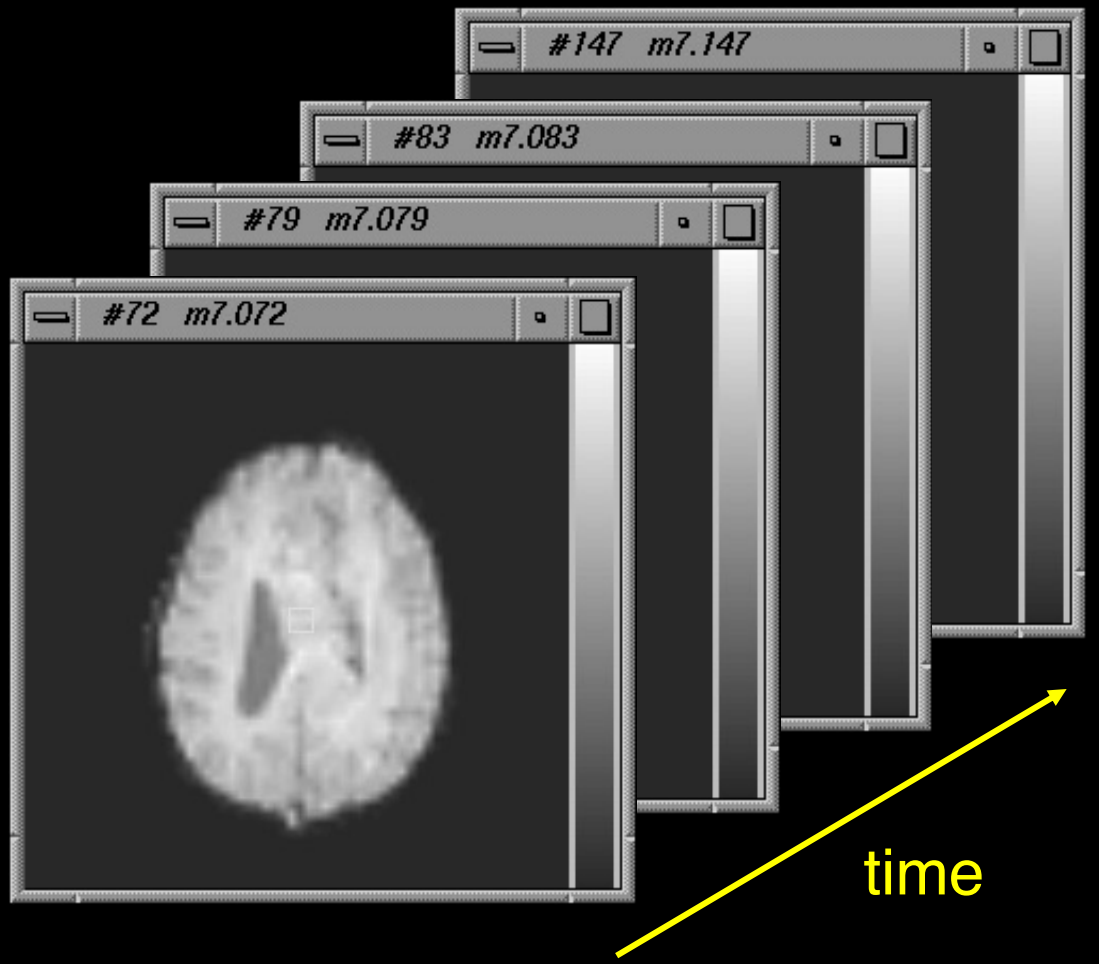
task

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.

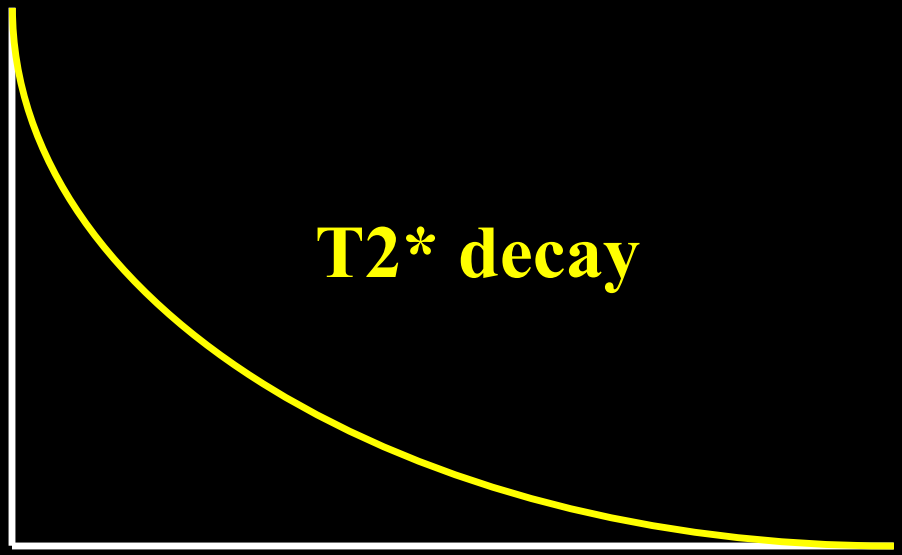


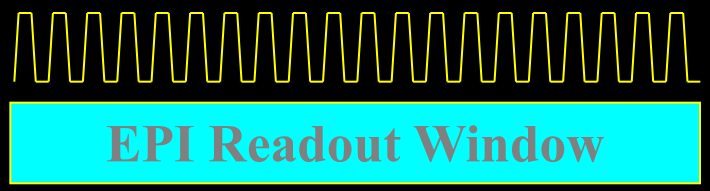


Anatomic

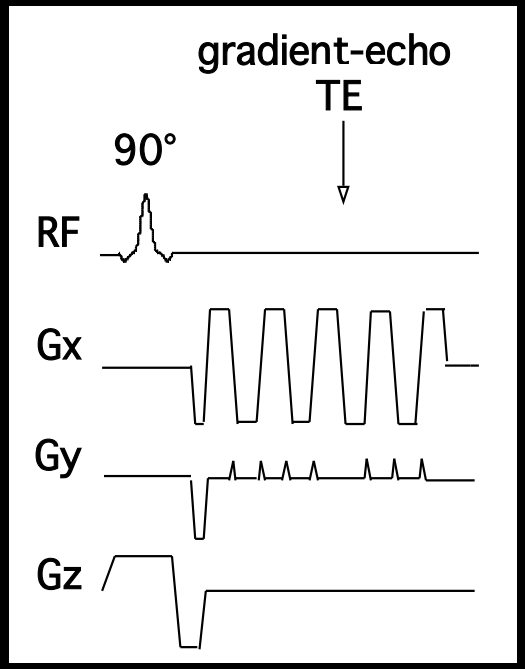
Functional

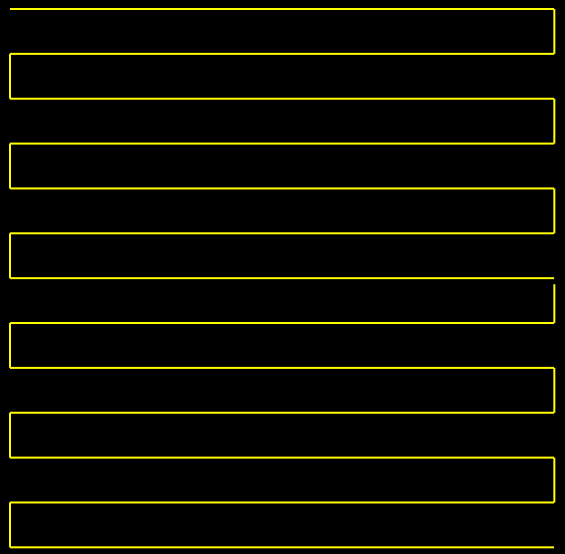
Single Shot EPI



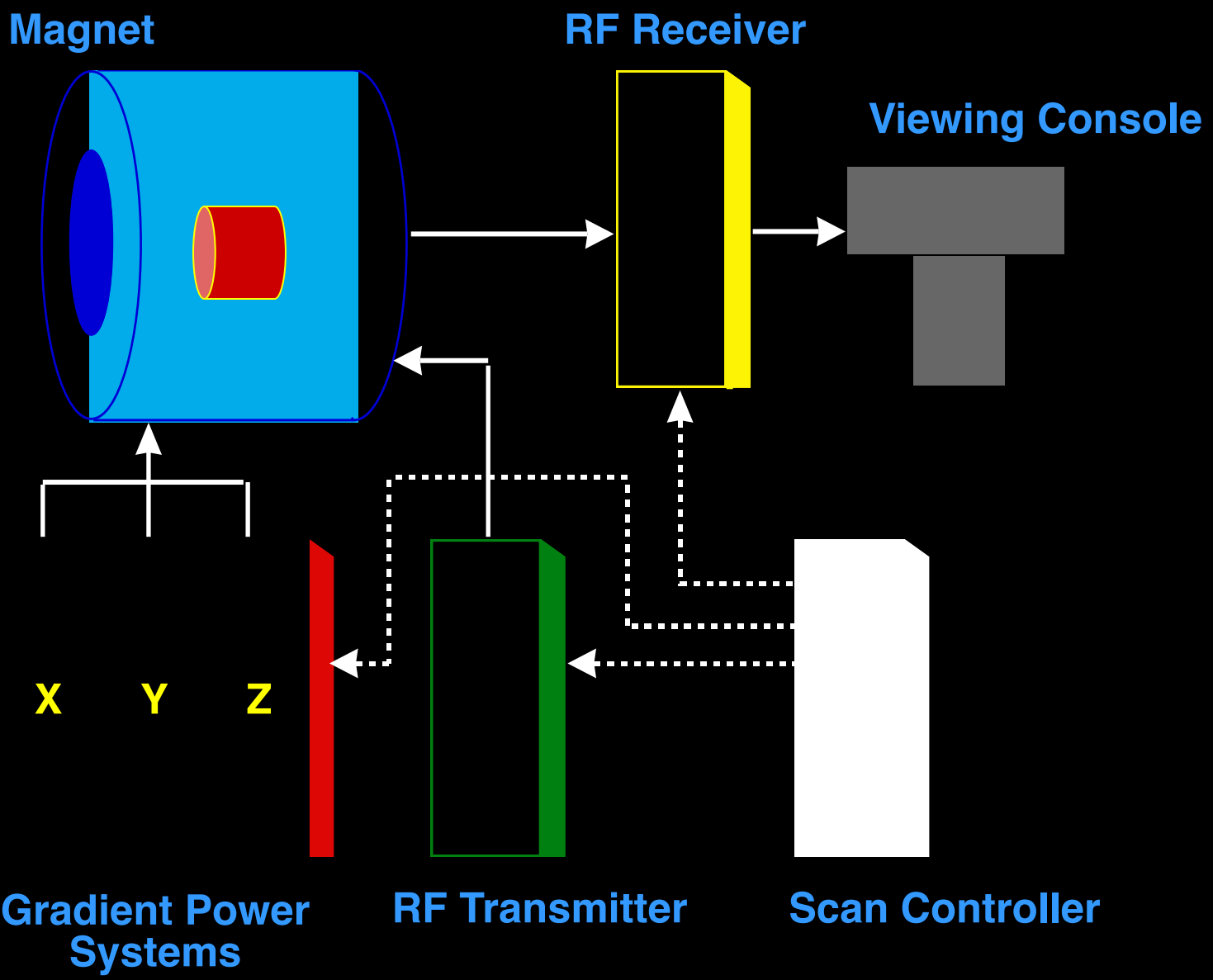


≈ 20 to 40 ms

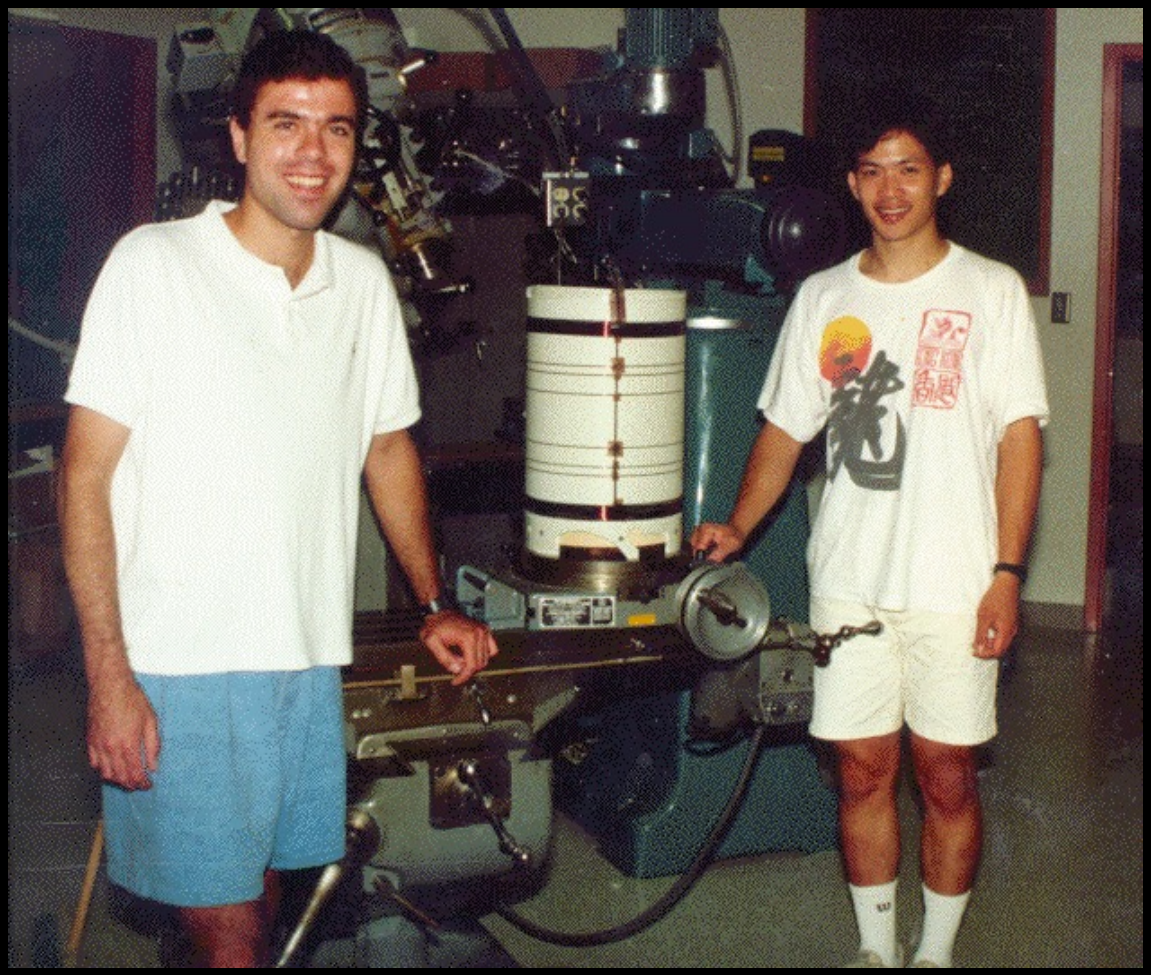




Imaging System Components



Local gradients solved the problem

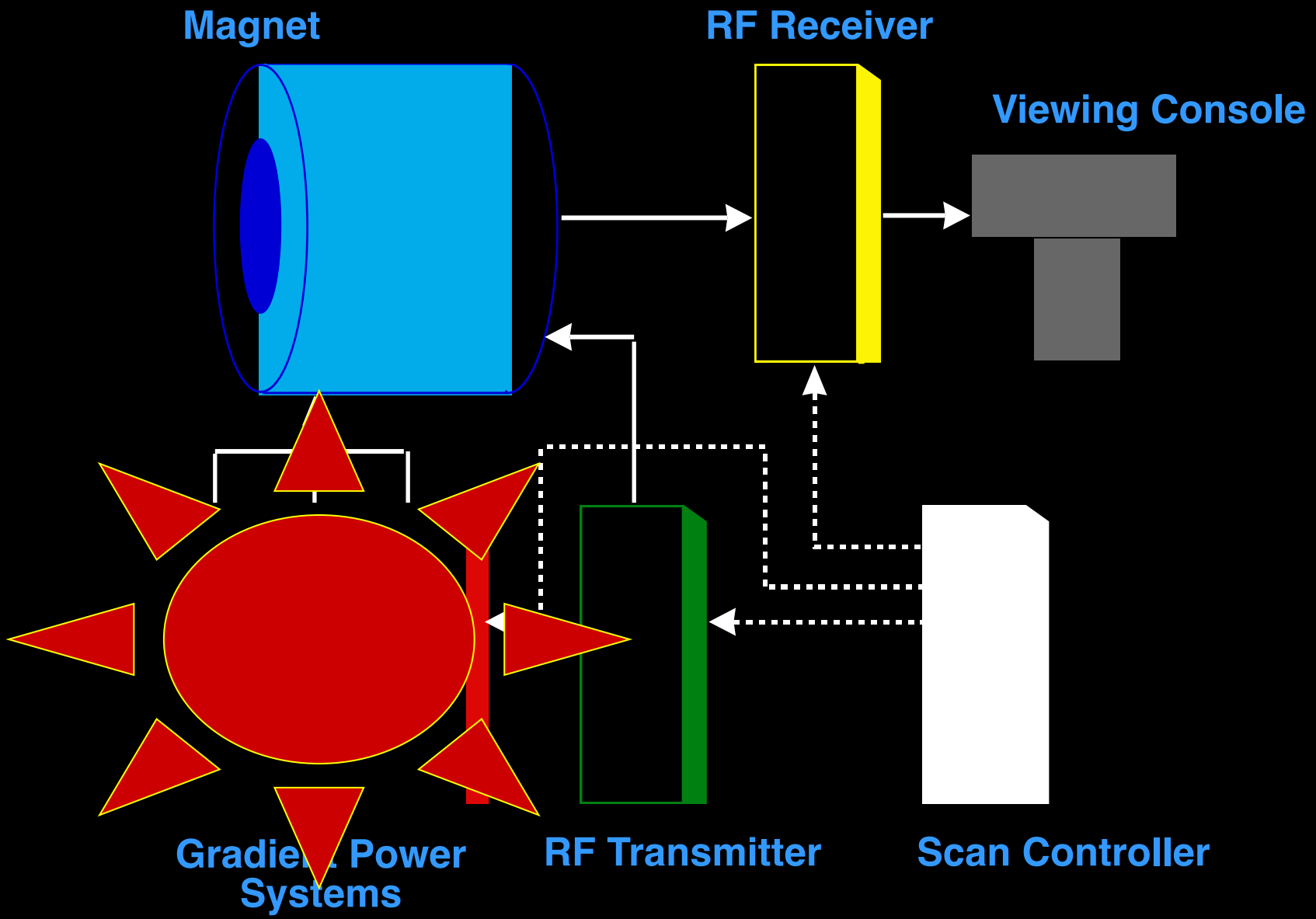


August, 1991

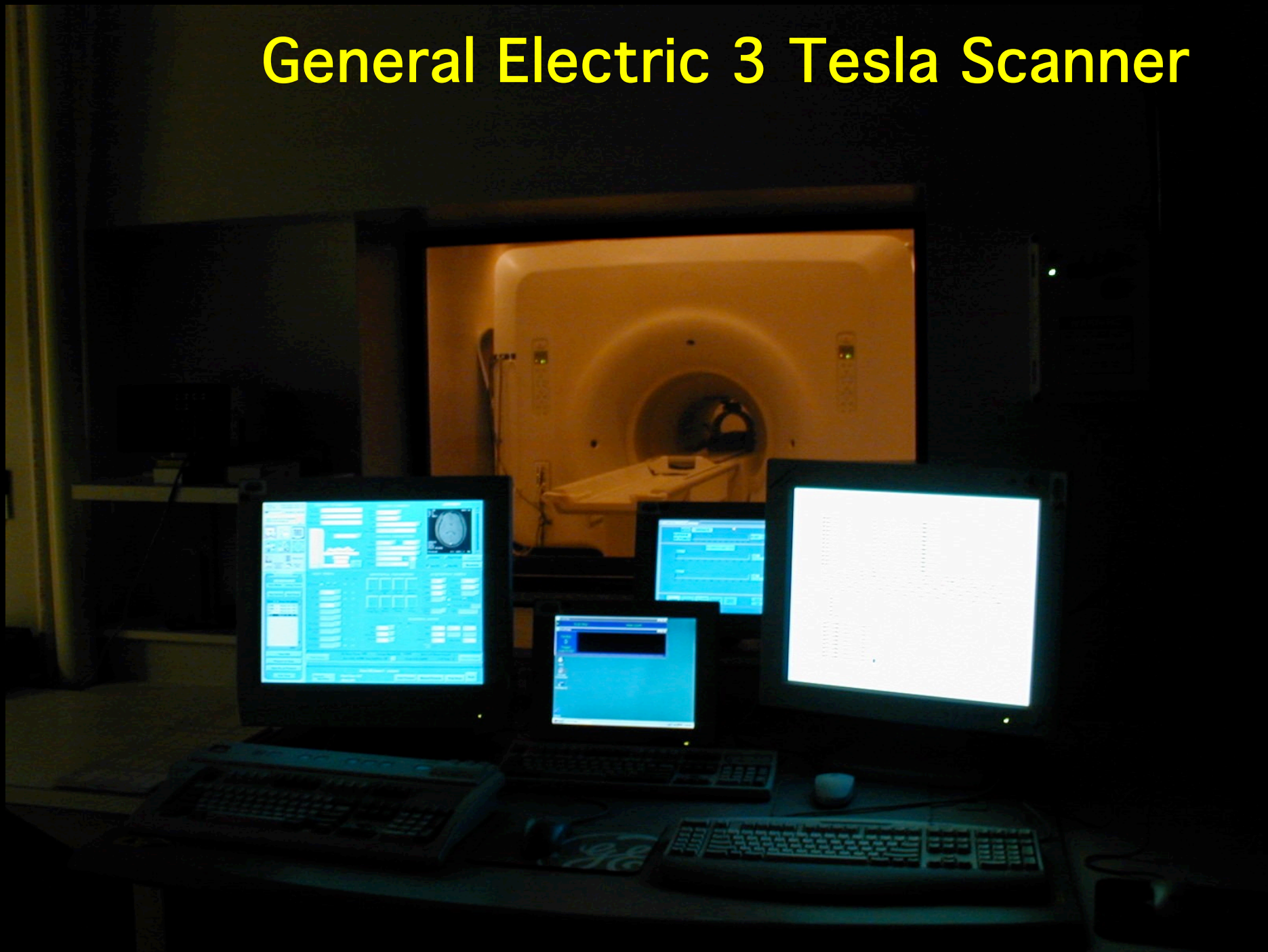
1991-1992

1992-1999

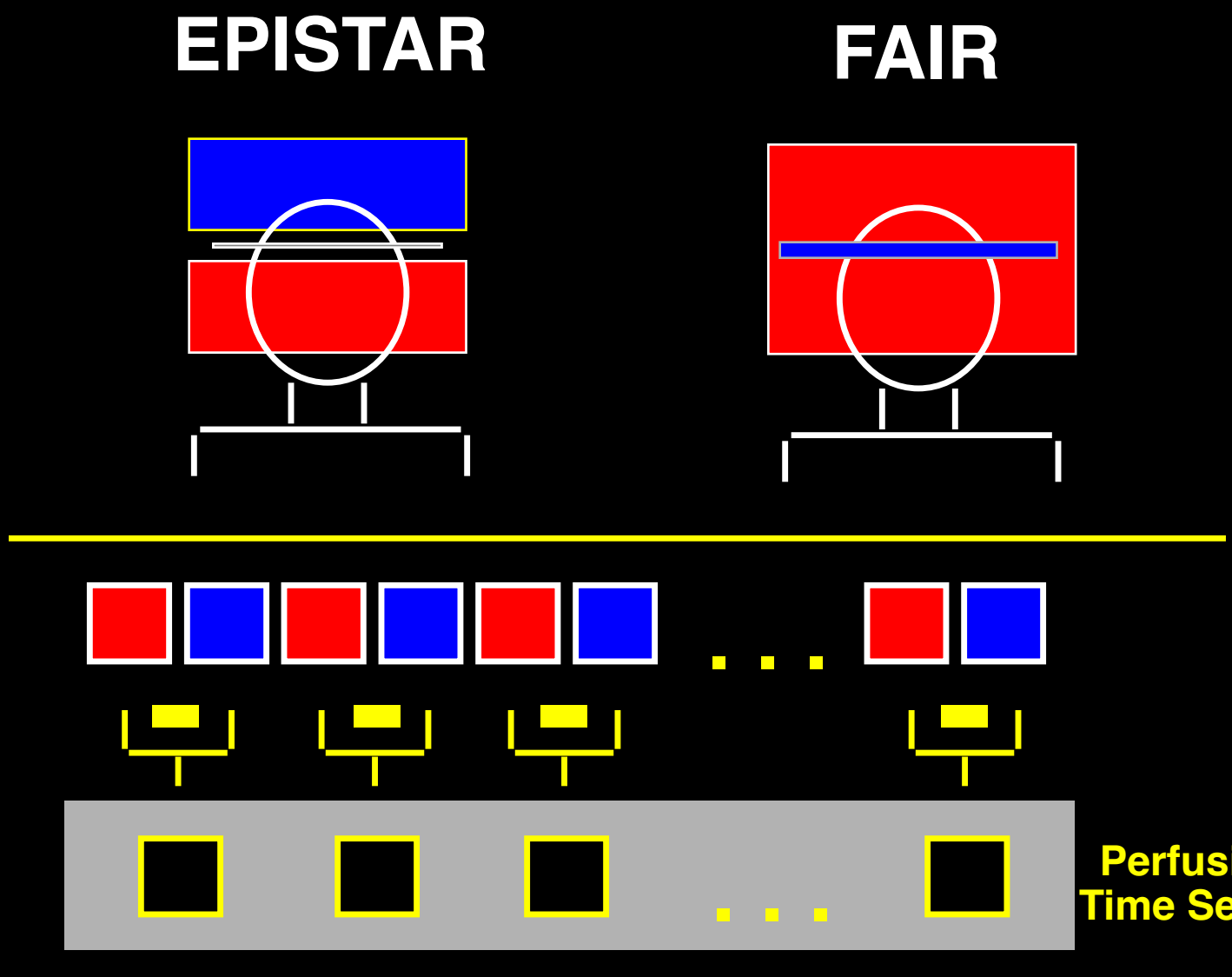
Imaging System Components

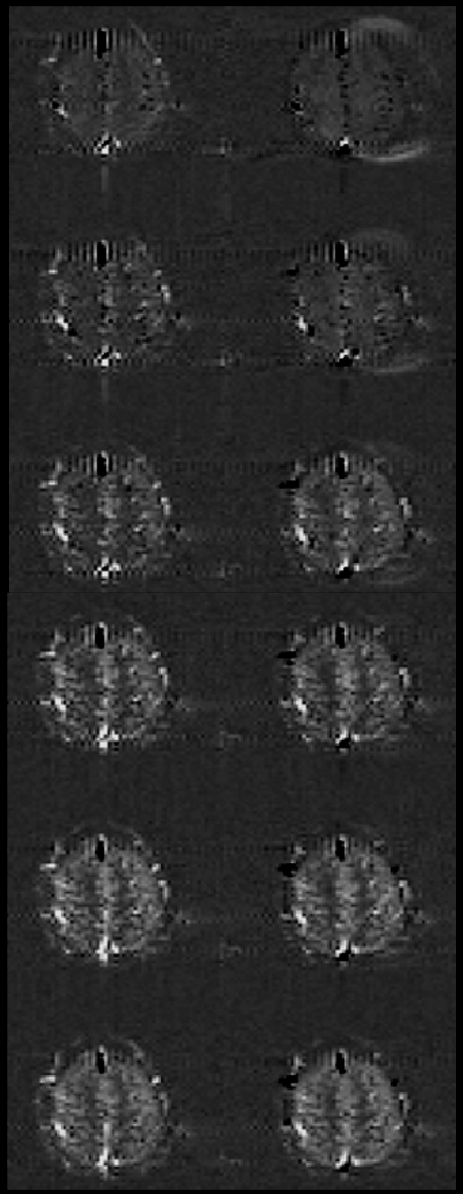


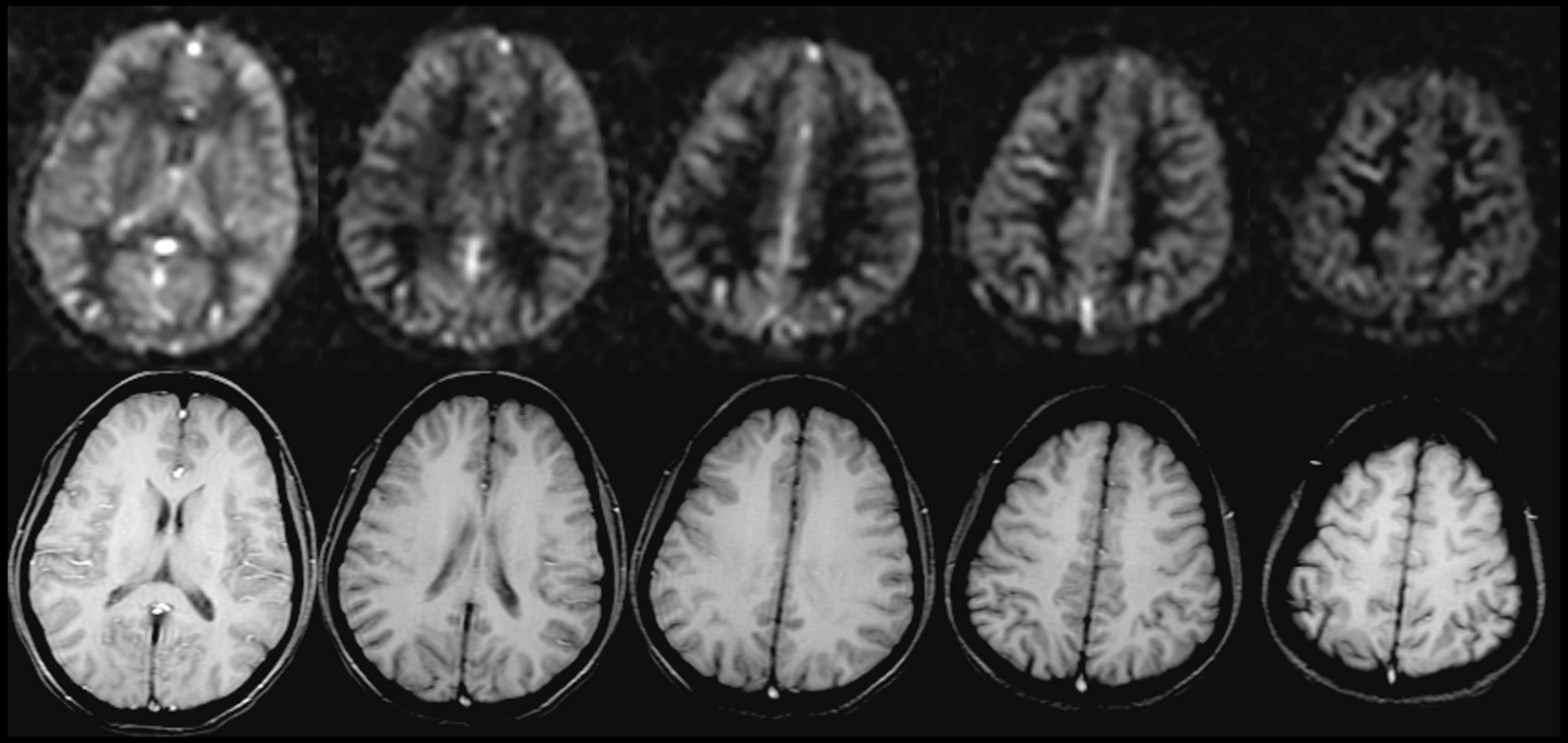
General Electric 3 Tesla Scanner



Blood Perfusion



TI (ms)	FAIR	EPISTAR
200		
400		
600		
800		
1000		
1200		

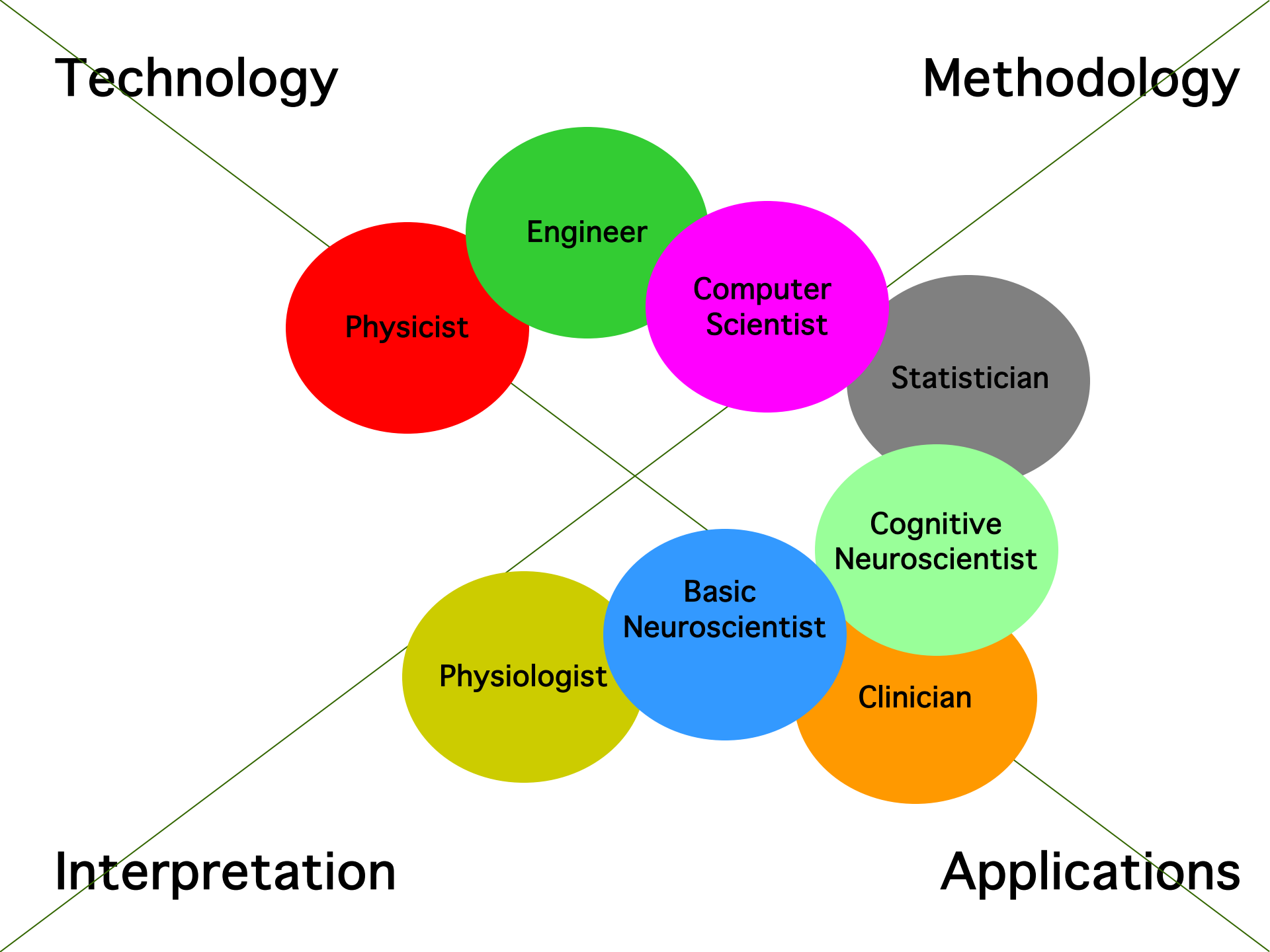


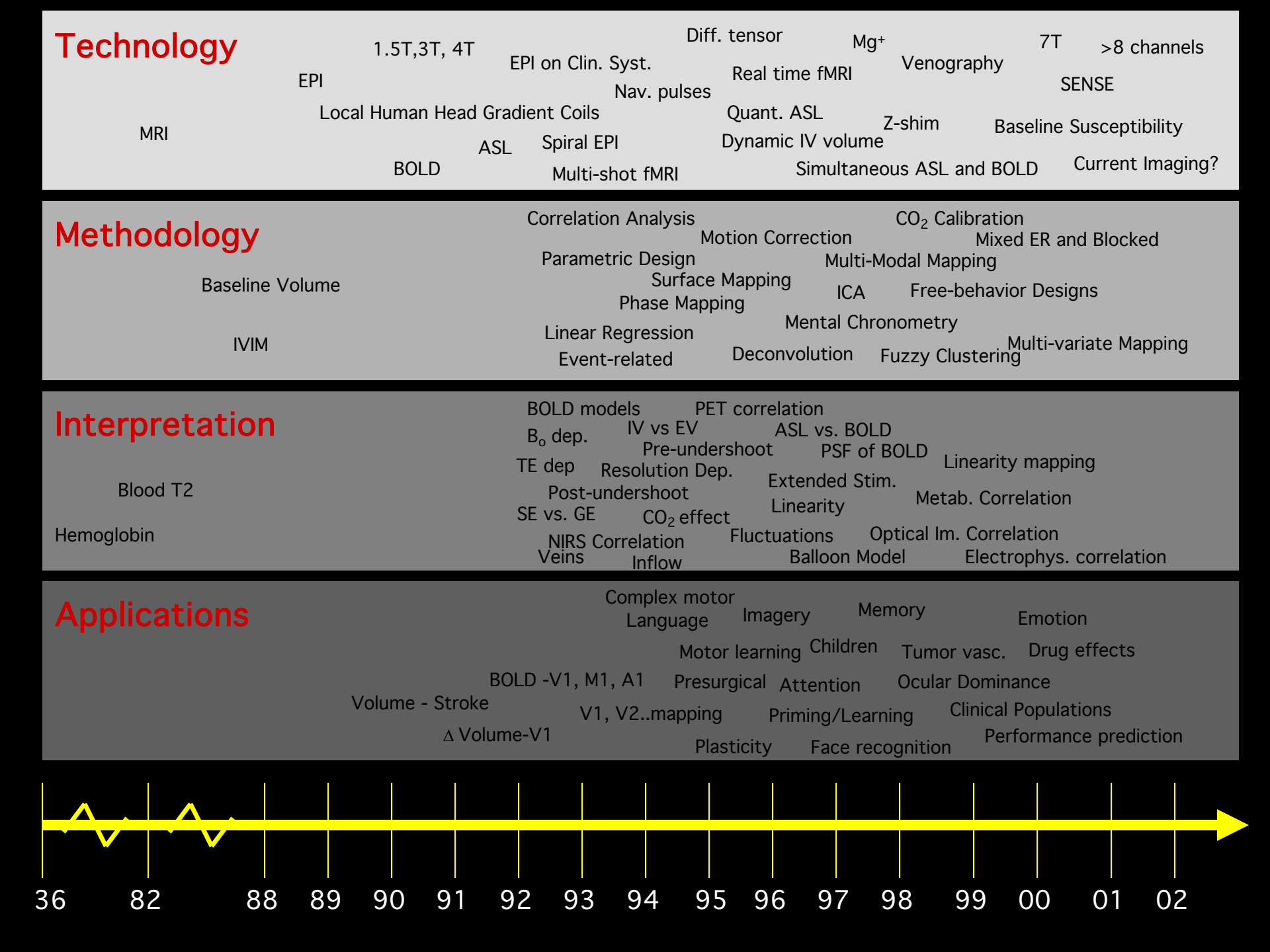
Williams, D. S., Detre, J. A., Leigh, J. S. & Koretsky, A. S. (1992) “Magnetic resonance imaging of perfusion using spin-inversion of arterial water.” Proc. Natl. Acad. Sci. USA 89, 212-216.

Edelman, R., Siewert, B. & Darby, D. (1994) “Qualitative mapping of cerebral blood flow and functional localization with echo planar MR imaging ans signal targeting with alternating radiofrequency (EPISTAR).” Radiology **192**, 1-8.

Kim, S.-G. (1995) “Quantification of relative cerebral blood flow change by flow-sensitive alternating inversion recovery (FAIR) technique: application to functional mapping.” Magn. Reson. Med. **34**, 293-301.

Kwong, K. K. et al. (1995) “MR perfusion studies with T1-weighted echo planar imaging.”Magn. Reson. Med. **34**, 878-887.


Technology
Methodology
Engineer
Physicist
Computer Scientist
Statistician
Cognitive Neuroscientist
Basic Neuroscientist
Physiologist
Clinician
Interpretation
Applications


Technology
1.5T,3T, 4T
Diff. tensor
Mg+
7T
>8 channels
EPI on Clin. Syst.
Venography
EPI
Real time fMRI
SENSE
Nav. pulses
Local Human Head Gradient Coils
Quant. ASL
Z-shim
Baseline Susceptibility
MRI
Dynamic IV volume
ASL
Spiral EPI
BOLD
Multi-shot fMRI
Simultaneous ASL and BOLD
Current Imaging?
Methodology
Correlation Analysis
CO2 Calibration
Motion Correction
Mixed ER and Blocked
Parametric Design
Multi-Modal Mapping
Surface Mapping
Baseline Volume
ICA
Free-behavior Designs
Phase Mapping
Mental Chronometry
Linear Regression
IVIM
Multi-variate Mapping
Event-related
Deconvolution
Fuzzy Clustering
Interpretation
BOLD models
PET correlation
IV vs EV
B0 dep.
ASL vs. BOLD
Pre-undershoot
PSF of BOLD
TE dep
Linearity mapping
Resolution Dep.
Extended Stim.
Blood T2
Post-undershoot
Metab. Correlation
Linearity
SE vs. GE
CO2 effect
Hemoglobin
Fluctuations
Optical Im. Correlation
NIRS Correlation
Veins
Balloon Model
Electrophys. correlation
Inflow
Applications
Complex motor
Language
Imagery
Memory
Emotion
Motor learning
Children
Tumor vasc.
Drug effects
BOLD -V1, M1, A1
Presurgical
Attention
Ocular Dominance
Volume - Stroke
V1, V2..mapping
Priming/Learning
Clinical Populations
Δ Volume-V1
Plasticity
Face recognition
Performance prediction
36
82
88
89
90
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99
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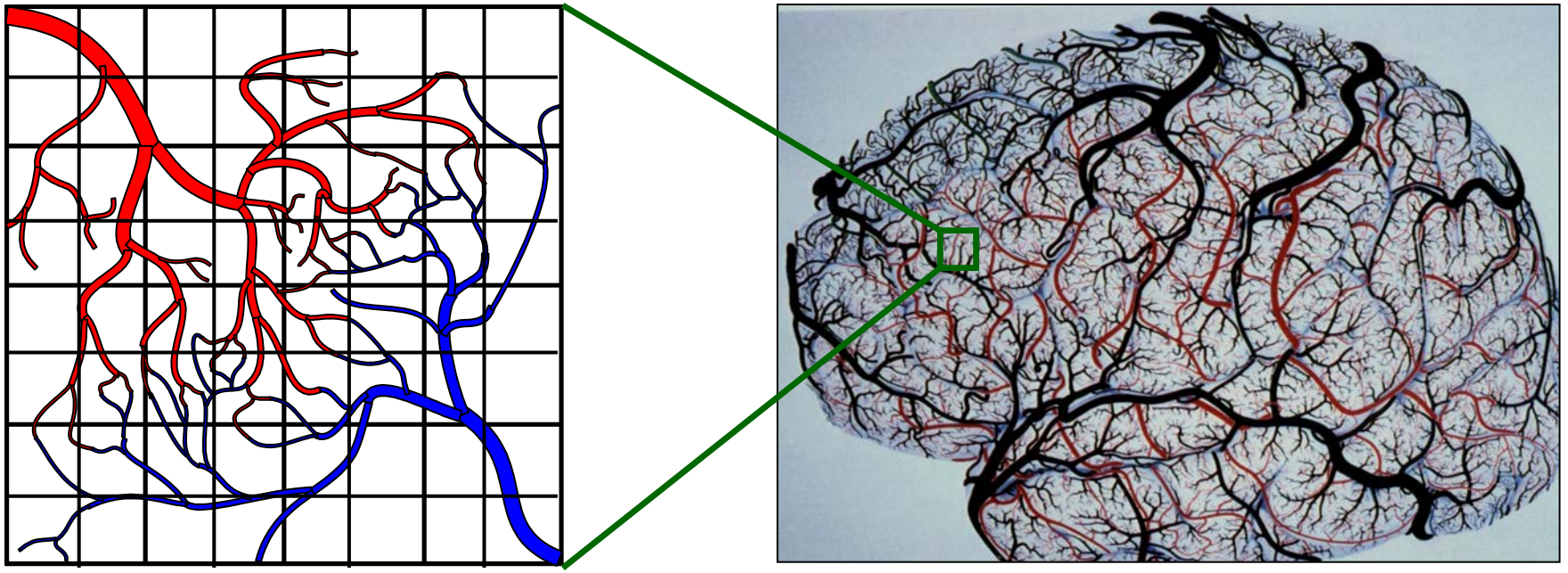
01
02

Neuronal Activation ? Measured Signal

? Hemodynamics ? Noise ?



Latest Developments...

1. Temporal Resolution
2. Spatial Resolution
3. Sensitivity and Noise
4. Information Content
5. Implementation

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1. Temporal Resolution
2. Spatial Resolution
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4. Information Content
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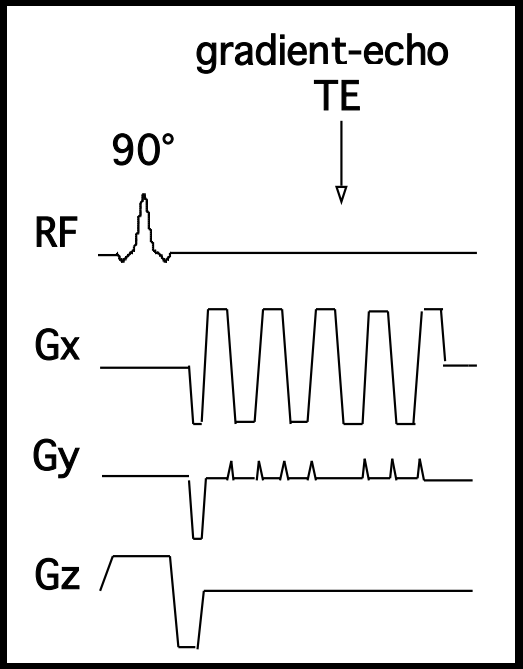
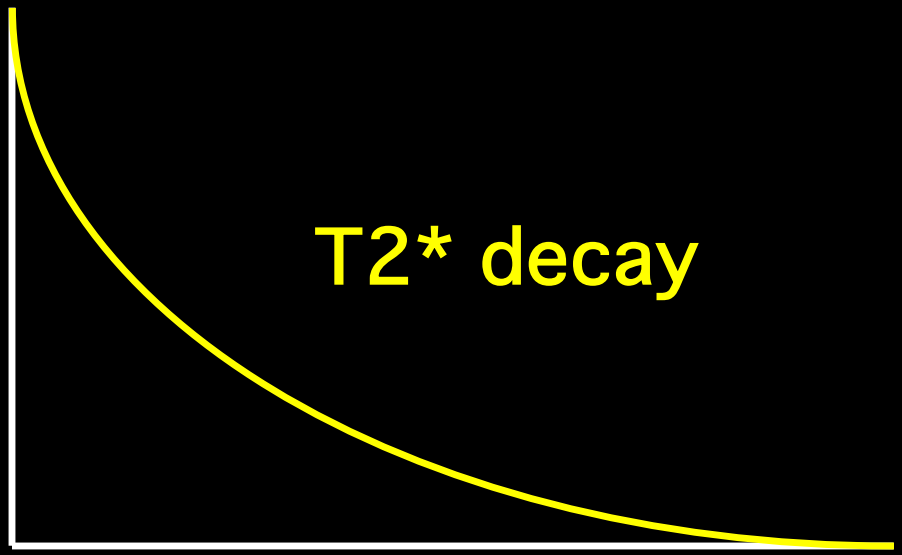
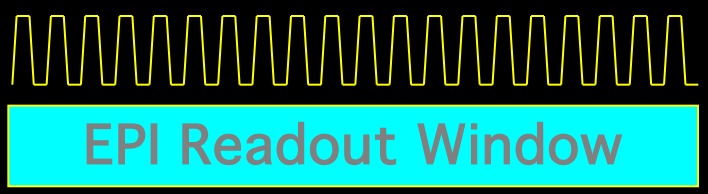
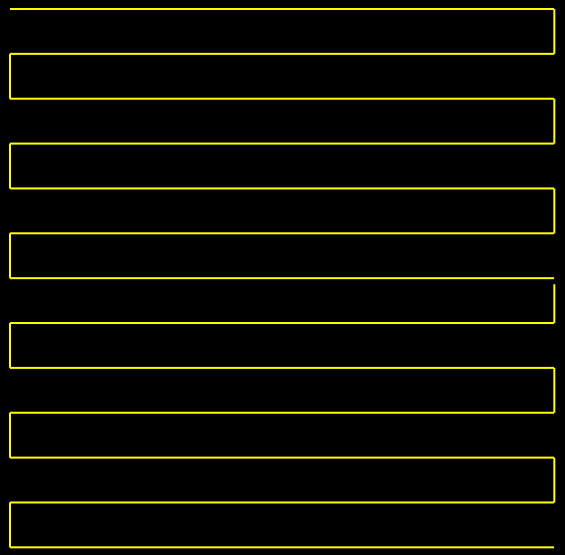
Single Shot EPI

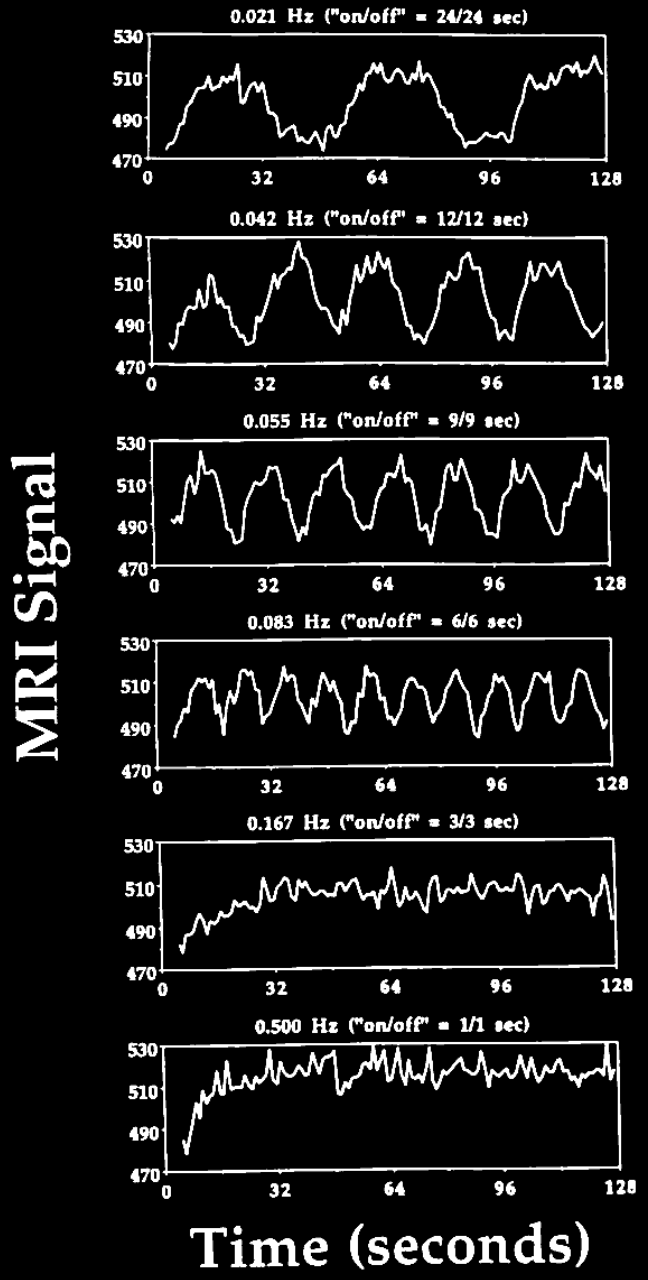


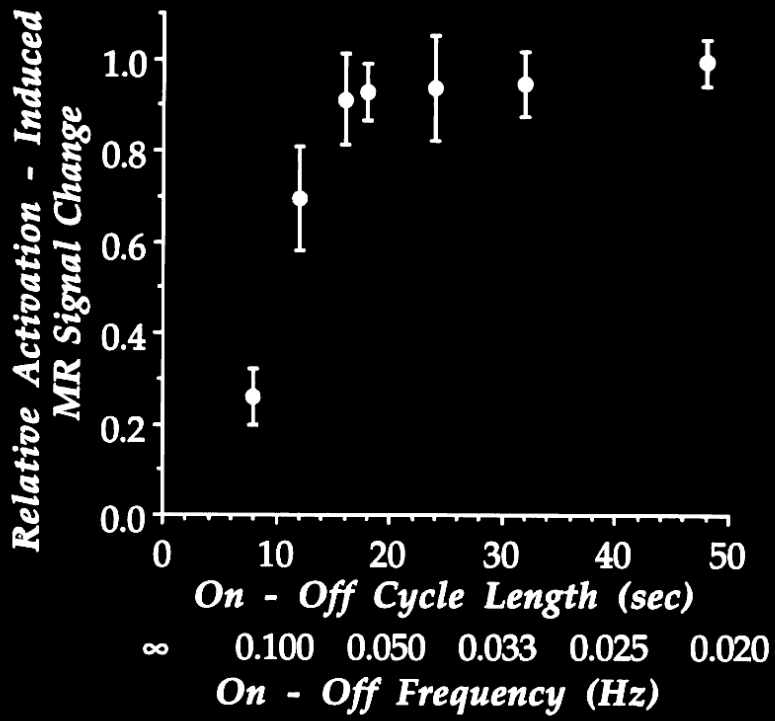




≈ 20 to 40 ms

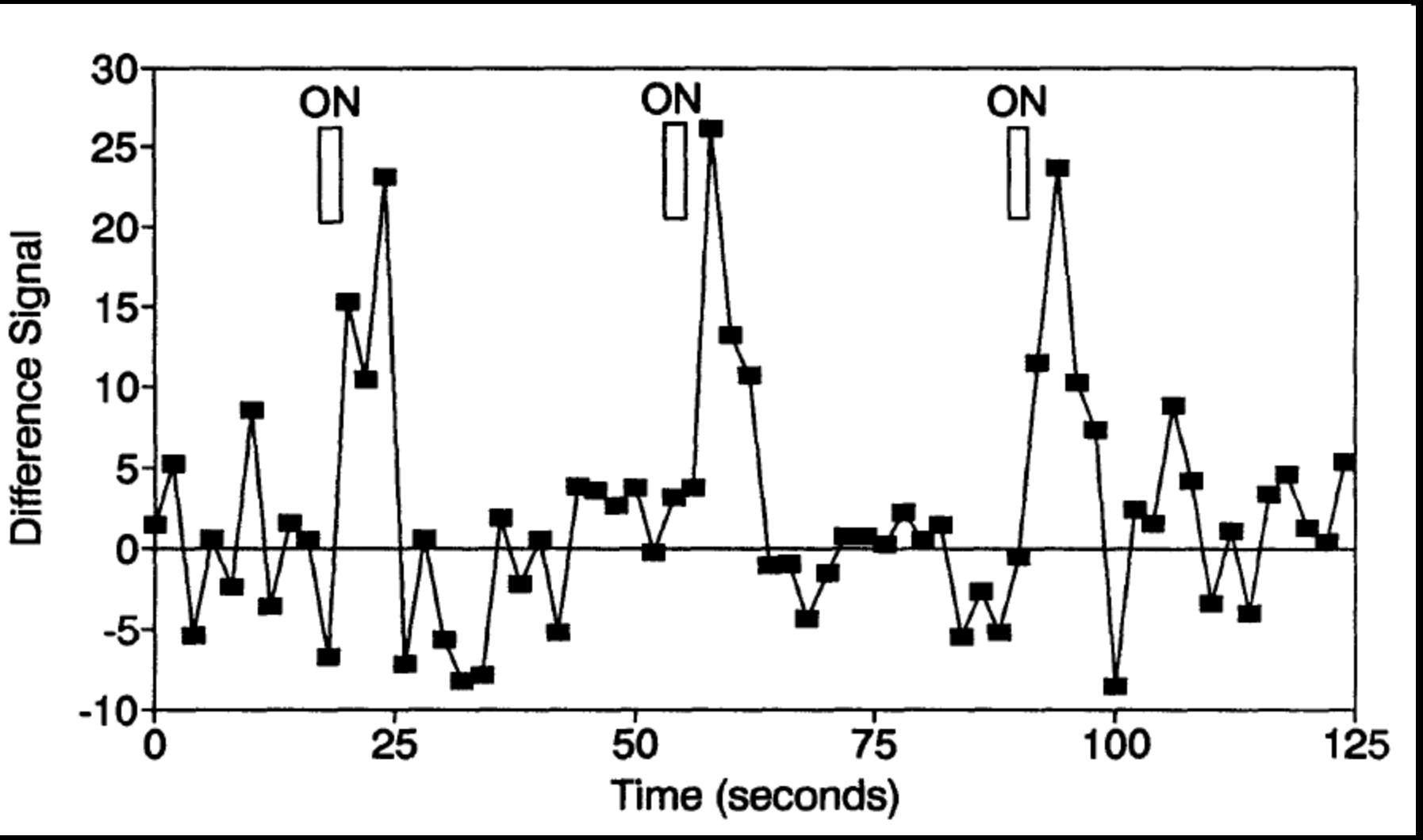






P. A. Bandettini, Functional MRI temporal resolution *in* "Functional MRI" (C. Moonen, and P. Bandettini., Eds.), p. 205-220, Springer - Verlag,. 1999.

First Event-related fMRI Results



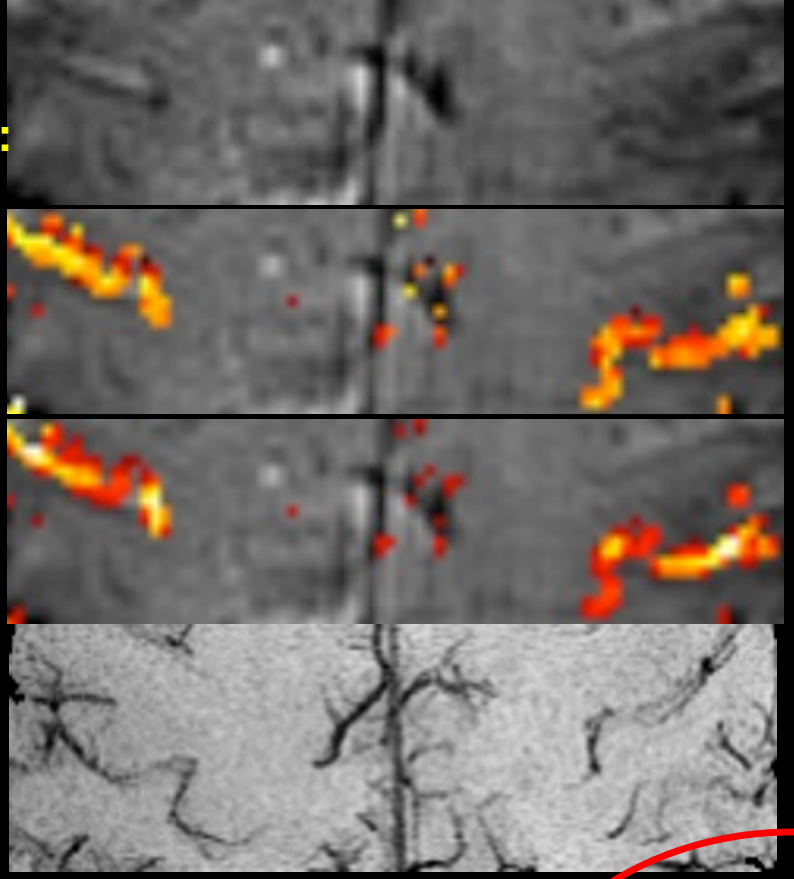
Blamire, A. M., et al. (1992). "Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging." Proc. Natl. Acad. Sci. USA 89: 11069-11073.

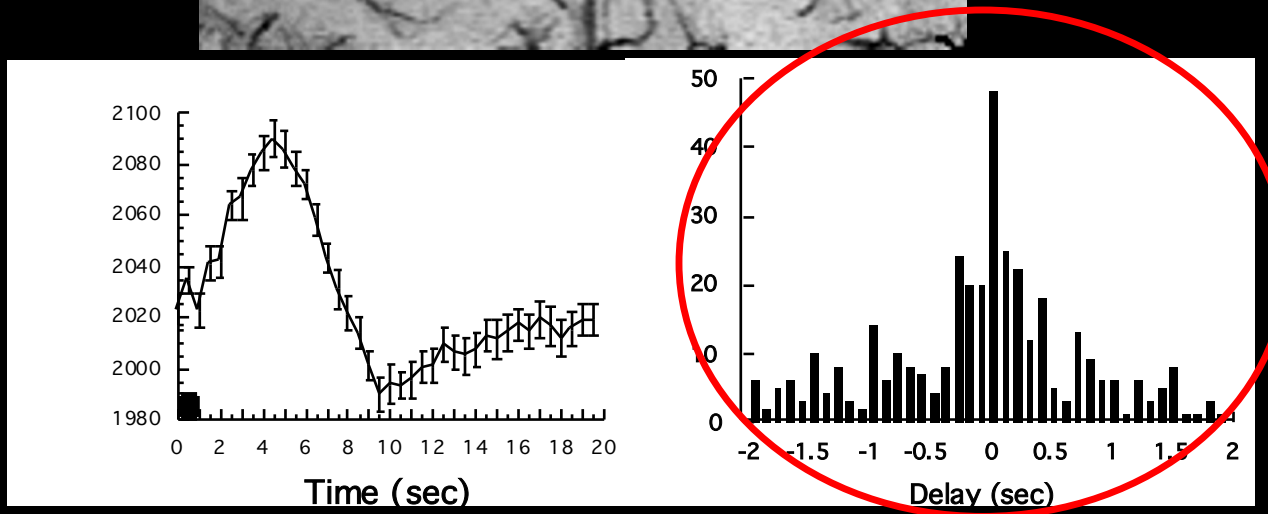
The major obstacle in BOLD contrast temporal resolution:

Latency

Magnitude

Venogram

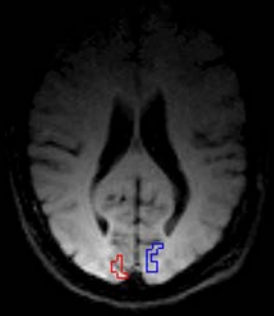




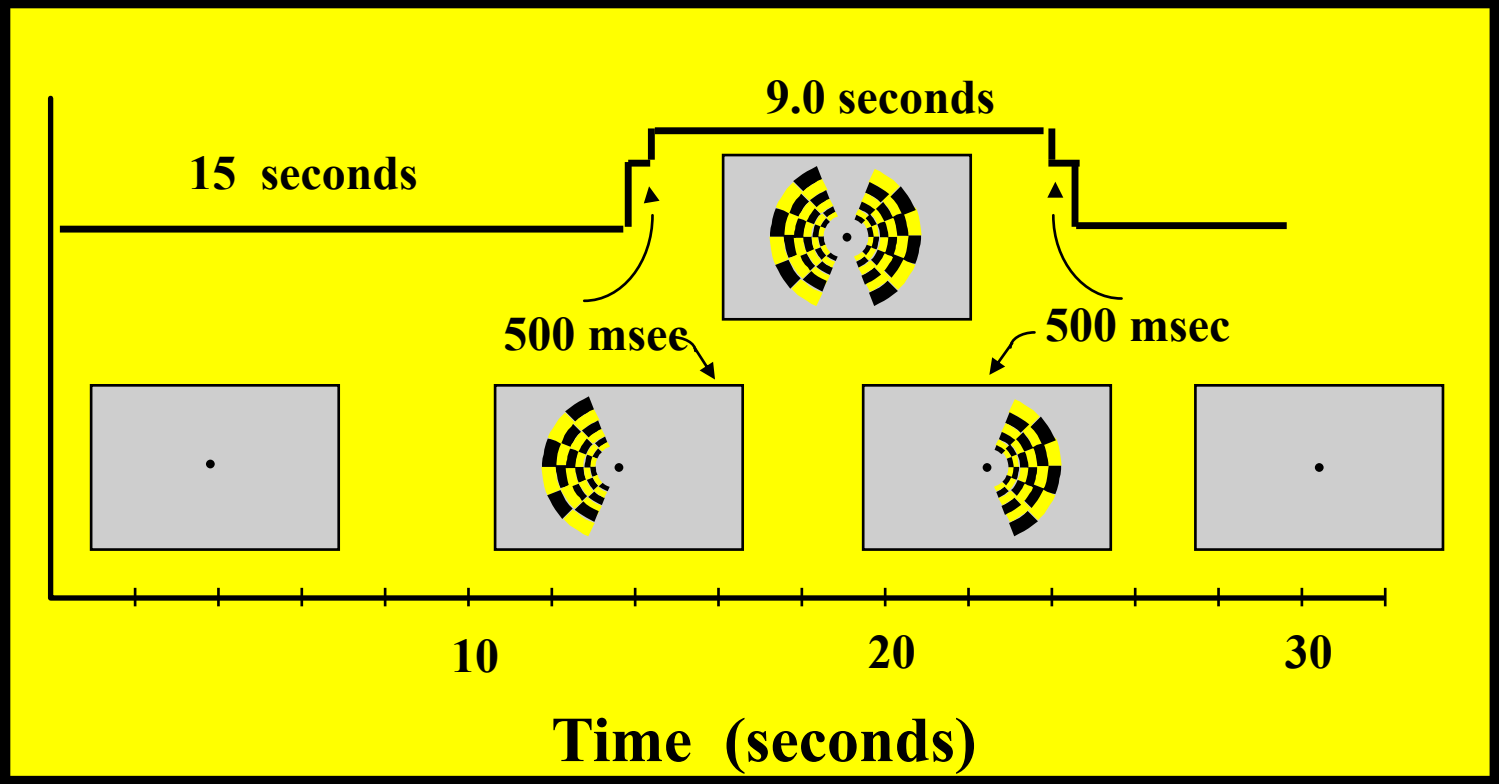
P. A. Bandettini, The temporal resolution of Functional MRI *in* "Functional MRI" (C. Moonen, and P. Bandettini., Eds.), p. 205-220, Springer - Verlag,. 1999.

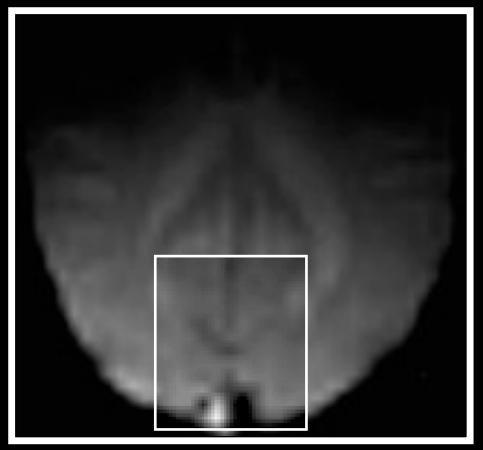
Hemi-Field Experiment

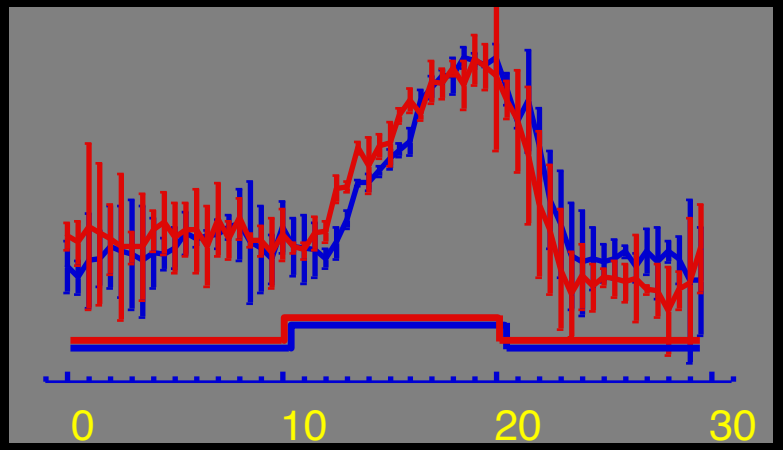
Right Hemisphere



Left Hemisphere







500 ms 500 ms

Right Hemifield

Left Hemifield

+ 2.5 s

0 s

- 2.5 s

Cognitive Neuroscience Application:

Understanding neural system dynamics through task modulation and measurement of functional MRI amplitude, latency, and width

PNAS

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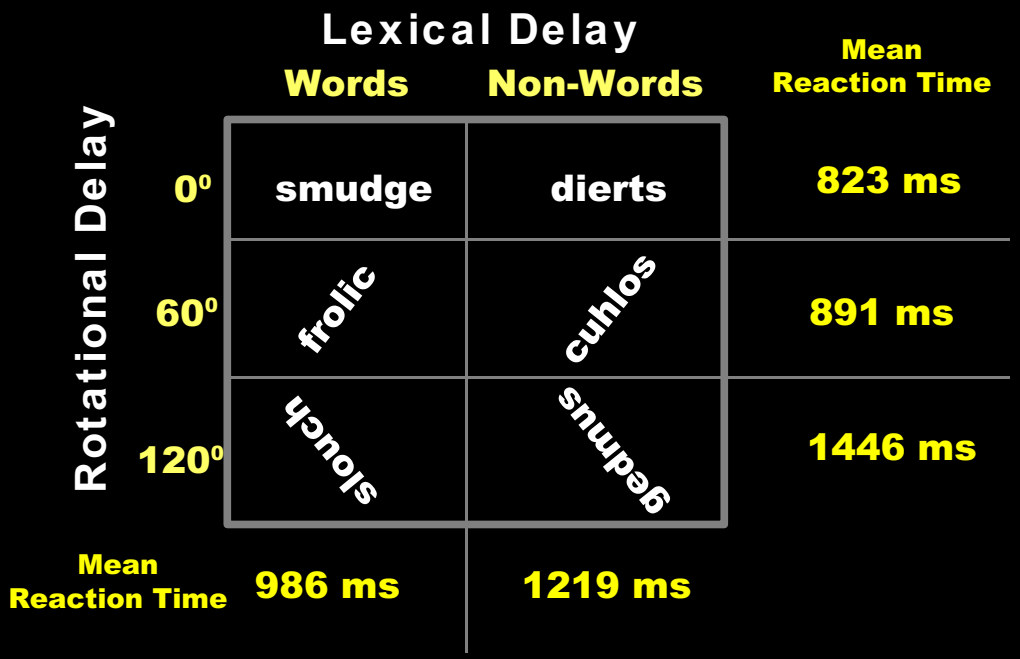
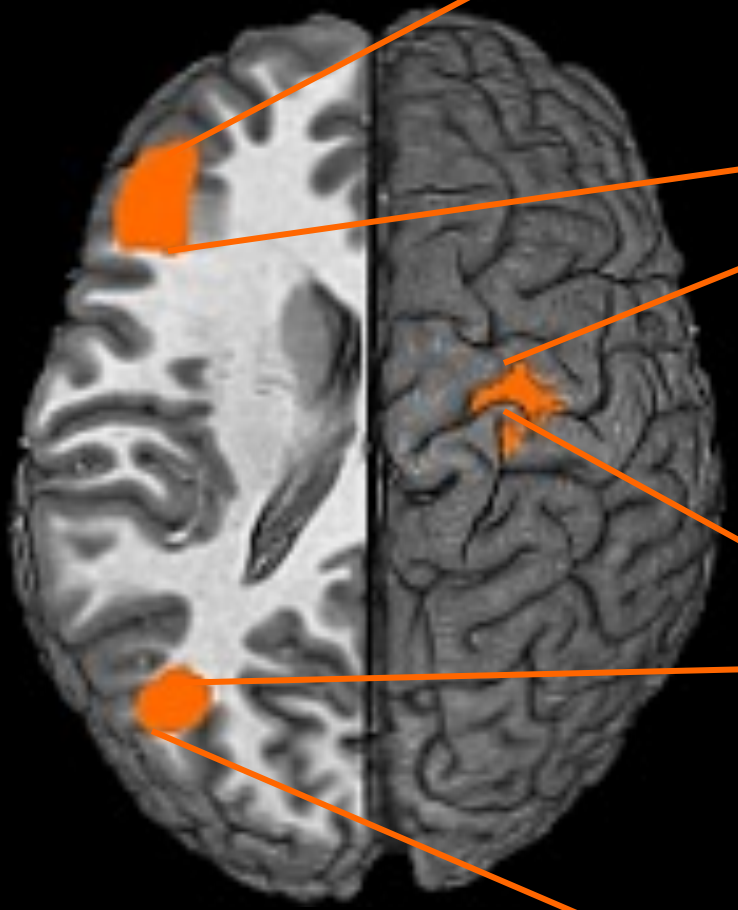
*Laboratory of Brain and Cognition and ‡Scientific and Statistical Computing Core, National Institute of Mental Health, Bethesda, MD 20892

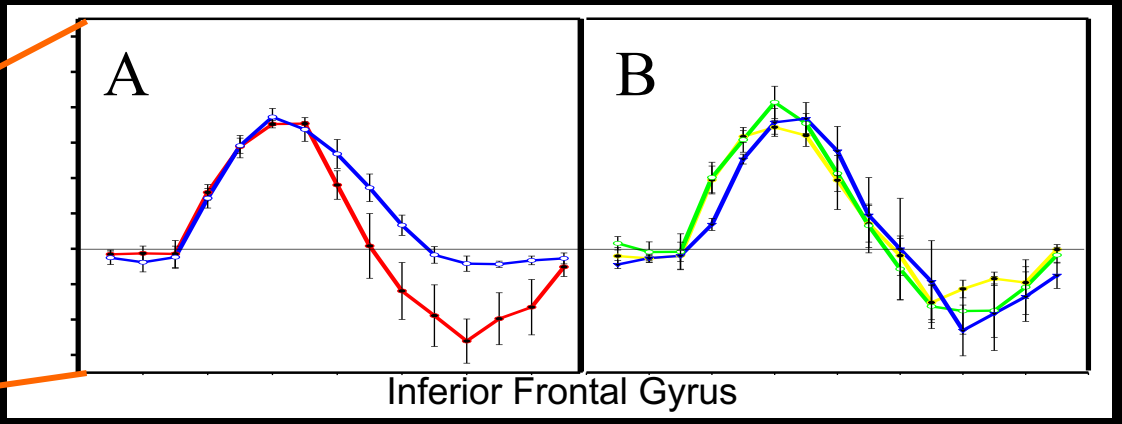
Communicated by Leslie G. Ungerleider, National Institutes of Health, Bethesda, MD, December 19, 2002 (received for review October 31, 2002)



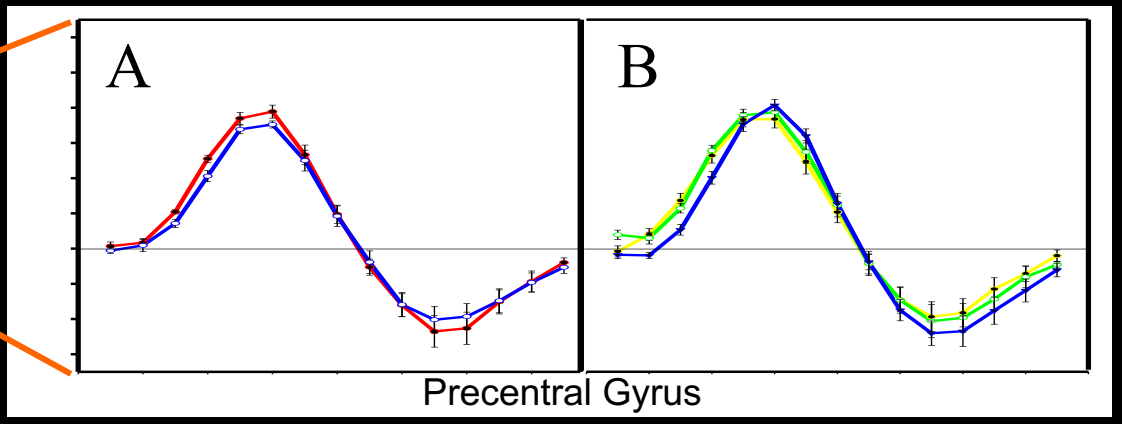
Word vs. Non-word 0°, 60°, 120° Rotation

Regions of Interest

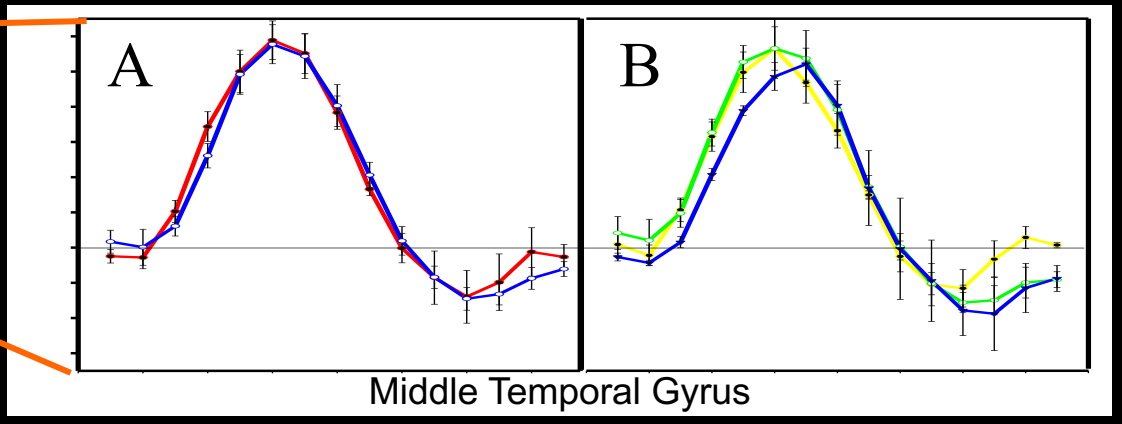




Inferior Frontal Gyrus

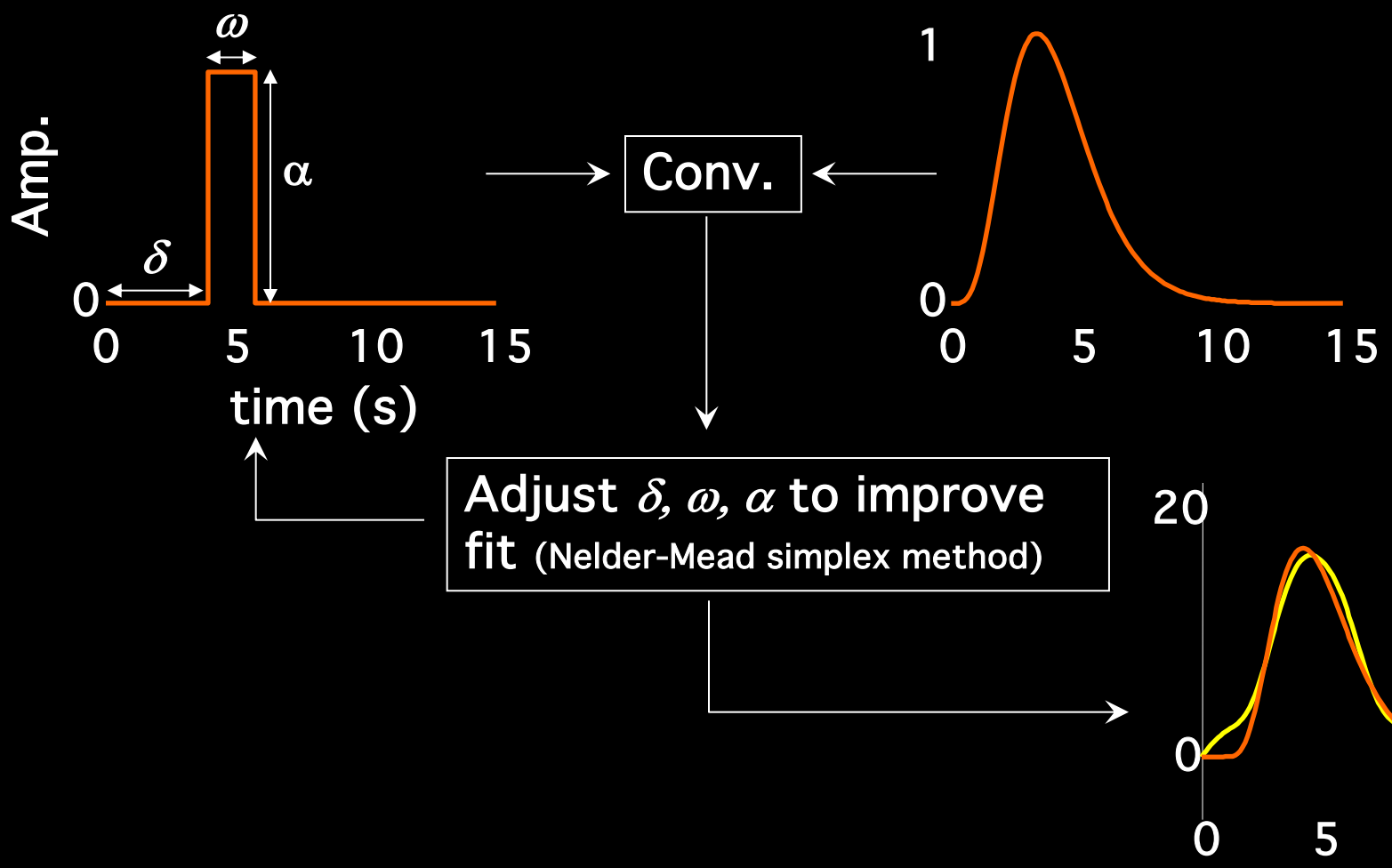


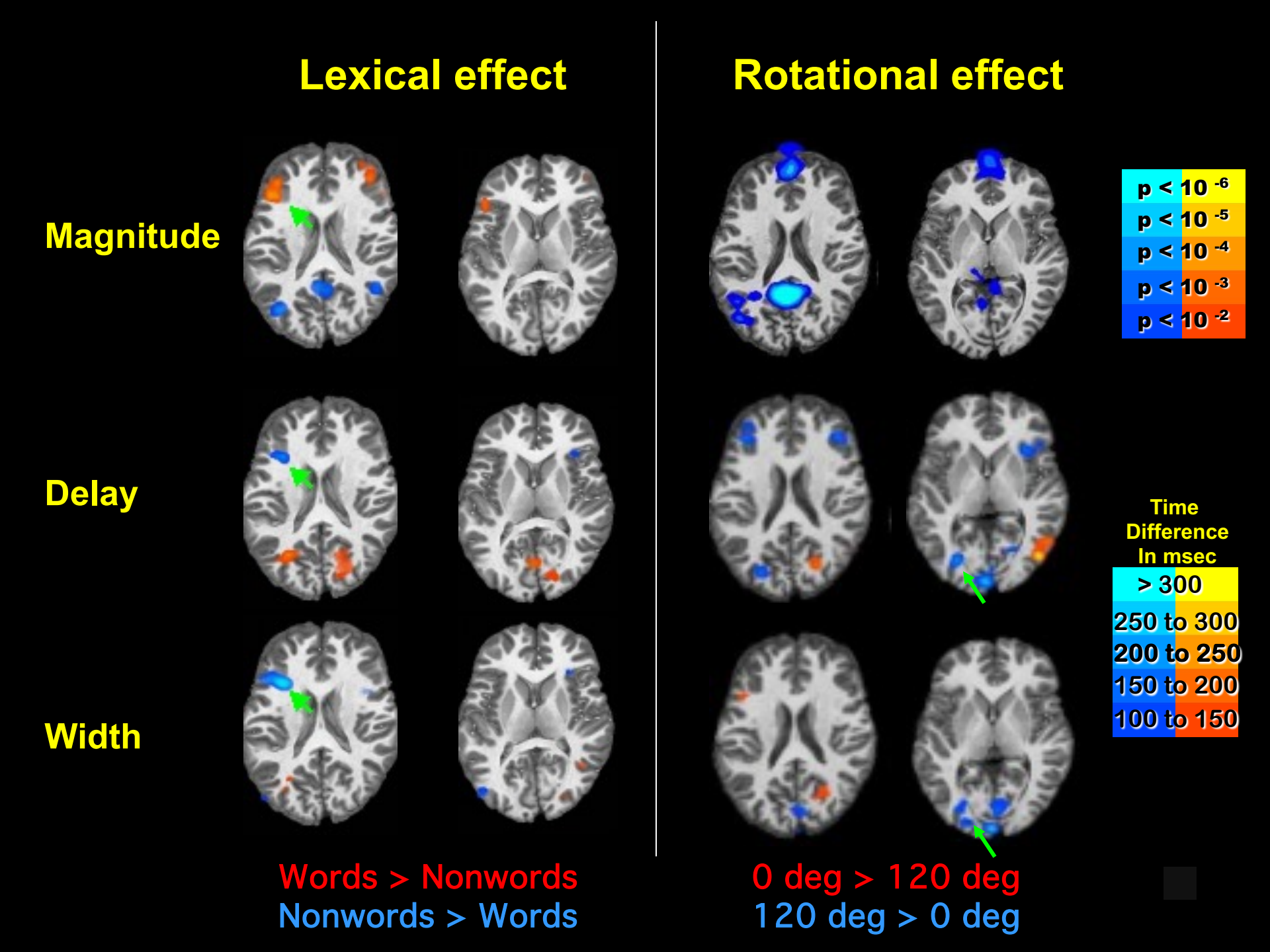
Precentral Gyrus



Middle Temporal Gyrus

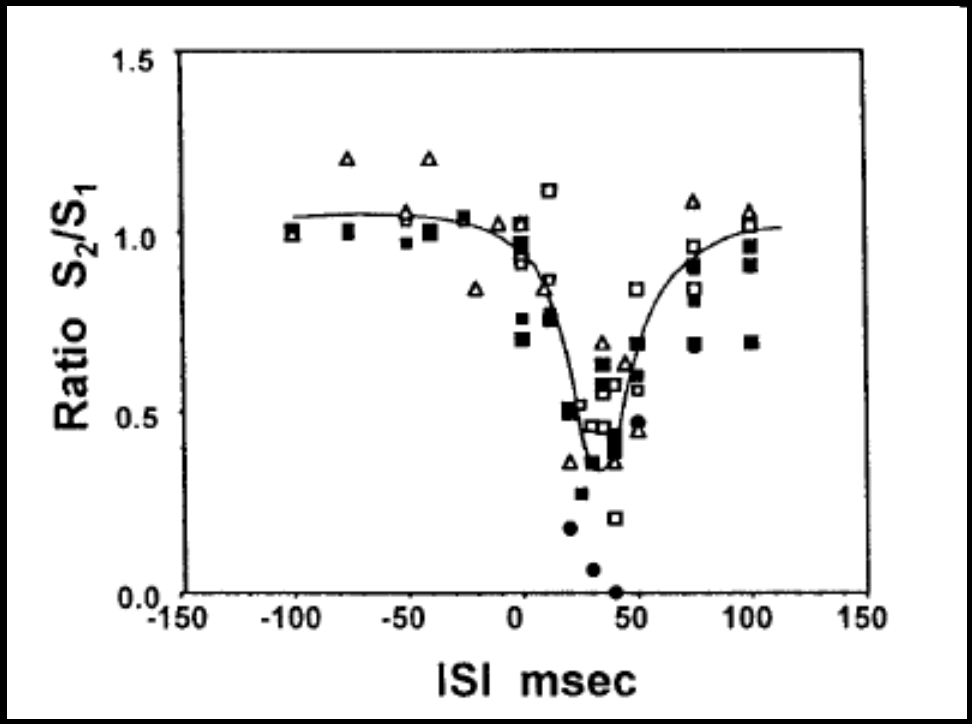
Estimation of Delay, Width & Amplitude




Lexical effect
Rotational effect
Magnitude
Delay
Width
p < 10 -6
p < 10 -5
p < 10 -4
p < 10 -3
p < 10 -2
Time Difference In msec
> 300
250 to 300
200 to 250
150 to 200
100 to 150
Words > Nonwords
Nonwords > Words
0 deg > 120 deg
120 deg > 0 deg

An approach to probe some neural systems interaction by functional MRI at neural time scale down to milliseconds

Seiji Ogawa[†‡], Tso-Ming Lee[†], Ray Stepnoski[†], Wei Chen[§], Xiao-Hong Zhu[§], and Kamil Ugurbil[§]

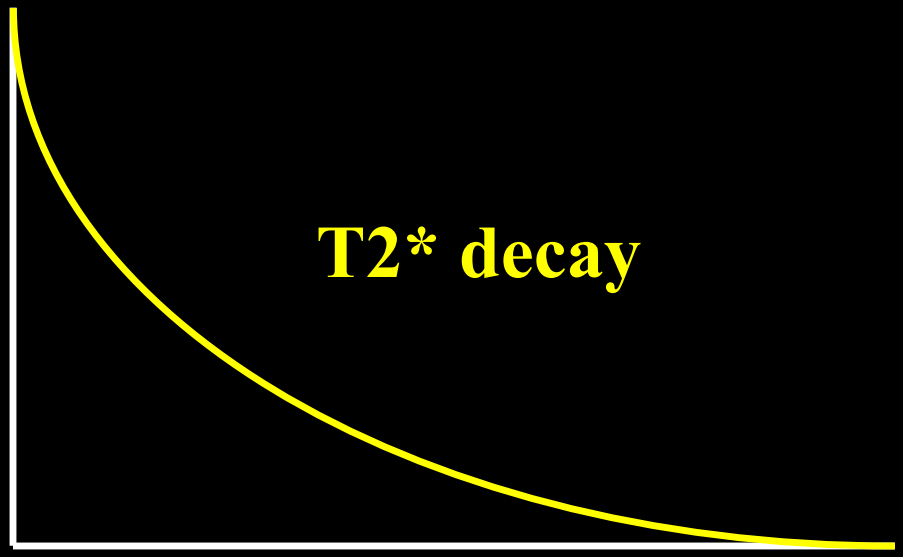


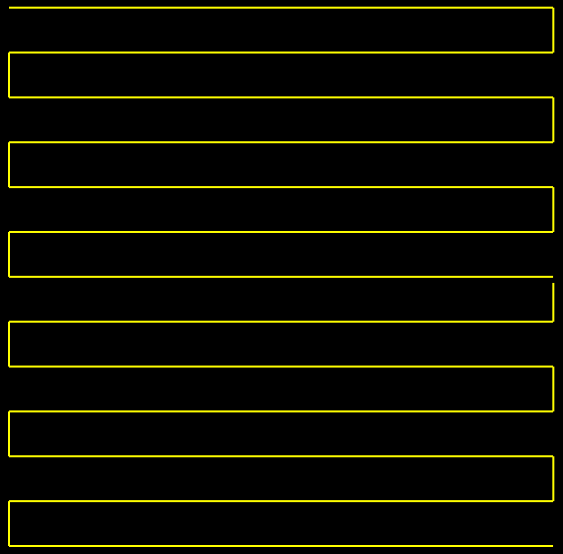
11026–11031 PNAS **September 26, 2000** vol. 97 no. 20

Latest Developments...

1. Temporal Resolution
2. Spatial Resolution
3. Sensitivity and Noise
4. Information Content
5. Implementation

Single Shot Imaging

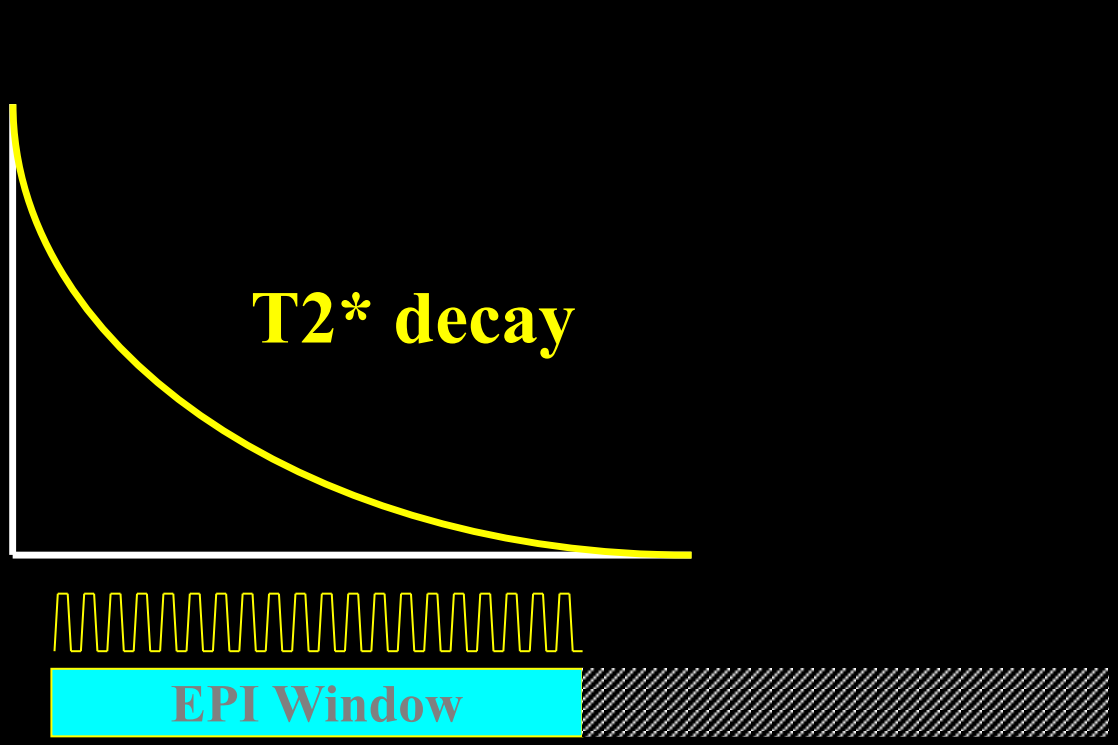


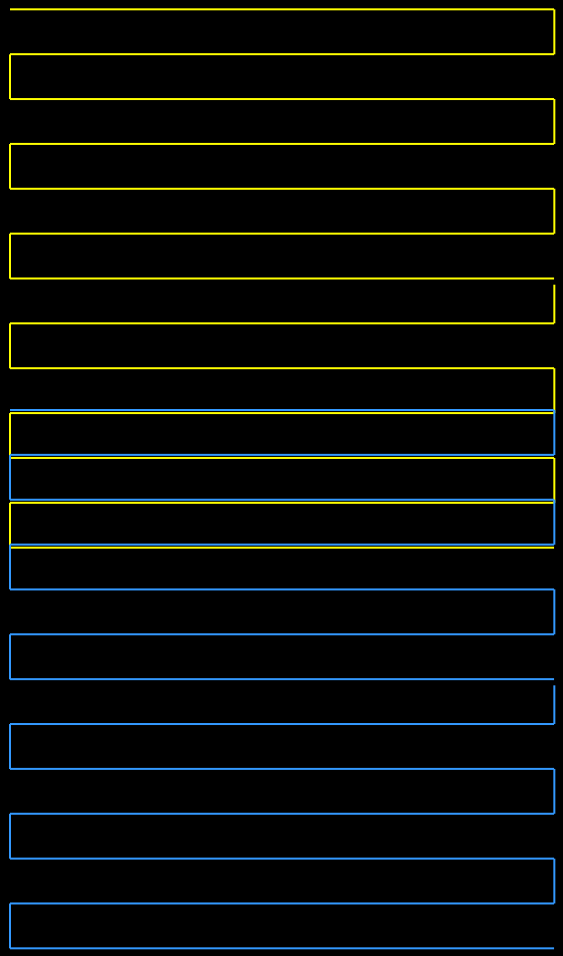


EPI Readout Window

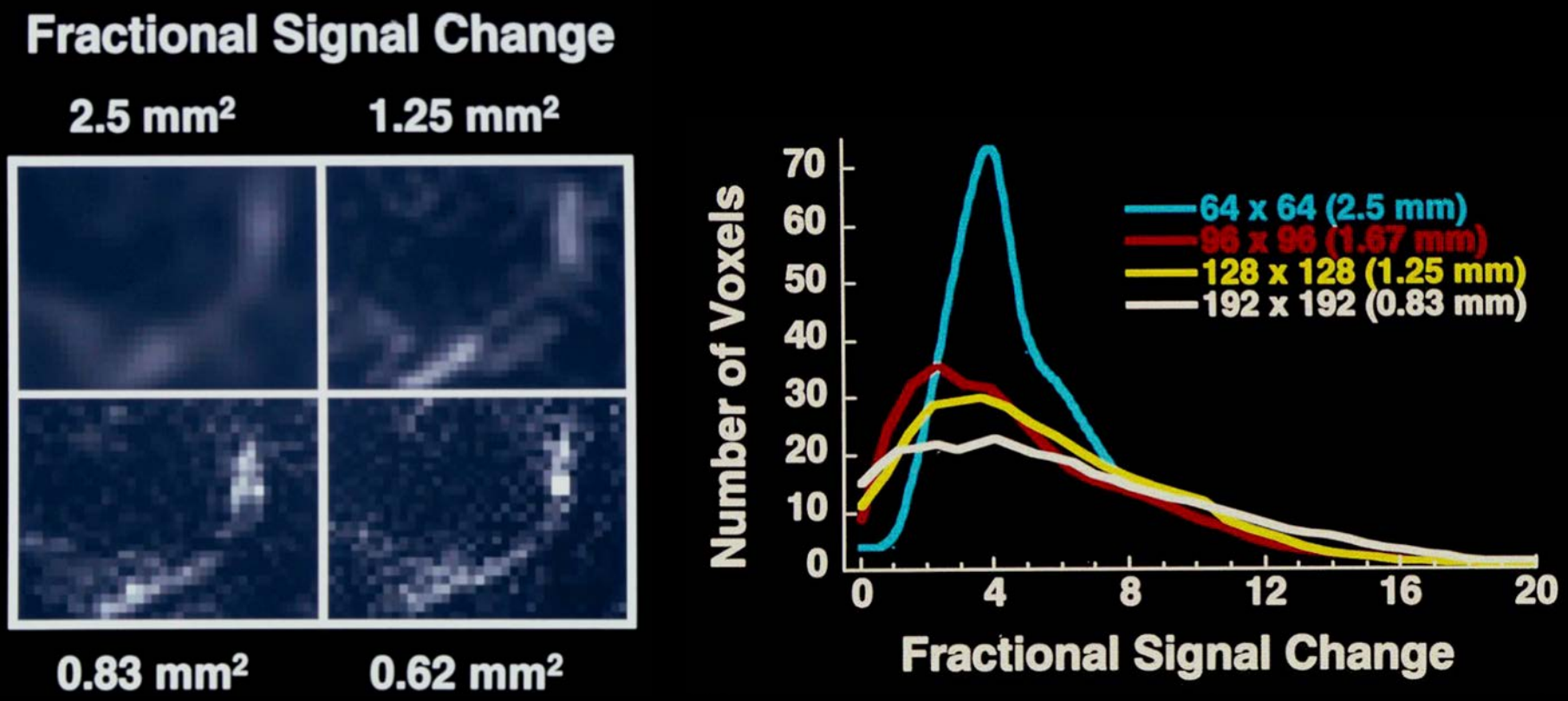
≈ 20 to 40 ms

Partial k-space imaging



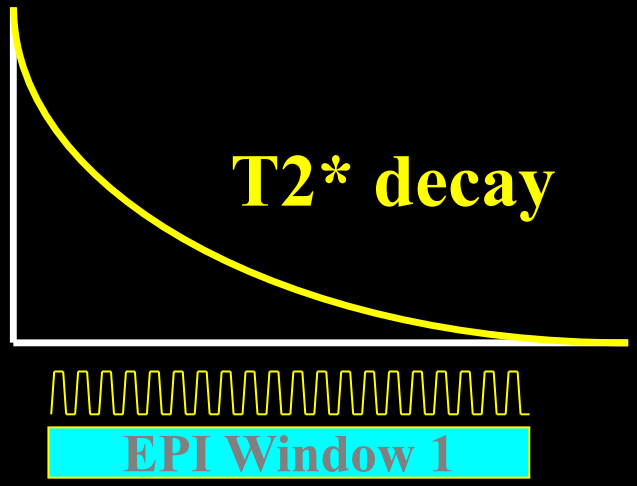


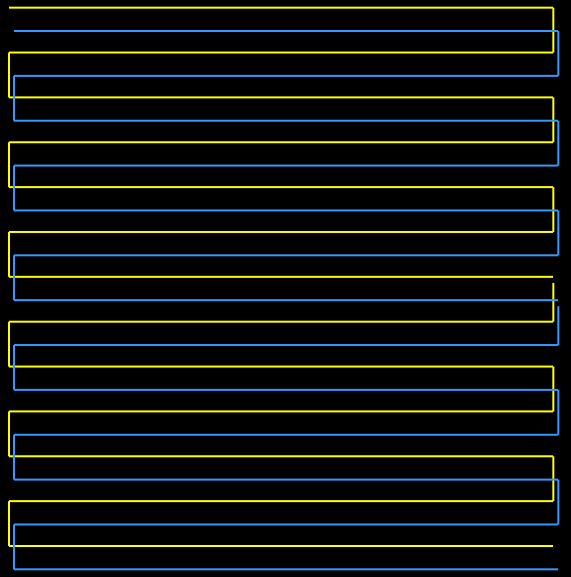
Partial k-space imaging

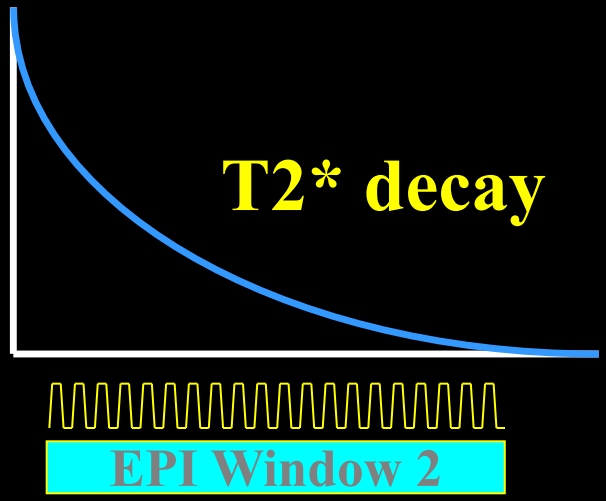


Jesmanowicz, P. A. Bandettini, J. S. Hyde, (1998) "Single shot half k-space high resolution EPI for fMRI at 3T." *Magn. Reson. Med.* 40, 754-762.

Multishot Imaging

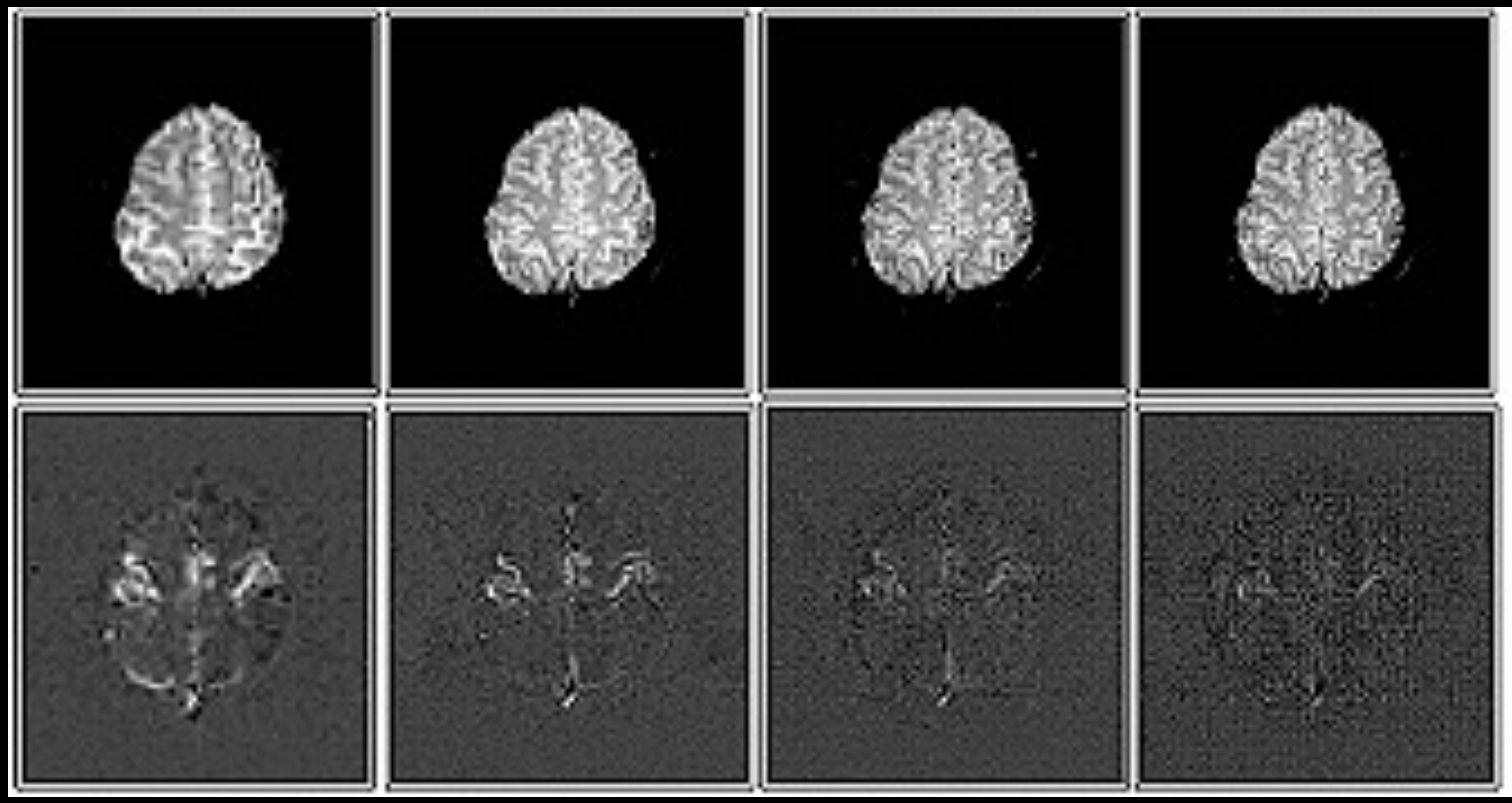




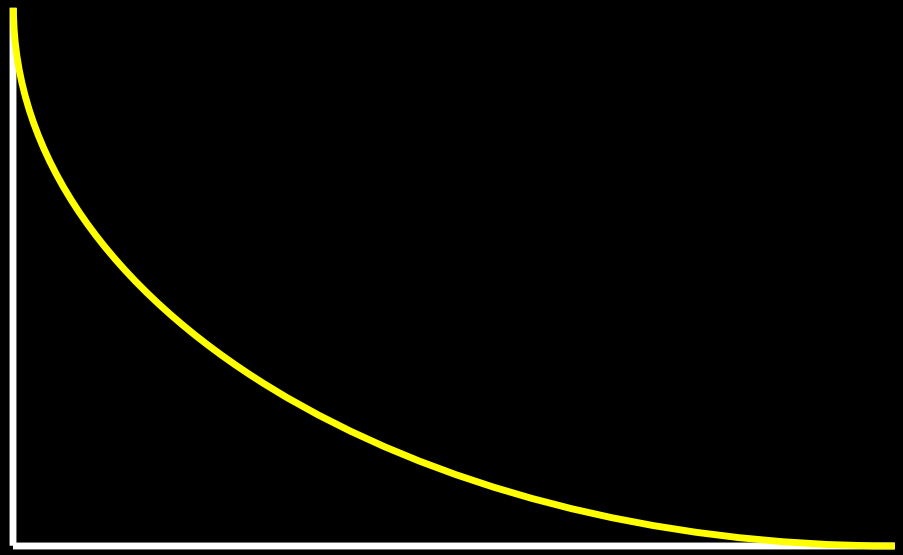


Multi Shot EPI

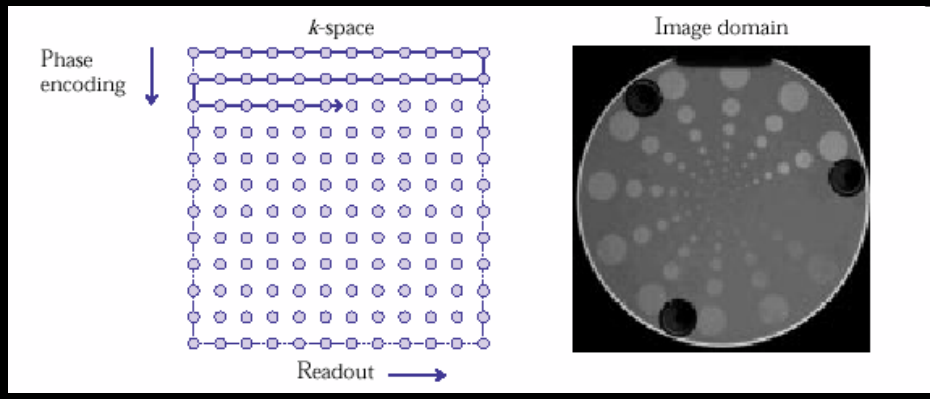
Excitations	1	2	4	8	
Matrix Size	64 x 64		128 x 128	256 x 128	256

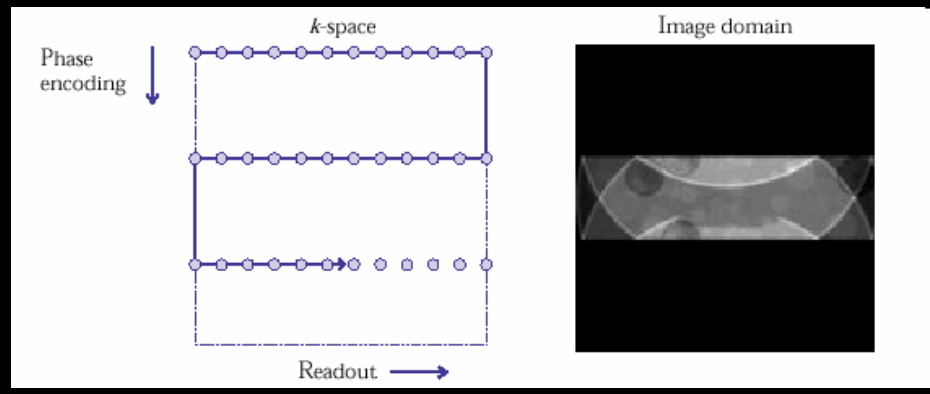


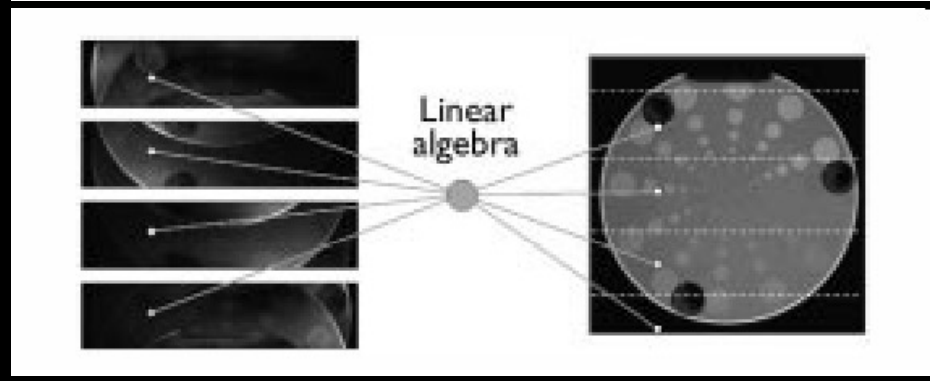
SENSE Imaging



≈ 5 to 30 ms



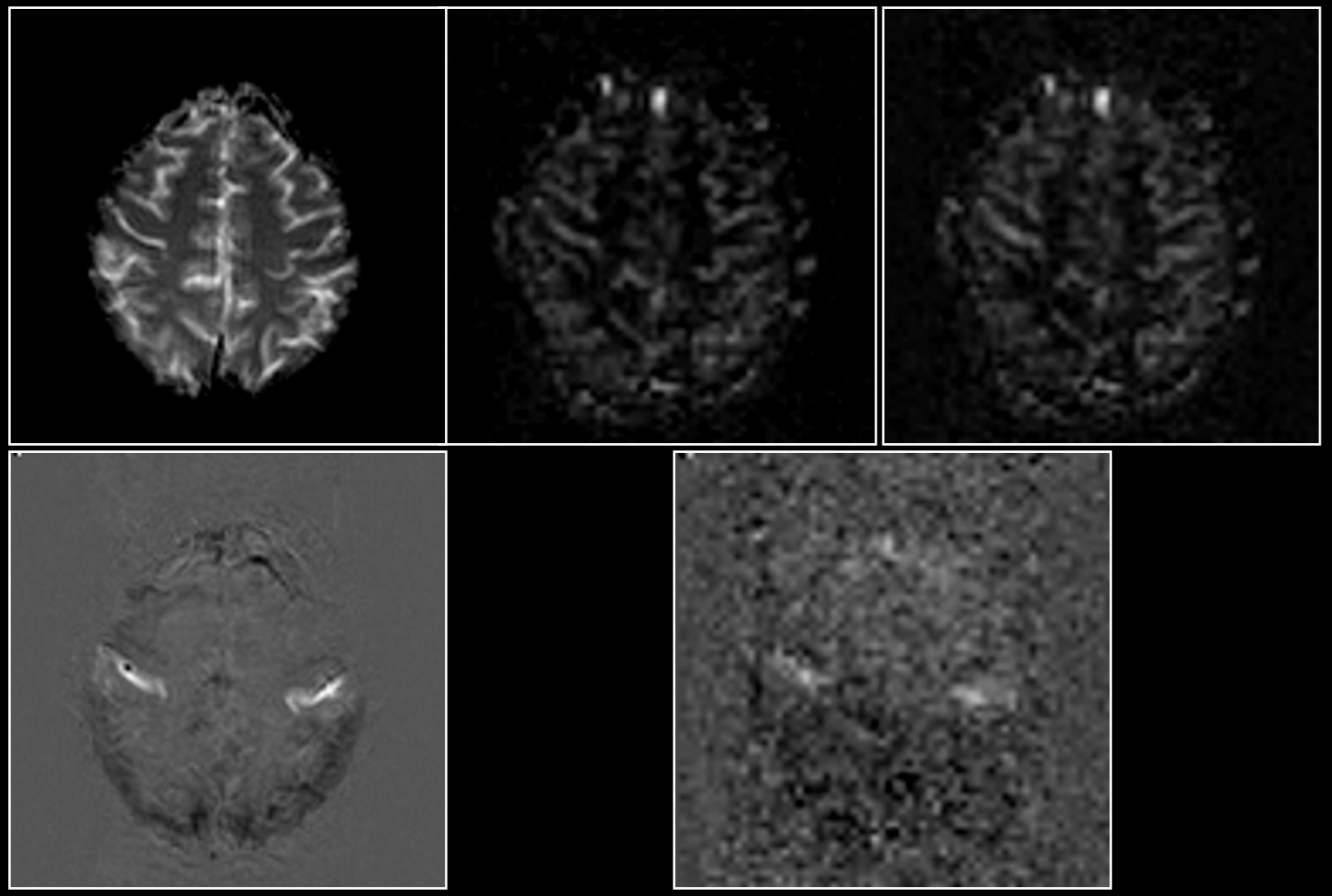




Pruessmann, et al.

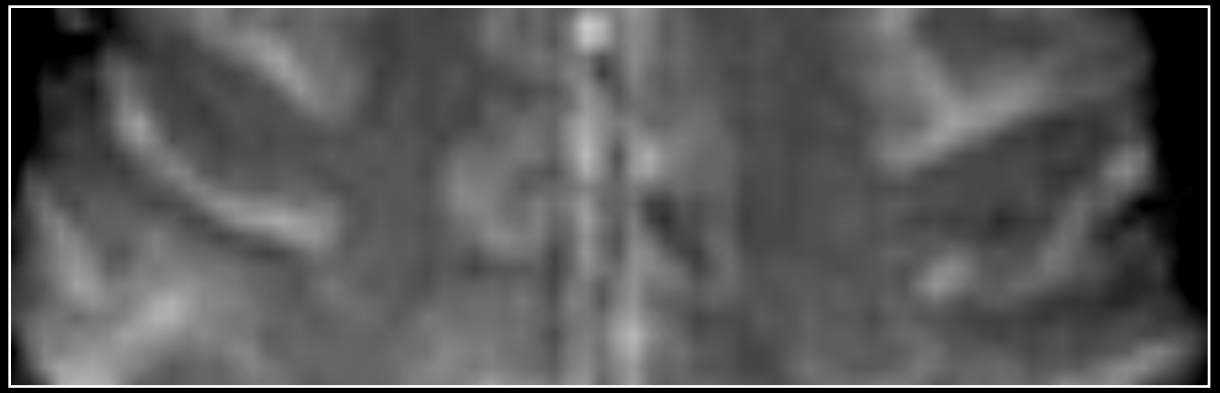
Perfusion

BOLD *Rest* *Activation*

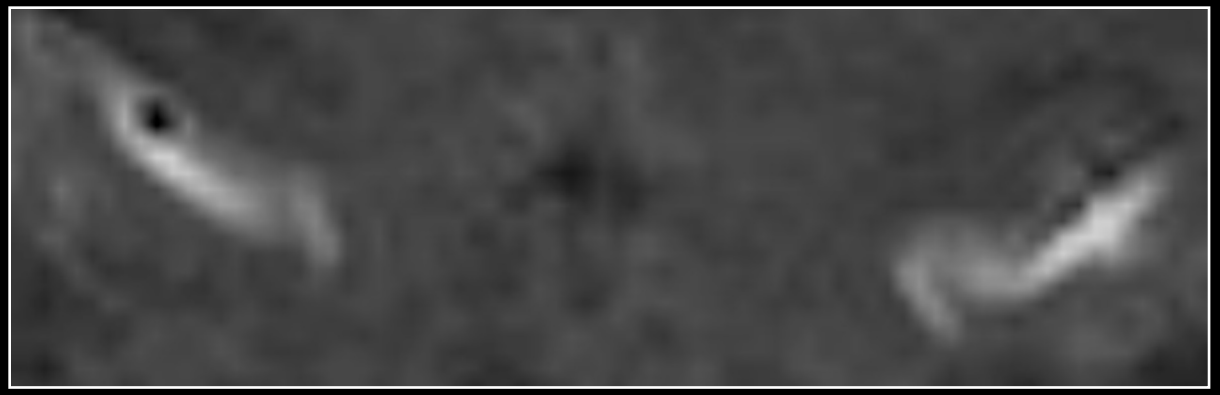


P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

Anatomy

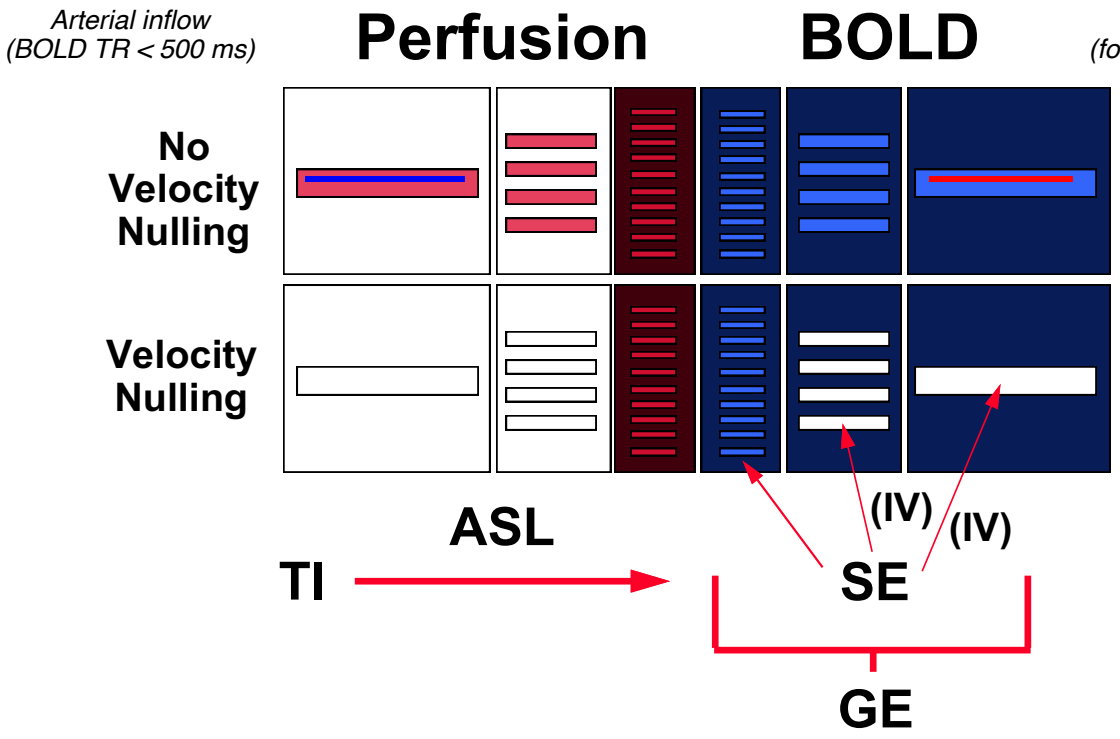


BOLD



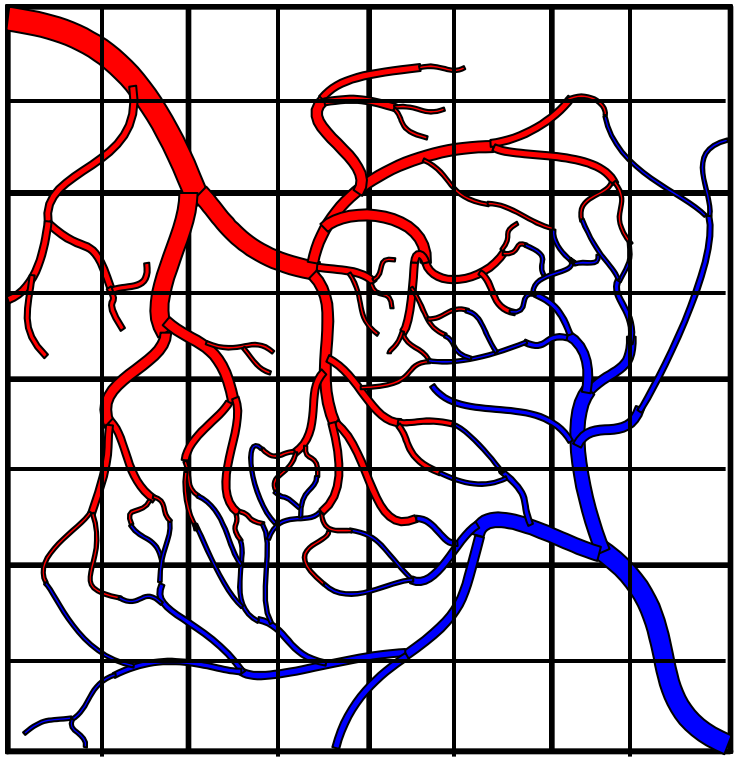
Perfusion

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.



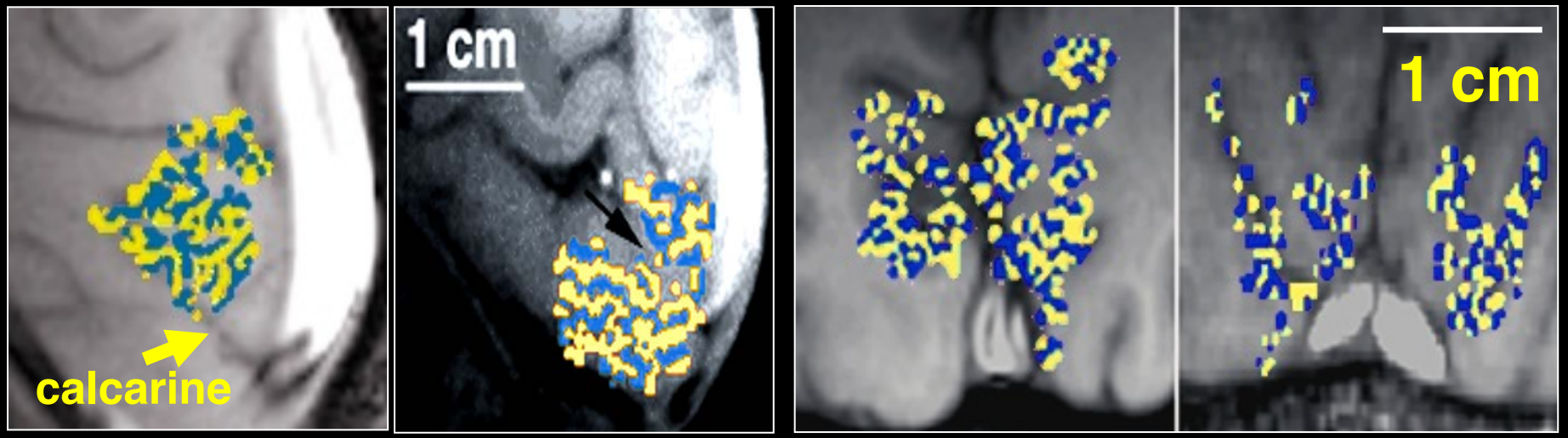
Pulse Sequence Sensitivity

Spatial Heterogeneity



Menon, et al

ODC Maps using fMRI



- Identical in size, orientation, and appearance to those obtained by optical imaging[1] and histology[3,4].

[1]Malonek D, Grinvald A. *Science* 272, 551-4 (1996).
[3]Horton JC, Hocking DR. *J Neurosci* 16, 7228-39 (1996).
[4]Horton JC, et al. *Arch Ophthalmol* 108, 1025-31 (1990).

Latest Developments...

1. Temporal Resolution
2. Spatial Resolution
3. Sensitivity and Noise
4. Information Content
5. Implementation

The spatial extent of the BOLD response

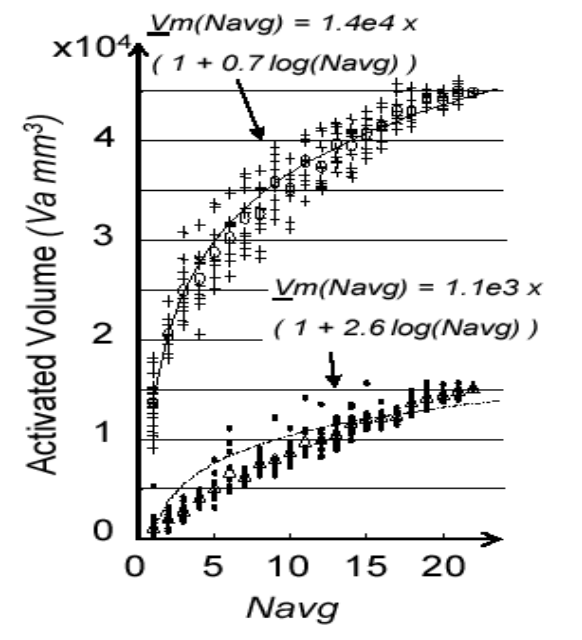
Ziad S. Saad,[a,b,*] Kristina M. Ropella,[b] Edgar A. DeYoe,[c] and Peter A. Bandettini[a]

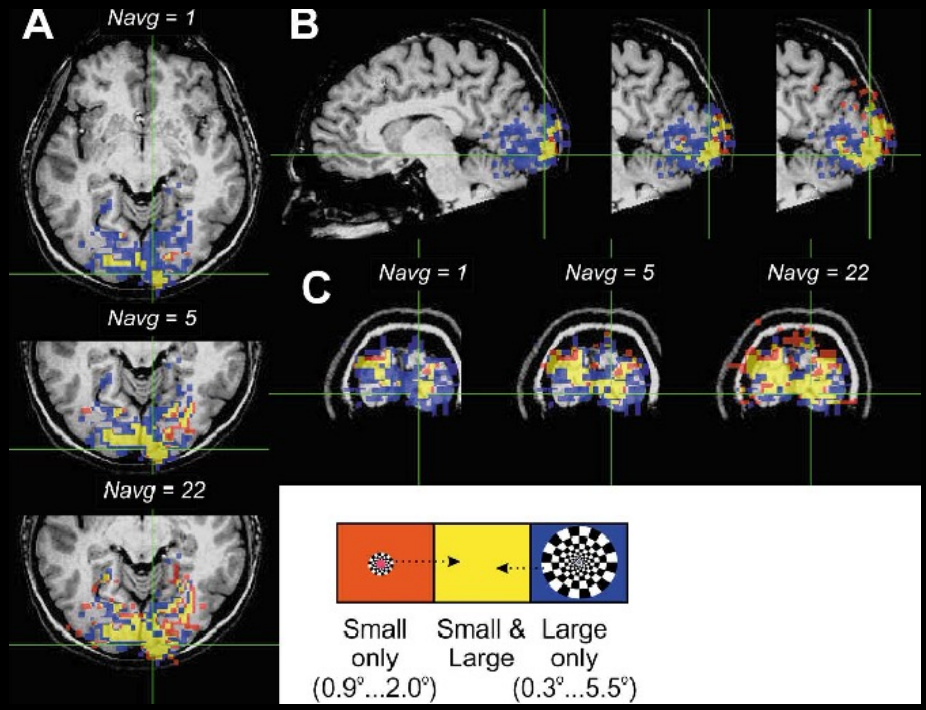
[a] Laboratory of Brain and Cognition, National Institute of Mental Health, NIH, Bethesda, MD 20892-1148, USA
[b] Department of Biomedical Engineering Marquette University, Milwaukee, WI 53233, USA
[c] Department of Cell Biology, Neurobiology and Anatomy, Medical College of Wisconsin, Milwaukee, WI 53226, USA

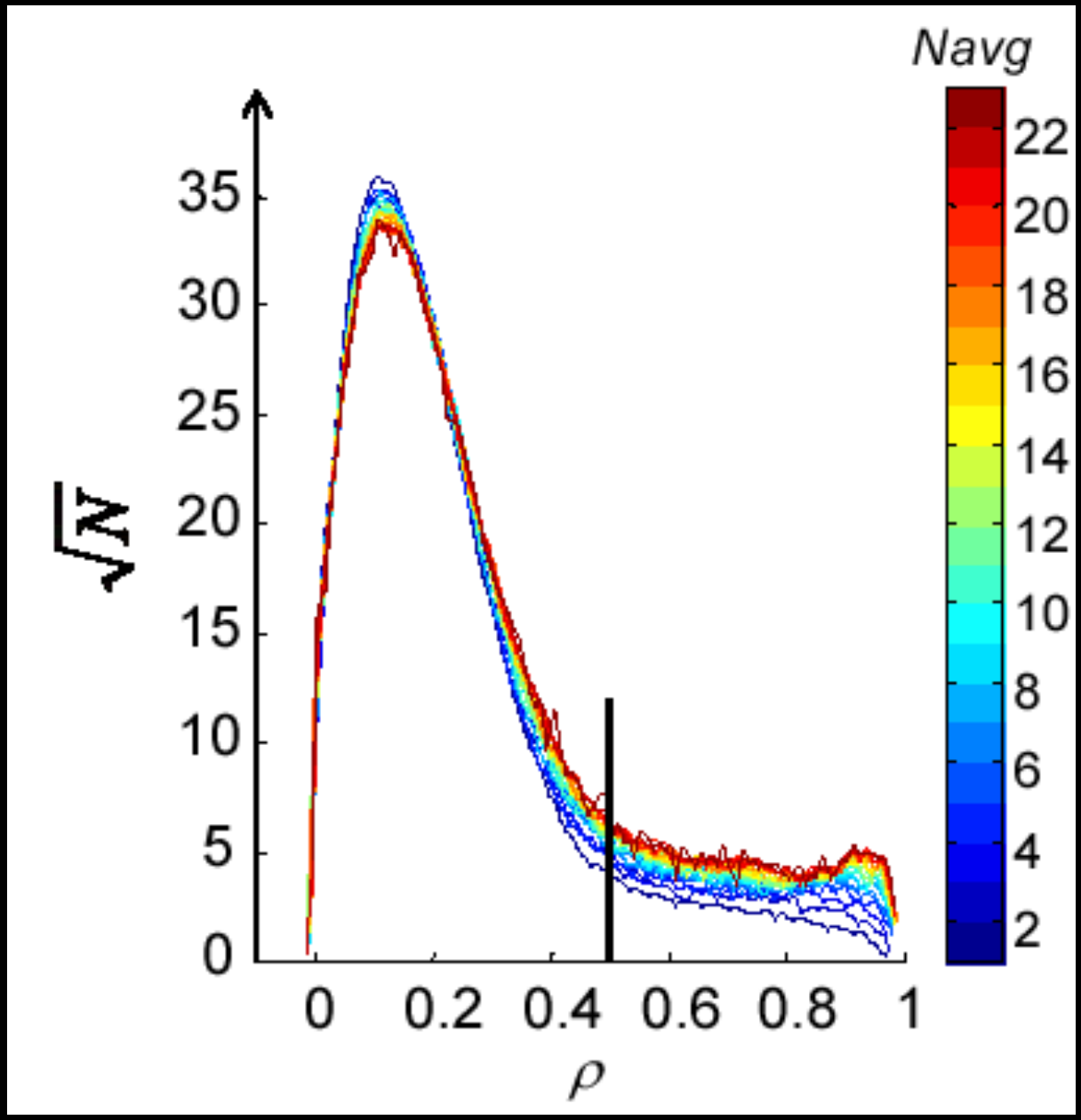
Received 16 August 2002; revised 29 October 2002; accepted 21 November 2002

NeuroImage

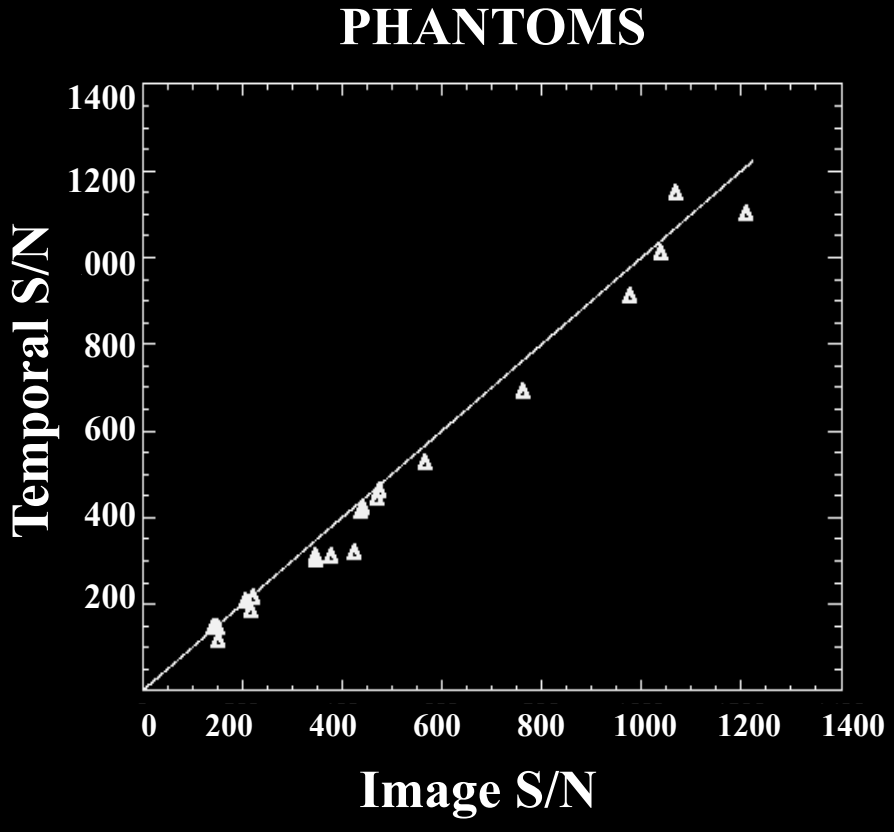
Question: What is the "true" spatial extent of BOLD contrast?
Paradigm: Repeated averaging of simple visual task

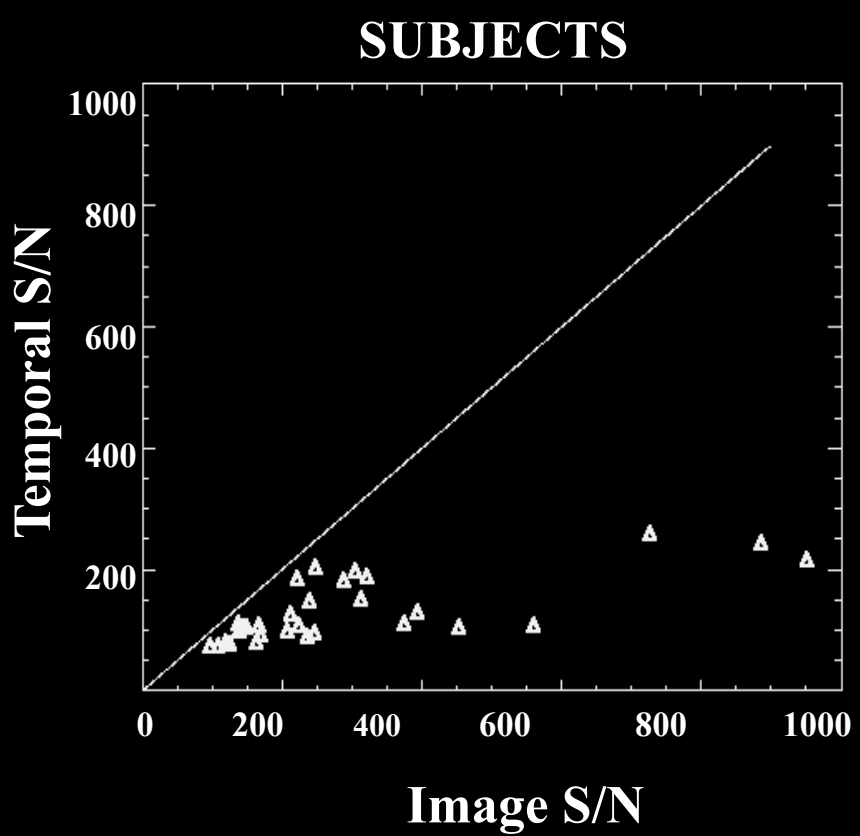




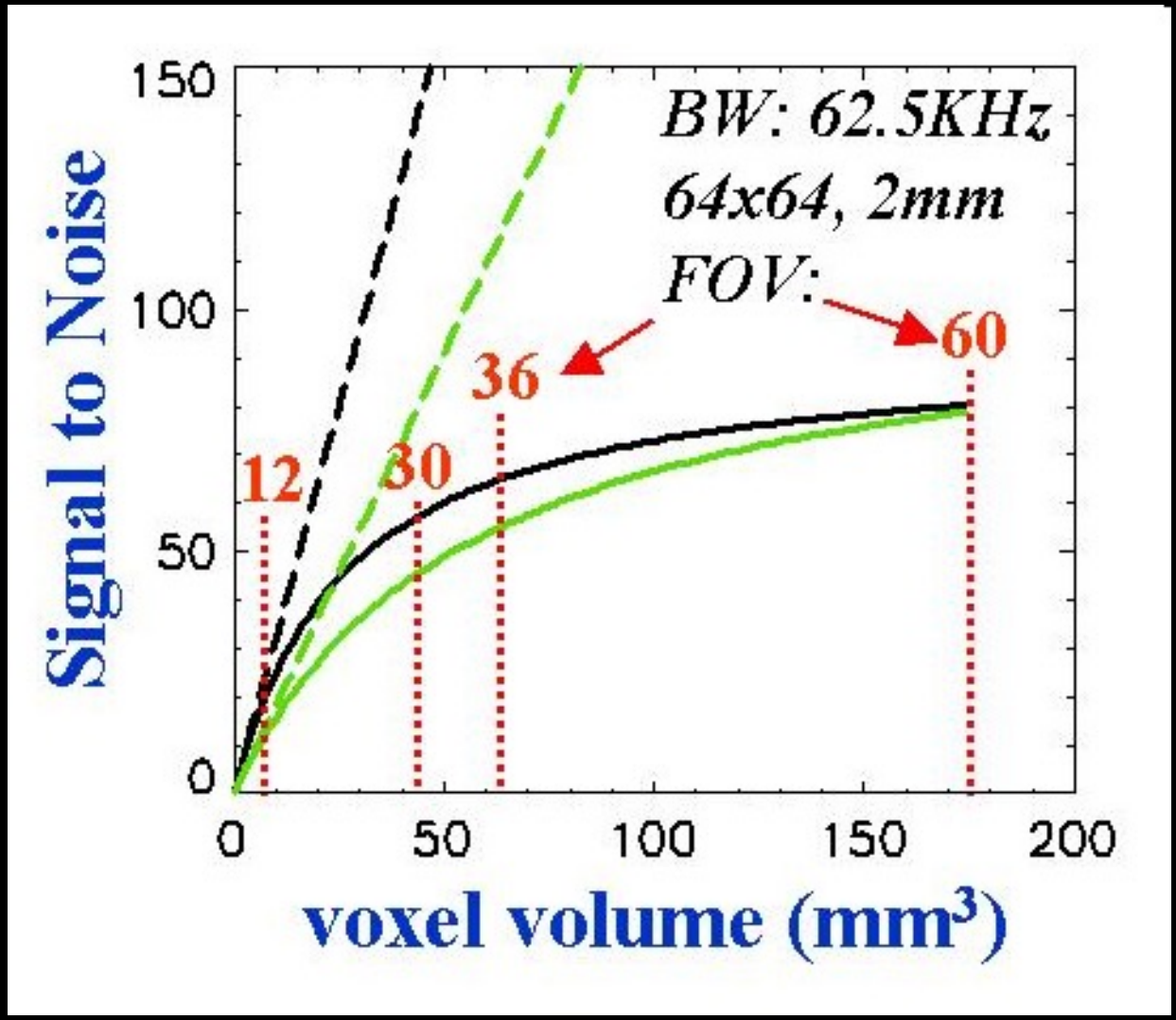

Navg
22
20
18
16
14
12
10
8
6
4
2
35
30
25
20
15
10
5
0
$\sqrt{N}$
0
0.2
0.4
0.6
0.8
1
ρ

Temporal S/N vs. Image S/N





N. Petridou


Signal to Noise
voxel volume (mm³)
BW: 62.5KHz
64x64, 2mm
FOV:
12
30
36
60
0
50
100
150
200

Single shot full k-space echo-planar-imaging with an eight-channel phase array coil at 3T.

Jerzy Bodurka[1], Peter van Gelderen[2], Patrick Ledden[3], Peter Bandettini[1], Jeff Duyn[2]
[1]Functional MRI Facility NIMH/NIH, [2]Advance MRI NINDS/NIH, [3]Nova Medical Inc.

Quadrature Head Coil

8 Channel Array

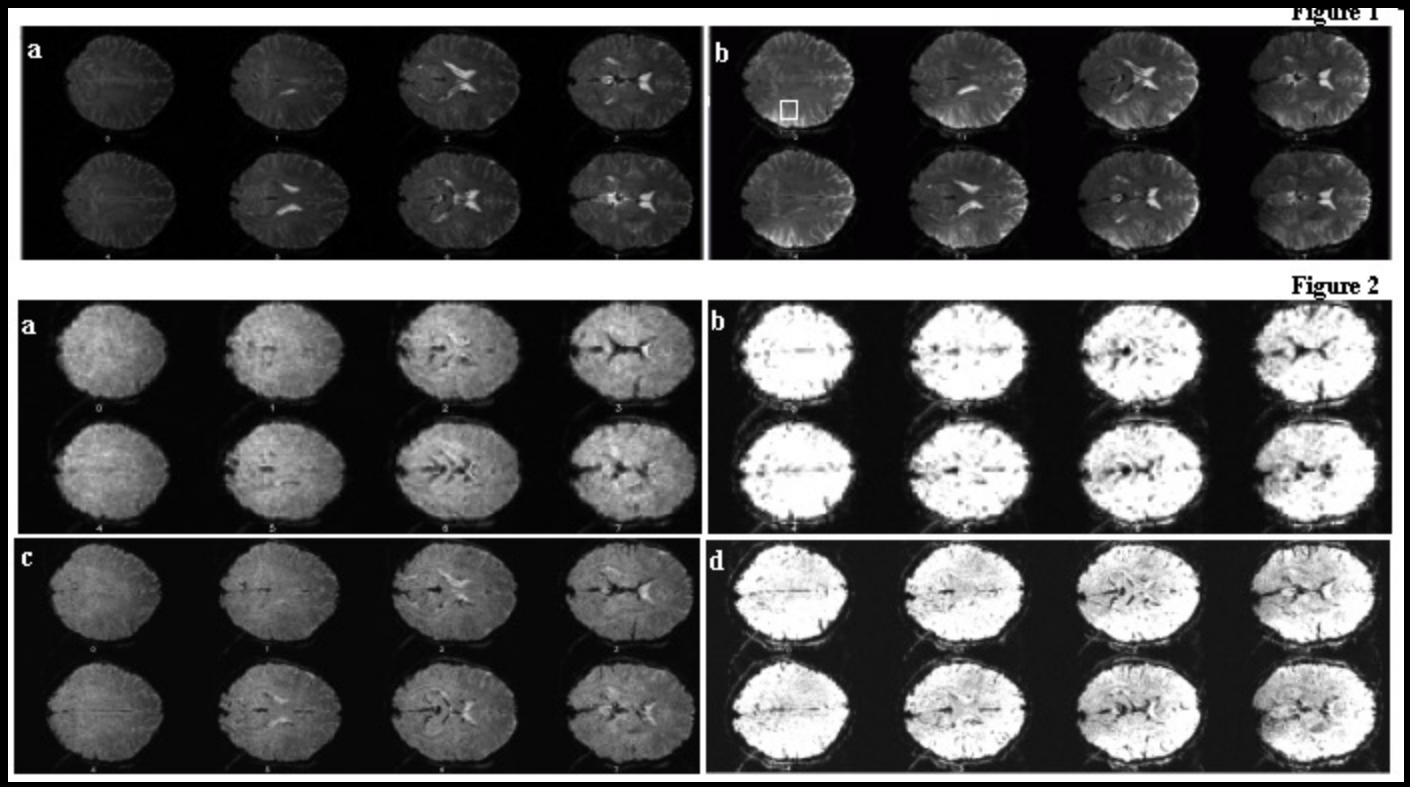
128 x 96

64 x 48

128 x 96

SNR

TSNR



Latest Developments...

1. Temporal Resolution
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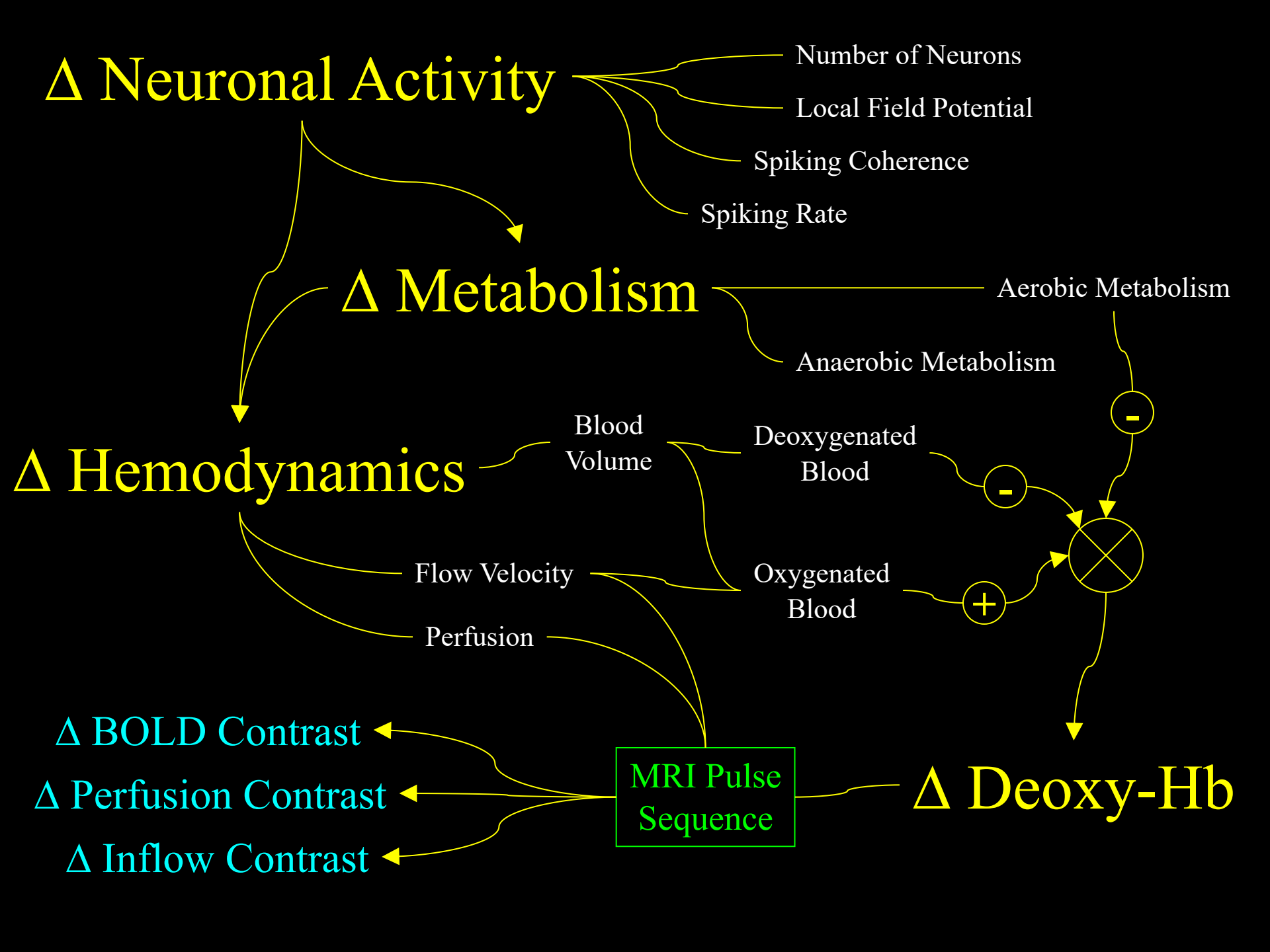
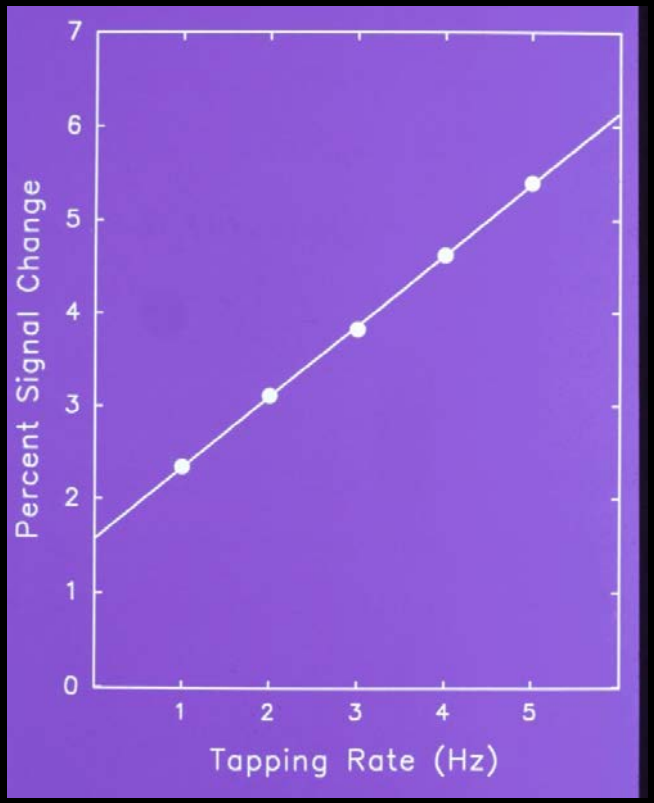
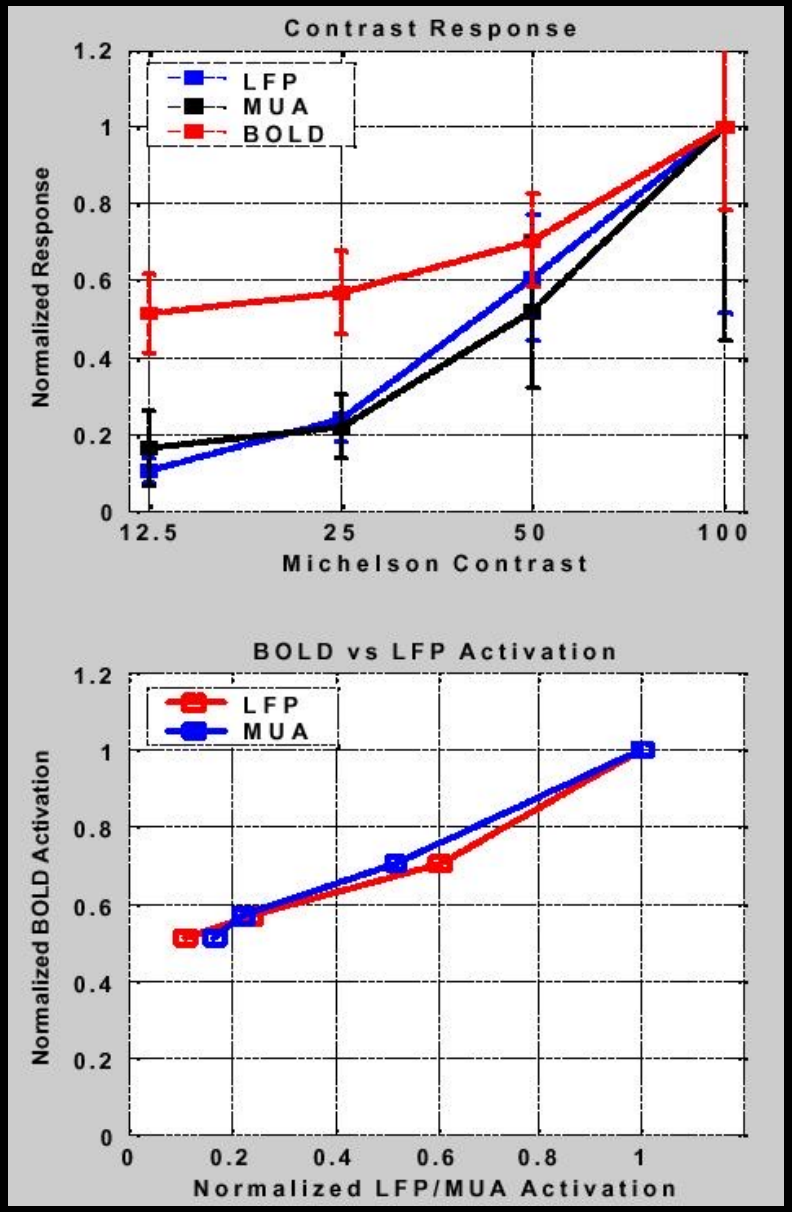

Δ Neuronal Activity
Number of Neurons
Local Field Potential
Spiking Coherence
Spiking Rate
Δ Metabolism
Aerobic Metabolism
Anaerobic Metabolism
Δ Hemodynamics
Blood Volume
Deoxygenated Blood
Flow Velocity
Oxygenated Blood
Perfusion
-
-
+
Δ BOLD Contrast
Δ Perfusion Contrast
Δ Inflow Contrast
MRI Pulse Sequence
Δ Deoxy-Hb



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.

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



Spatial Heterogeneity of the Nonlinear Dynamics in the FMRI BOLD Response

Rasmus M. Birn, Ziad S. Saad, and Peter A. Bandettini

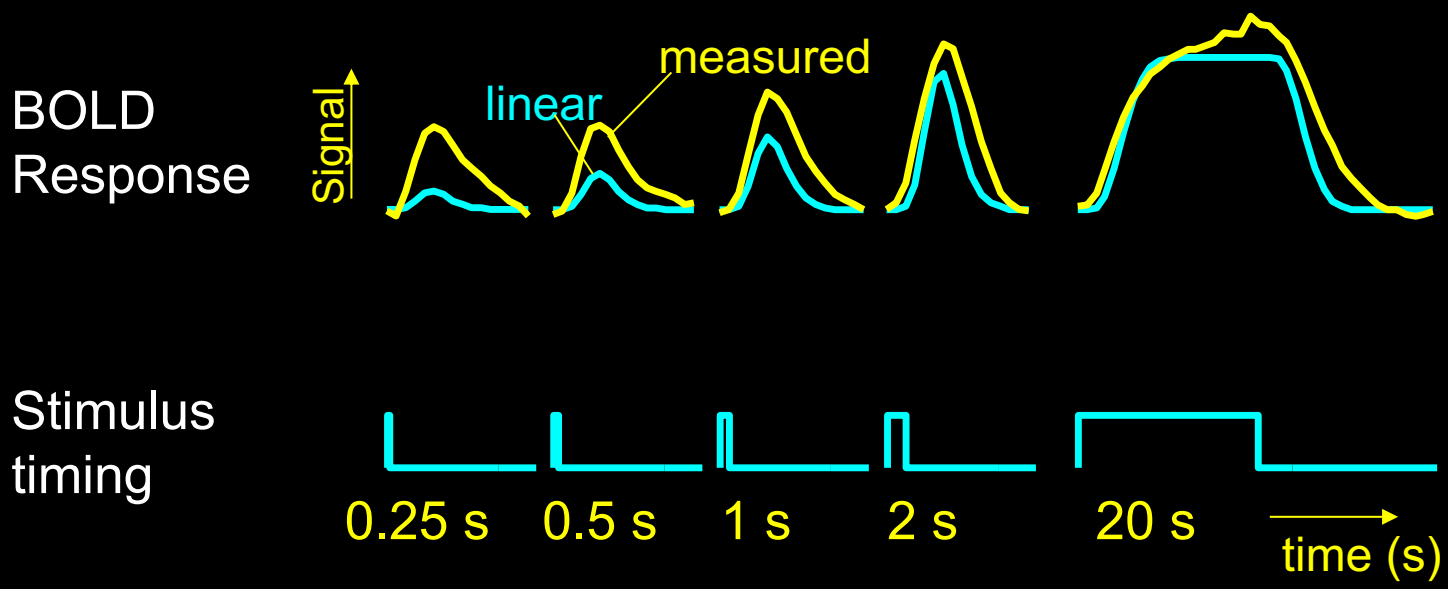
Laboratory of Brain and Cognition, National Institute of Mental Health, NIH Bethesda, Maryland

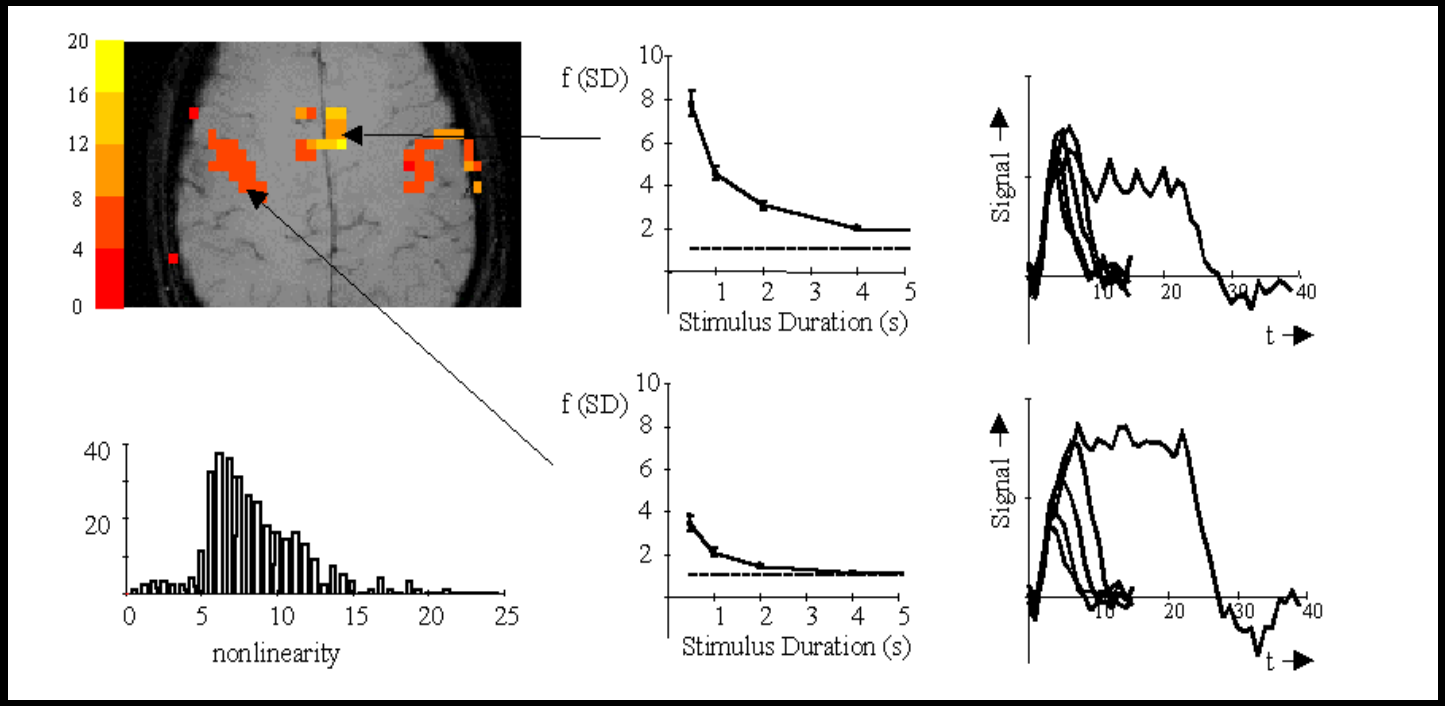
Received October 18, 2000

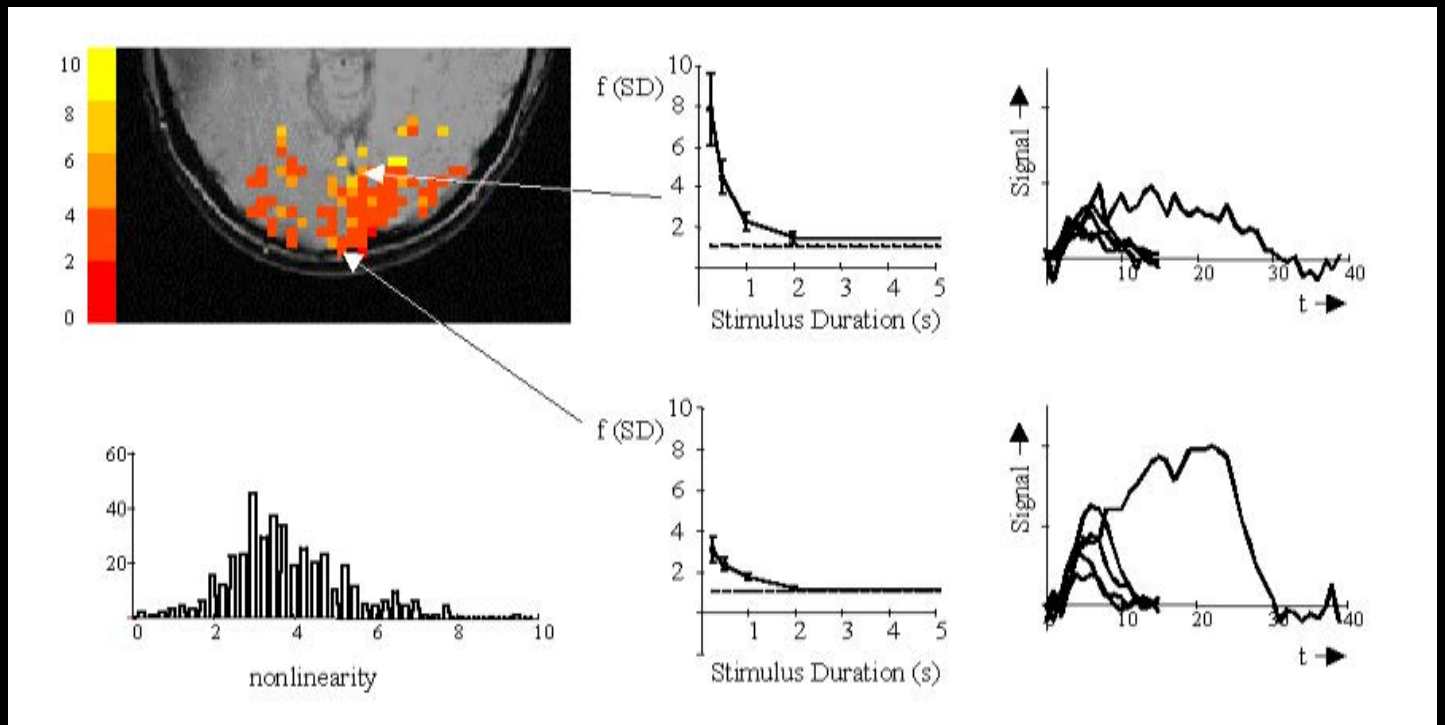
NeuroImage

Question: Do BOLD nonlinearities exhibit spatial heterogeneity?

Paradigm: Stimulus duration modulation from 50 ms to 20 sec.




20
16
12
8
4
0
f (SD)
10
8
6
4
2
1 2 3 4 5
Stimulus Duration (s)
Signal
10 20 30 40
t
40
20
0 5 10 15 20 25
nonlinearity
f (SD)
Stimulus Duration (s)
Signal
t

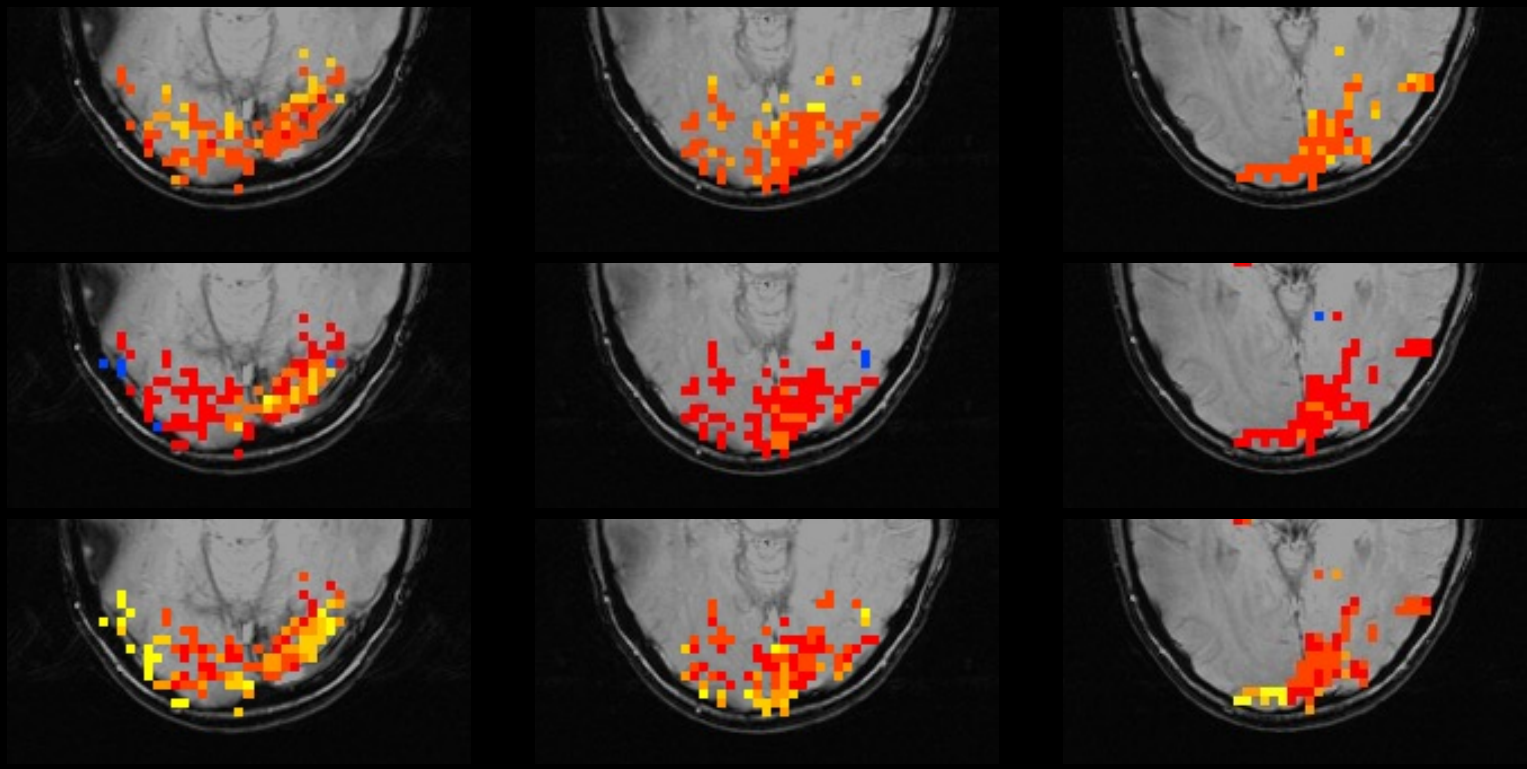

10
8
6
4
2
0
f (SD)
1 2 3 4 5
Stimulus Duration (s)
Signal
10 20 30 40
t
60
40
20
0 2 4 6 8 10
nonlinearity
f (SD)
Stimulus Duration (s)
Signal
t

Results – visual task

Nonlinearity

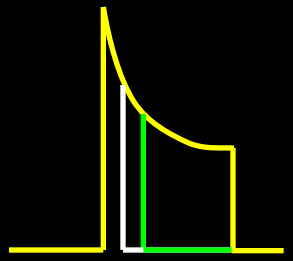
Magnitude

Latency

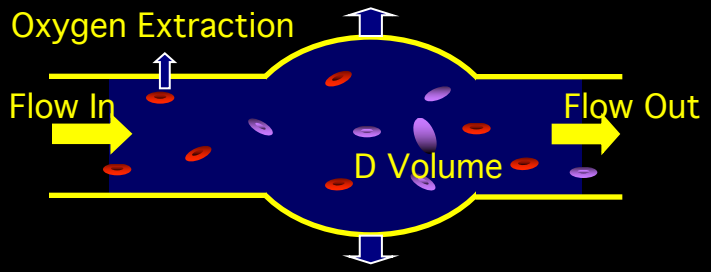


Sources of this Nonlinearity

- Neuronal

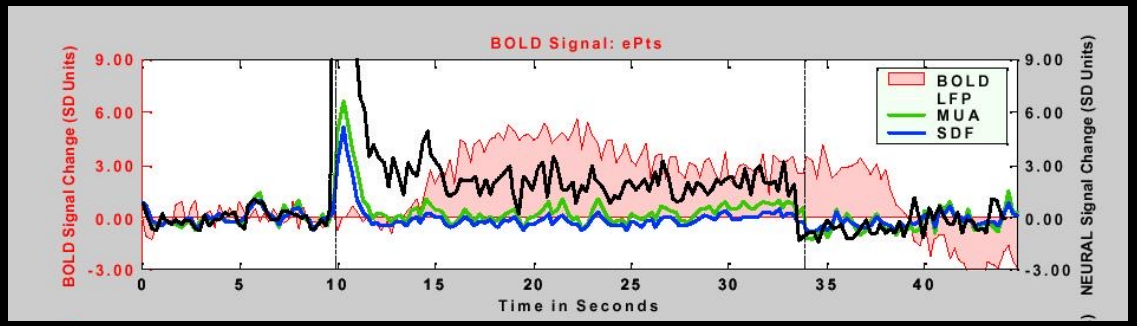


- Hemodynamic
  - Oxygen extraction
  - Blood volume dynamics

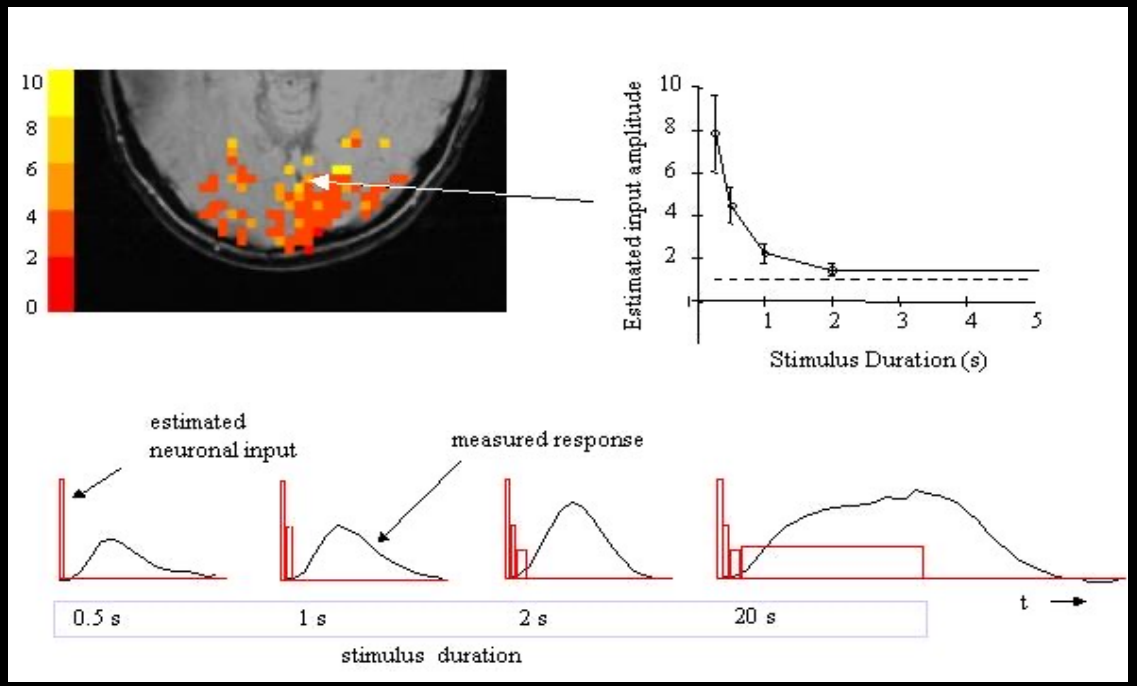


BOLD Correlation with Neuronal Activity

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.



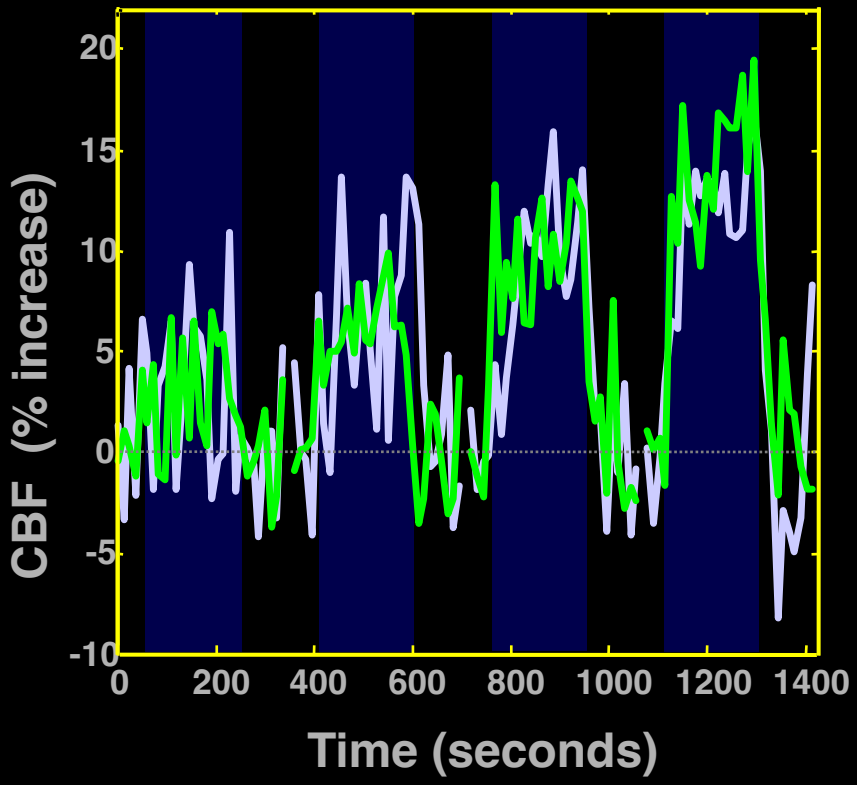
Proc. Natl. Acad. Sci. USA
Vol. 96, pp. 9403–9408, August 1999
Neurobiology

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

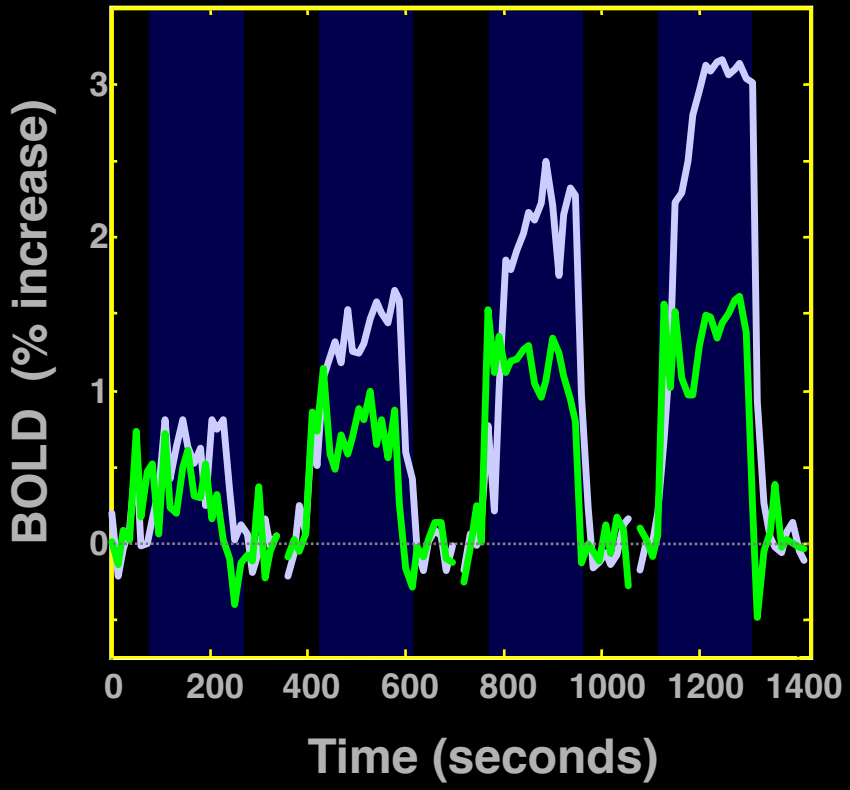
RICHARD D. HOGE*†, JEFF ATKINSON*, BRAD GILL*, GÉRARD R. CRELIER*, SEAN MARRETT‡, AND G. BRUCE PIKE*

*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



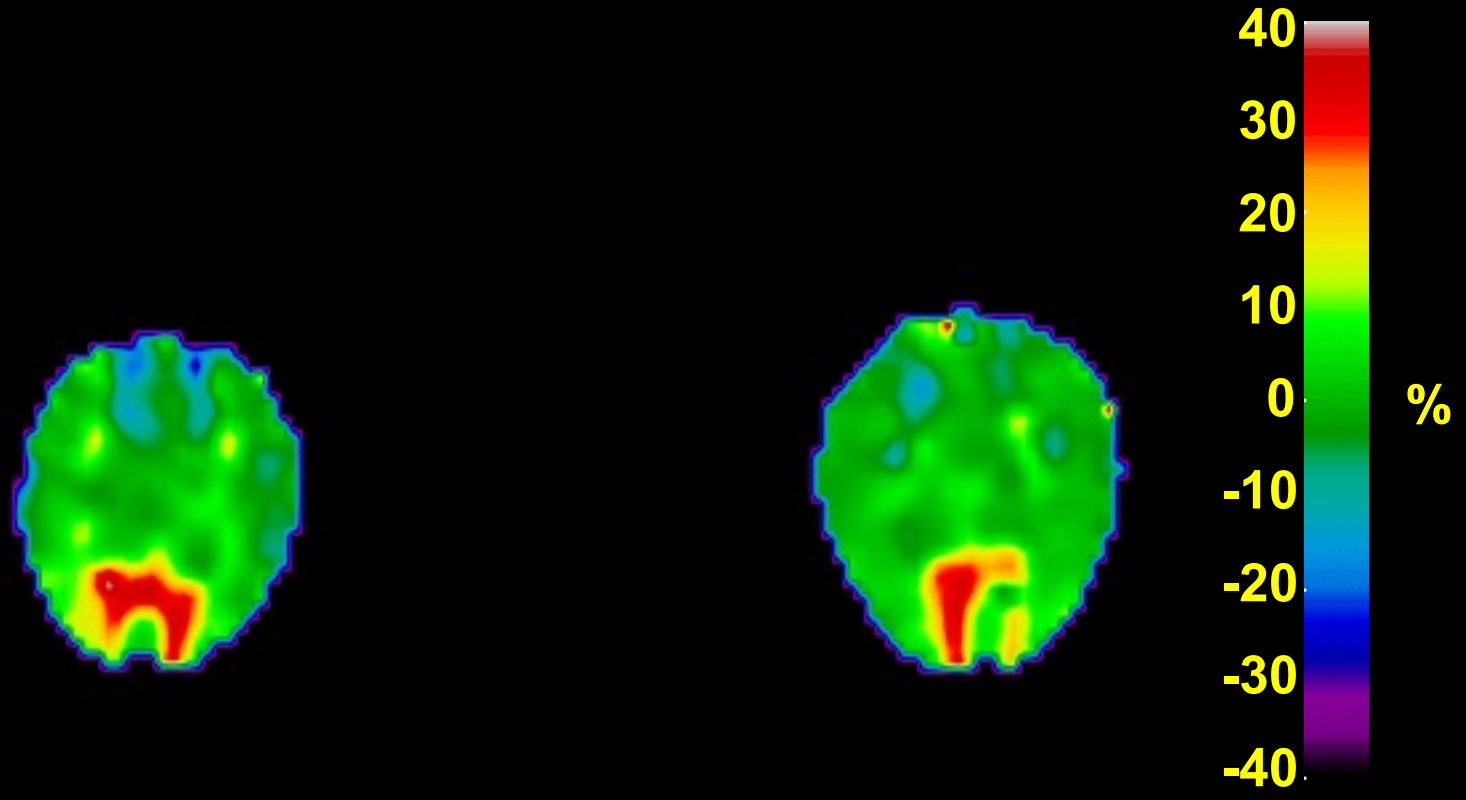
BOLD



Simultaneous Perfusion and BOLD imaging during graded visual activation and hypercapnia

N=12

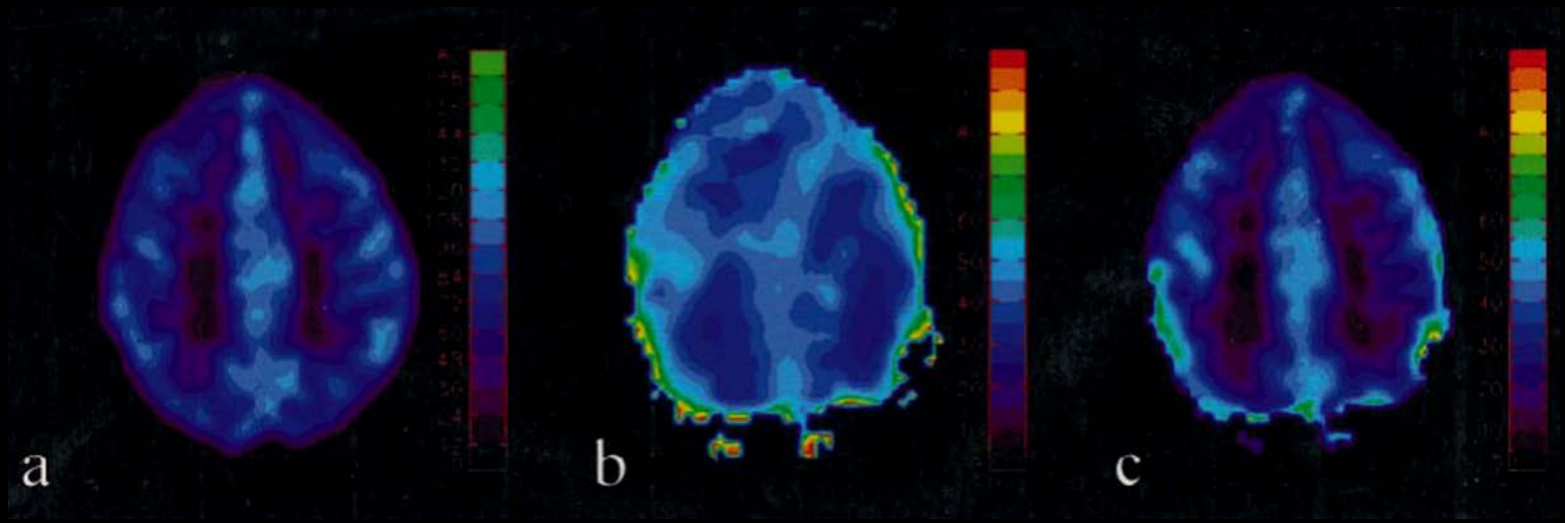
Computed $CMRO_2$ Changes



NMR IN BIOMEDICINE
NMR Biomed. 2001;**14**:441–447
DOI:10.1002/nbm.717

Quantitative measurements of cerebral metabolic rate of oxygen utilization using MRI: a volunteer study

Hongyu An,[1] Weili Lin,[2]* Azim Celik[3] and Yueh Z. Lee[2]



CBF OEF $CMRO_2$

Latest Developments...

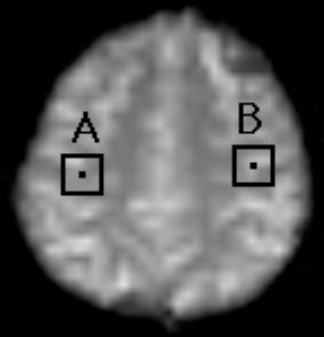
1. Temporal Resolution
2. Spatial Resolution
3. Sensitivity and Noise
4. Information Content
5. Implementation

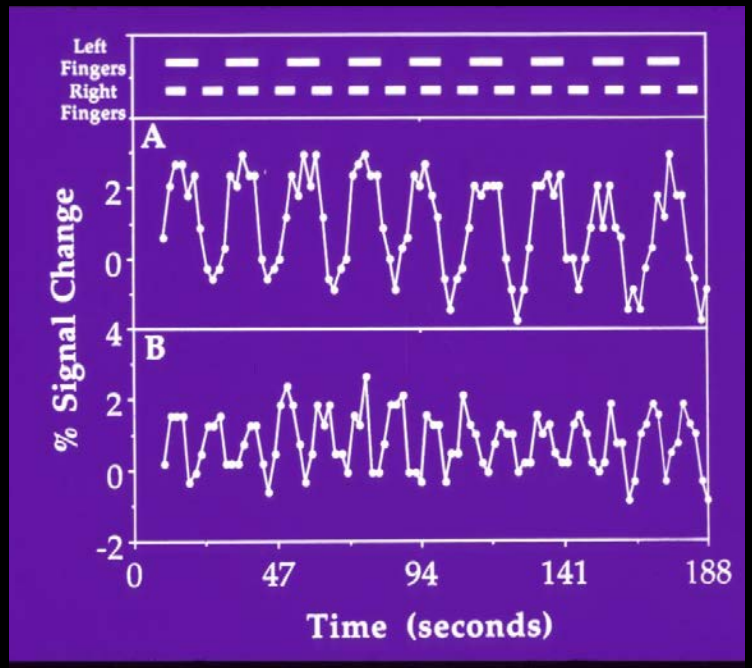
Neuronal Activation Input Strategies

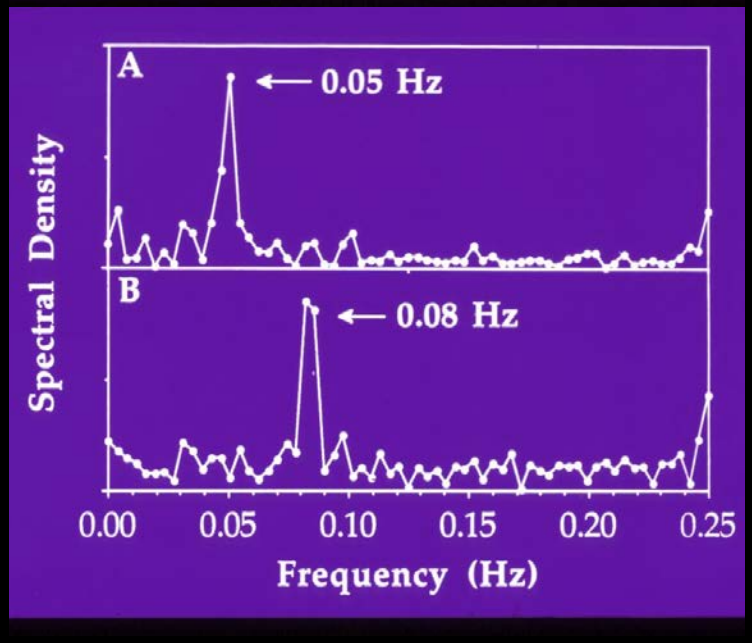
1. Block Design
2. Parametric Design
3. Frequency Encoding
4. Phase Encoding
5. Event Related
6. Orthogonal Design
7. Free Behavior Design

Neuronal Activation Input Strategies

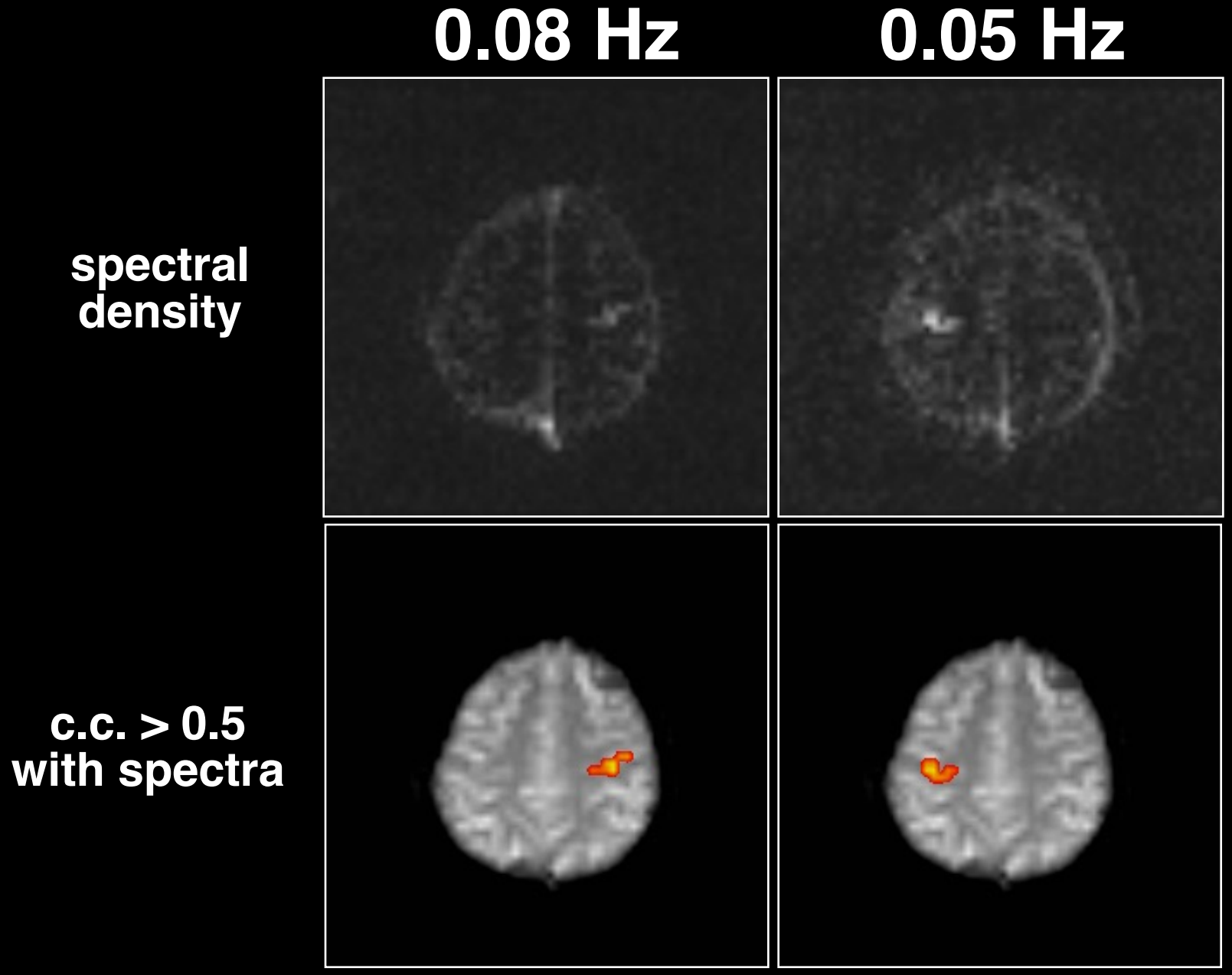
1. Block Design
2. Parametric Design
3. **Frequency Encoding**
4. Phase Encoding
5. Event Related
6. Orthogonal Design
7. Free Behavior Design







P. A. Bandettini, A. Jesmanowicz, E. C. Wong, J. S. Hyde, Processing strategies for time-course data sets in functional MRI of the human brain. *Magn. Reson. Med.* 30, 161-173 (1993).



P. A. Bandettini, A. Jesmanowicz, E. C. Wong, J. S. Hyde, Processing strategies for time-course data sets in functional MRI of the human brain. *Magn. Reson. Med.* 30, 161-173 (1993).

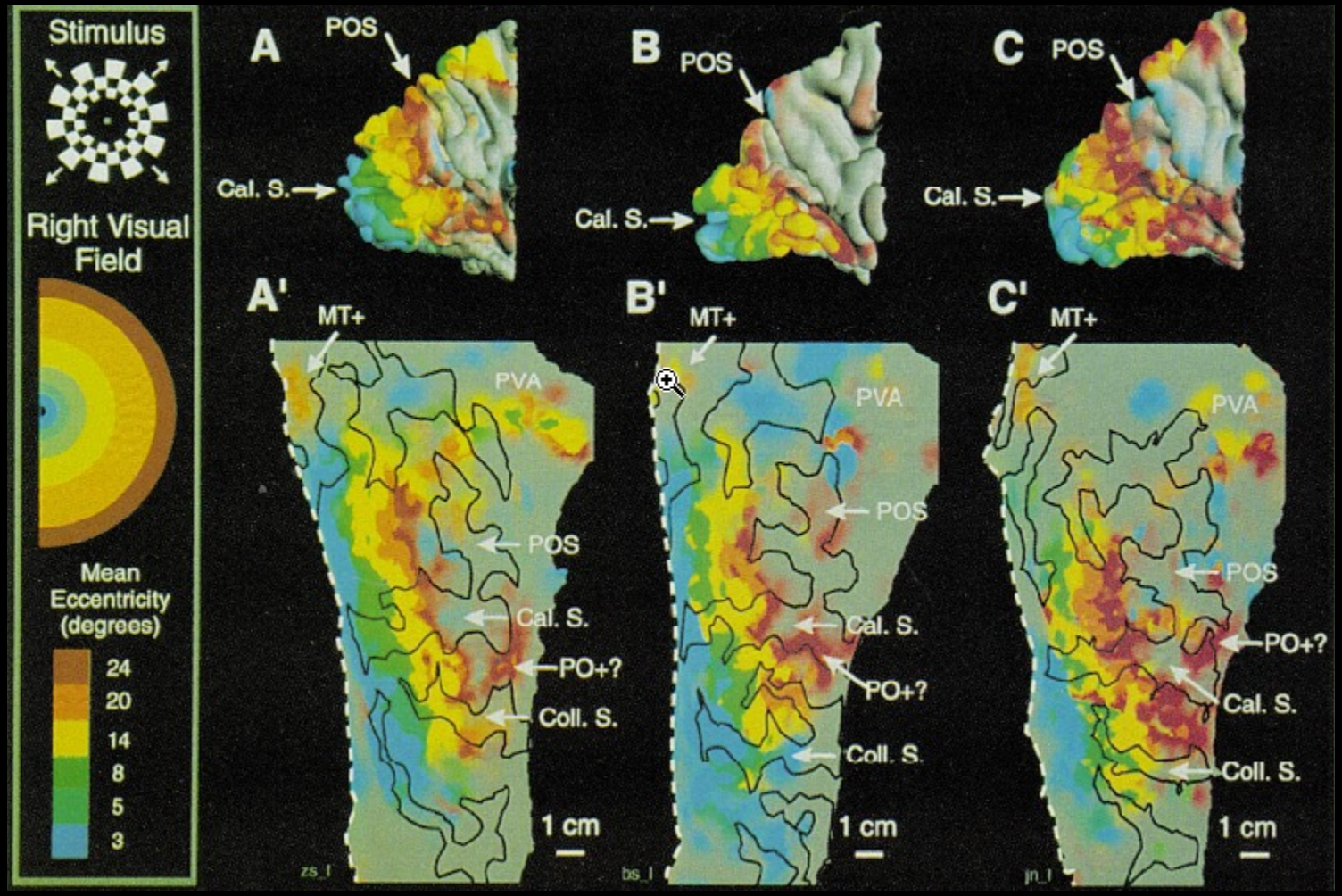
Neuronal Activation Input Strategies

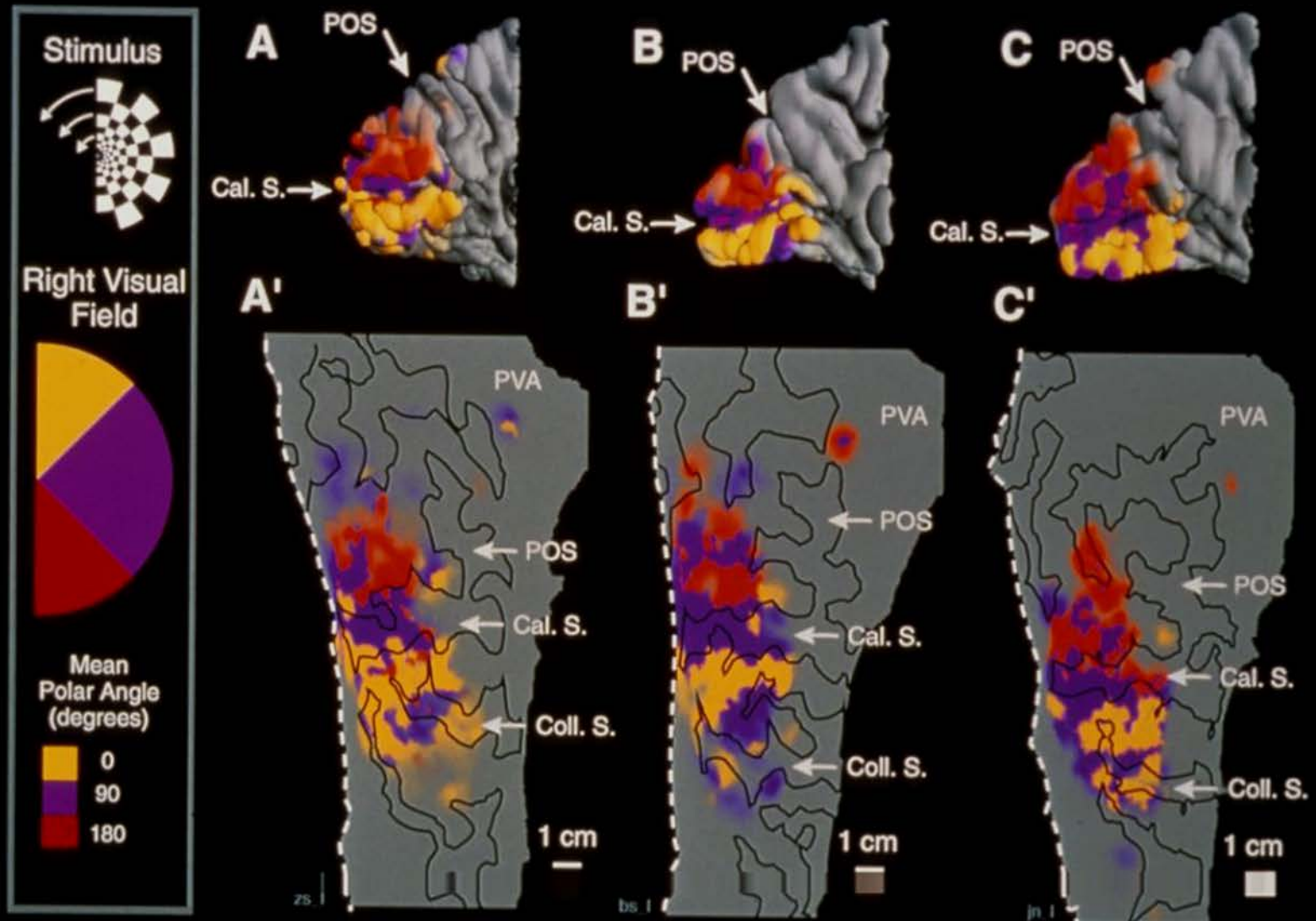
1. Block Design
2. Parametric Design
3. Frequency Encoding
4. **Phase Encoding**
5. Event Related
6. Orthogonal Design
7. Free Behavior Design

Proc. Natl. Acad. Sci. USA
Vol. 93, pp. 2382–2386, March 1996
Neurobiology

Mapping striate and extrastriate visual areas in human cerebral cortex

EDGAR A. DEYOE*, GEORGE J. CARMAN†, PETER BANDETTINI‡, SETH GLICKMAN*, JON WIESER*, ROBERT COX§, DAVID MILLER¶, AND JAY NEITZ*



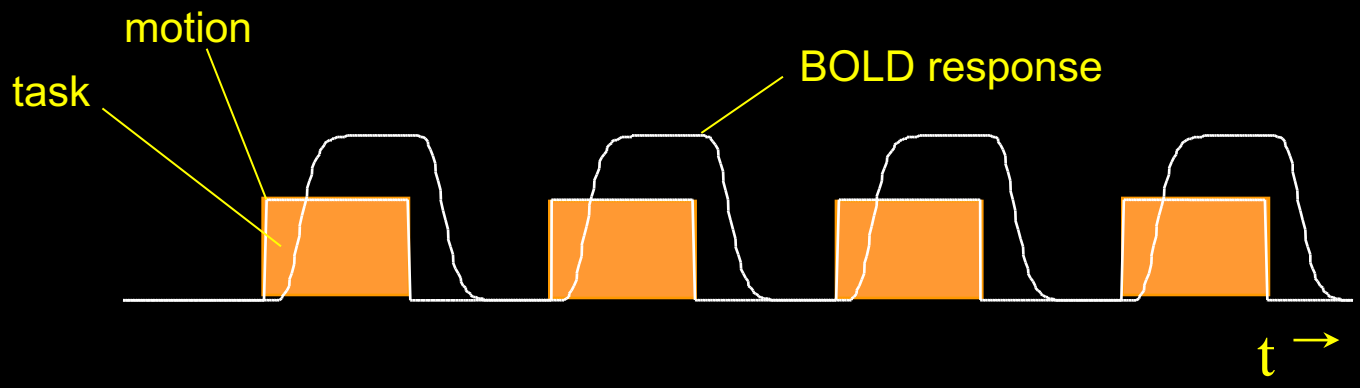

Stimulus
Right Visual Field
Mean Polar Angle (degrees)
0
90
180
A
POS
Cal. S.
B
POS
Cal. S.
C
POS
Cal. S.
A'
PVA
POS
Cal. S.
Coll. S.
1 cm
zs
B'
PVA
POS
Cal. S.
Coll. S.
1 cm
bs
C'
PVA
POS
Cal. S.
Coll. S.
1 cm
jn

Neuronal Activation Input Strategies

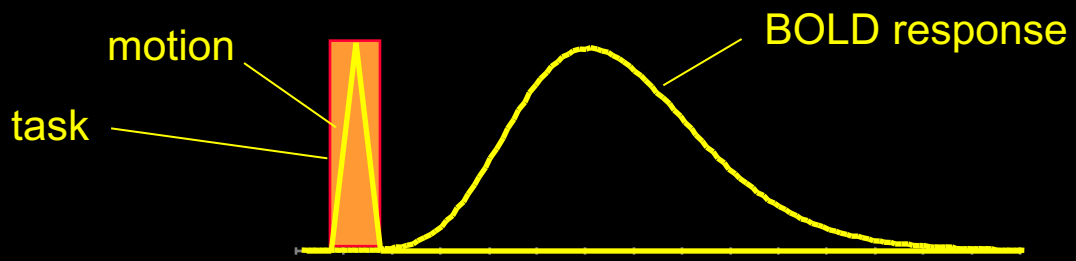
1. Block Design
2. Parametric Design
3. Frequency Encoding
4. Phase Encoding
5. **Event Related**
6. Orthogonal Design
7. Free Behavior Design

fMRI during tasks that involve brief motion

Blocked Design

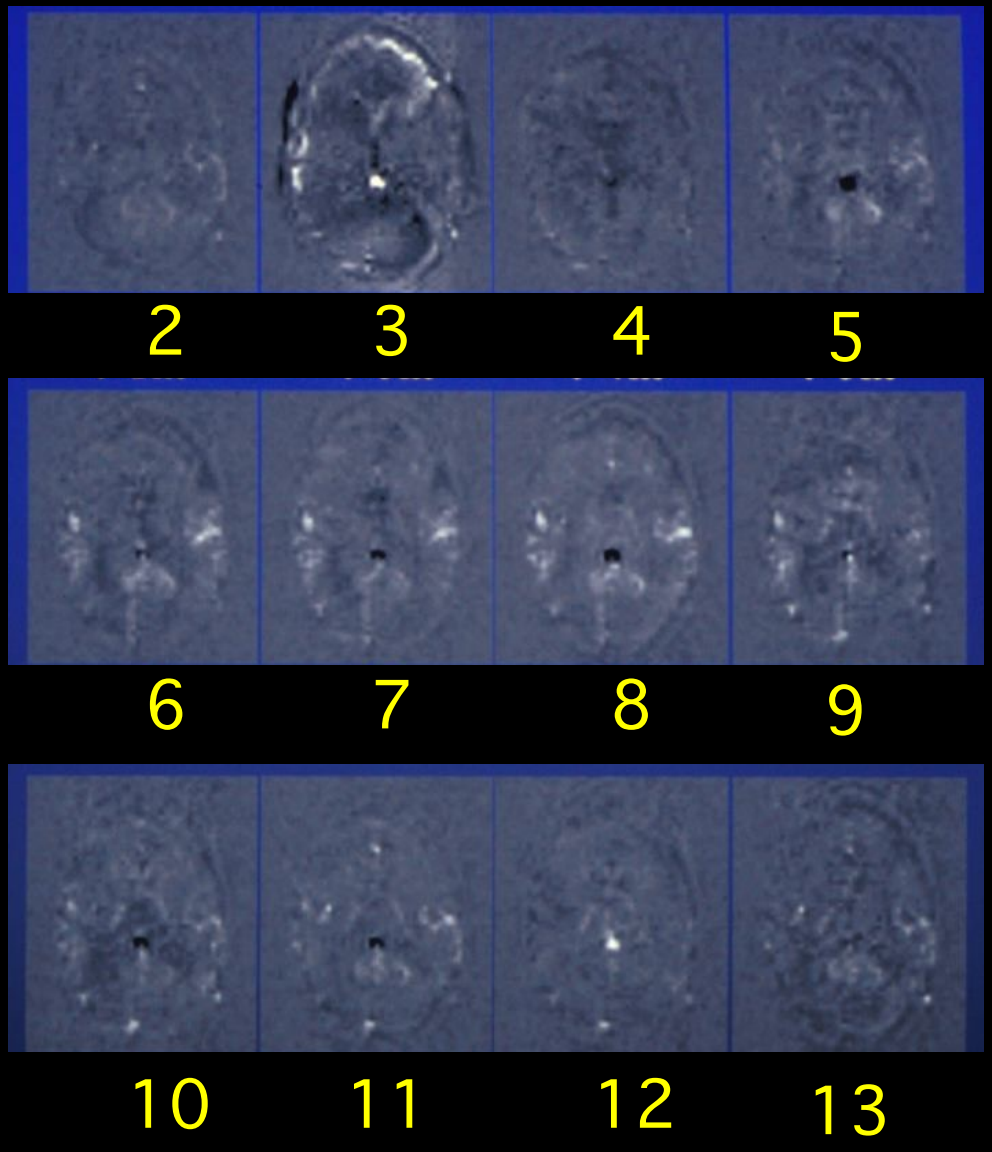


Event-Related Design



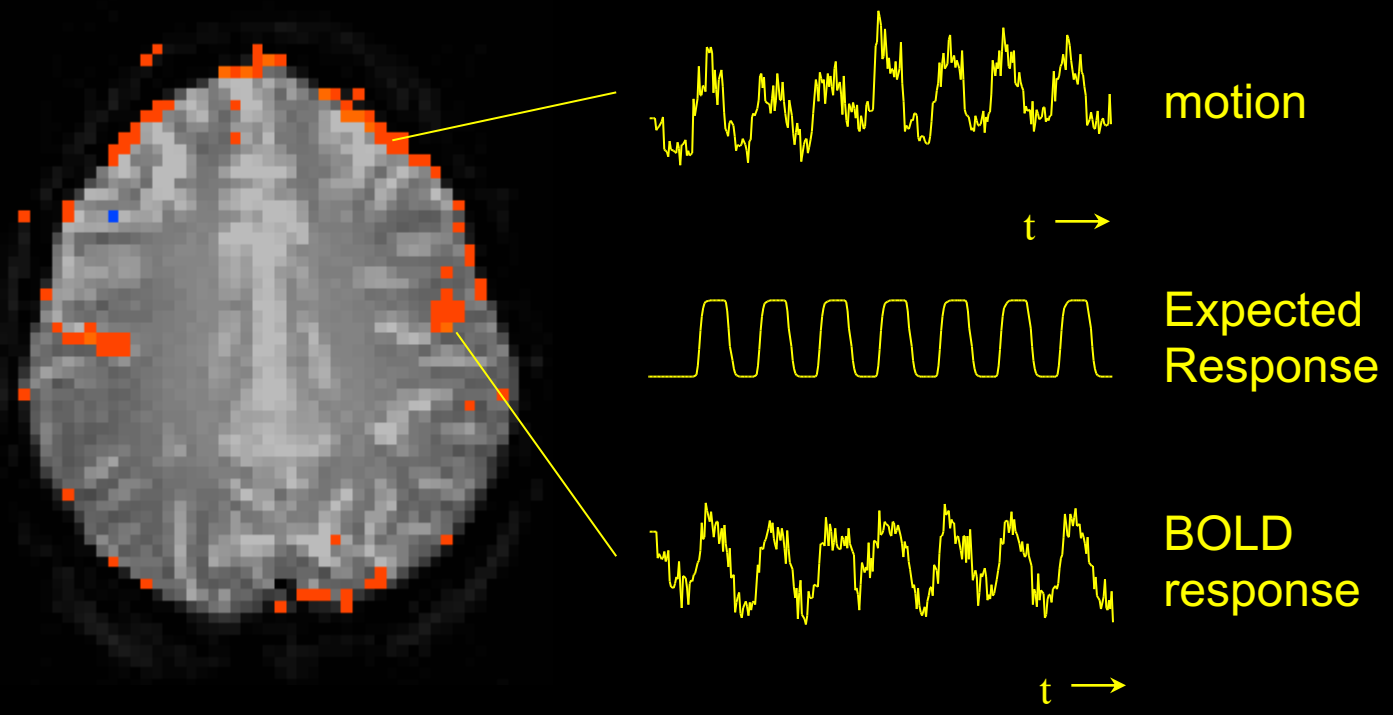
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Overt Word Production



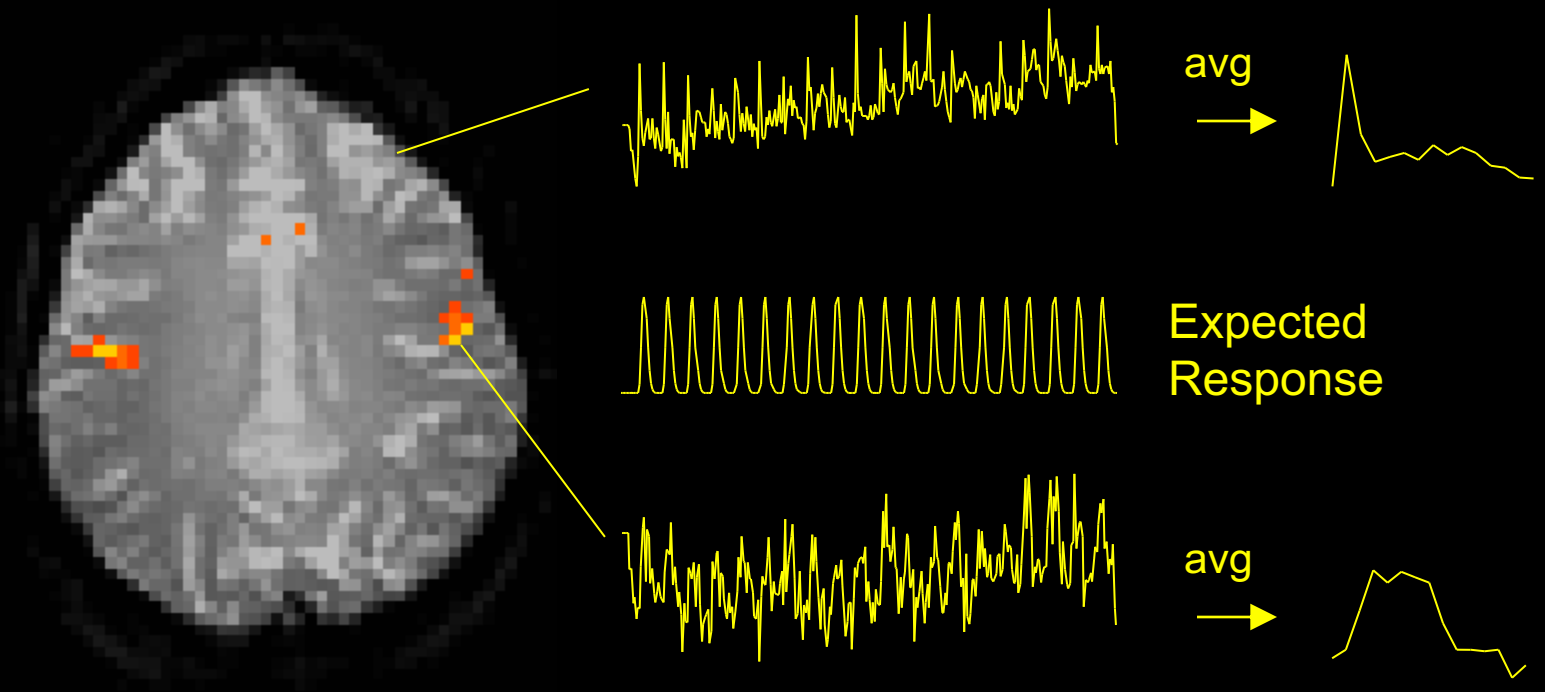
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Speaking - Blocked Trial

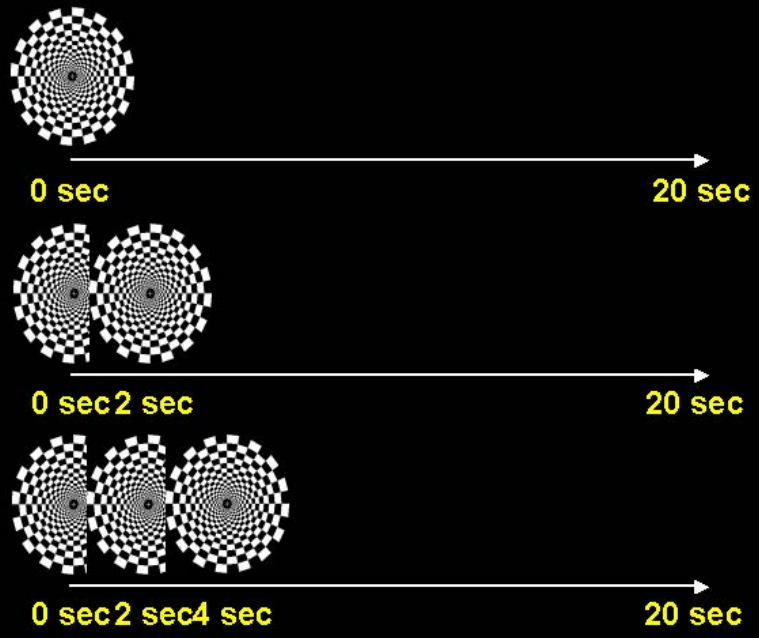


R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Speaking - ER-fMRI



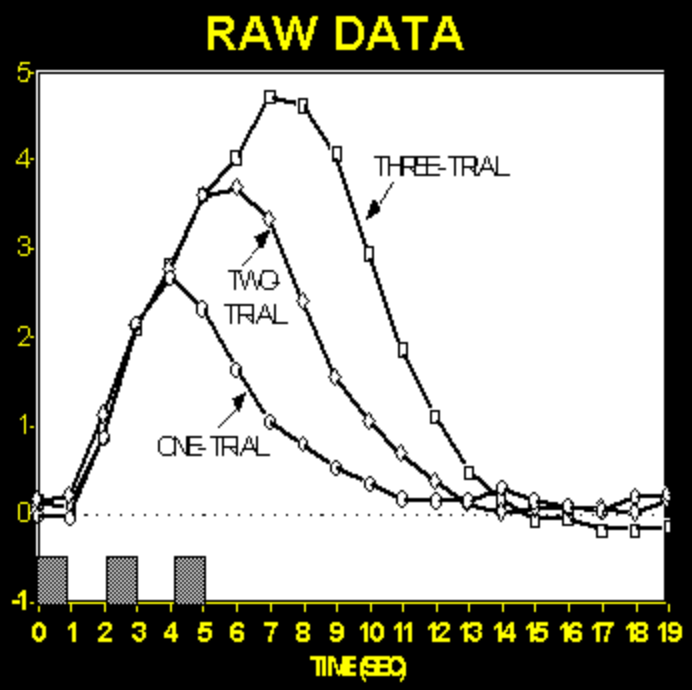
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

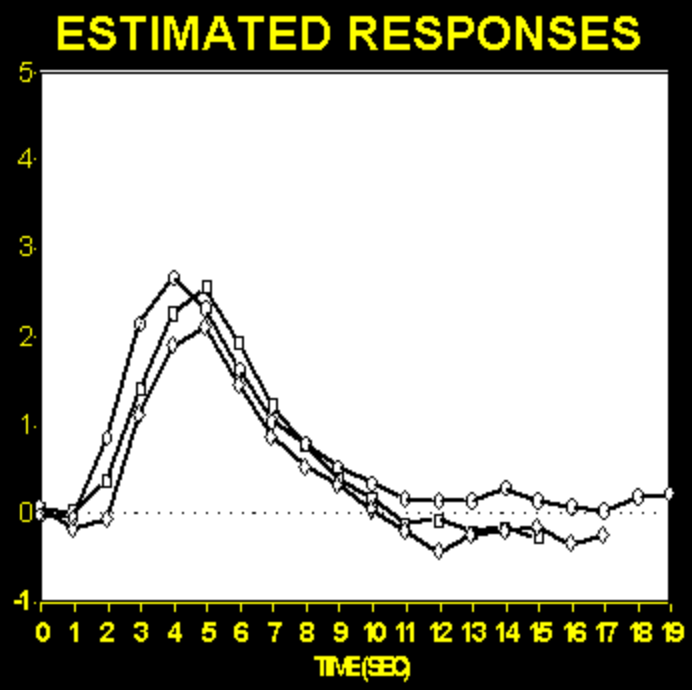


Human Brain Mapping 5:329–340(1997)

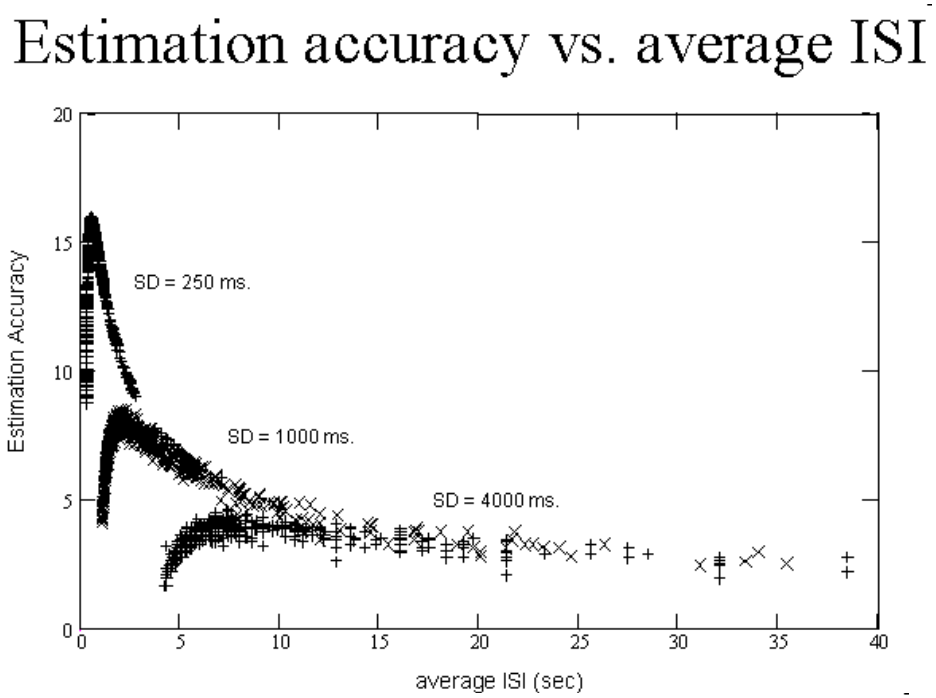
Selective Averaging of Rapidly Presented Individual Trials Using fMRI

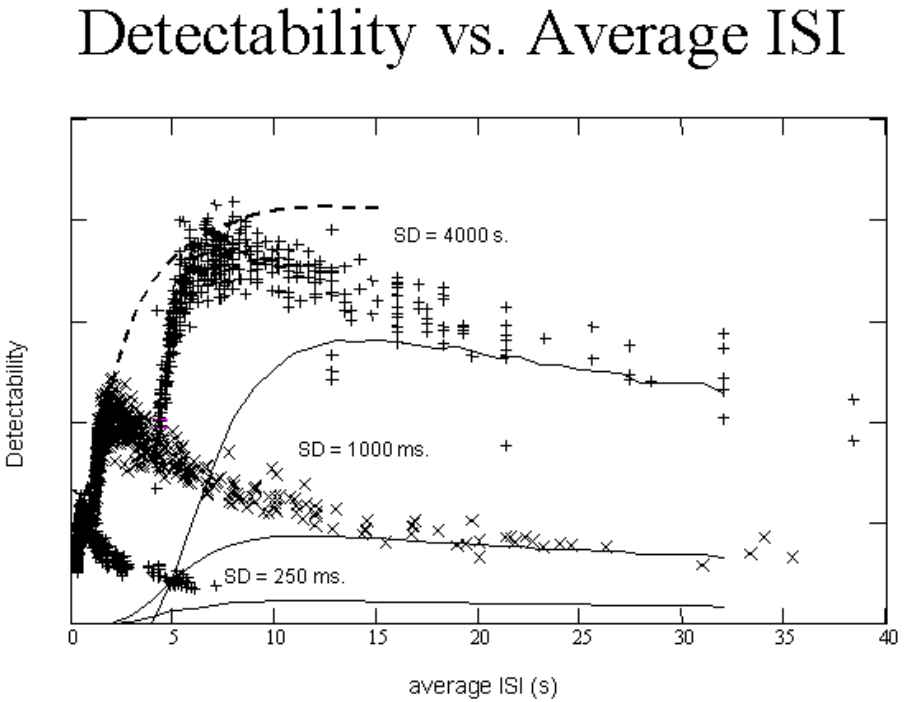
Anders M. Dale* and Randy L. Buckner





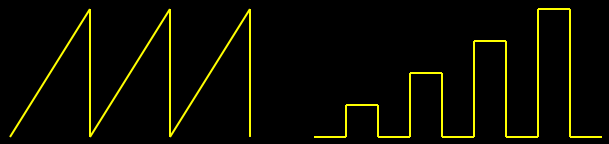
R. M. Birn, R. W. Cox, P. A. Bandettini, Detection versus estimation in Event-Related fMRI: choosing the optimal stimulus timing. *NeuroImage* 15: 262-264, (2002).



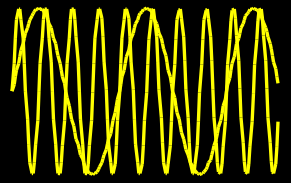


Neuronal Activation Input Strategies

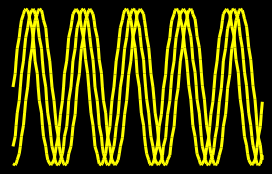
1. Block Design



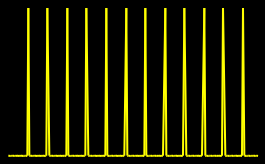
2. Parametric Design



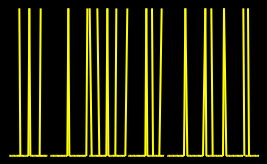
3. Frequency Encoding



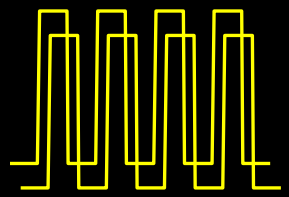
4. Phase Encoding



5. Event Related



6. Orthogonal Design



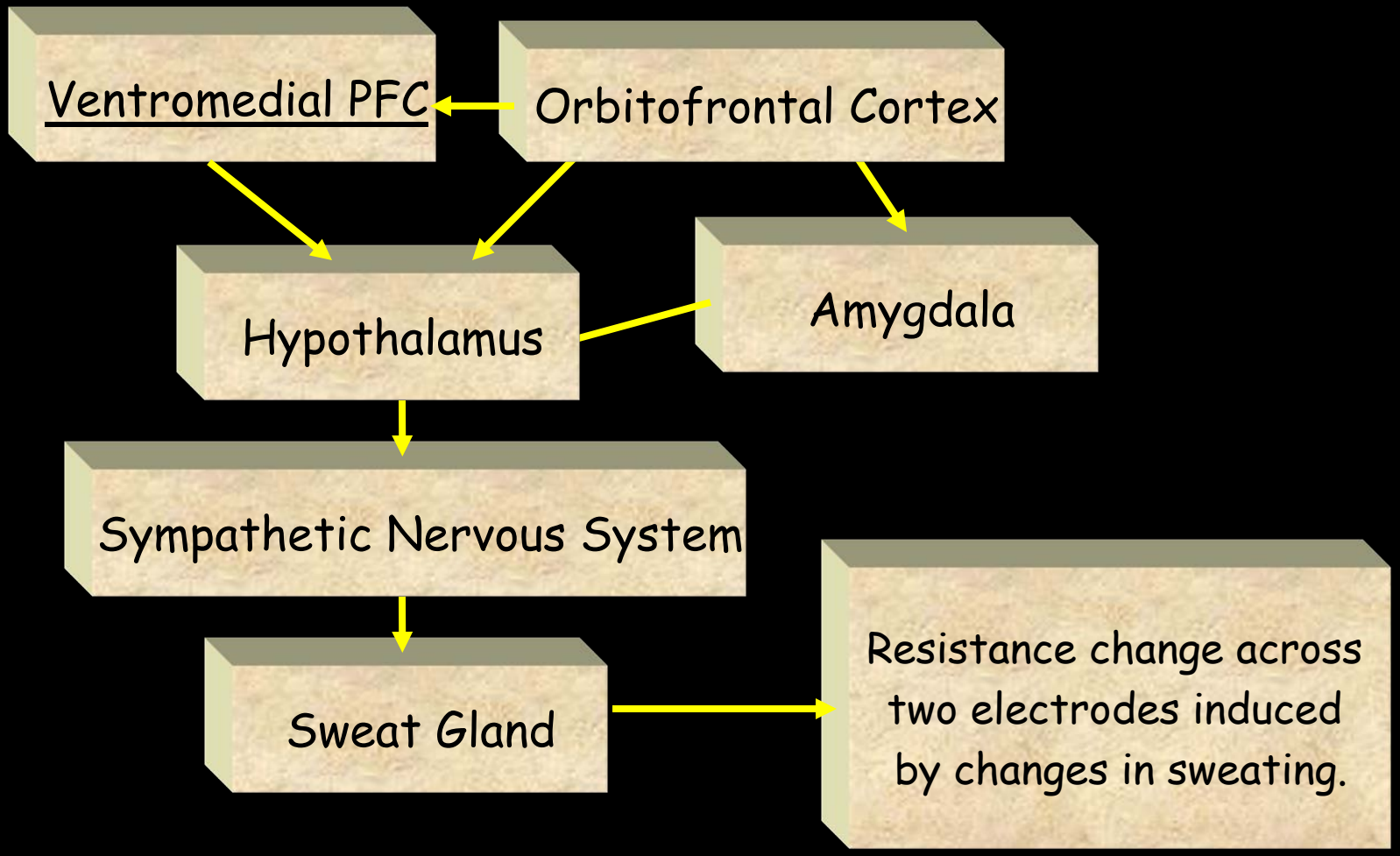
7. Free Behavior Design

Free Behavior Design

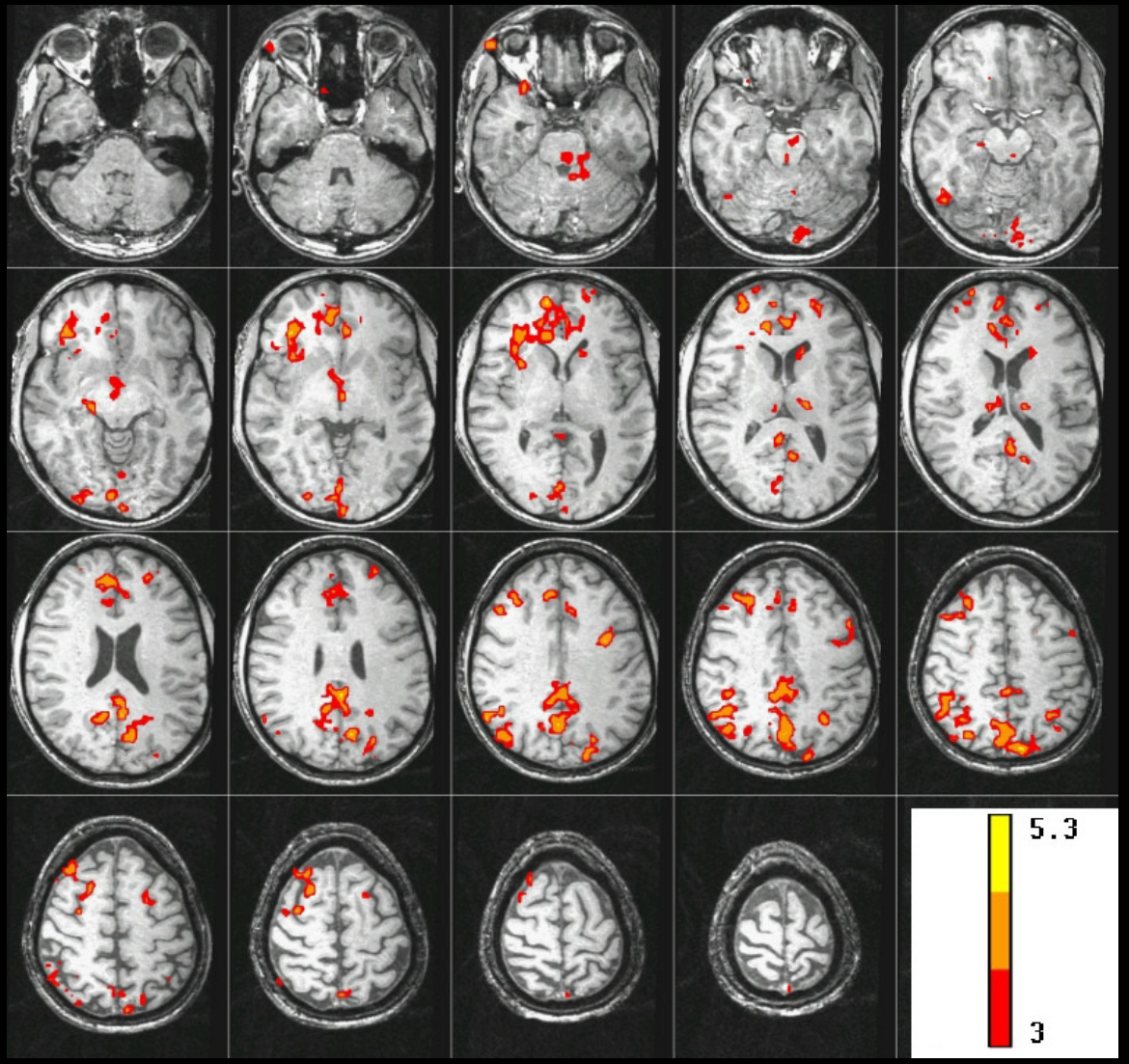
Use a continuous measure as a reference function:

- Task performance
- Skin Conductance
- Heart, respiration rate..
- Eye position
- EEG

The Skin Conductance Response (SCR)



Brain activity correlated with SCR during "Rest"



J. C. Patterson II, L. G. Ungerleider, and P. A Bandettini, Task - independent functional brain activity correlation with skin conductance changes: an fMRI study. *NeuroImage* (in press)

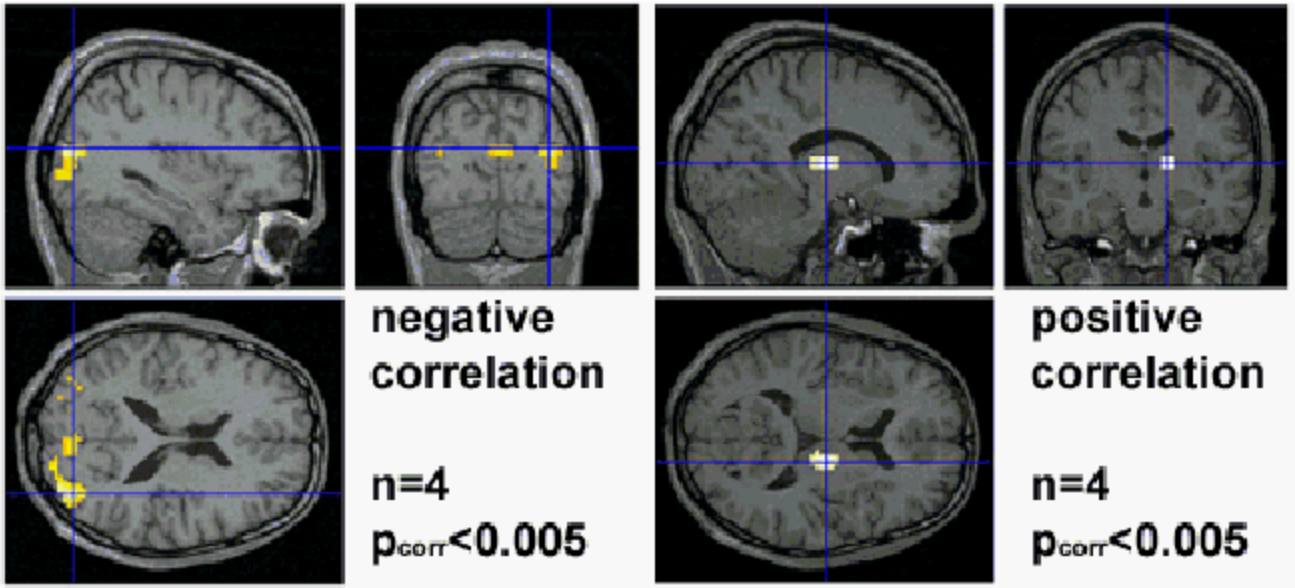
Order to appear: 20

OHBM 2002

Correlates of Alpha Rhythm in BOLD-fMRI

Matthias Moosmann, Petra Ritter, Andrea Brink, Ina Krastel, Sebastian Thees, Felix Blankenburg, Birol Taskin, Jan Ruben, Arno Villringer

The group analysis based on four volunteers showed a negative correlation between alpha-power and fMRI signal in the occipital cortex (figure, left side) and a positive correlation in the thalamus (figure, right side). These findings were not present for the beta band.



Discussion:

Localization of alpha activity in the occipital lobe agrees with previous electrophysiological findings. The negative correlations of fMRI signal and alpha suggests less energy consumption with higher degrees of synchronization. Positive correlations in the thalamus suggest the thalamus to be an active energy consuming generator of alpha synchronization. Our results are in concordance with findings recently reported by other groups, showing deactivations in the occipital pole and activations in the thalamus or in the brain stem using PET (Sadato et al. 1998) and fMRI (Goldman et al. 2001).

Simultaneous EEG and fMRI of the alpha rhythm

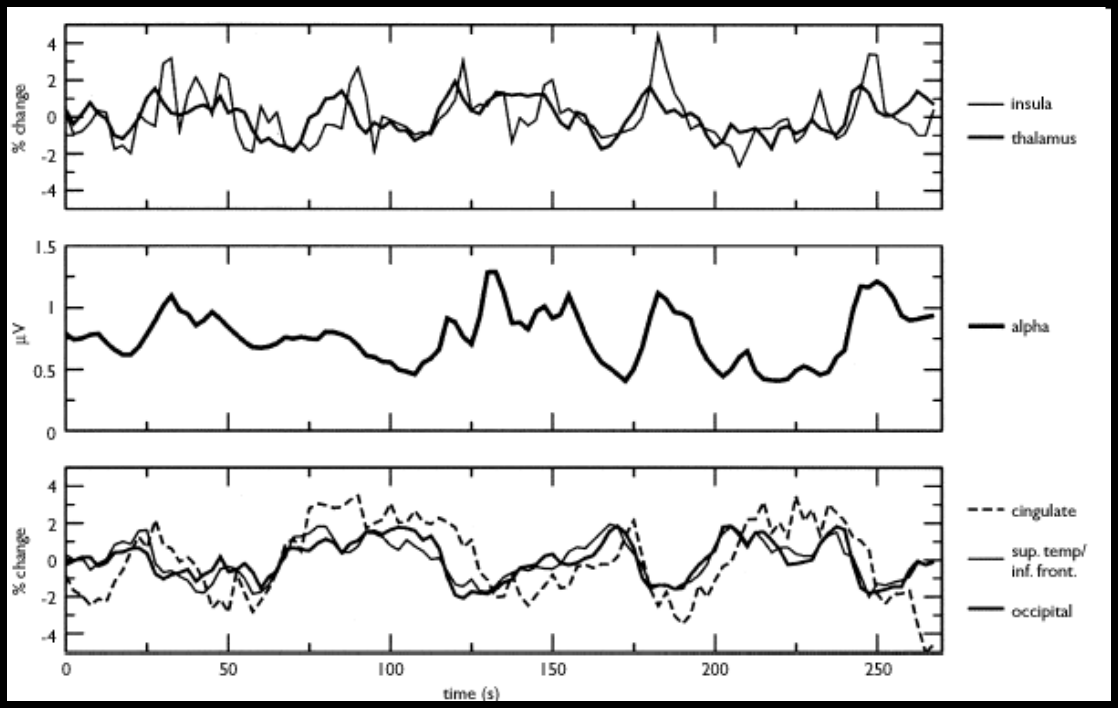
Robin I. Goldman,[2,CA] John M. Stern,[1] Jerome Engel Jr[1] and Mark S. Cohen

Ahmanson-Lovelace Brain Mapping Center, UCLA, 660 Charles Young Drive South, Los Angeles, CA 90095; [1]Department of Neurology, UCLA School of Medicine, Los Angeles, CA; [2]Hatch Center for MR Research, Columbia University, HSD, 710 W. 168th St., NIB-1, Mailbox 48, NY, NY 10032, USA

[CA,2]Corresponding Author and Address: rg2146@columbia.edu

Received 28 October 2002; accepted 30 October 2002

DOI: 10.1097/01.wnr.0000047685.08940.d0



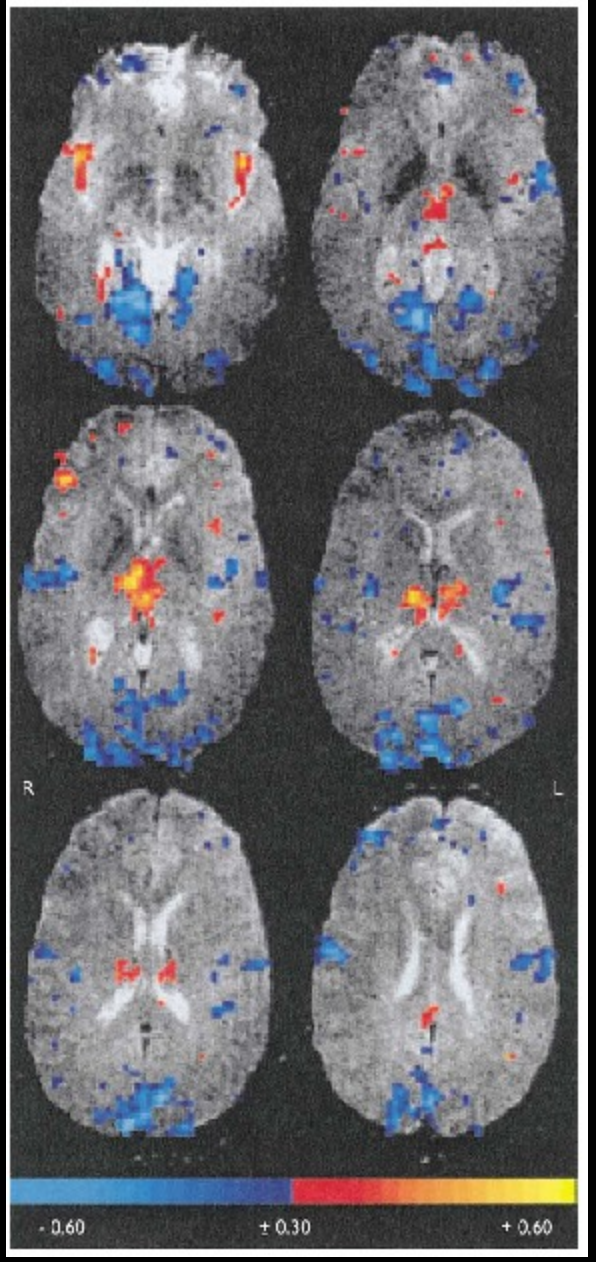
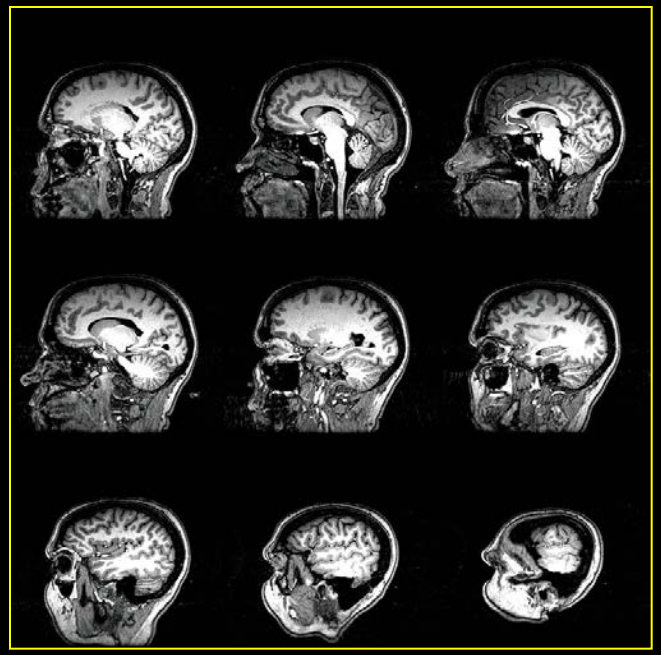
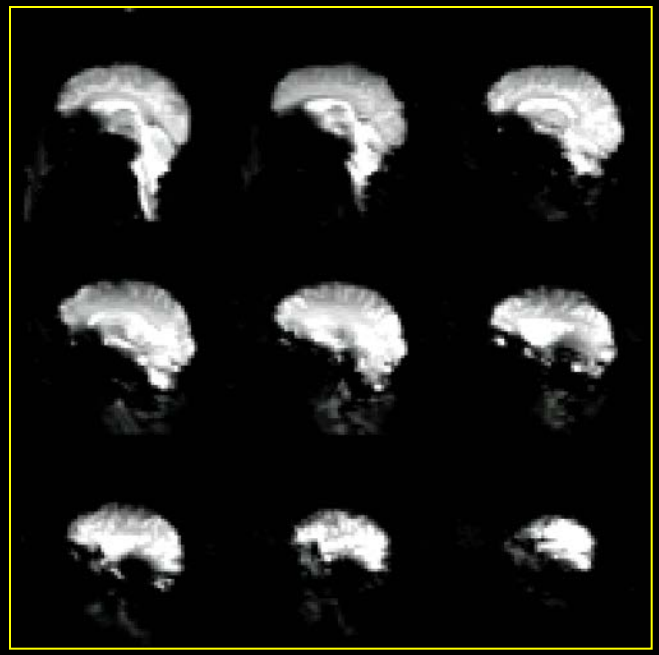
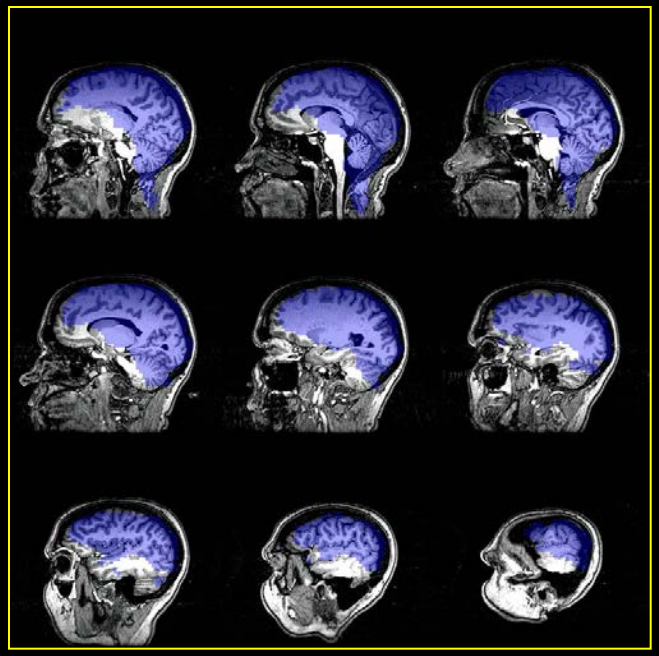


Image quality...



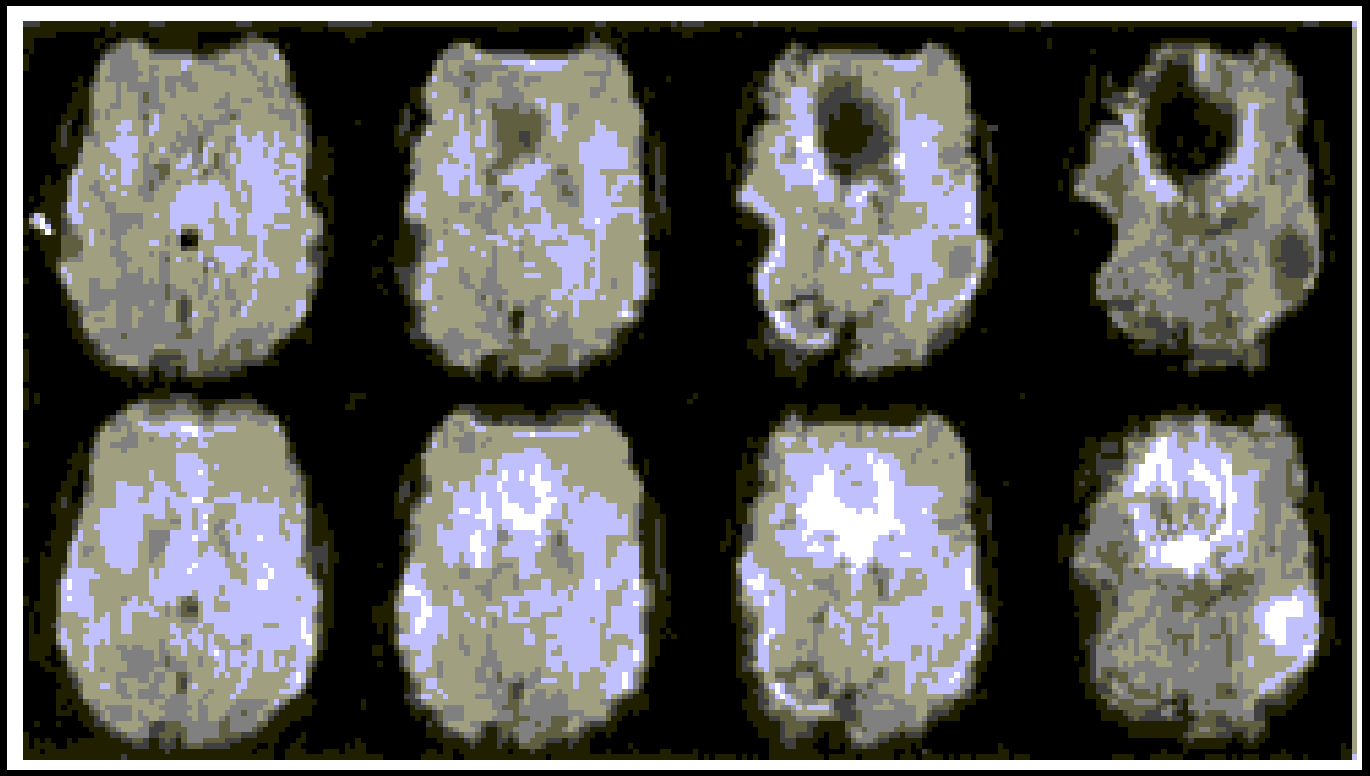




Magnetic Resonance in Medicine 42:290–299 (1999)

3D z-Shim Method for Reduction of Susceptibility Effects in BOLD fMRI

Gary H. Glover*



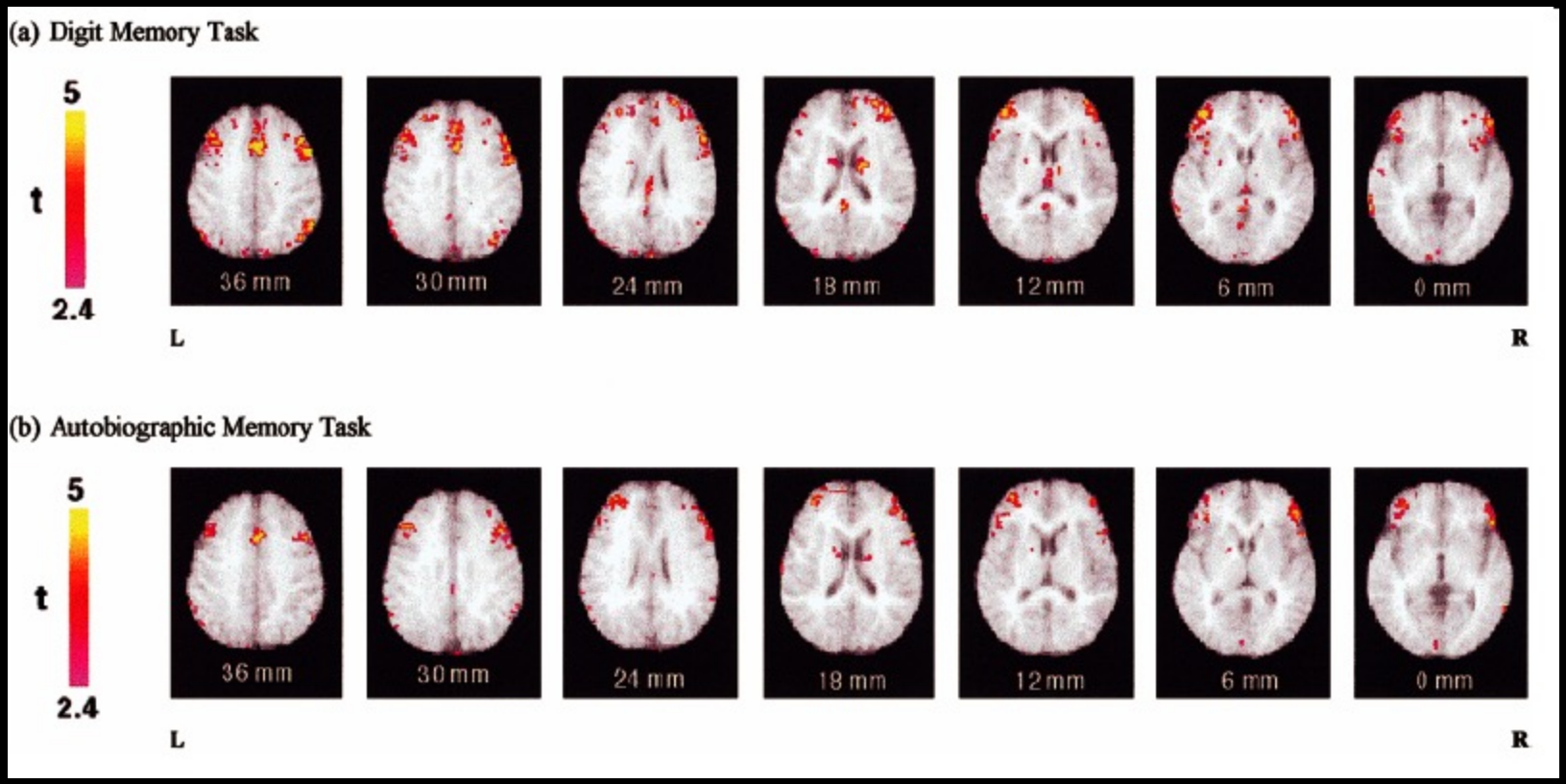
Extra Stuff..

Lie Detection

◆ Human Brain Mapping 15:157–164(2002) ◆
DOI 10.1002/hbm.10020

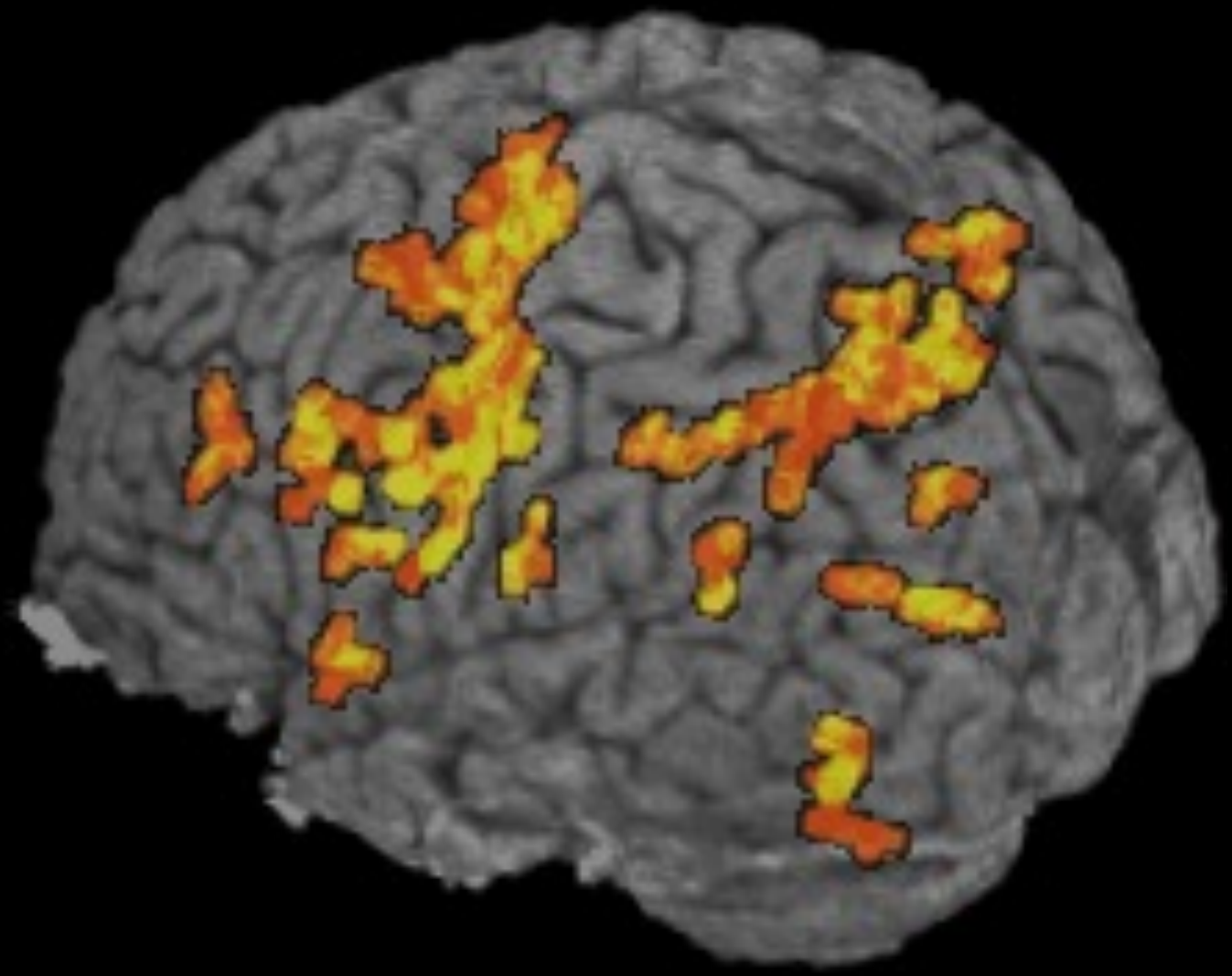
Lie Detection by Functional Magnetic Resonance Imaging

Tatia M.C. Lee,[1*] Ho-Ling Liu,[2] Li-Hai Tan,[3] Chetwyn C.H. Chan,[4]
Srikanth Mahankali,[5] Ching-Mei Feng,[5] Jinwen Hou,[5]
Peter T. Fox,[5] and Jia-Hong Gao[5]



Real Time fMRI

End of Acquisition



< 1 s to render

Blocked trials:
20 s on/20 s off
8 blocks

Blocks: 12345678

Color shows through brain

Correlation > 0.45

The End

Neuronal Current Imaging

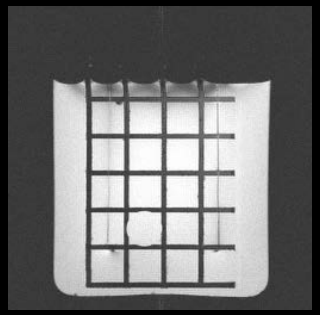
Toward Direct Mapping of Neuronal Activity: MRI Detection of Ultraweak, Transient Magnetic Field Changes

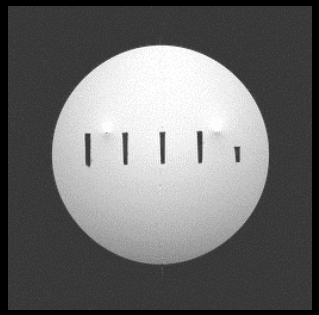
Jerzy Bodurka[1*] and Peter A. Bandettini[1,2]

- Preliminary models suggest that magnetic field changes on the order of 0.1 to 1 nT are induced (at the voxel scale) in the brain.

- These changes induce about a 0.01 Hz frequency shift or 0.09 deg (@ TE = 30 ms) phase shift.

- Question: Is this detectable?





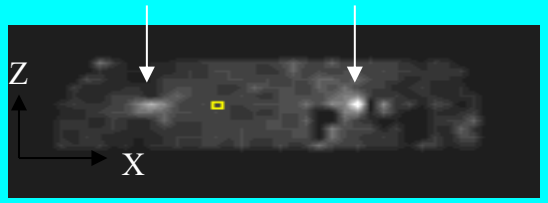
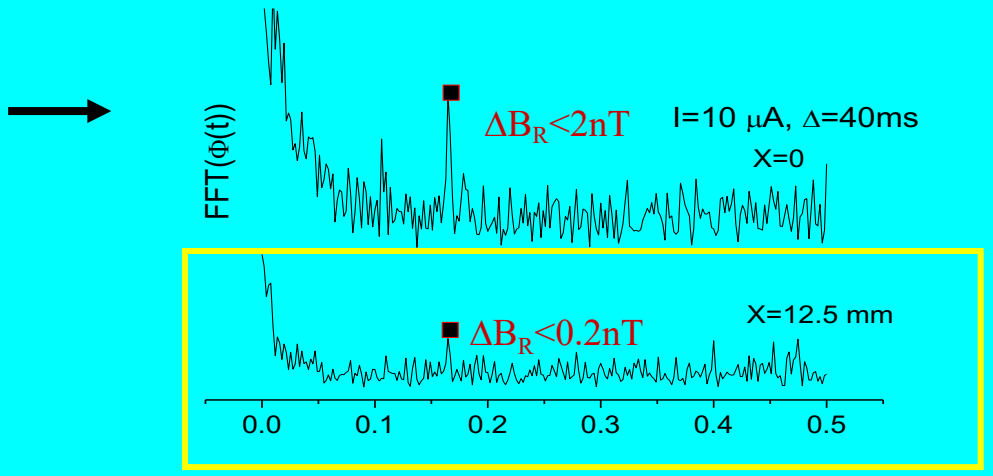
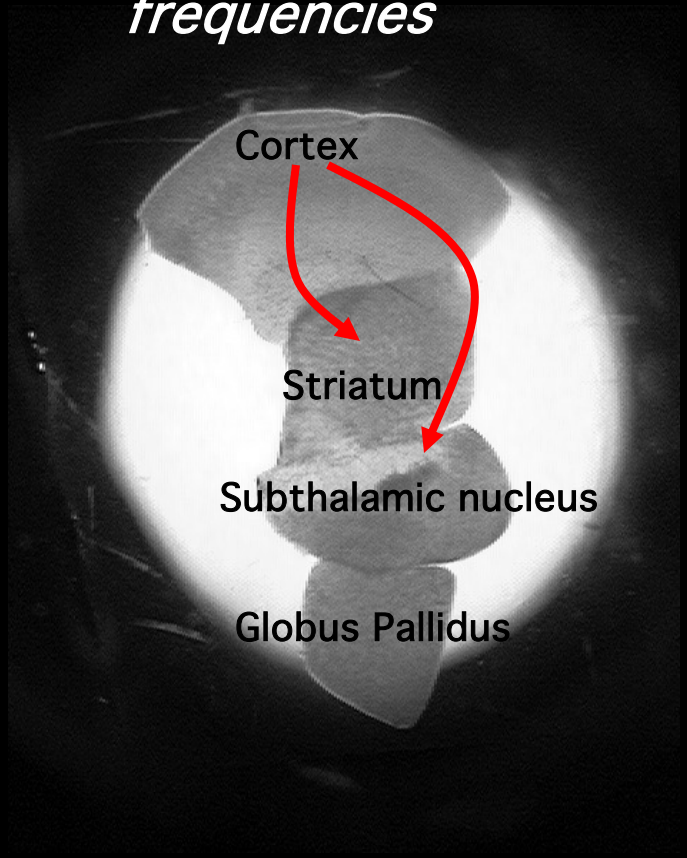

Z
X

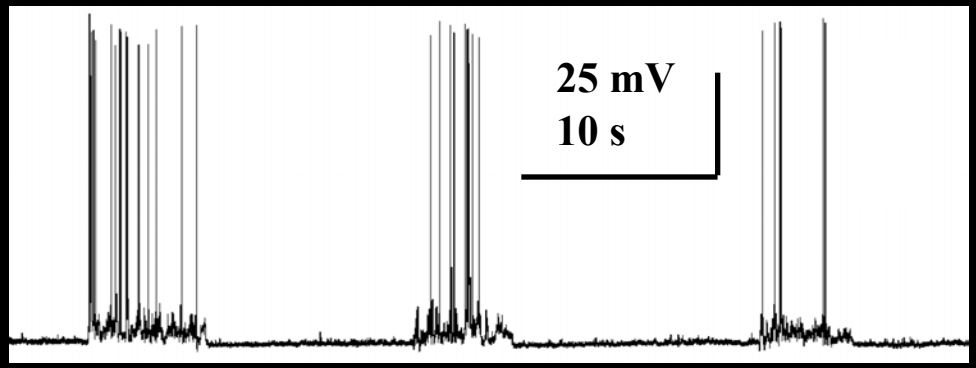
Figure 1


FFT(Φ(t))
ΔB_R<2nT
I=10 μA, Δ=40ms
X=0
ΔB_R<0.2nT
X=12.5 mm
0.0
0.1
0.2
0.3
0.4
0.5

In Vitro Results

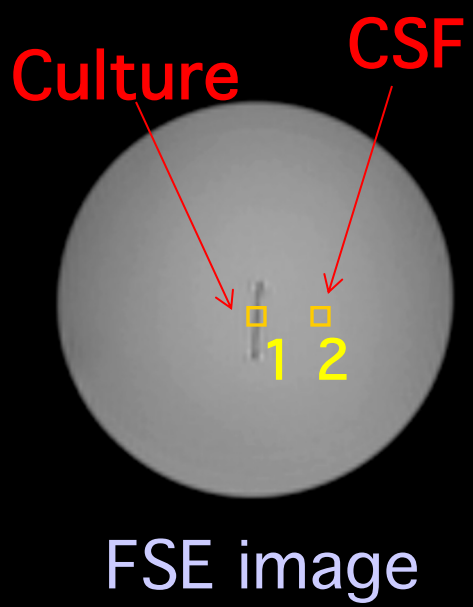
Newborn rat brains have been found to exhibit spontaneous and synchronous firing at specific frequencies

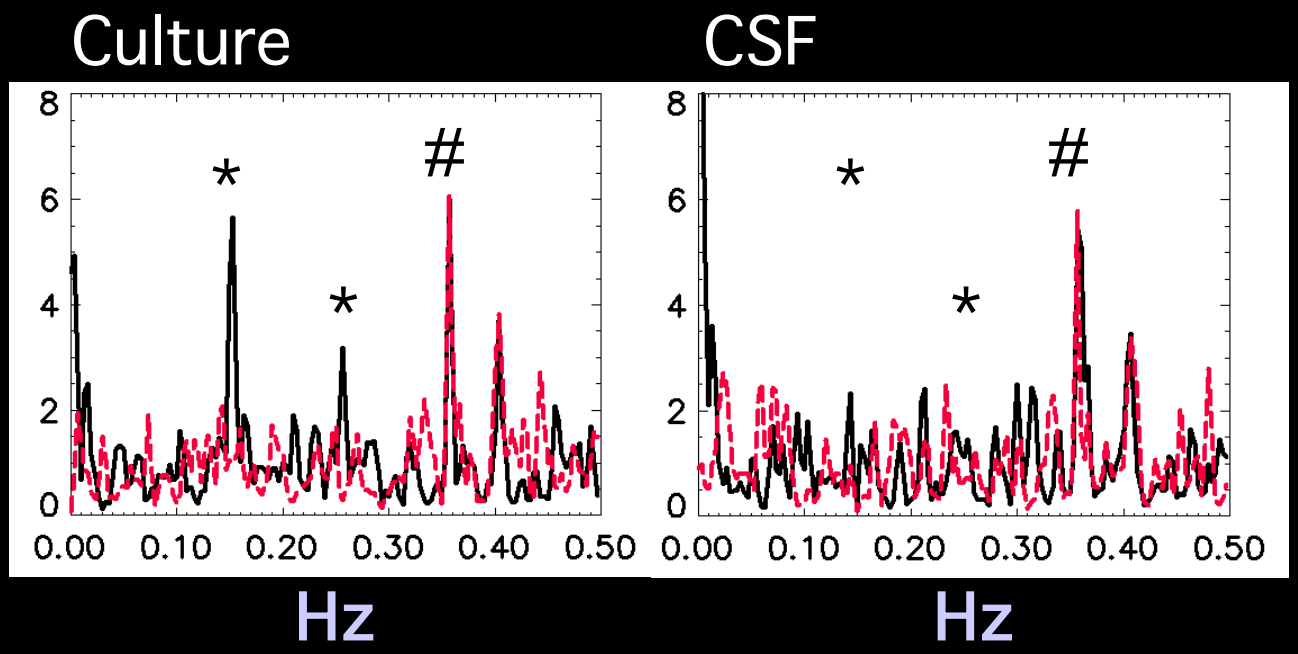




Plenz, D. and S.T. Kital. Nature, 1999. **400**: p. 677-682.

Results





Active state: 10 min, Inactive state: 10 min after TTX admin.

*: activity

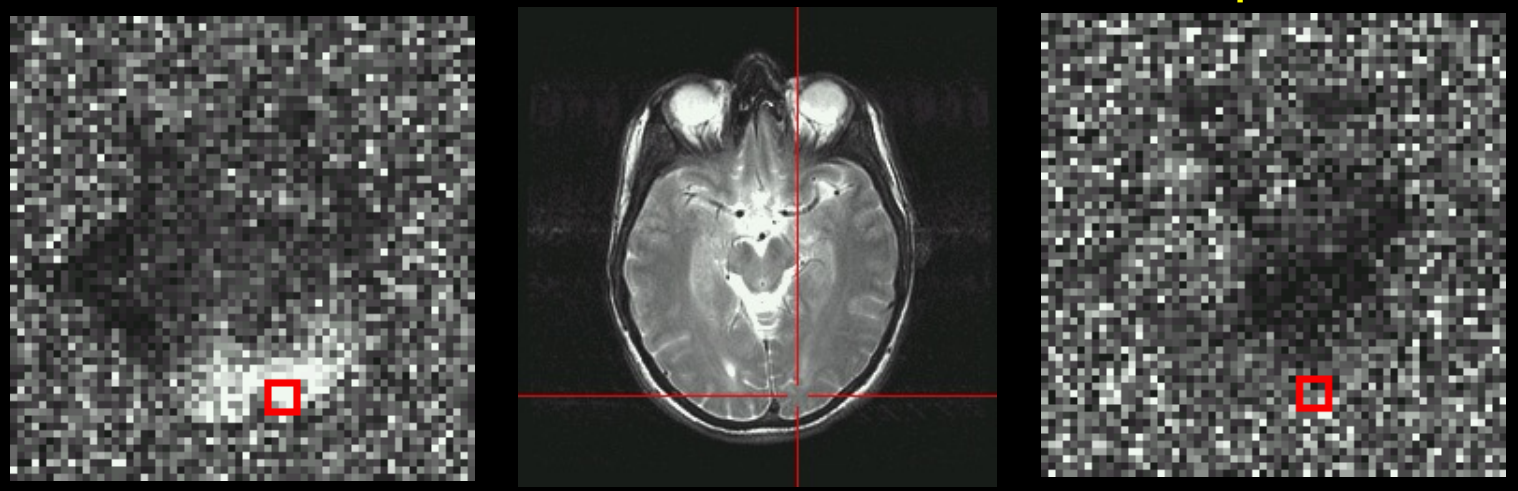
#: scanner pump frequency

Petridou et al.

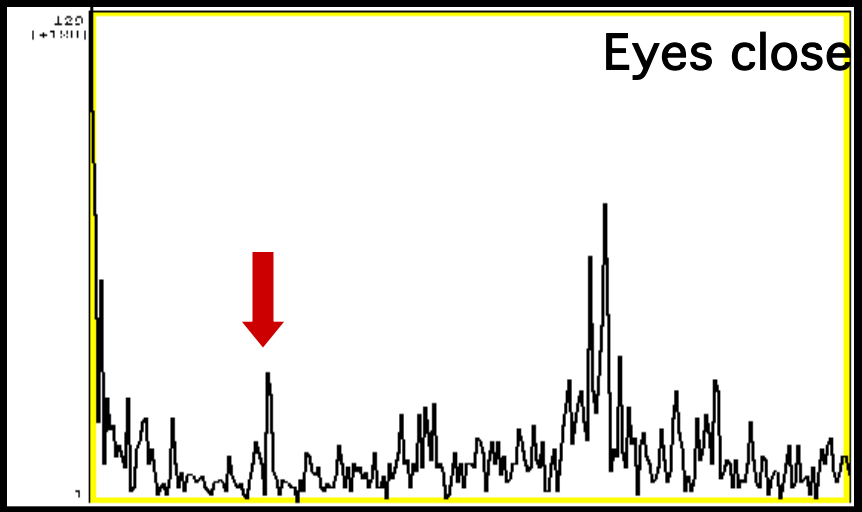
Phase v=0.12Hz

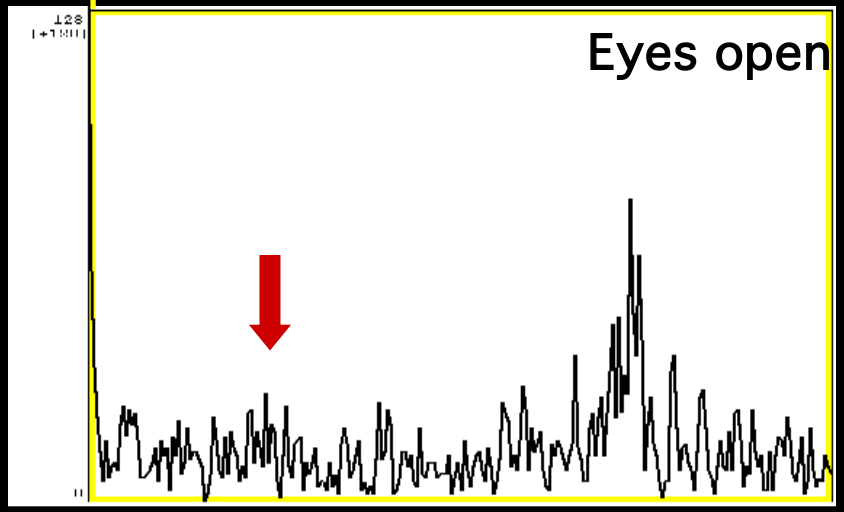
Closed

Open



Power spectra

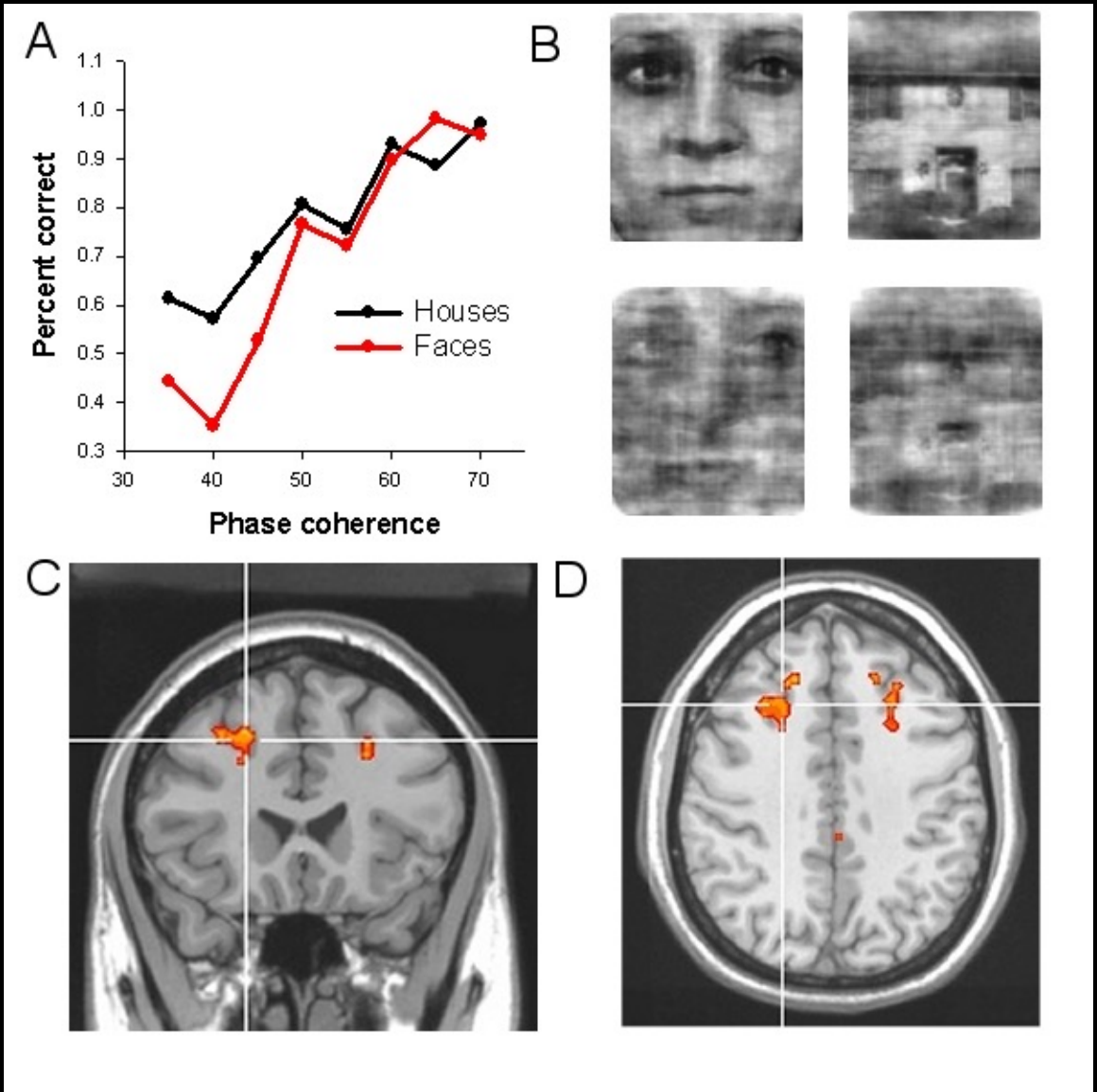




0.5 Hz

0.5 Hz

Decision Making



Heekeren et al

- Shimming
- Acoustic Noise
- Multishot Techniques
- Increased Gradient Performance
- Higher Field Strengths
- Surface Coil Arrays
- Calibration / Quantification
- Embedded Functional Contrast
- Noise / Fluctuations
- Direct Neuronal Current Imaging
- Clinical Populations
- Neuronal,Vascular, and Metabolic Informatic

UFIM & FMRIF

Director:

Peter Bandettini

Staff Scientists:

Sean Marrett

Jerzy Bodurka

Frank Ye

Wen-Ming Luh

Computer Specialist:

Adam Thomas

Post Docs:

Rasmus Birn

Hauke Heekeren

David Knight

Patrick Bellgowan

Ziad Saad

Graduate Student:

Natalia Petridou

Post-Bac. IRTA Students:

Elisa Kapler

August Tuan

Dan Kelley

Hahn Nguen

Visiting Fellows:

Sergio Casciaro

Marta Maieron

Guosheng Ding

Clinical Fellow:

James Patterson

Psychologist:

Julie Frost

Summer Students:

Hannah Chang

Courtney Kemps

Douglass Ruff

Carla Wettig

Kang-Xing Jin

Program Assistant:

Kay Kuhns

Scanning Technologists:

Karen Bove-Bettis

Paula Rowser