

New Frontiers in Functional Imaging

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Unit on Functional Imaging Methods
Laboratory of Brain and Cognition
&
Functional MRI Core Facility



Technology

Methodology

Engineering

Physics

Computer
Science

Statistics

Cognitive
Science

Neuroscience

Physiology

Medicine

Interpretation

Applications

Focus of most of this talk is fMRI

**...but the key to neuroimaging advances is in
the integration of multiple techniques**

**-electrical, hemodynamic, metabolic changes
with activation**

Technology

MRI	EPI	1.5T,3T, 4T	EPI on Clin. Syst.		Diff. tensor	Mg ⁺	7T	>8 channels
		Local Human Head Gradient Coils	Nav. pulses	Real time fMRI	Venography		SENSE	"vaso"
		ASL	Spiral EPI	Quant. ASL	Z-shim			
		BOLD	Multi-shot fMRI	Dynamic IV volume	Simultaneous ASL and BOLD		Baseline Susceptibility	
							Current Imaging?	

Methodology

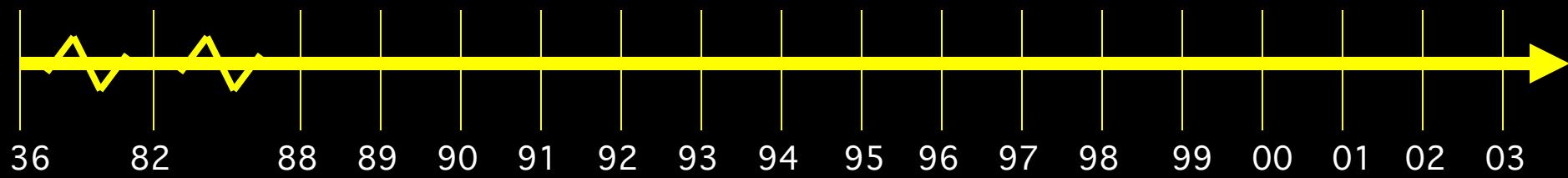
IVIM	Baseline Volume	Correlation Analysis		CO ₂ Calibration				
		Motion Correction				Latency and Width Mod		
		Parametric Design		Multi-Modal Mapping				
		Surface Mapping						
		Phase Mapping		ICA	Free-behavior Designs			
		Linear Regression		Mental Chronometry		Multi-variate Mapping		
		Event-related		Deconvolution	Fuzzy Clustering			

Interpretation

Blood T2	BOLD models	PET correlation						
	B ₀ dep.	IV vs EV	ASL vs. BOLD			Layer spec. latency		
		Pre-undershoot	PSF of BOLD					
	TE dep	Resolution Dep.		Extended Stim.			Excite and Inhibit	
		Post-undershoot						
	SE vs. GE	CO ₂ effect	Linearity		Metab. Correlation			
	NIRS Correlation	Fluctuations	Optical Im. Correlation					
	Veins	Inflow	Balloon Model		Electrophys. correlation			

Applications

Volume - Stroke	Complex motor							
	Language	Imagery	Memory			Emotion		
				Motor learning	Children	Tumor vasc.	Drug effects	
	BOLD -V1, M1, A1	Presurgical	Attention		Ocular Dominance		Mirror neurons	
	V1, V2..mapping		Priming/Learning		Clinical Populations			
	△ Volume-V1		Plasticity	Face recognition		Performance prediction		



- Functional contrast
- Signal interpretation
- Hardware and pulse sequences
- Paradigm design and processing

- Overview
- Current Limits
- Future Prospects

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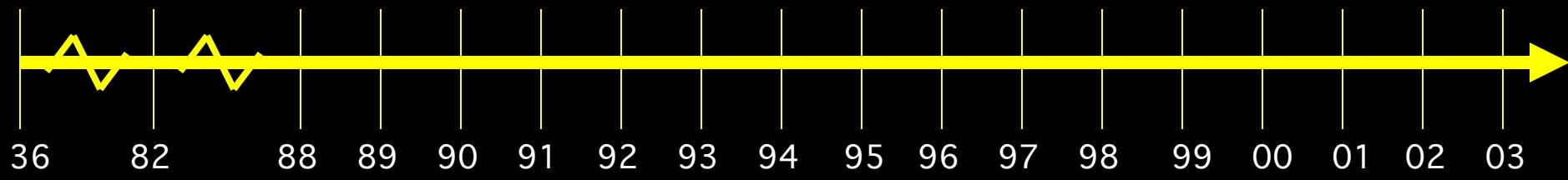
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	TE dep	Pre-undershoot	PSF of BOLD	
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		Post-undershoot	Extended Stim.	
Hemoglobin	SE vs. GE	CO ₂ effect	Linearity	Metab. Correlation
	NIRS Correlation	Fluctuations	Optical Im. Correlation	
	Veins	Inflow	Balloon Model	Electrophys. correlation

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	△ Volume-V1	Priming/Learning	Performance prediction	
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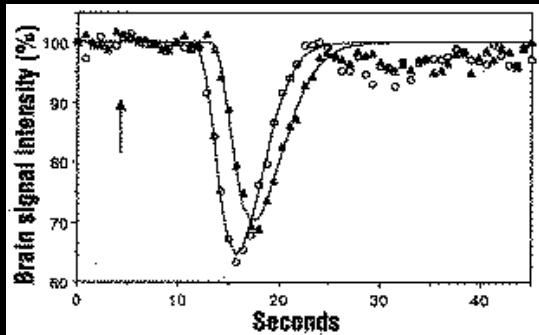
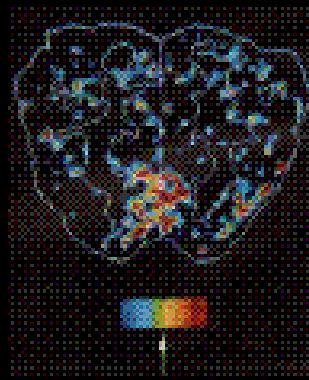
Blood Volume Imaging

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

Resting



Active

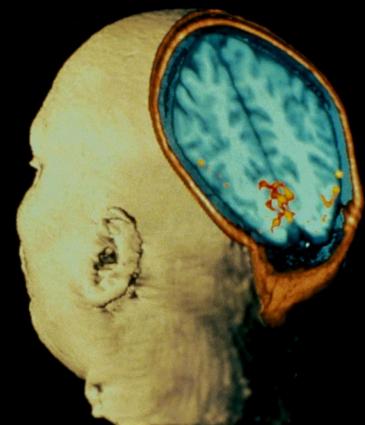


**Photic
Stimulation**

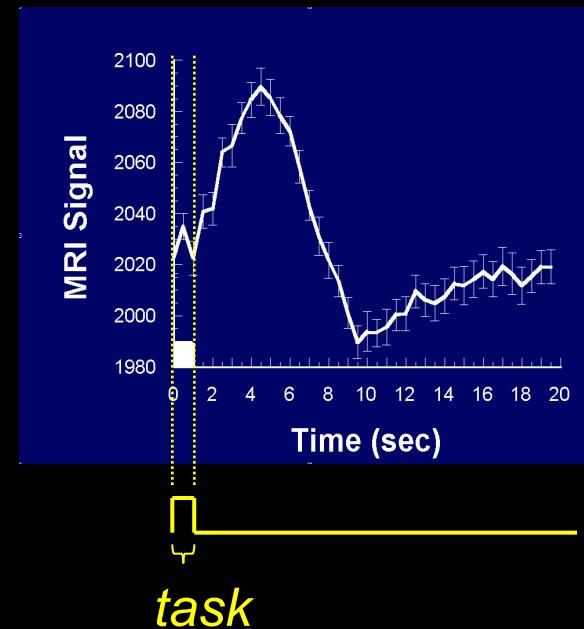
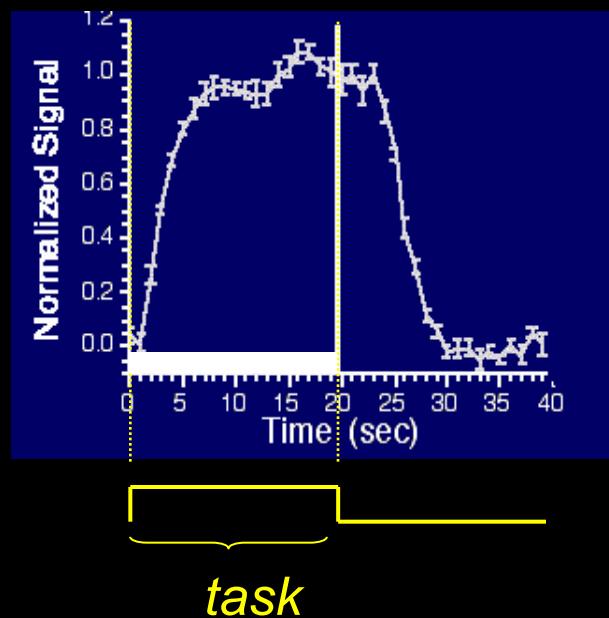
MRI Image showing activation of the Visual Cortex

From Belliveau, et al.
Science Nov 1991

MSC - perfusion

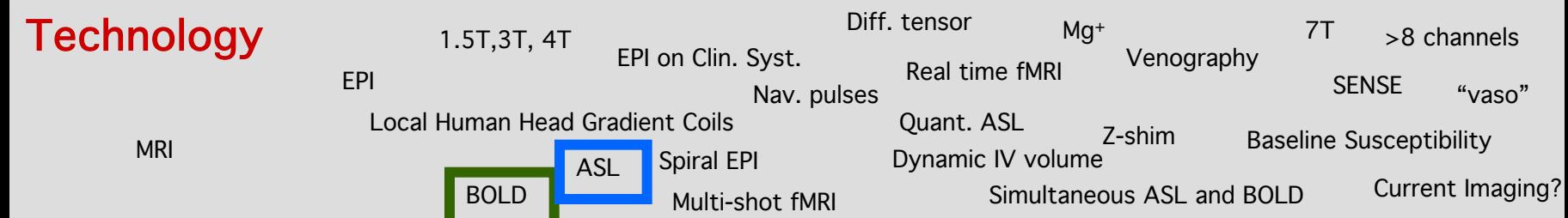


Blood Oxygenation Imaging

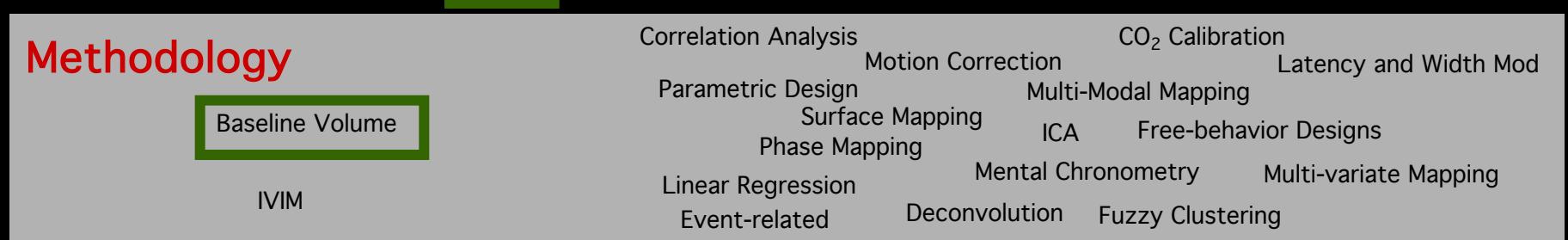


- K. K. Kwong, et al, (1992) “Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation.” Proc. Natl. Acad. Sci. USA. 89, 5675-5679.
- S. Ogawa, et al., (1992) “Intrinsic signal changes accompanying sensory stimulation: functional brain mapping with magnetic resonance 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.

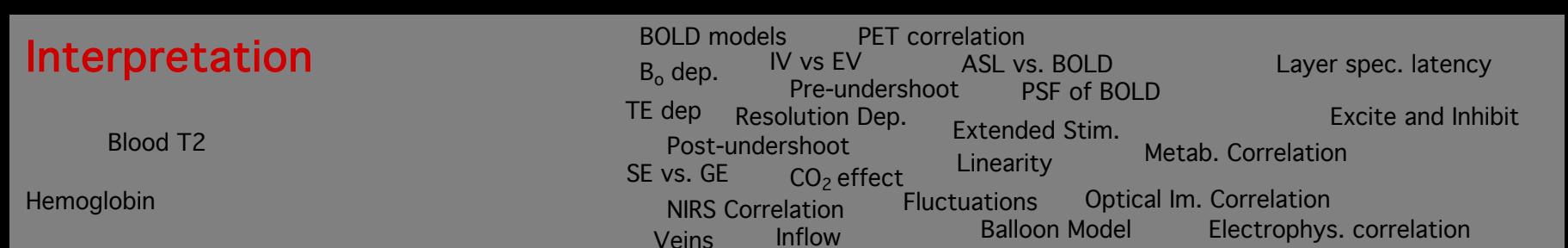
Technology



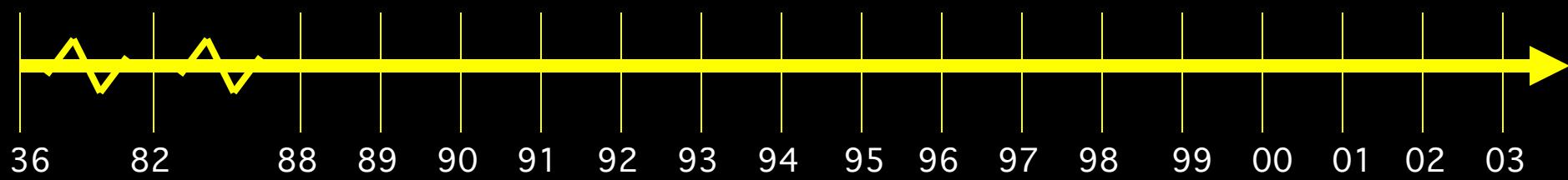
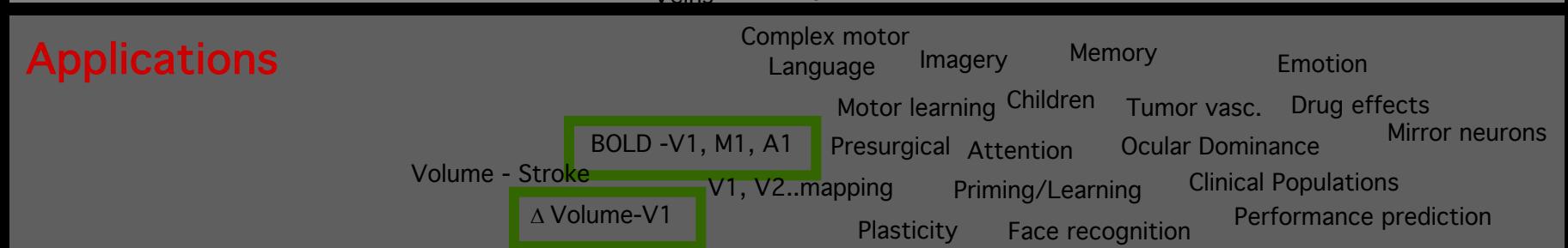
Methodology



Interpretation

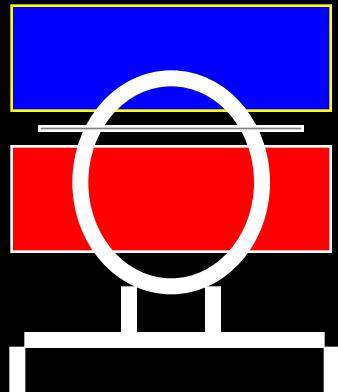


Applications

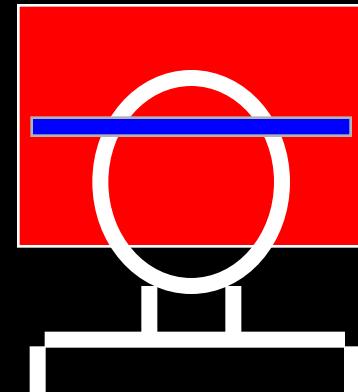


Blood Perfusion Imaging

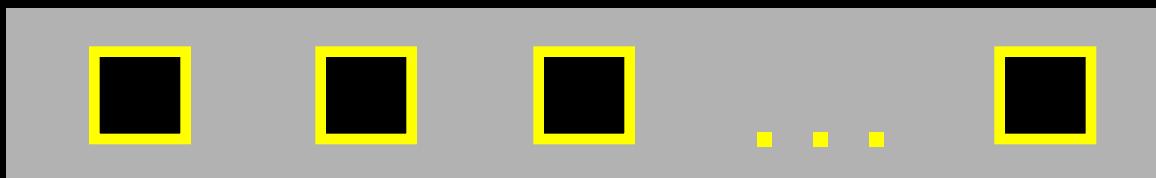
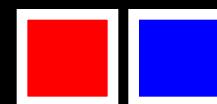
EPISTAR

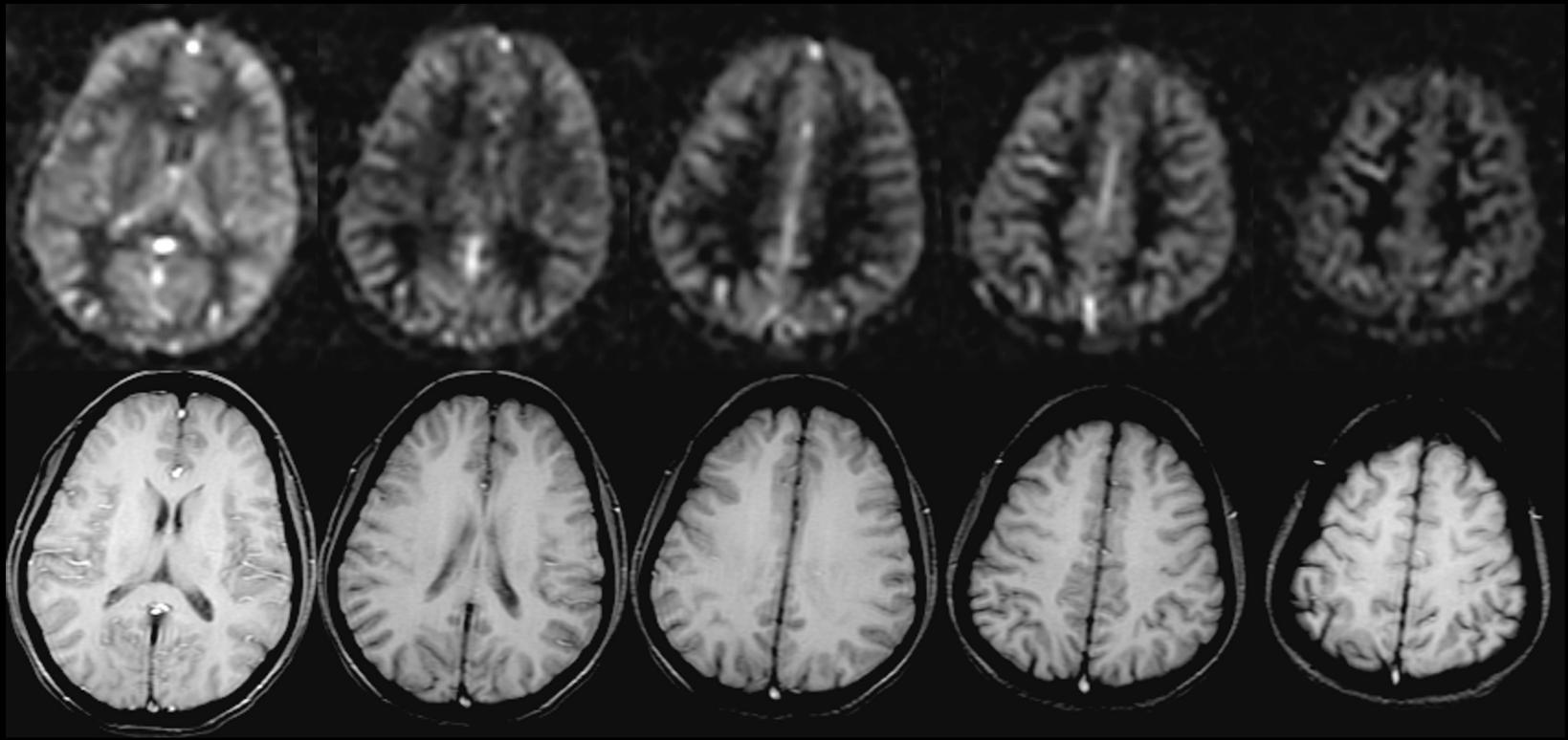


FAIR



...





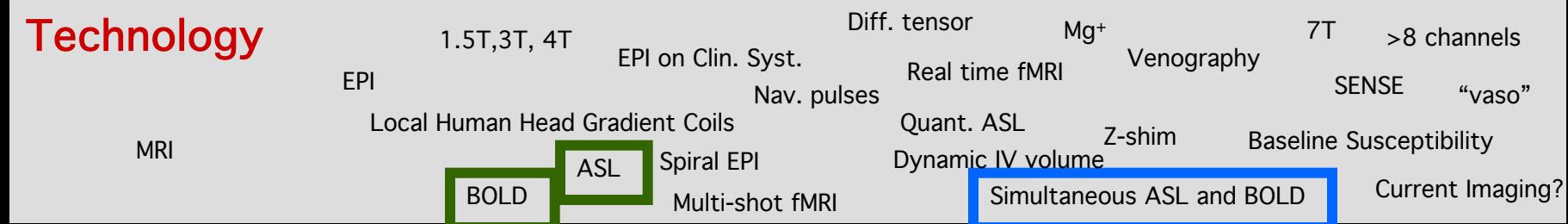
Williams, D. S., Detre, J. A., Leigh, J. S. & Koretsky, A. S. (1992) "Magnetic resonance imaging of perfusion using spin-inversion of arterial water." Proc. Natl. Acad. Sci. USA 89, 212-216.

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

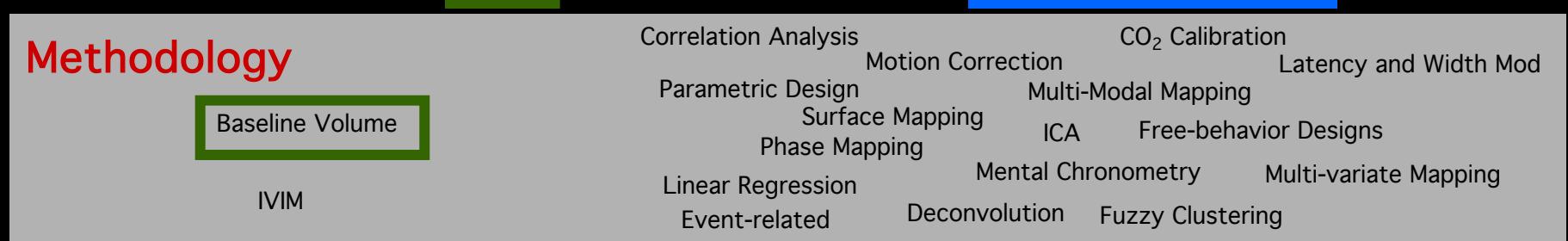
Kim, S.-G. (1995) "Quantification of relative cerebral blood flow change by flow-sensitive alternating inversion recovery (FAIR) technique: application to functional mapping." Magn. Reson. Med. 34, 293-301.

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

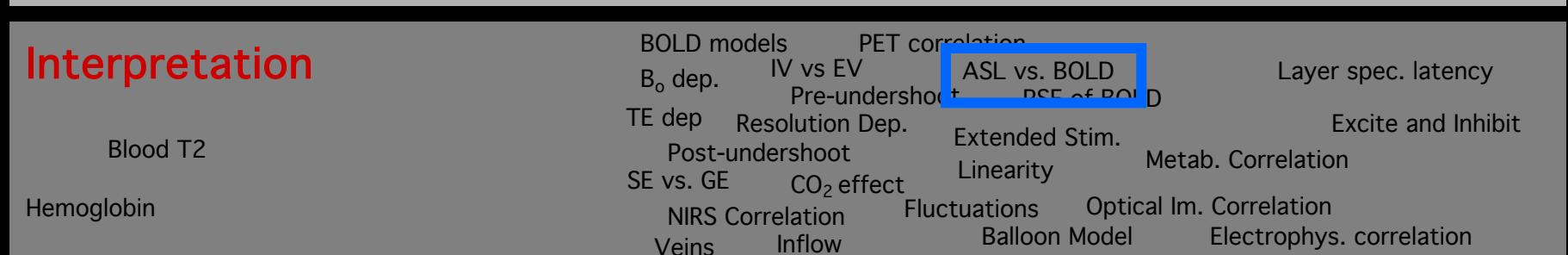
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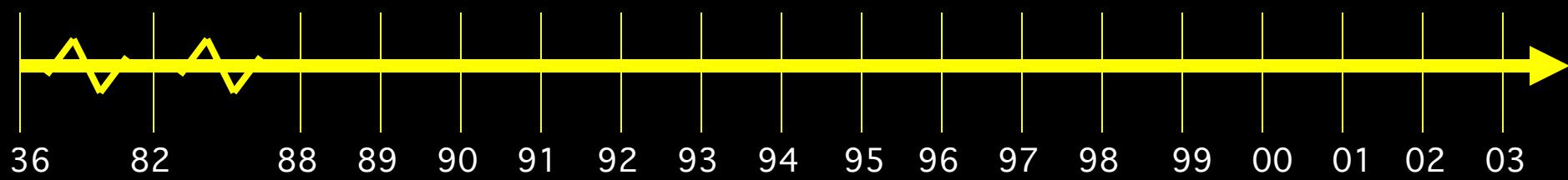
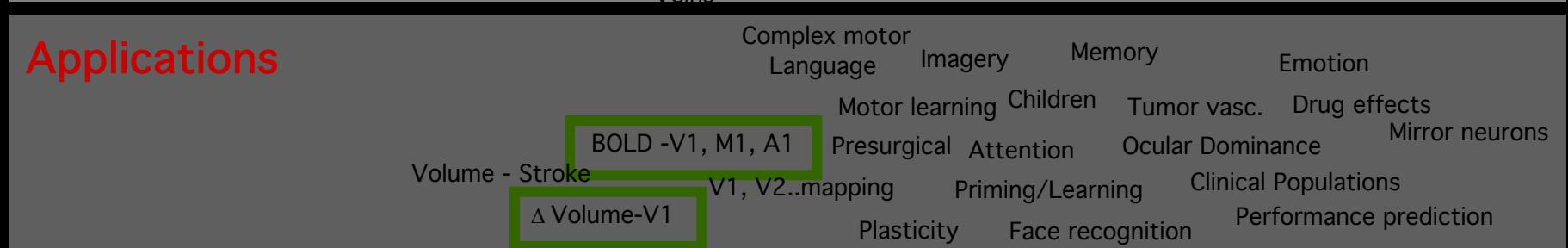
Methodology



Interpretation



Applications



Simultaneous BOLD and Perfusion



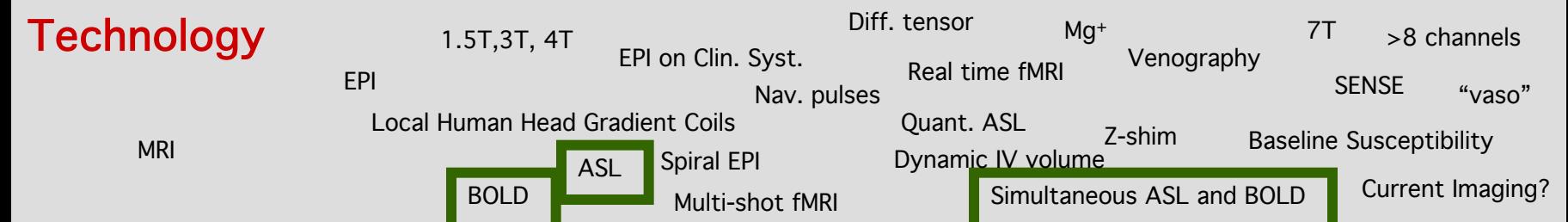
BOLD



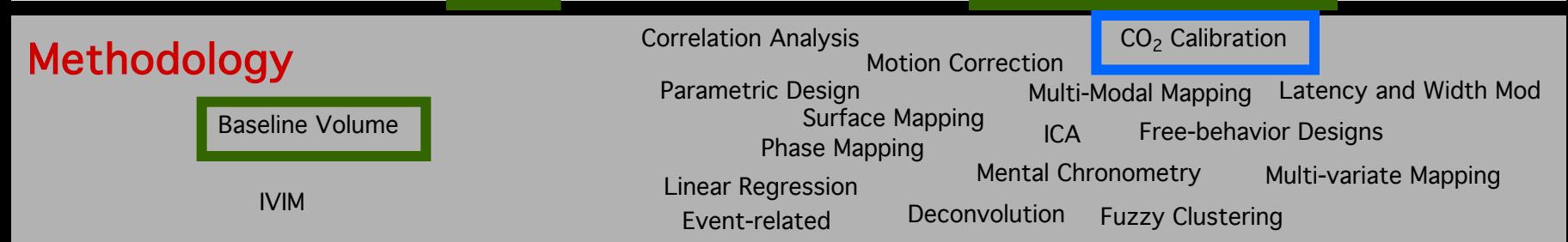
Perfusion



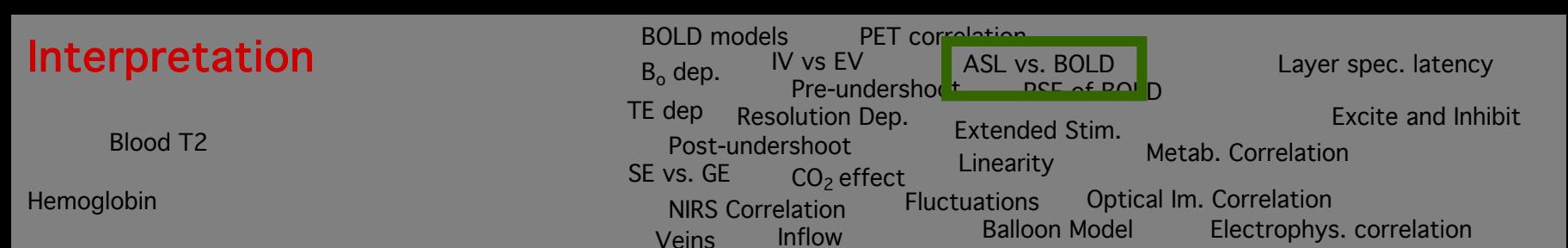
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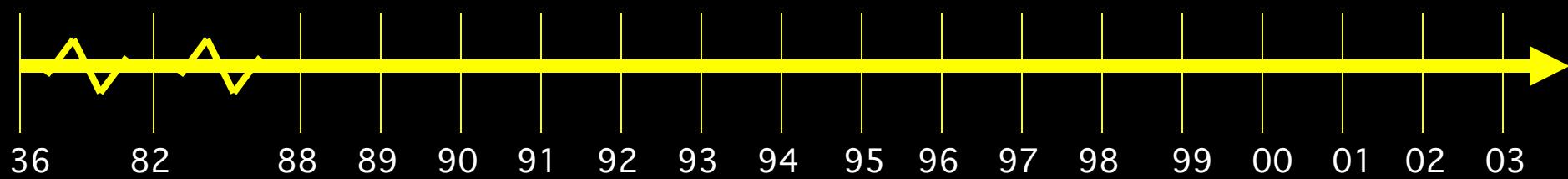
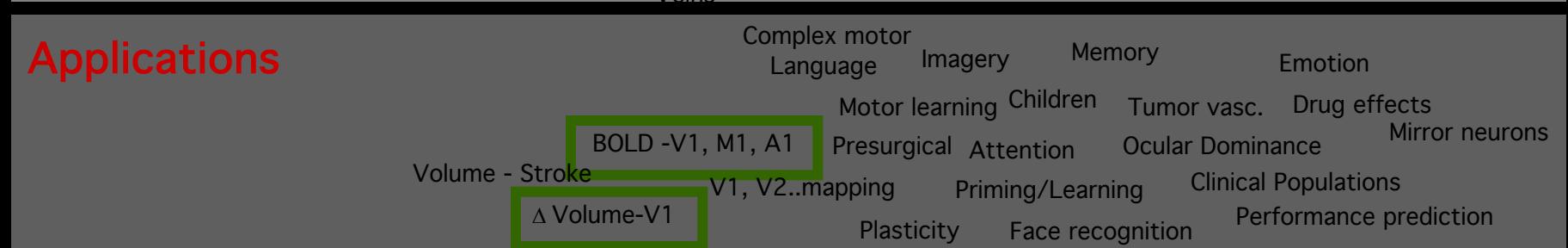
Methodology



Interpretation



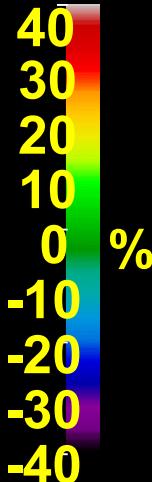
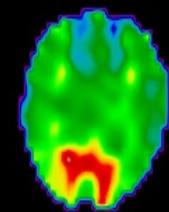
Applications



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

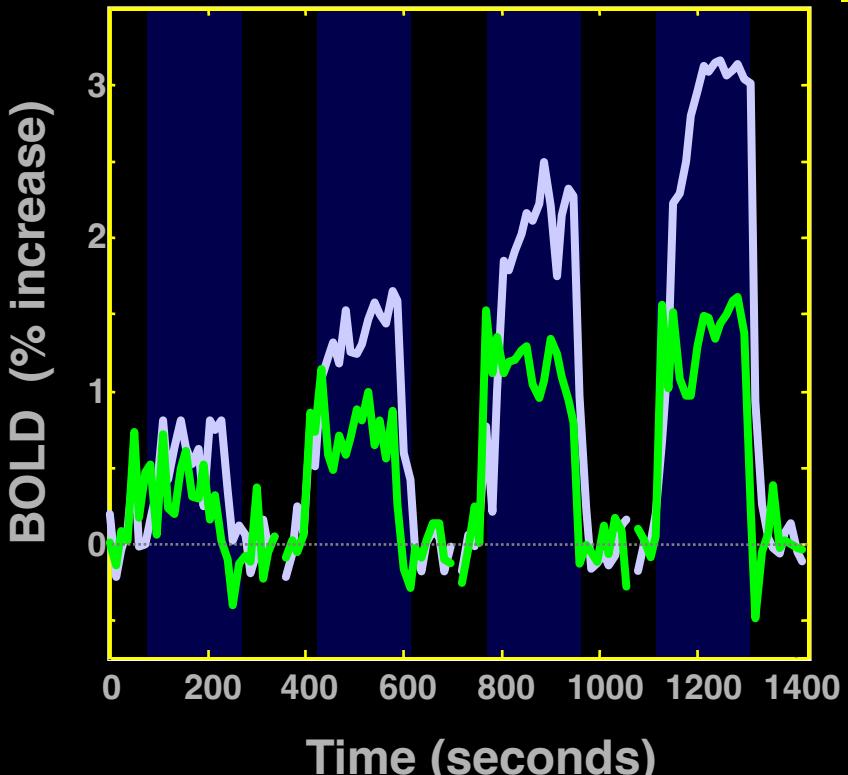
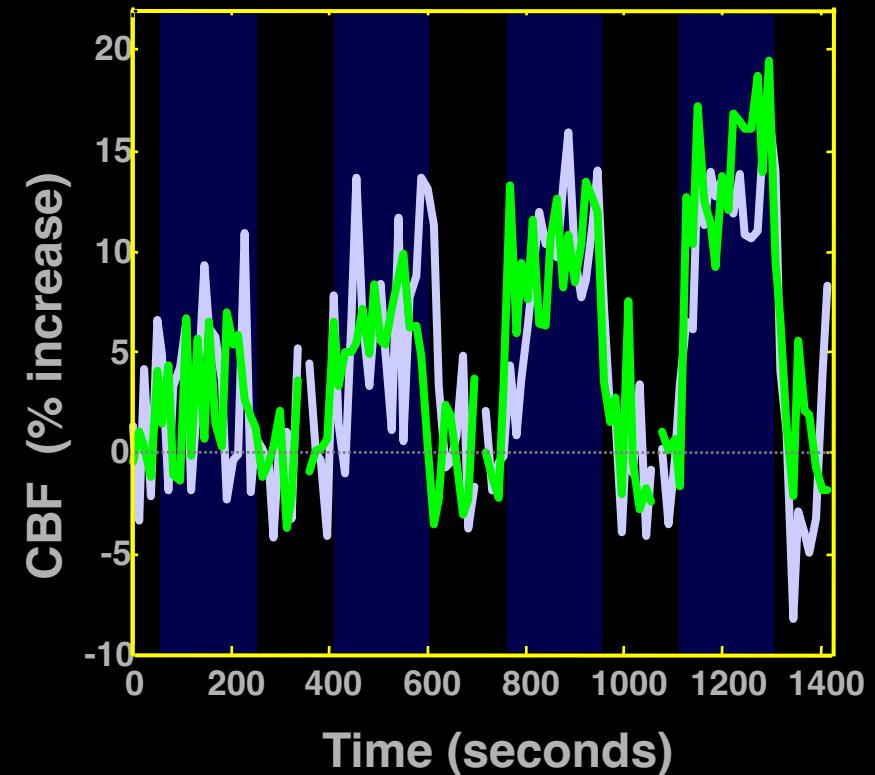
RICHARD D. HOGE^{*†}, JEFF ATKINSON*, BRAD GILL*, GÉRARD R. CRELIER*, SEAN MARRETT[†], AND G. BRUCE PIKE*

*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

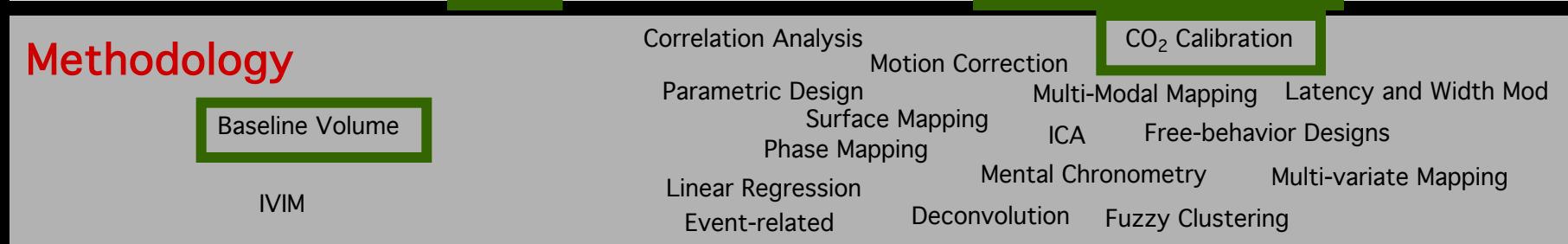


Simultaneous Perfusion and BOLD imaging during graded visual activation and hypercapnia

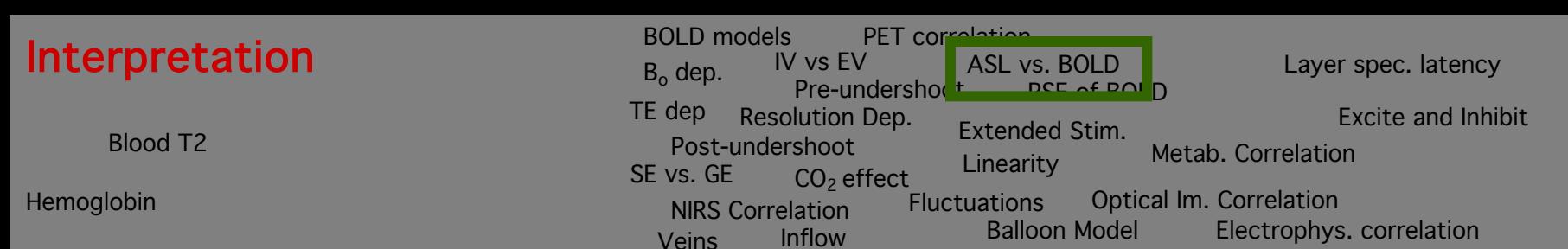
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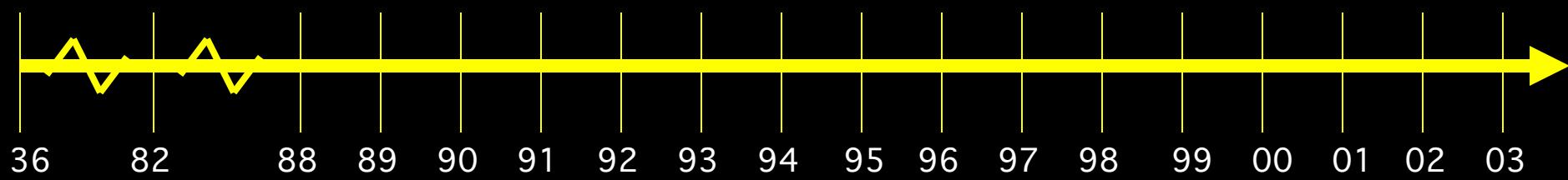
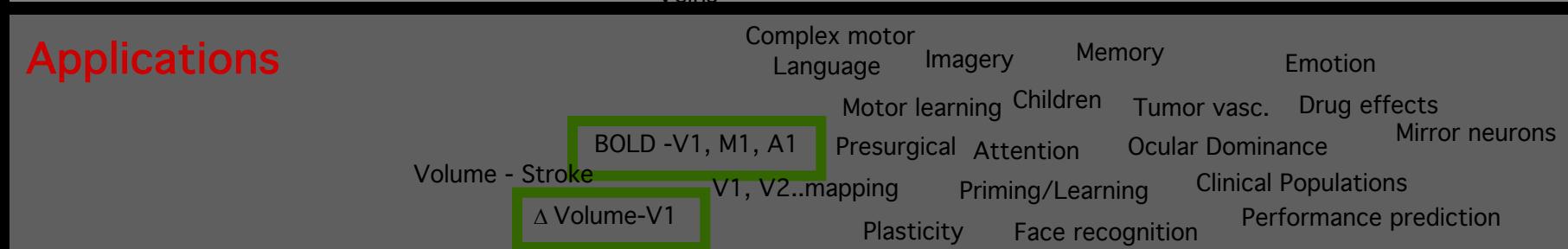
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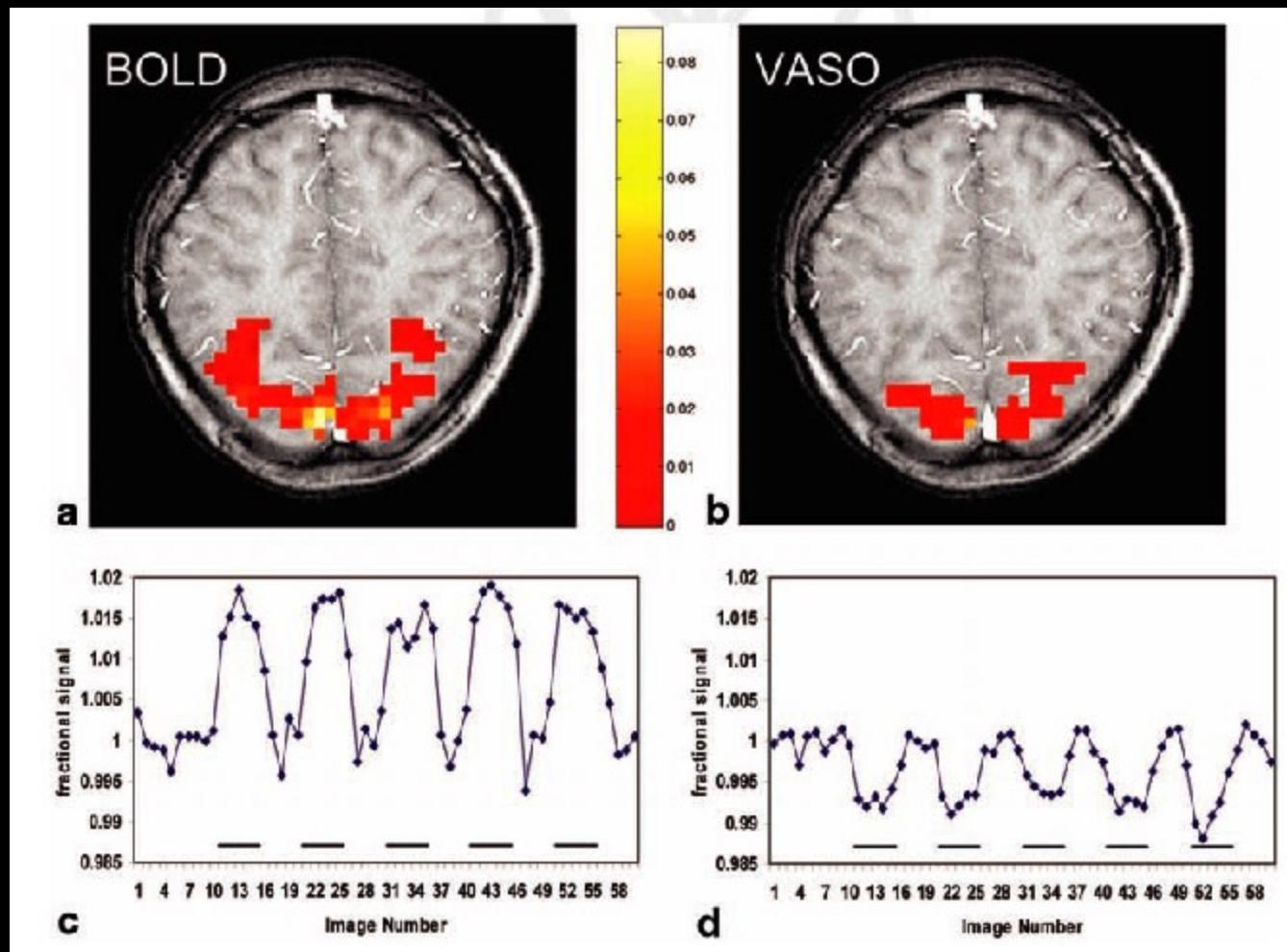
Applications



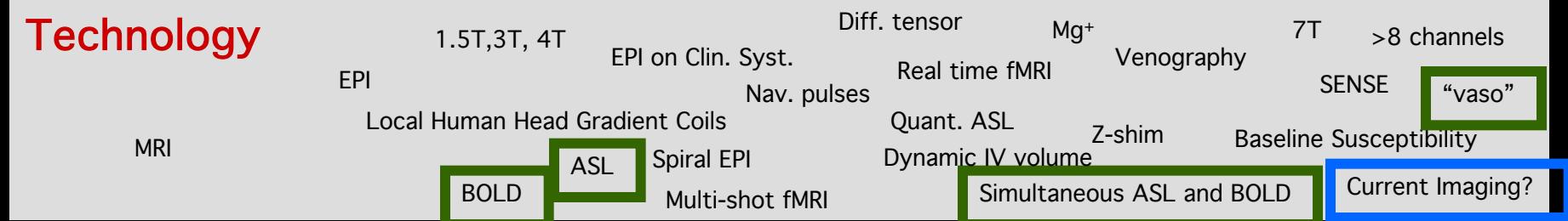
Functional Magnetic Resonance Imaging Based on Changes in Vascular Space Occupancy

Hanzhang Lu,^{1,3} Xavier Golay,^{1,3} James J. Pekar,^{1,3} and Peter C.M. van Zijl^{1,3*}

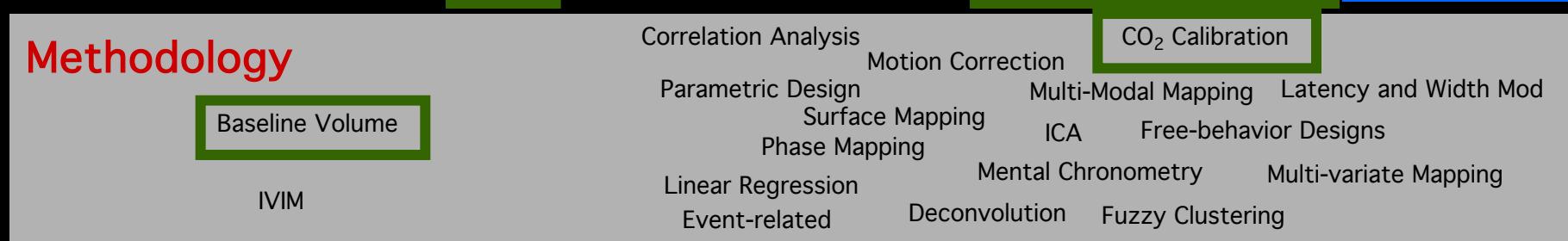
MAGNET RESON MED 50 (2): 263-274 AUG 2003



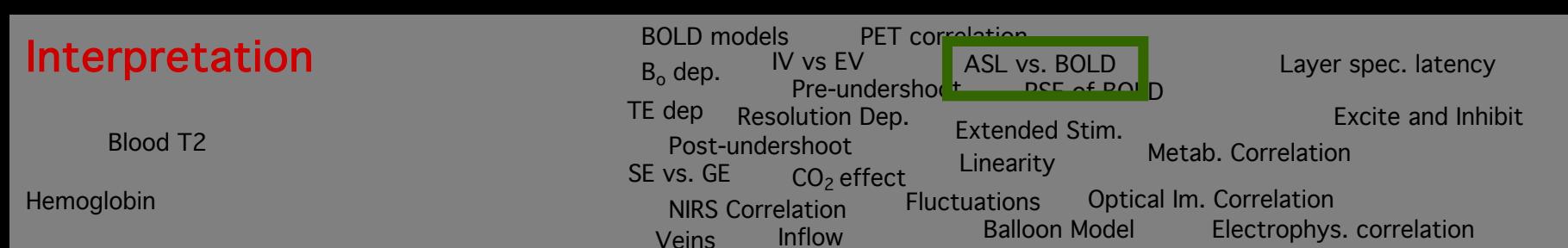
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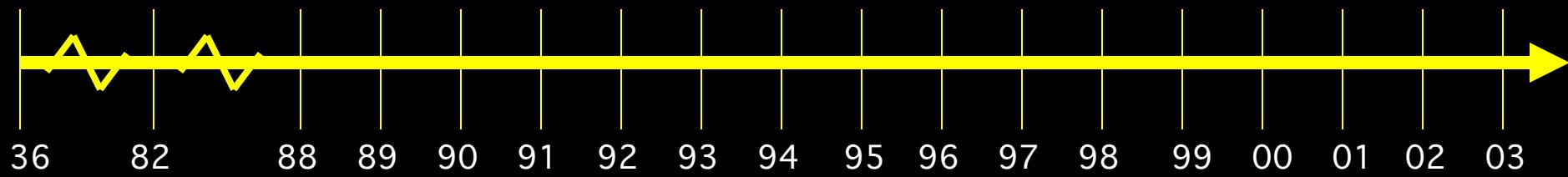
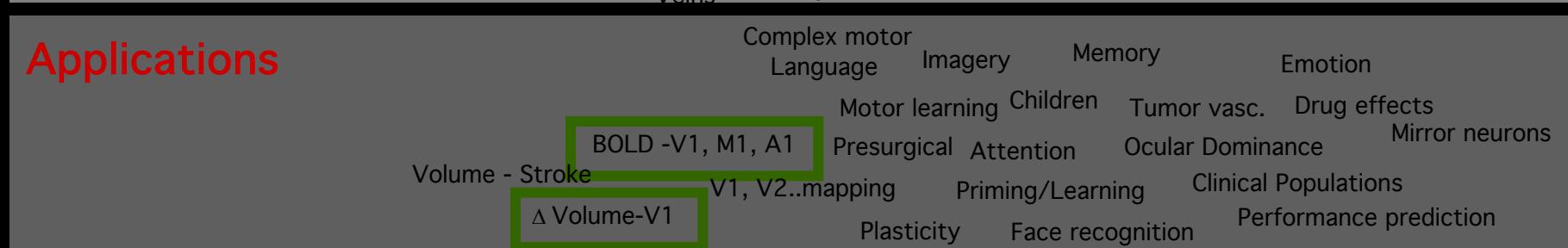
Methodology



Interpretation



Applications



Neuronal Current Imaging

- Neuronal activity is directly associated with ionic currents.
- These bio-currents induce **spatially distributed and transient** magnetic flux density changes and magnetic field gradients.
- In the context of MRI, these currents therefore alter **the magnetic phase** of surrounding water protons.

Derivation of B field generated in an MRI voxel by a current dipole

Single dendritic tree having a diameter d, and length L behaves like a conductor with conductivity σ . Resistance is $R=V/I$, where $R=4L/(\pi d^2 \sigma)$. From Biot-Savart:

$$B = \frac{\mu_0}{4\pi} \frac{Q}{r^2} = \frac{\mu_0}{16} \frac{d^2 \sigma V}{r^2}$$

by substituting $d = 4\mu\text{m}$, $\sigma \approx 0.25 \Omega^{-1} \text{ m}^{-1}$, $V = 10\text{mV}$ and

$r = 4\text{cm}$ (measurement distance when using MEG) the resulting value is: **$B \approx 0.002 \text{ fT}$**

Because **$B_{MEG}=100\text{fT}$** (or more) is measured by MEG on the scalp, a large number of neurons, ($0.002 \text{ fT} \times 50,000 = 100 \text{ fT}$), must coherently act to generate such field. These bundles of neurons produce, within a typical voxel, $1 \text{ mm} \times 1 \text{ mm} \times 1 \text{ mm}$, a field of order:

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

$B_{MRI} \approx 0.2 \text{nT}$

J. Bodurka, P. A. Bandettini. Toward direct mapping of neuronal activity: MRI detection of ultra weak transient magnetic field changes, Magn. Reson. Med. 47: 1052-1058, (2002).

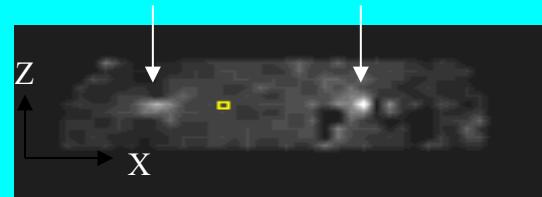
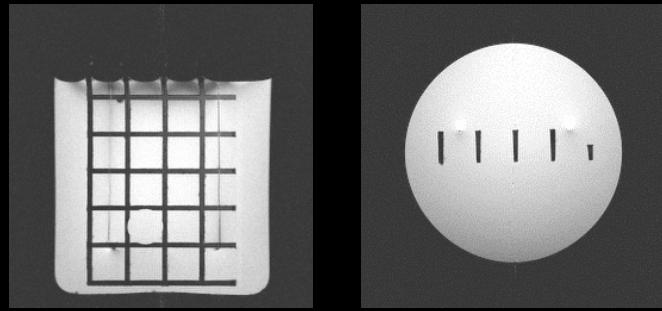
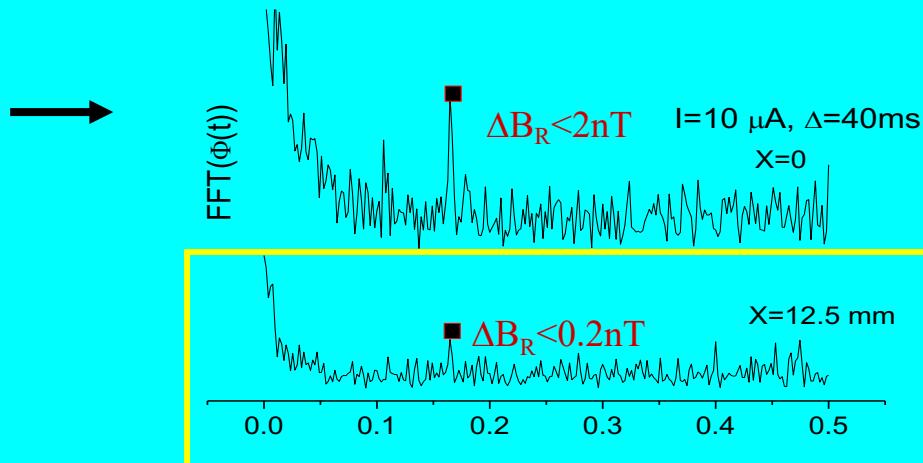
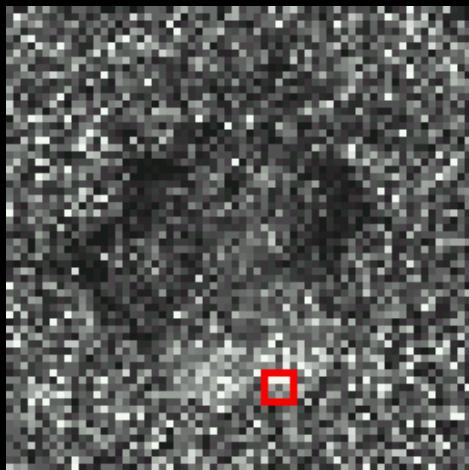


Figure 1

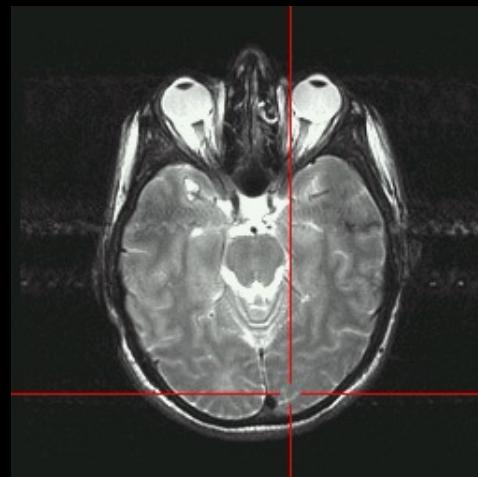


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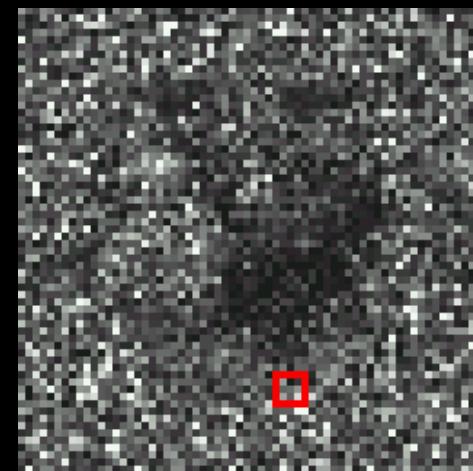
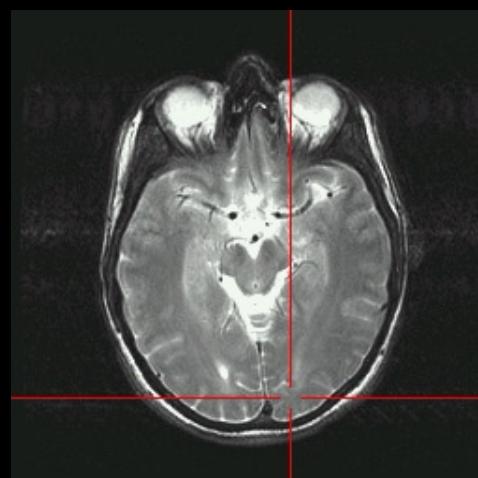
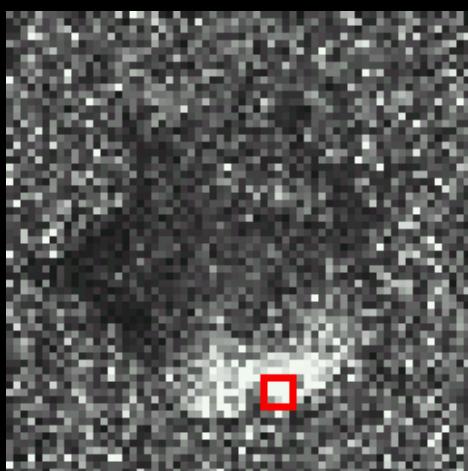
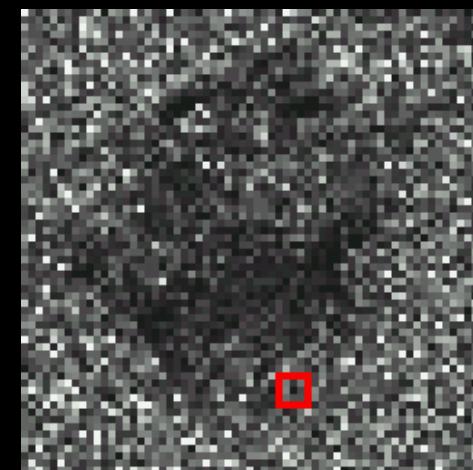
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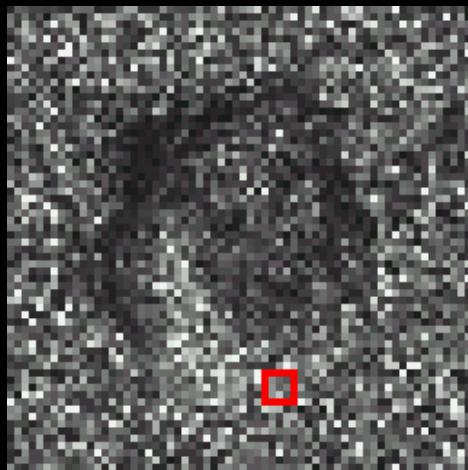
Phase v=0.12Hz



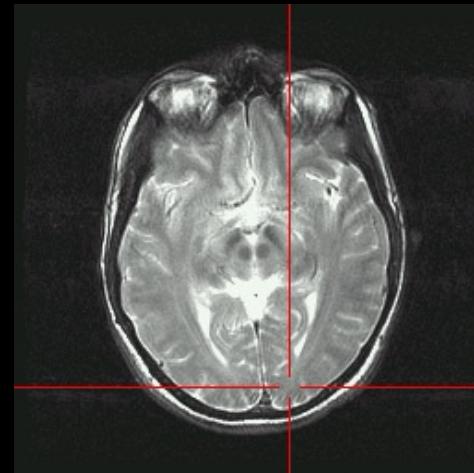
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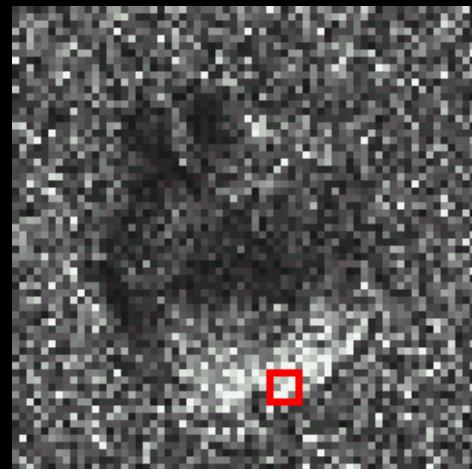
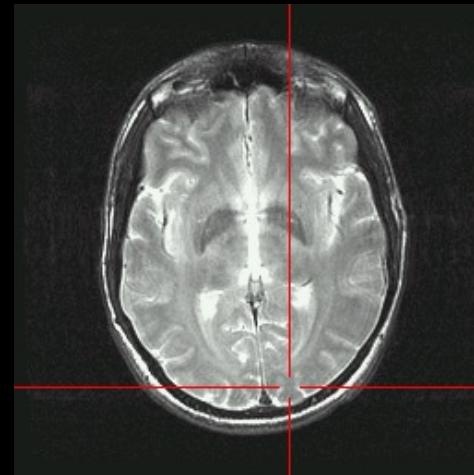
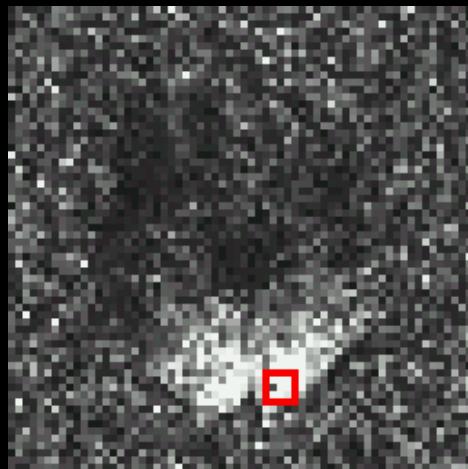
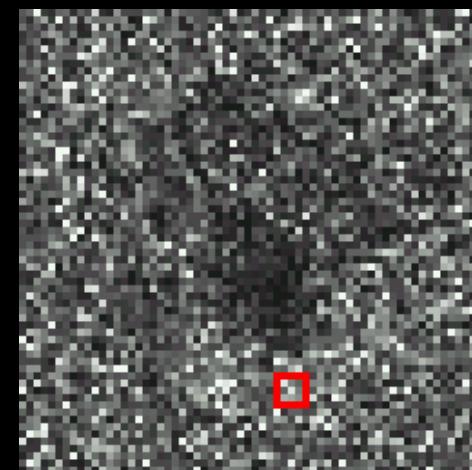
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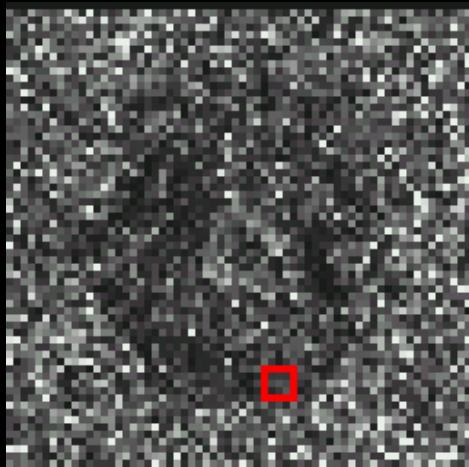
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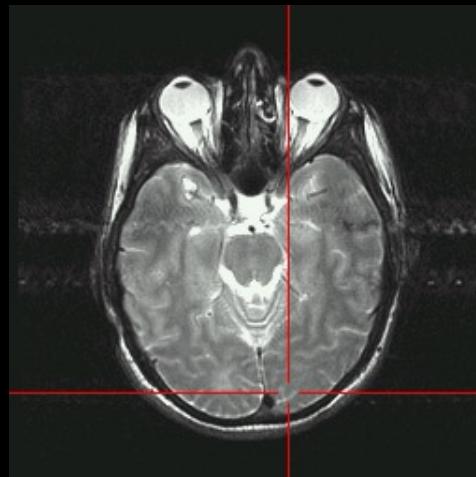
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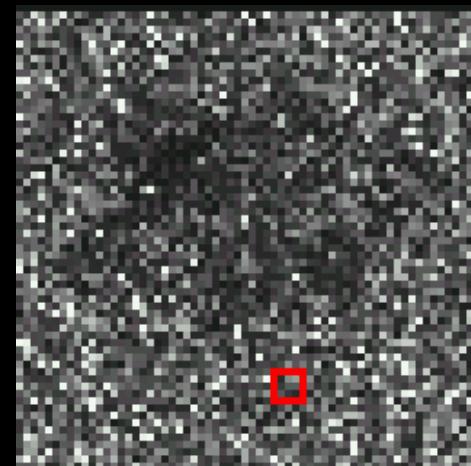
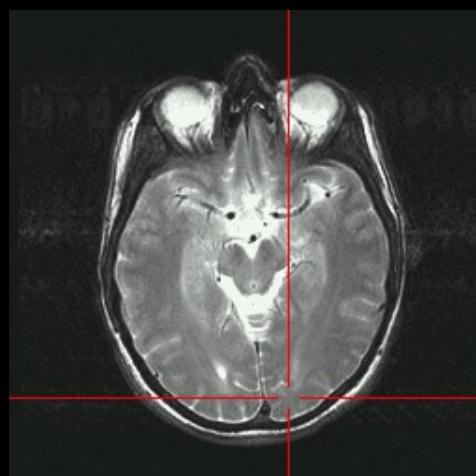
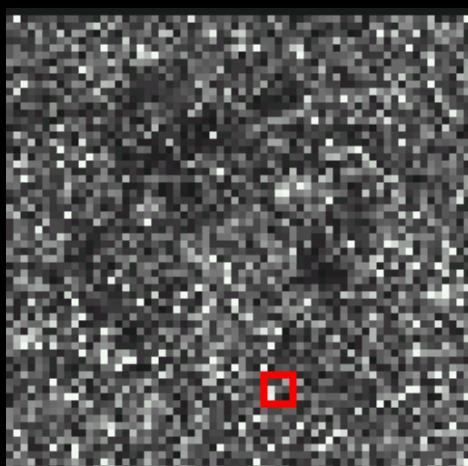
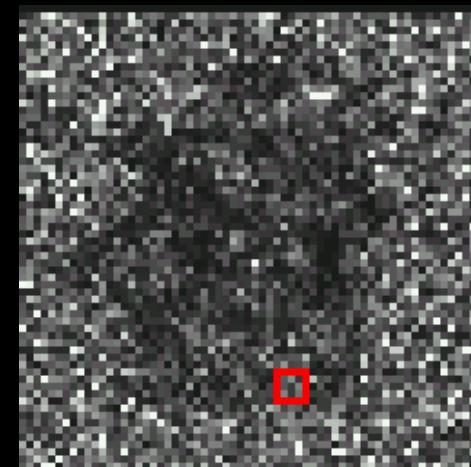
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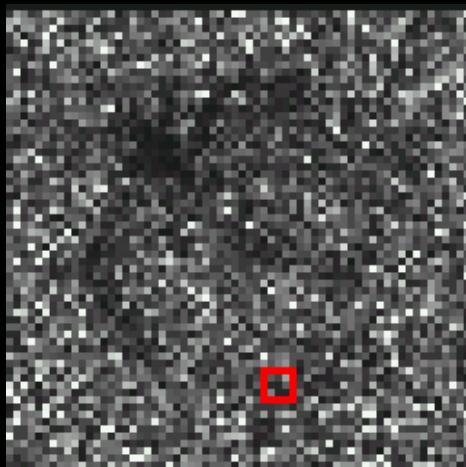
Magnitude v=0.12Hz



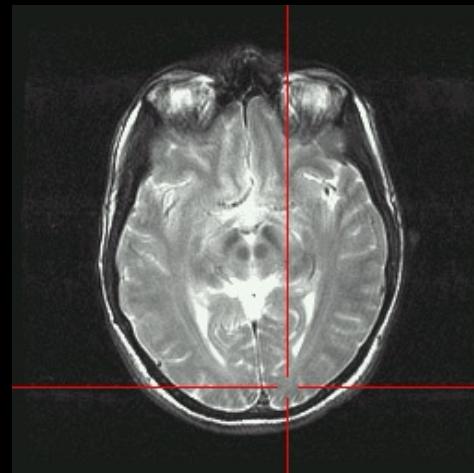
Open



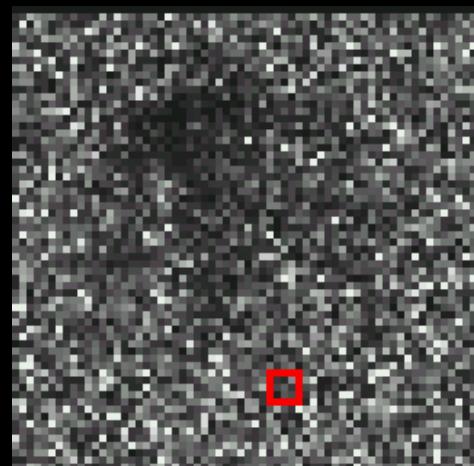
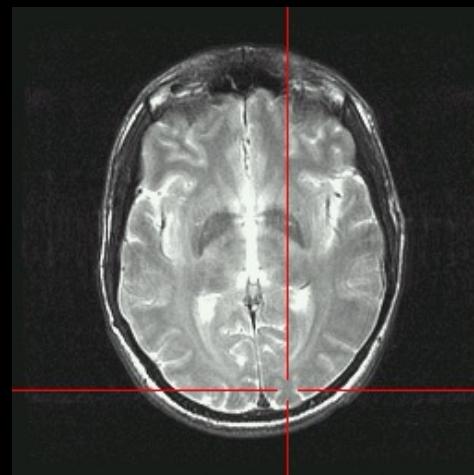
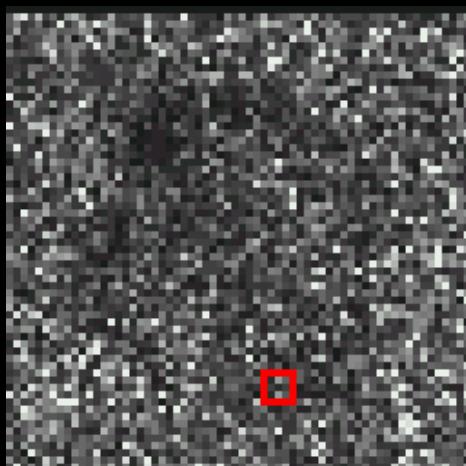
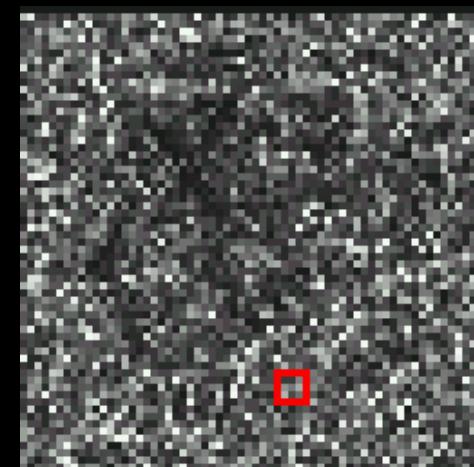
Closed

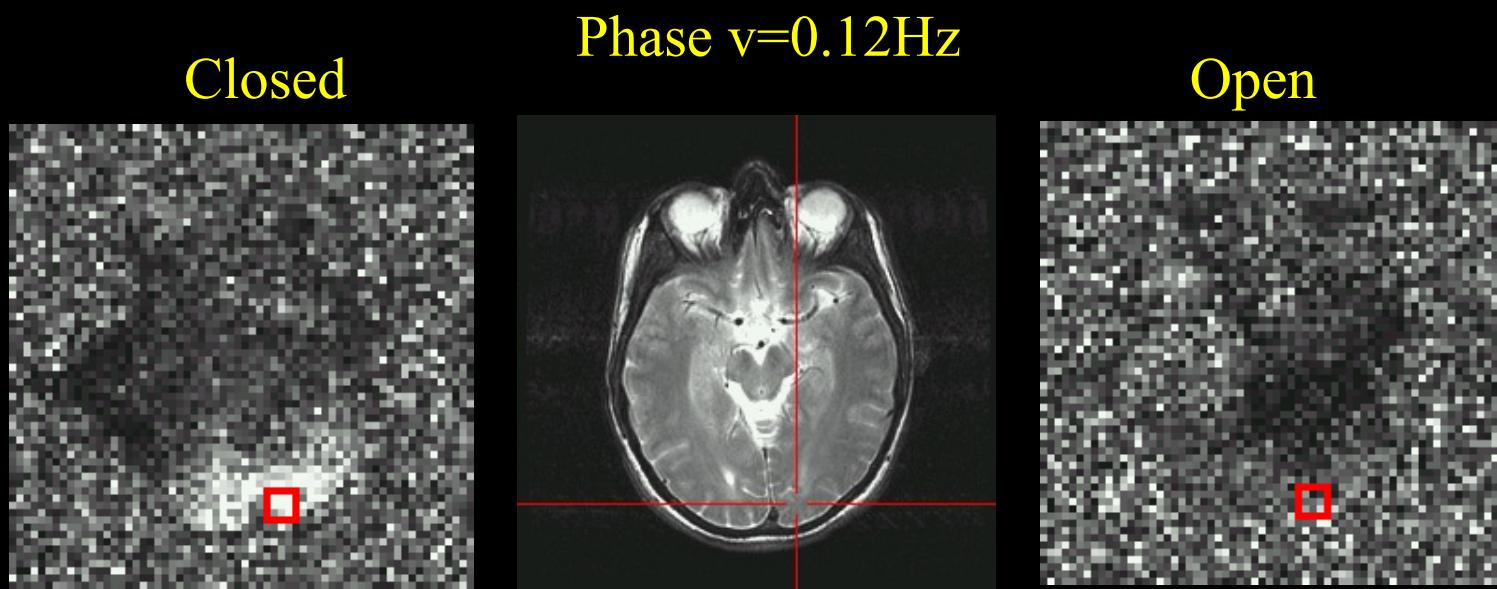


Magnitude v=0.12 Hz

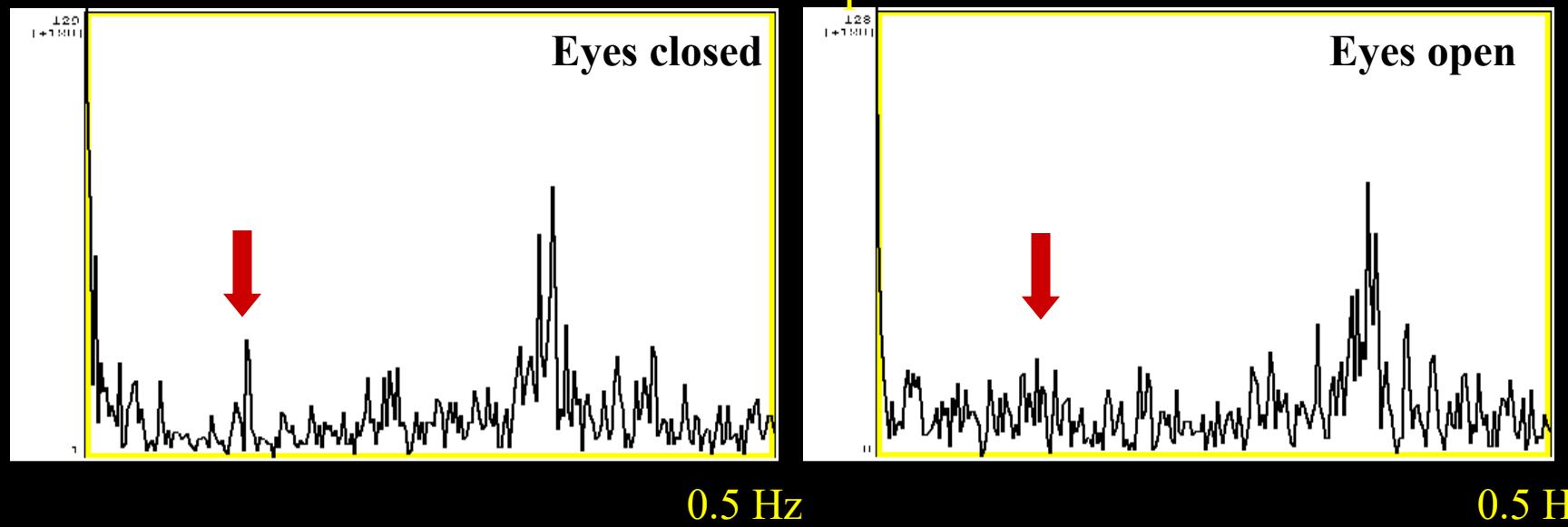


Open



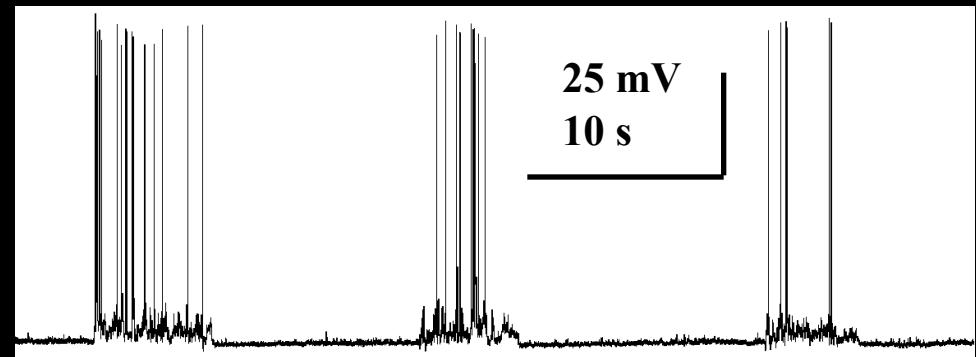
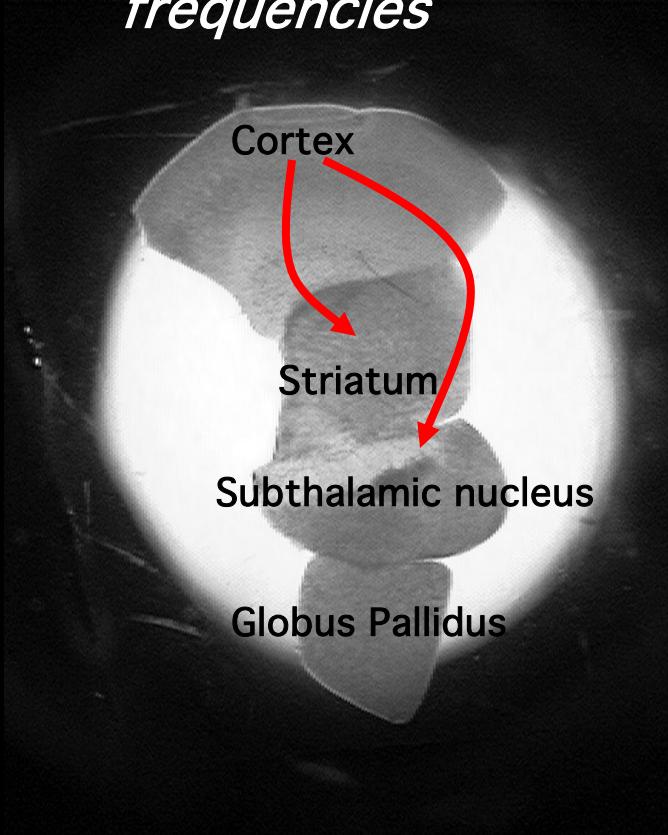


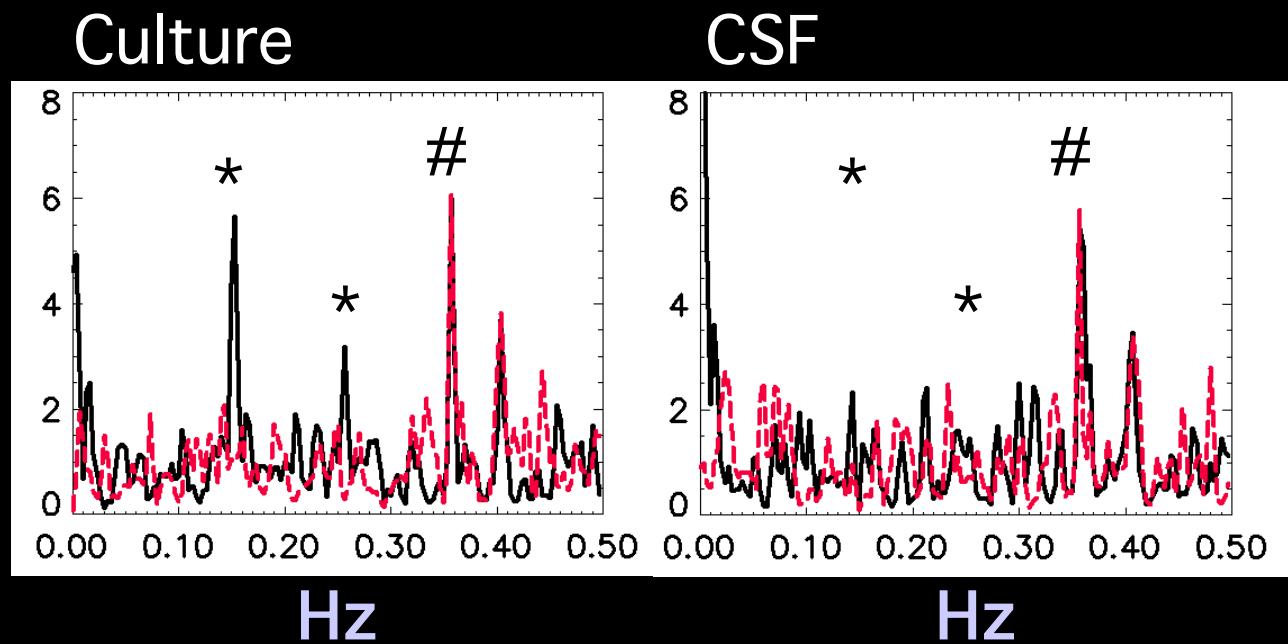
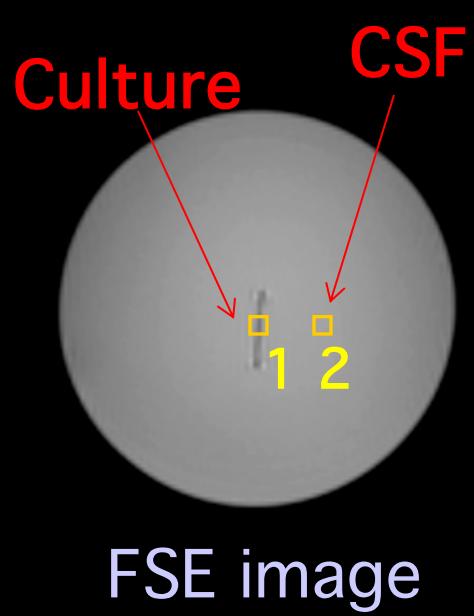
Power spectra



In Vitro Results

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





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

*: activity

#: scanner pump frequency

Petridou et al.

- Functional contrast
- **Signal interpretation**
- Hardware and pulse sequences
- Paradigm design and processing

- Overview
- Current Limits
- Future Prospects

Neuronal Activation

Measured Signal



?

Hemodynamics



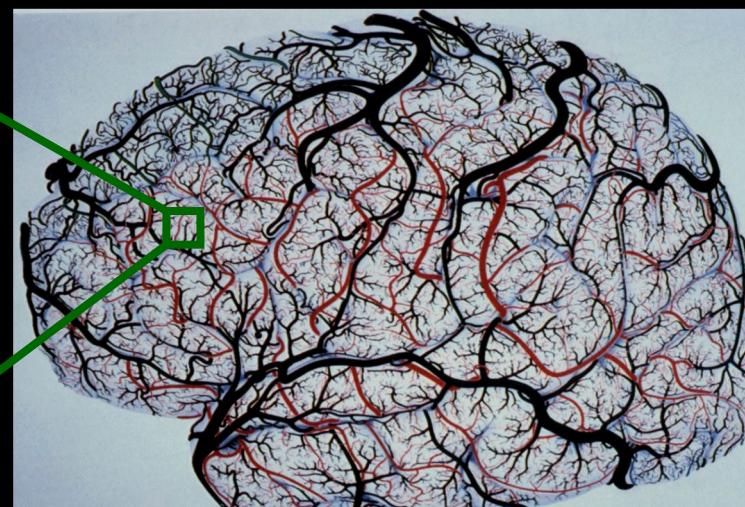
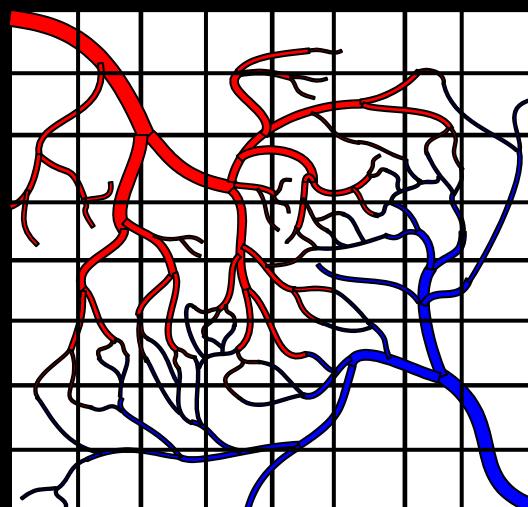
?

Measured Signal

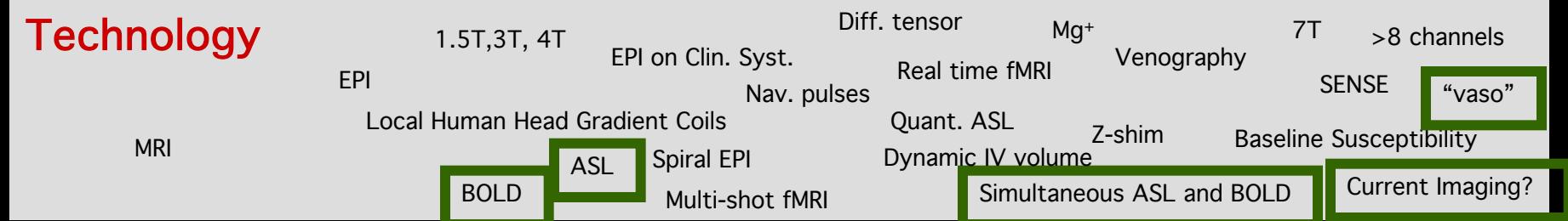


?

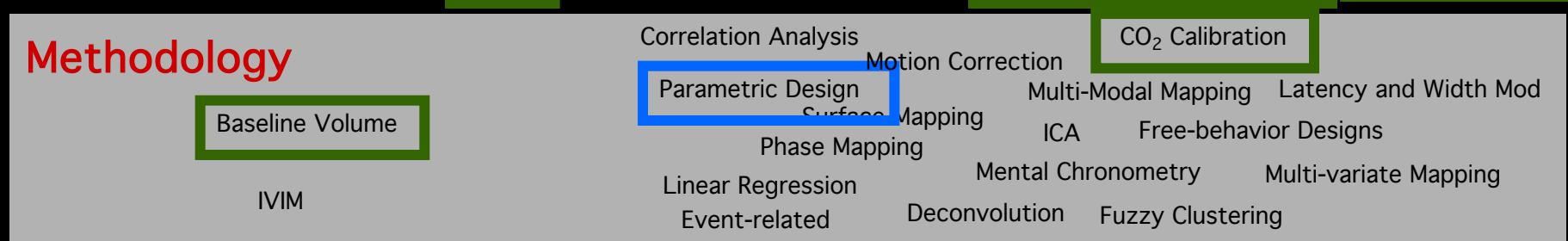
Noise



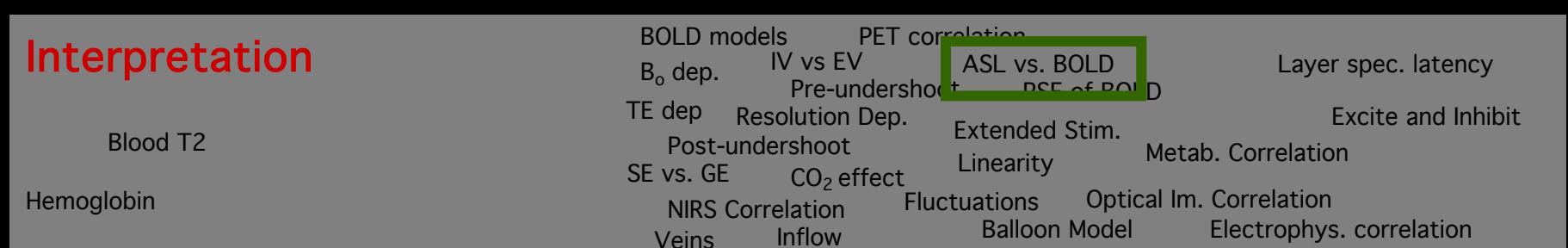
Technology



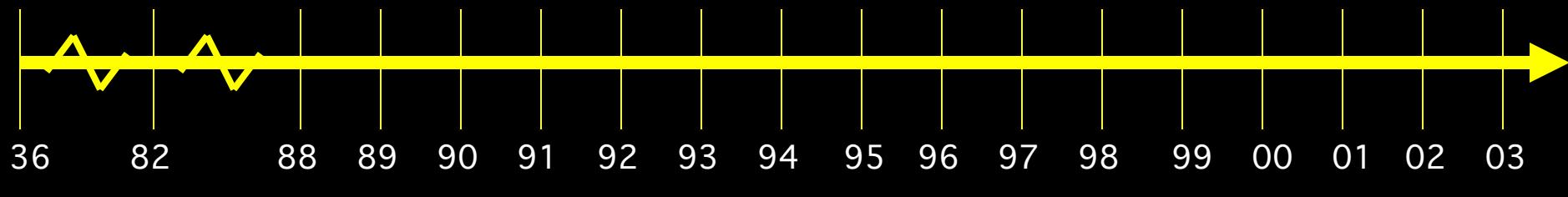
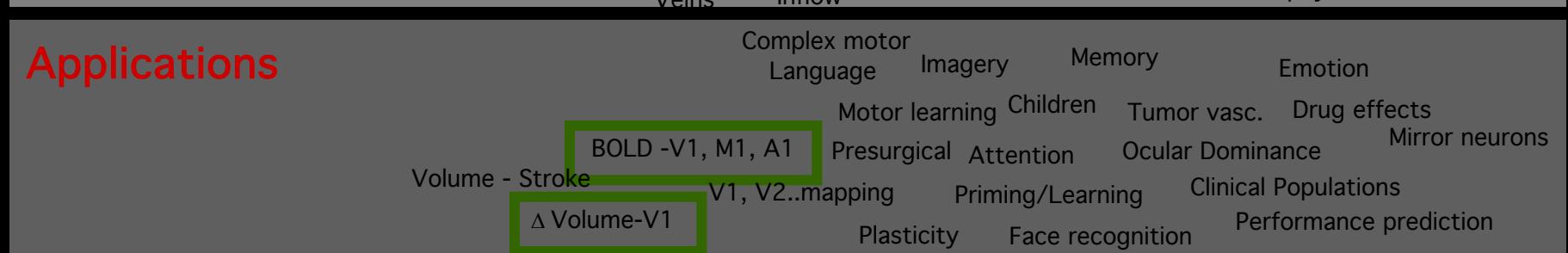
Methodology



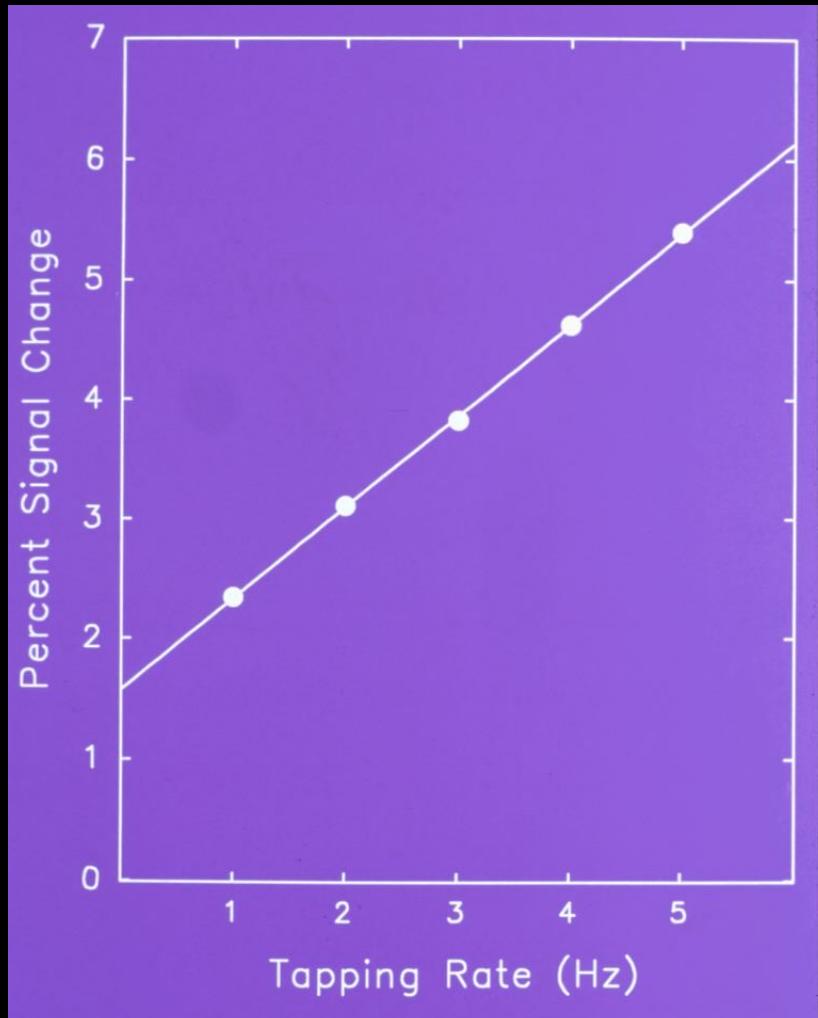
Interpretation



Applications

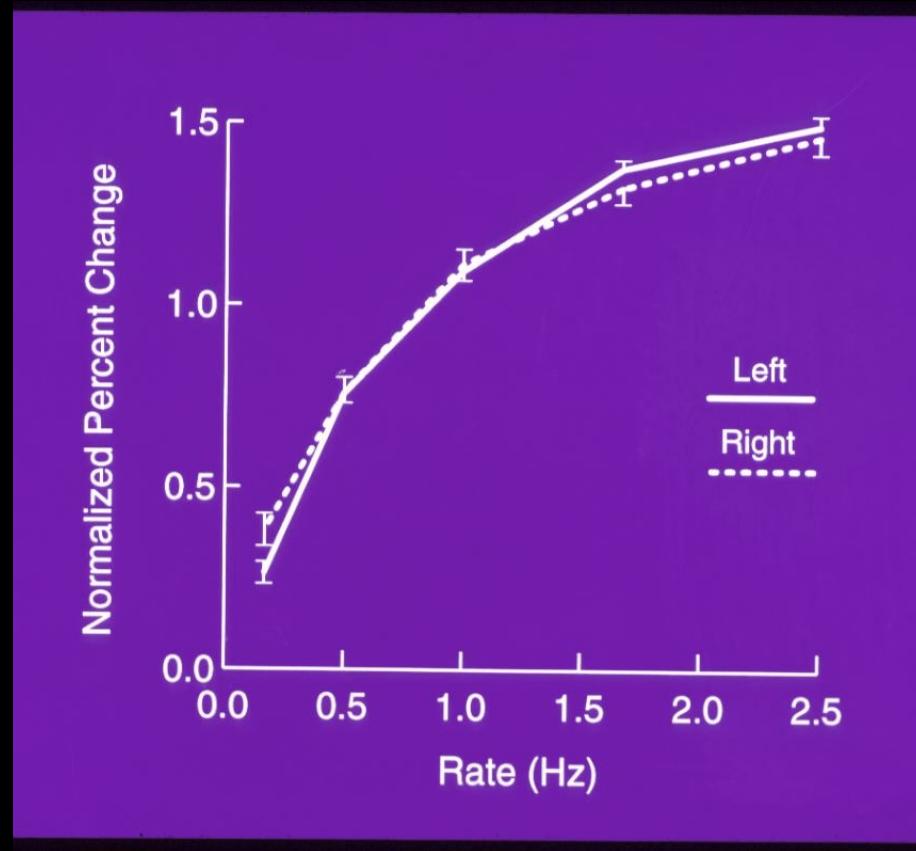


Motor Cortex



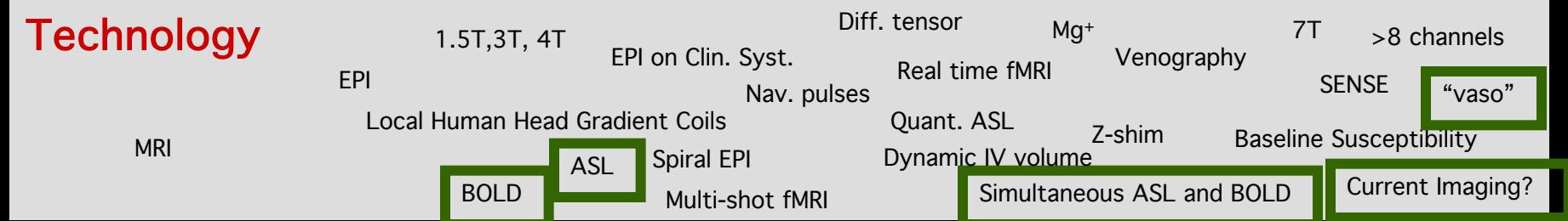
S. M. Rao et al, (1996) “Relationship between finger movement rate and functional magnetic resonance signal change in human primary motor cortex.” *J. Cereb. Blood Flow and Met.* 16, 1250-1254.

Auditory Cortex

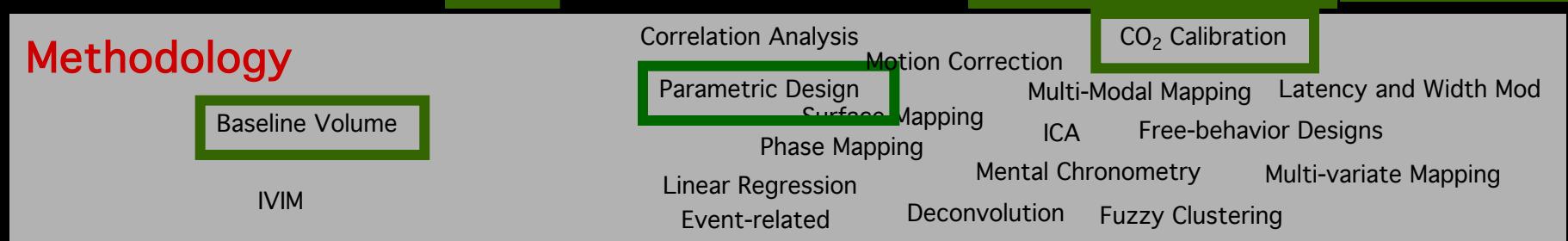


J. R. Binder, et al, (1994). “Effects of stimulus rate on signal response during functional magnetic resonance imaging of auditory cortex.” *Cogn. Brain Res.* 2, 31-38

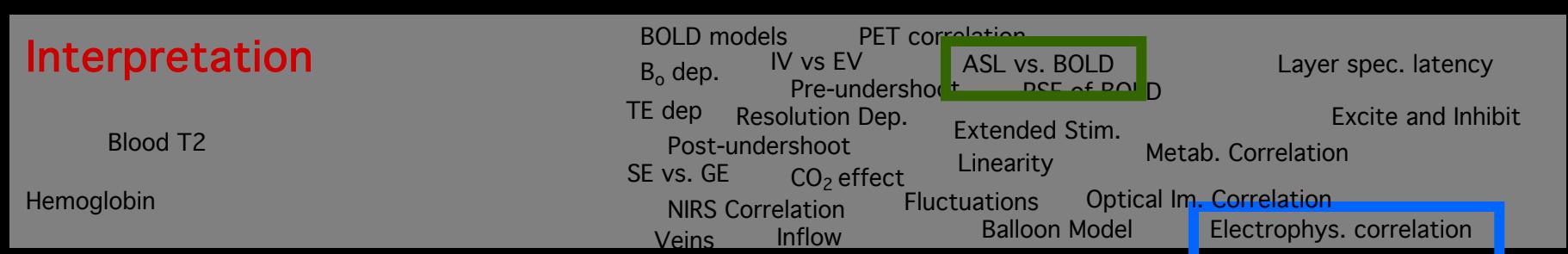
Technology



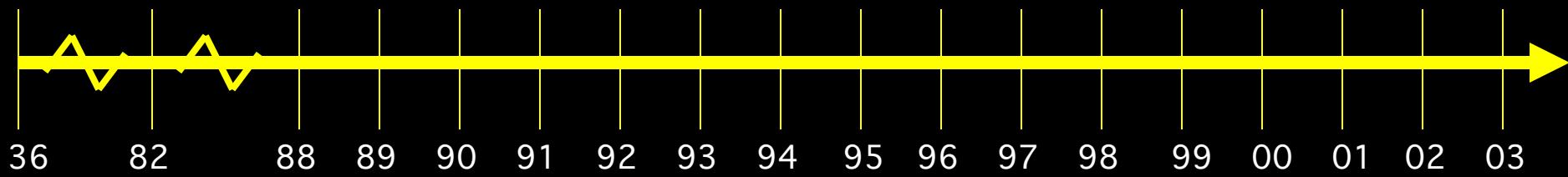
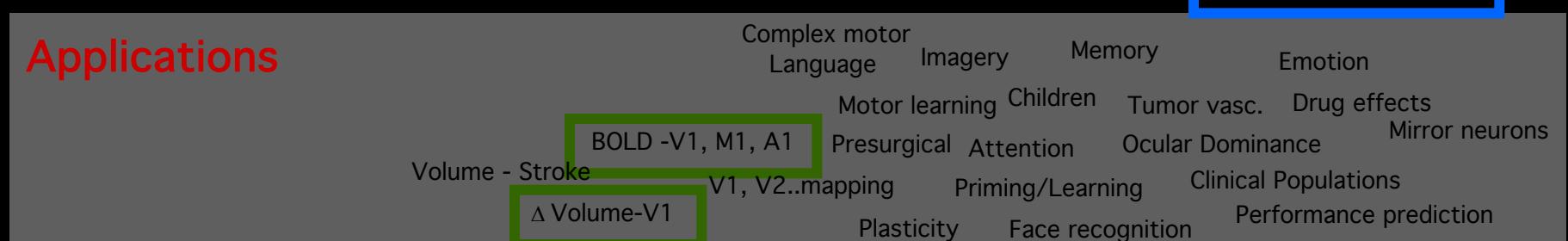
Methodology



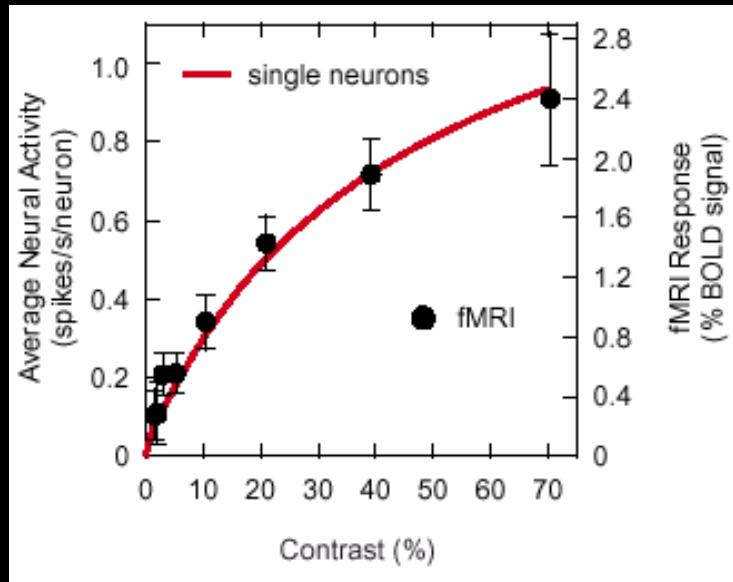
Interpretation



Applications



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



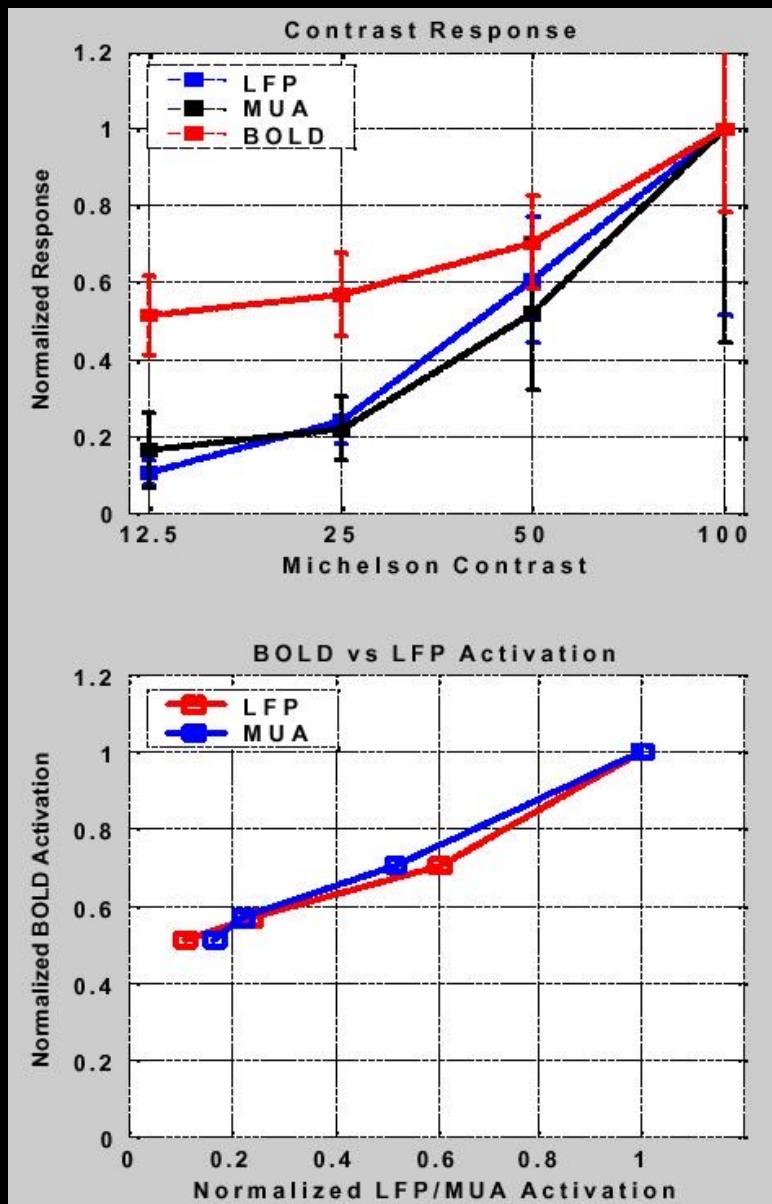
Heeger, D. J., Huk, A. C., Geisler, W. S., and Albrecht, D. G. 2000. Spikes versus BOLD: What does neuroimaging tell us about neuronal activity? *Nat. Neurosci.* 3: 631–633.

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

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



HBM 2003

Poster number: 308

The Negative BOLD Response in Monkey V1 Is Associated with Decreases in Neuronal Activity

Amir Shmuel*,†, Mark Augath, Axel Oeltermann, Jon Pauls, Yusuke Murayama, Nikos K. Logothetis

Figure 1

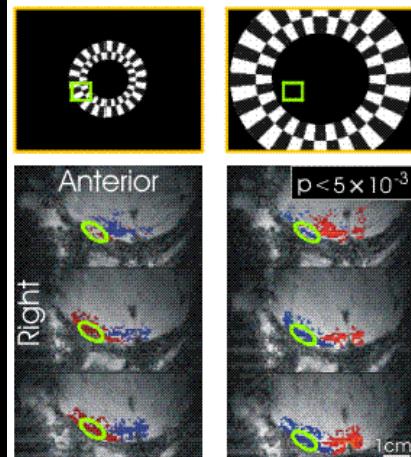


Figure 2

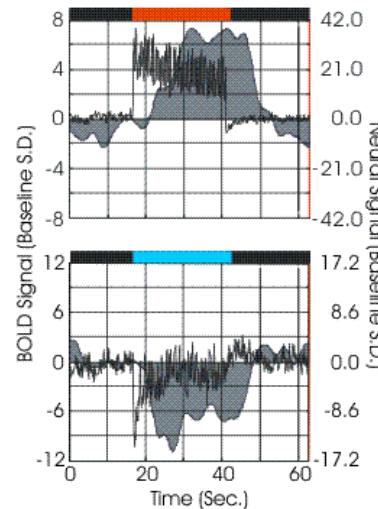
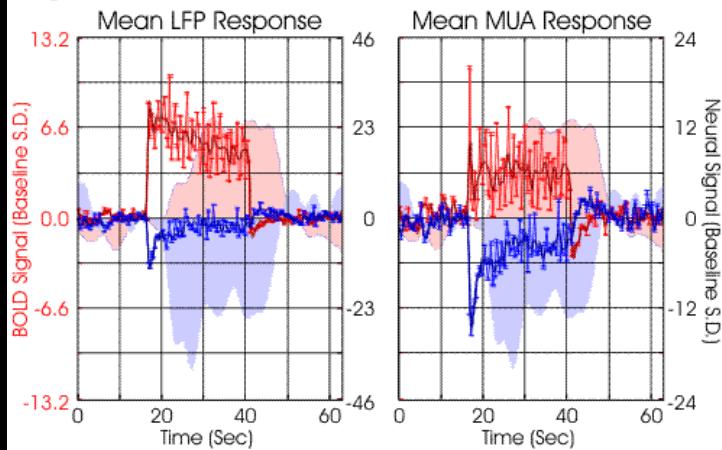
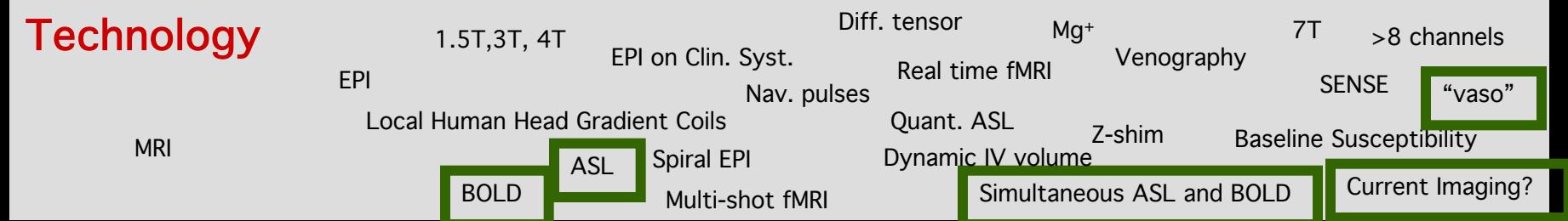


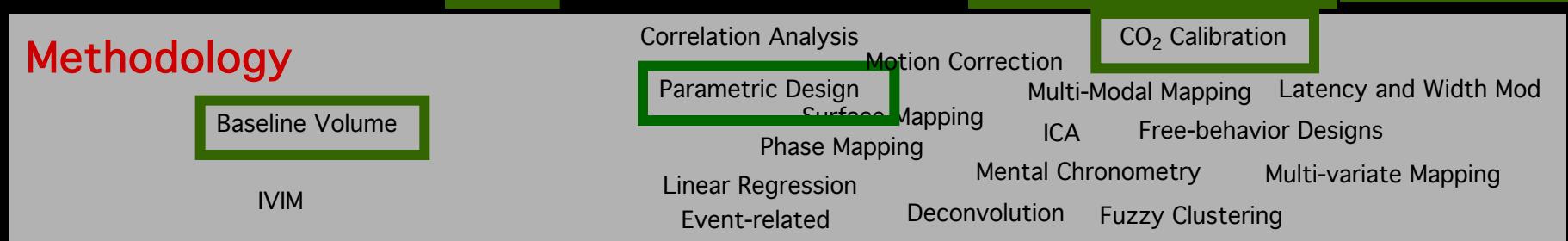
Figure 3



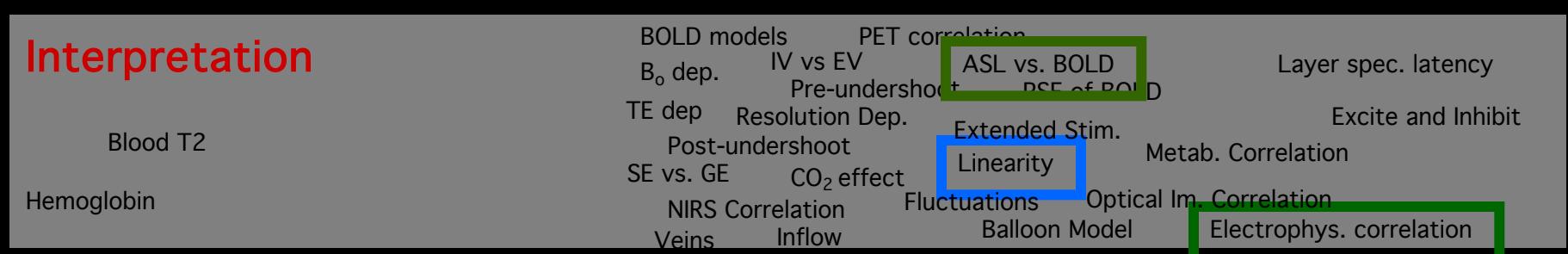
Technology



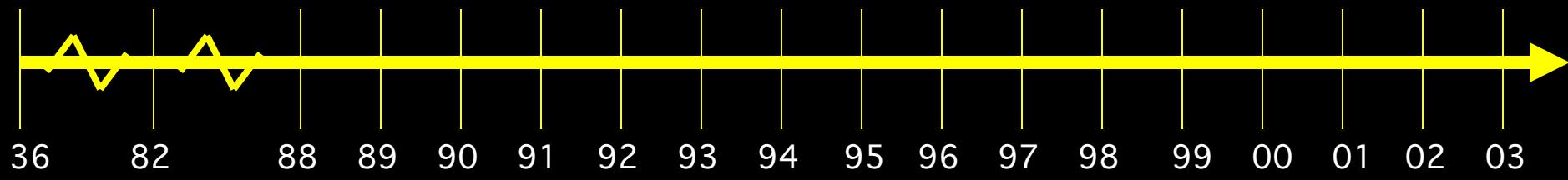
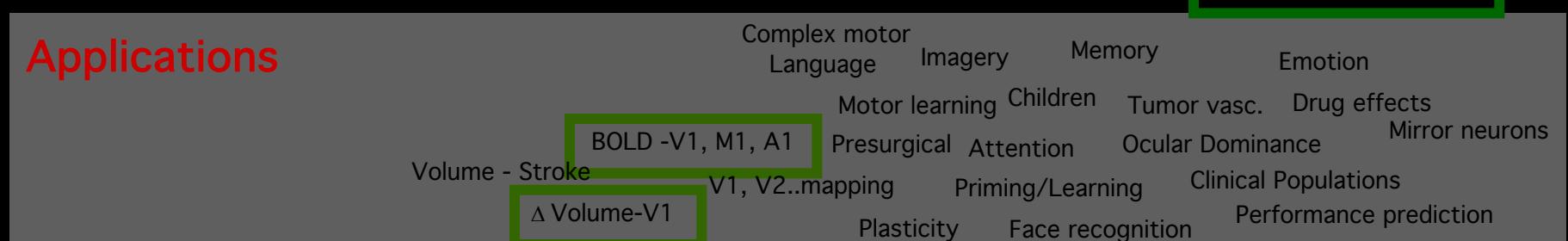
Methodology



Interpretation

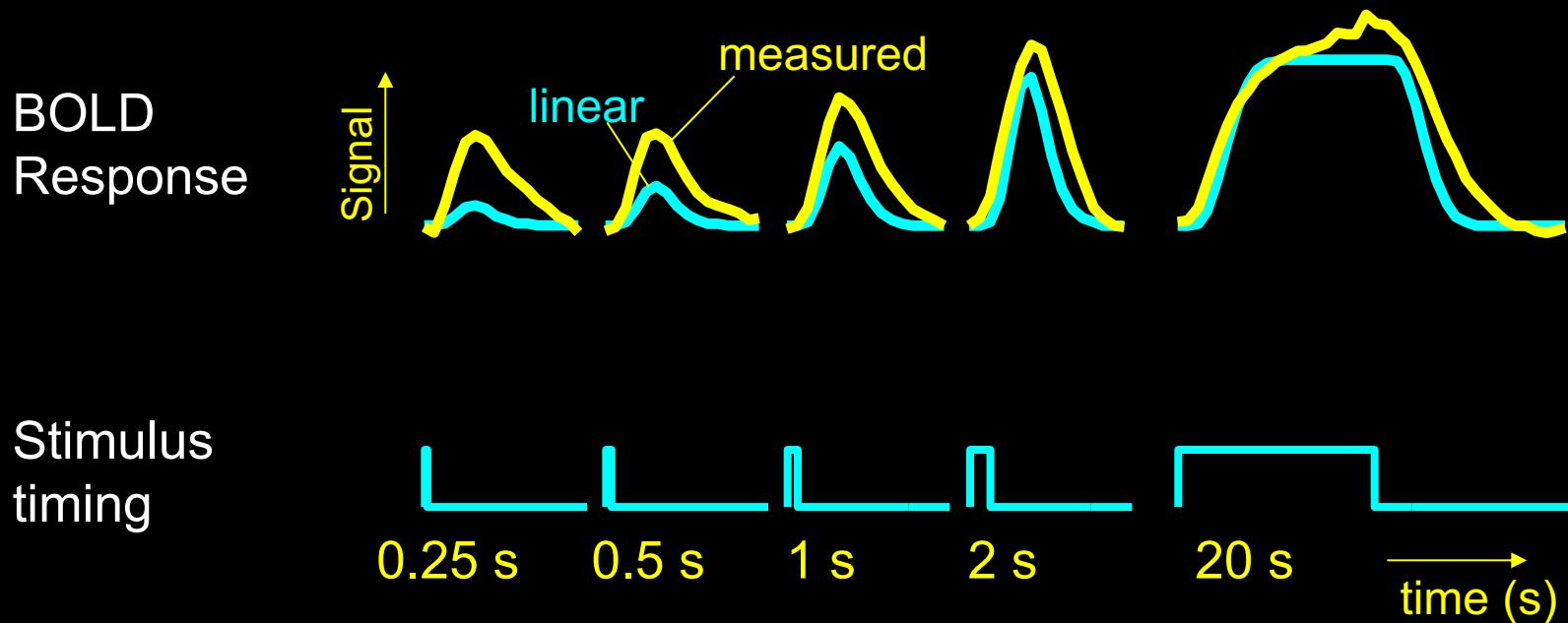


Applications



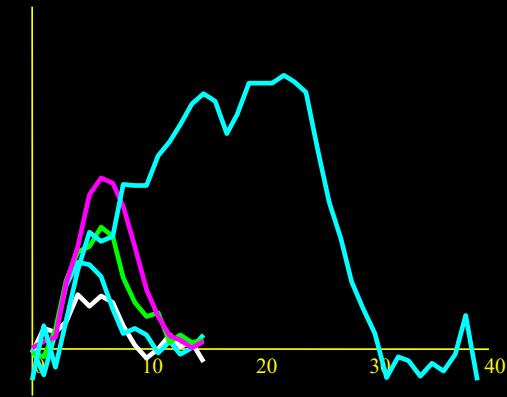
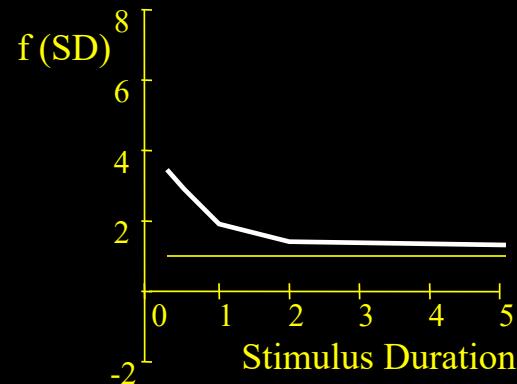
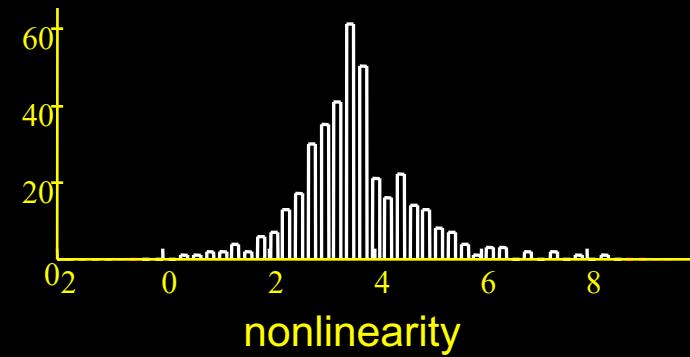
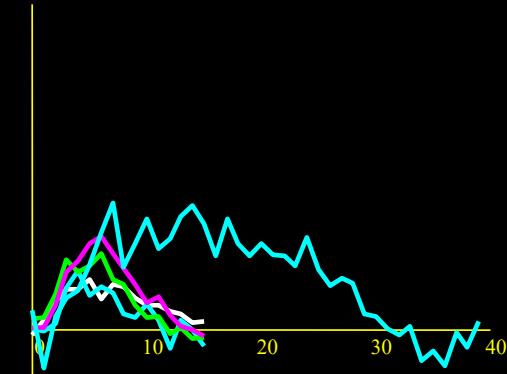
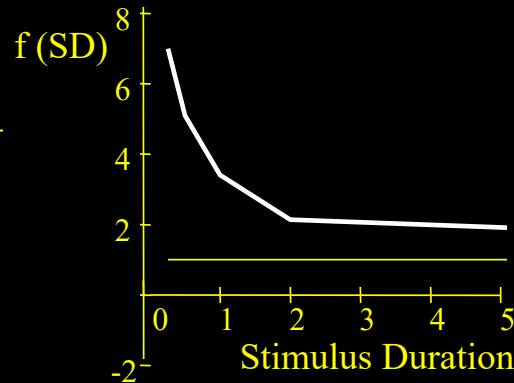
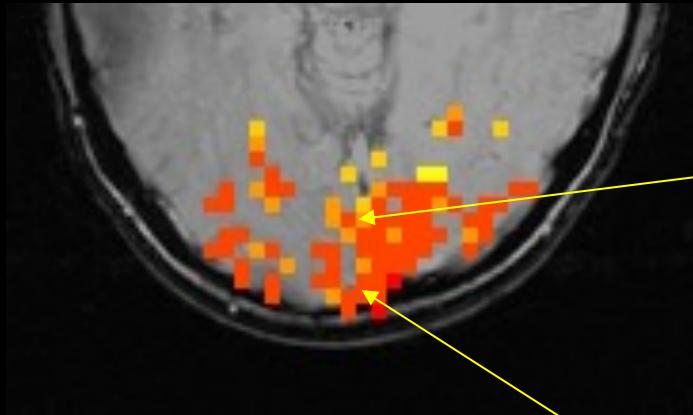
Dynamic Nonlinearity Assessment

Different stimulus “ON” periods



Brief stimuli produce larger responses than expected

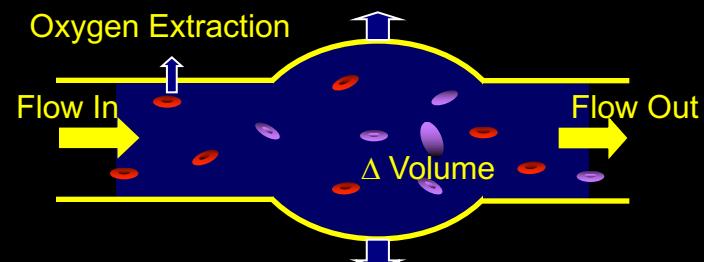
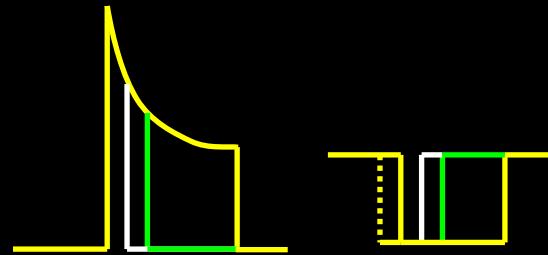
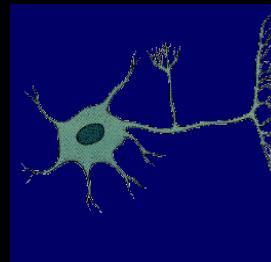
Spatial Heterogeneity of BOLD Nonlinearity



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

Sources of this Nonlinearity

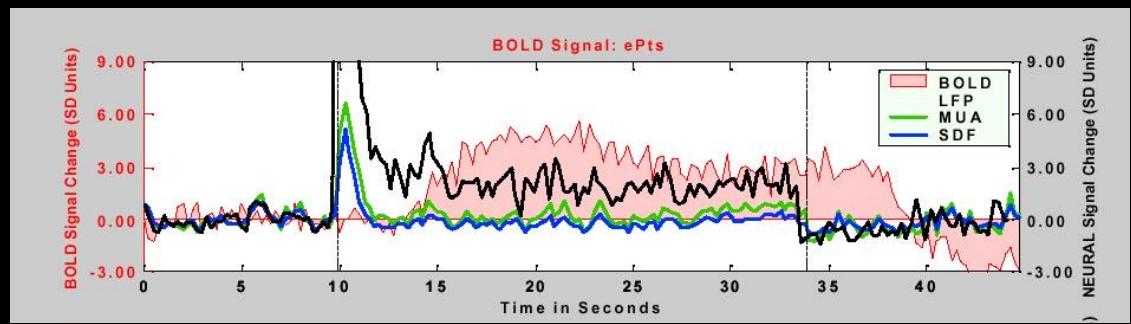
- Neuronal
- Hemodynamic
 - Oxygen extraction
 - Blood volume dynamics



BOLD Correlation with Neuronal Activity

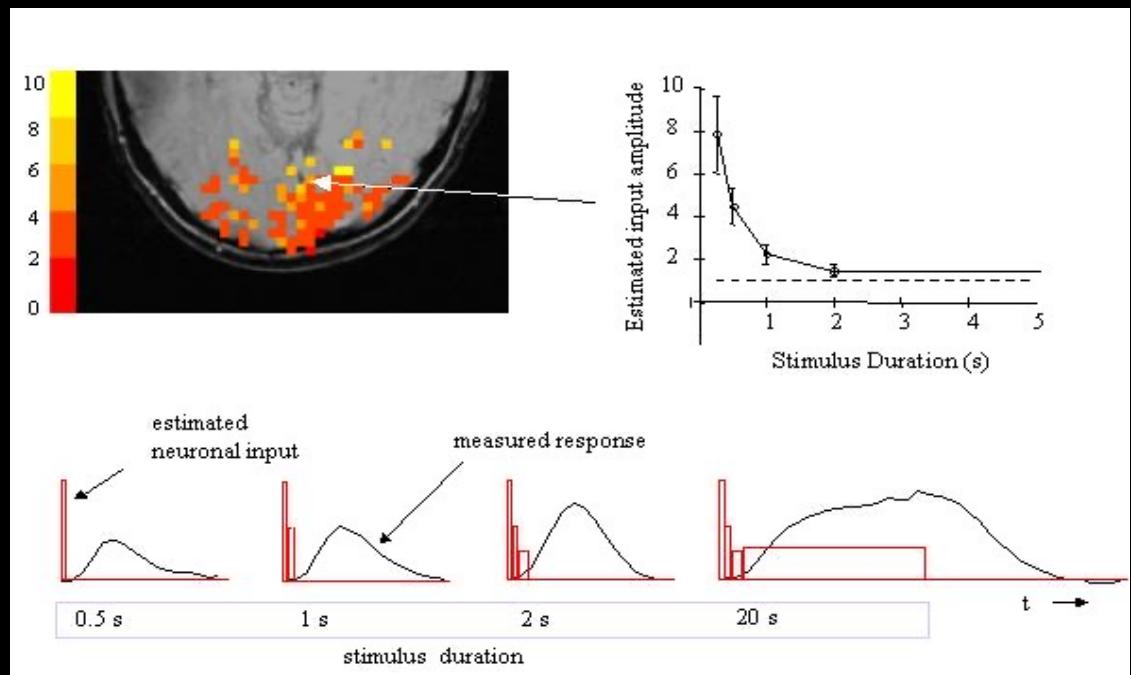
Logothetis et al. (2001)

“Neurophysiological investigation
of the basis of the fMRI signal”
Nature, 412, 150-157.



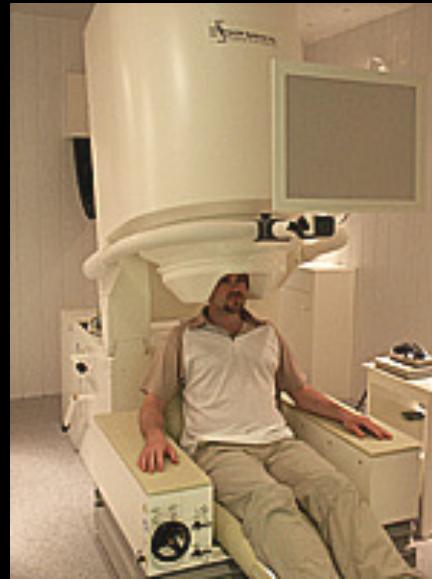
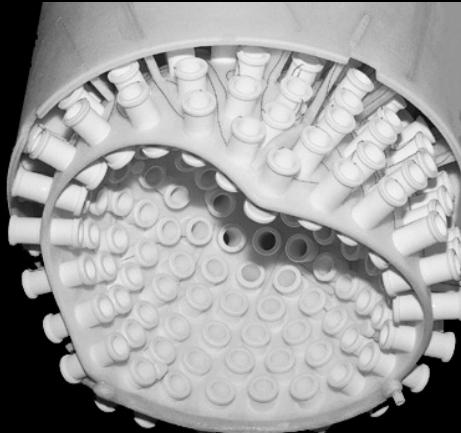
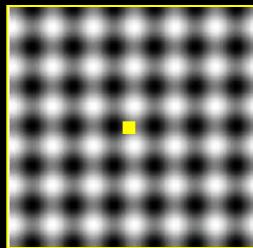
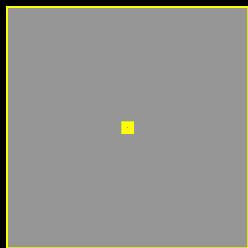
P. A. Bandettini and L. G.

Ungerleider, (2001) “From neuron
to BOLD: new connections.”
Nature Neuroscience, 4: 864-866.

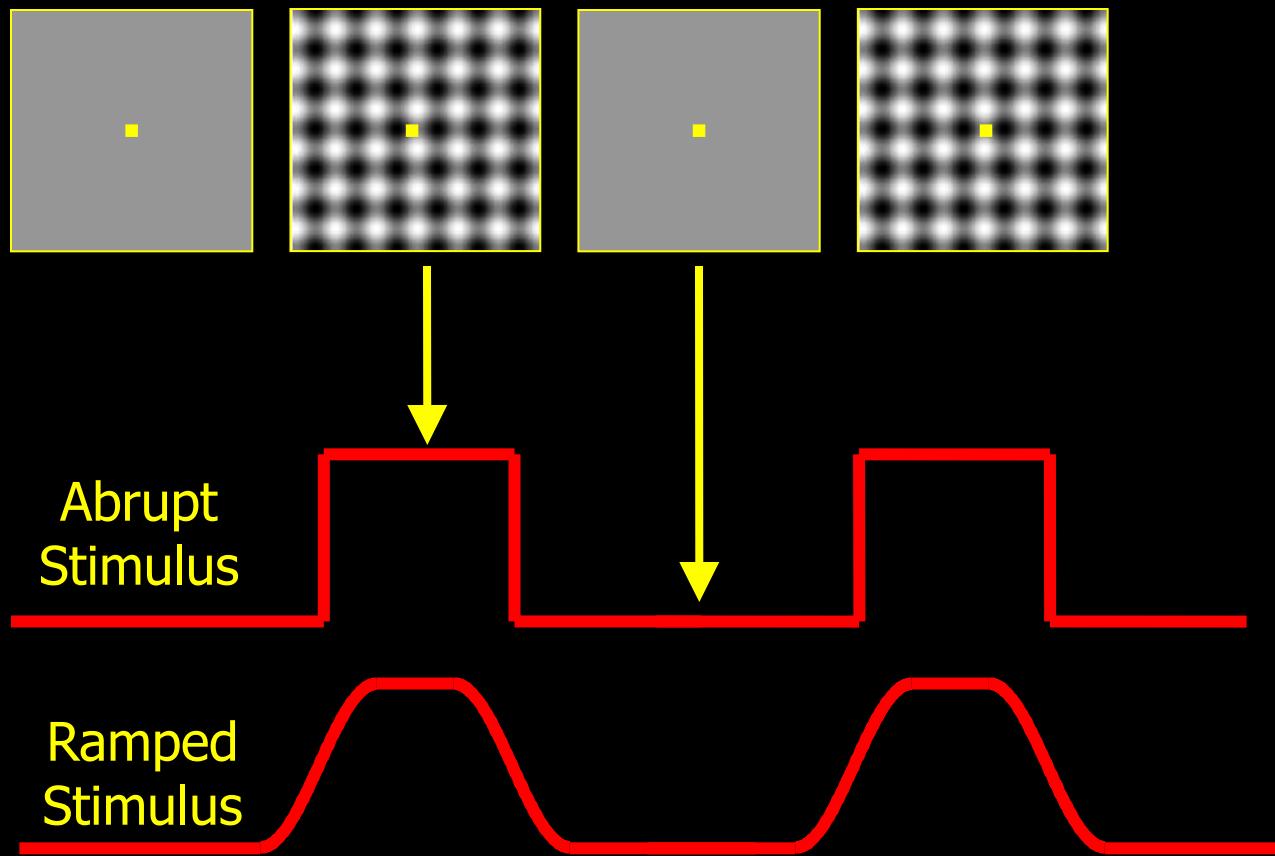


MEG and Ramped Stimulus

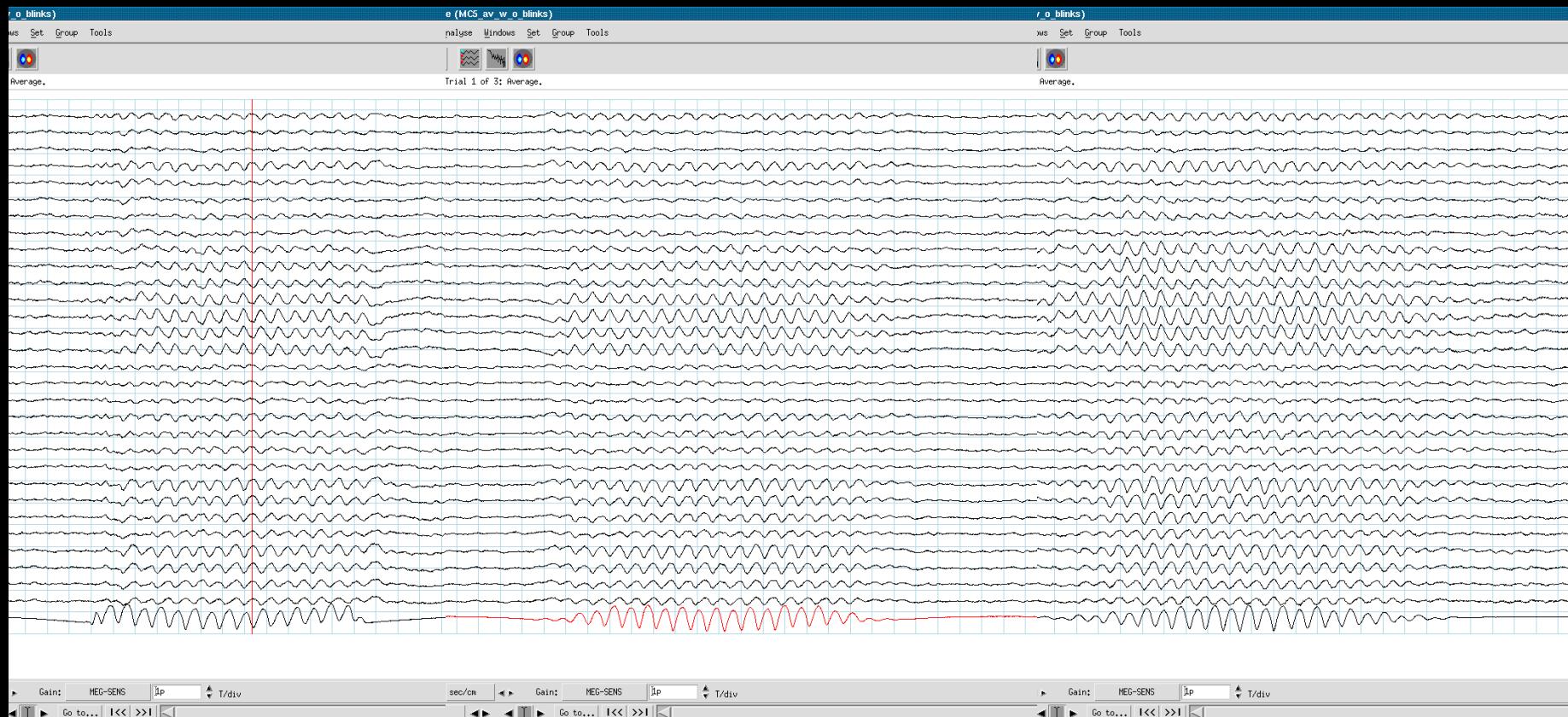
- 6 subjects
- SD: 1 or 2 seconds
- Ramp: 0, 0.5, 1 second
- 8 Hz Counterphase-modulated checkerboards
- Fixation without task
 - No blinking point
- 45 repeats
- 3 sec ISI
- 275 channels
- 600 Hz



MEG – Ramped stimuli



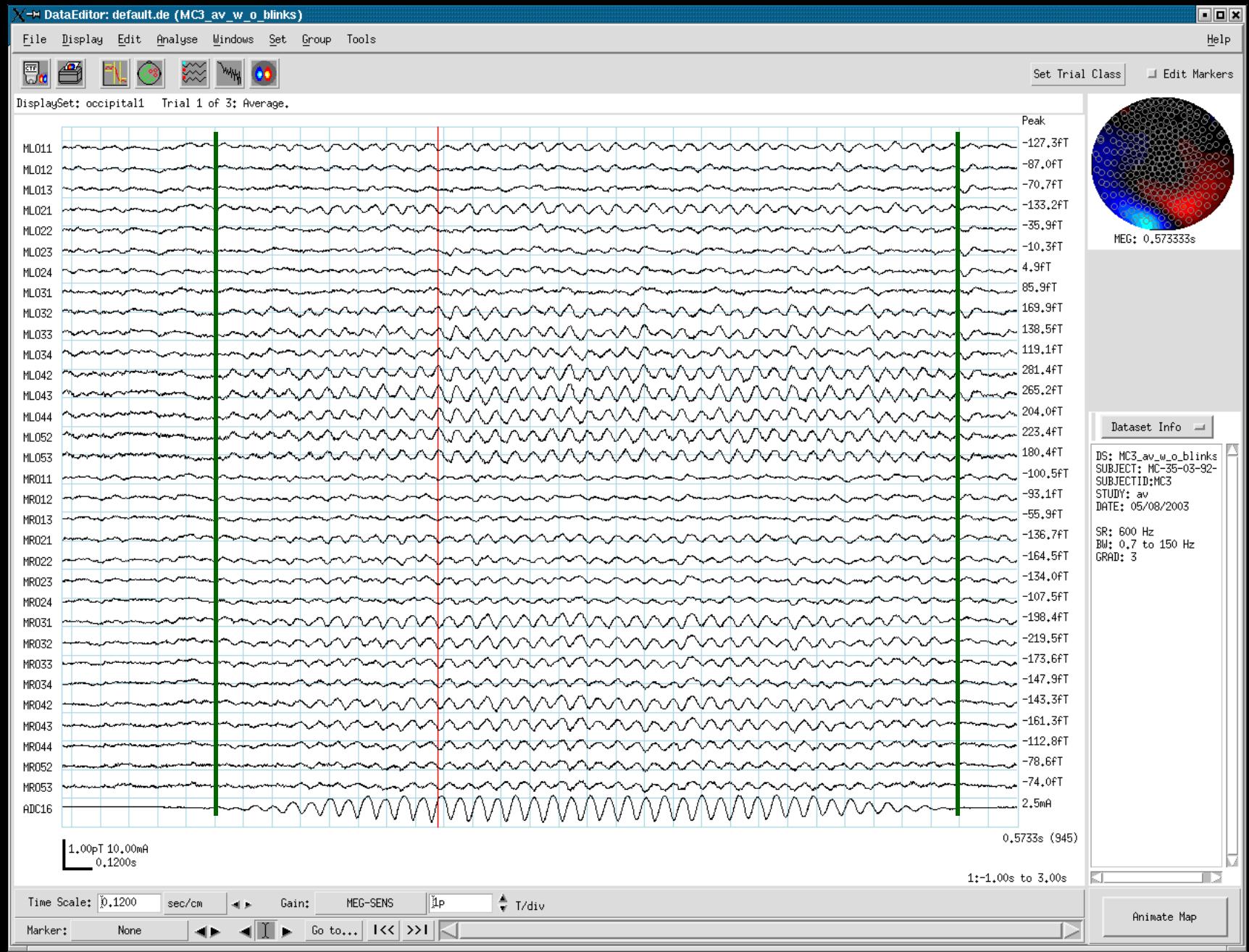
Composite – 1 second Stimulus Duration



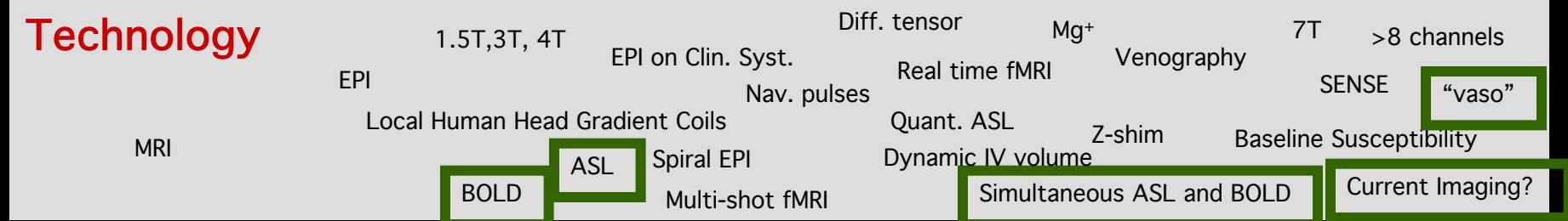
No Ramp

0.5 second Ramp

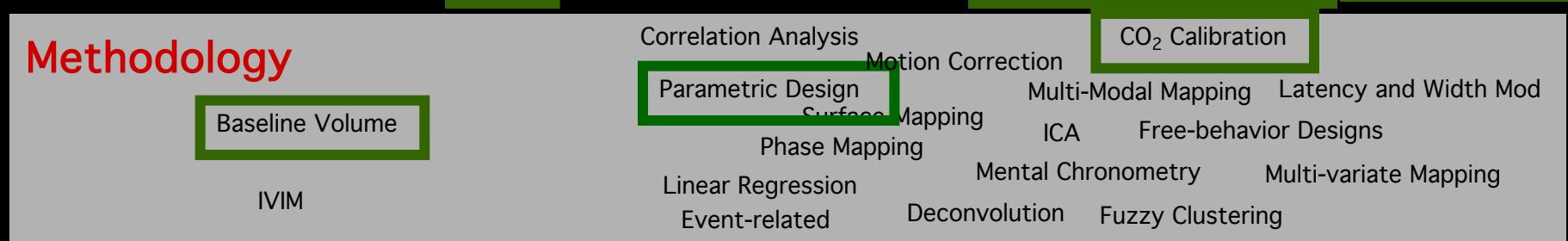
1 second Ramp



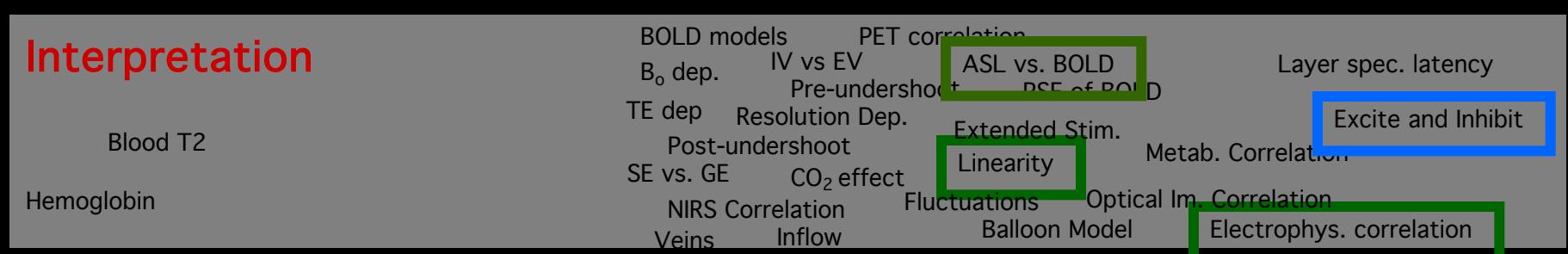
Technology



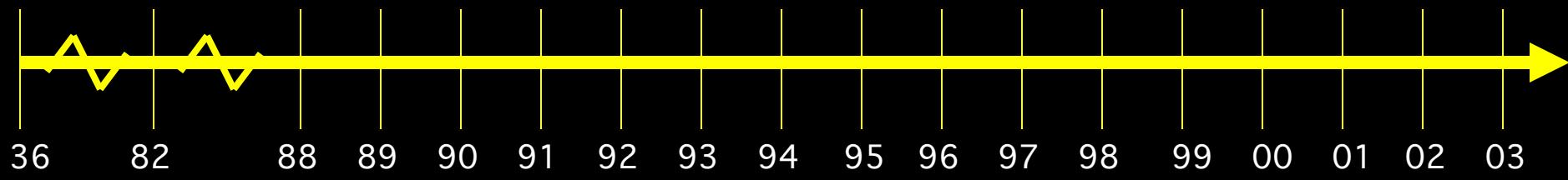
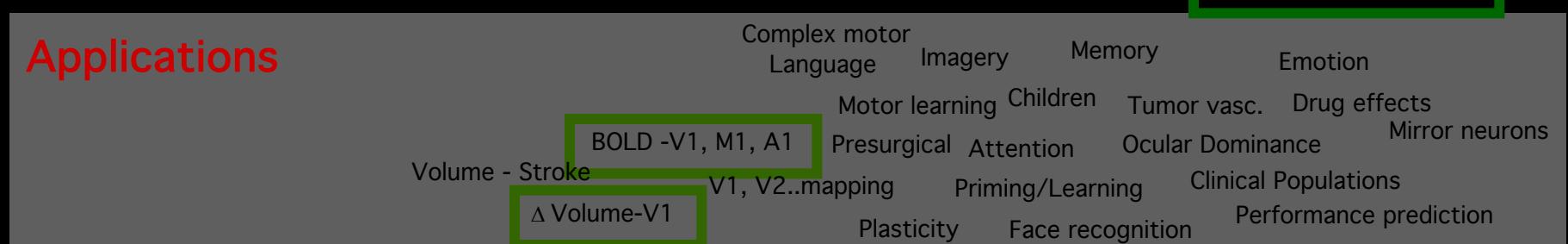
Methodology



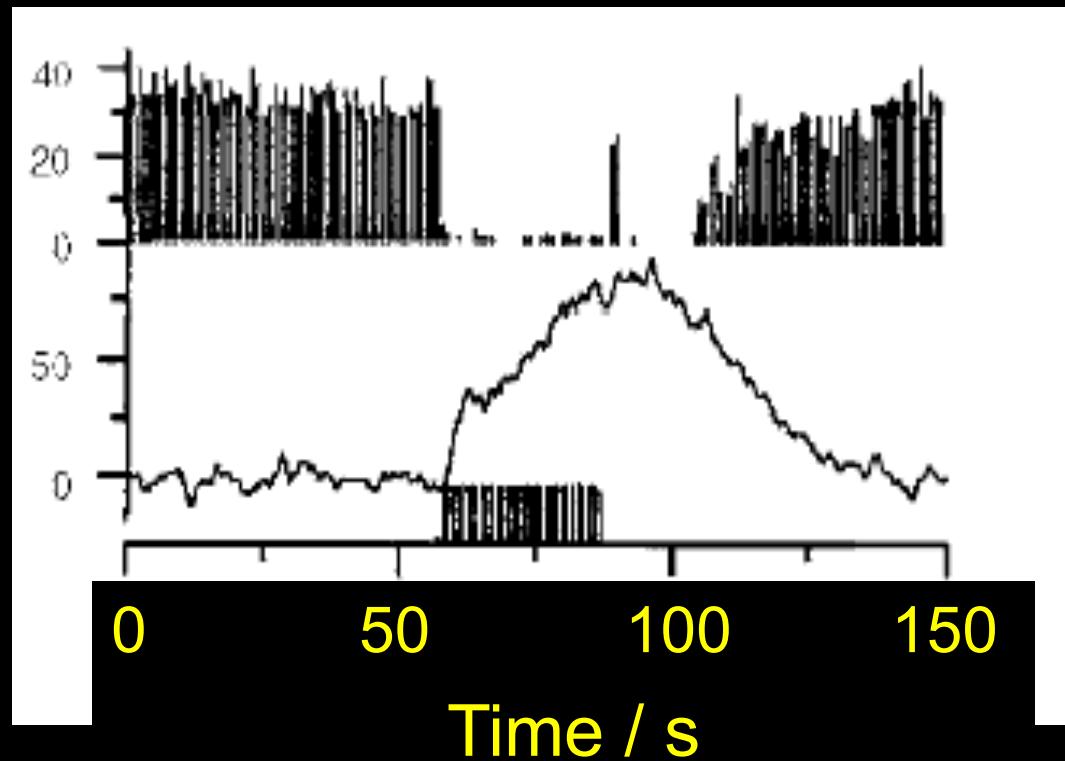
Interpretation



Applications



Divergence of spike rate and blood flow during parallel fiber stimulation

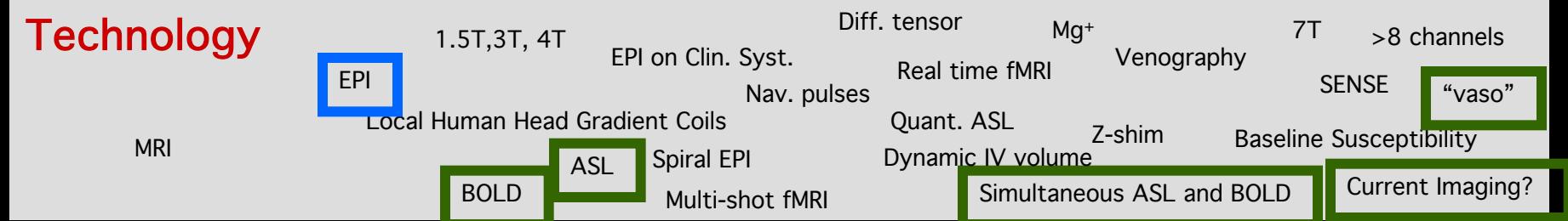


Mathiesen, Caesar, Akgören, Lauritzen (1998), J Physiol 512.2:555-566

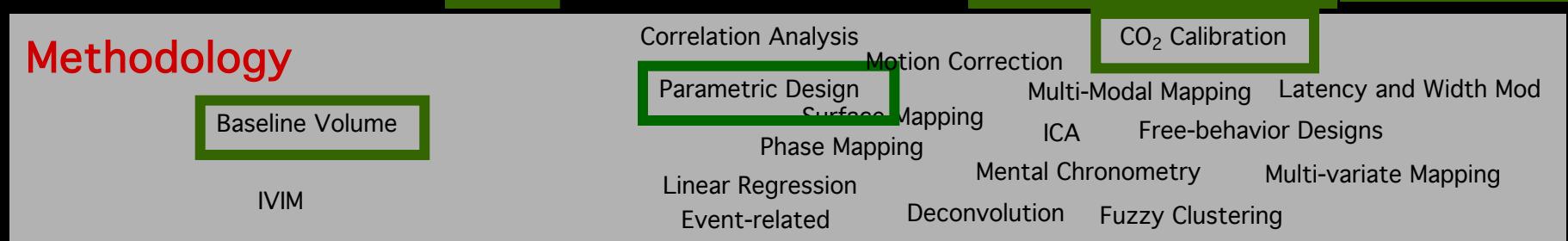
- Functional contrast
- Signal interpretation
- **Hardware and pulse sequences**
- Paradigm design and processing
- Spatial and temporal resolution

- Overview
- Current Limits
- Future Prospects

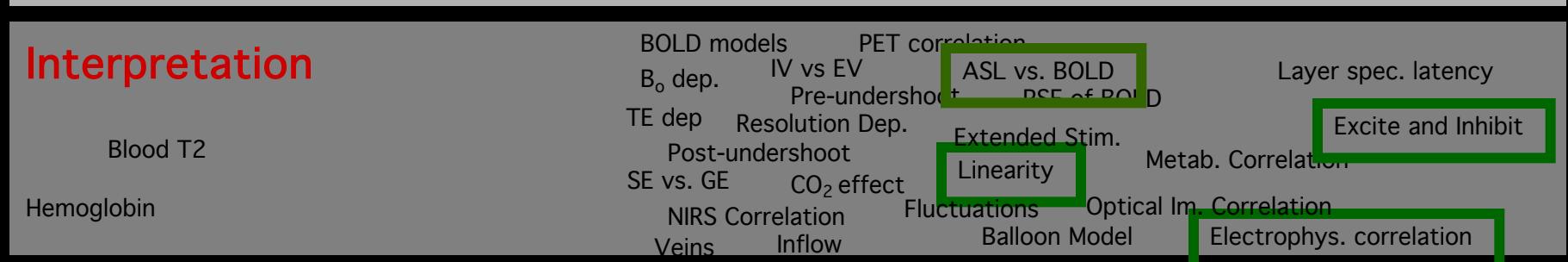
Technology



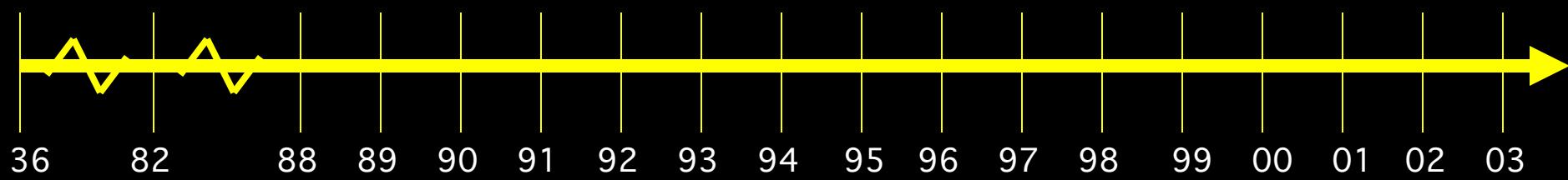
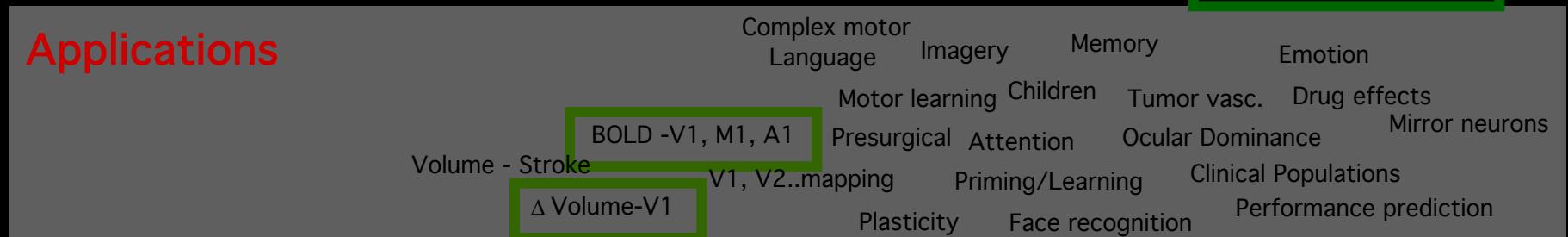
Methodology



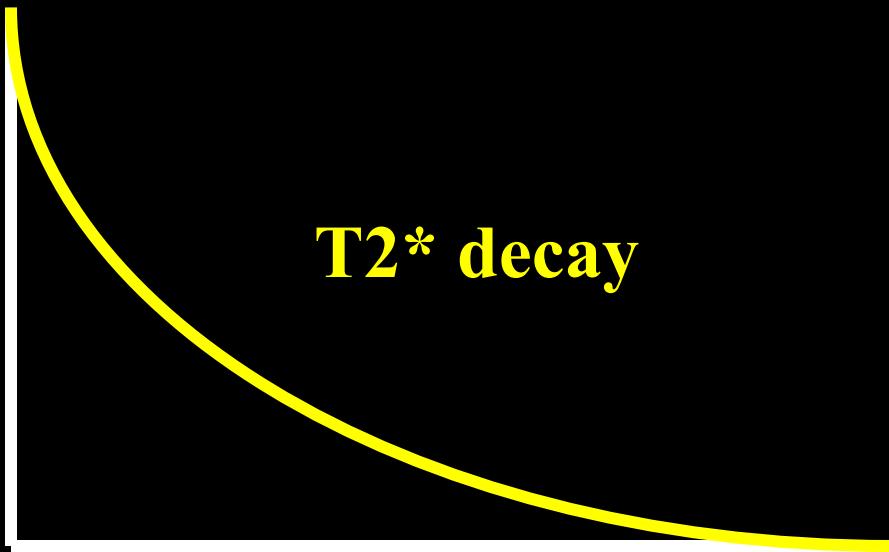
Interpretation



Applications



Single Shot EPI

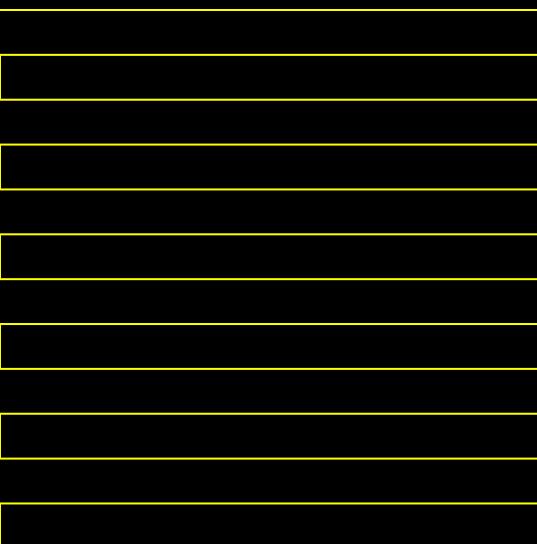
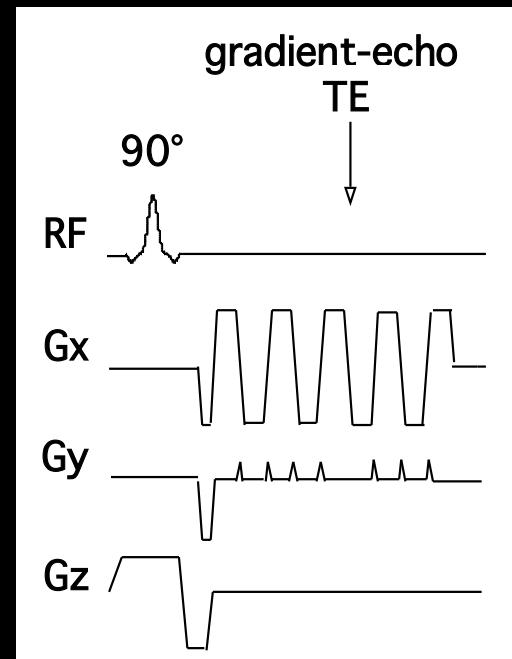


T_{2*} decay



EPI Readout Window

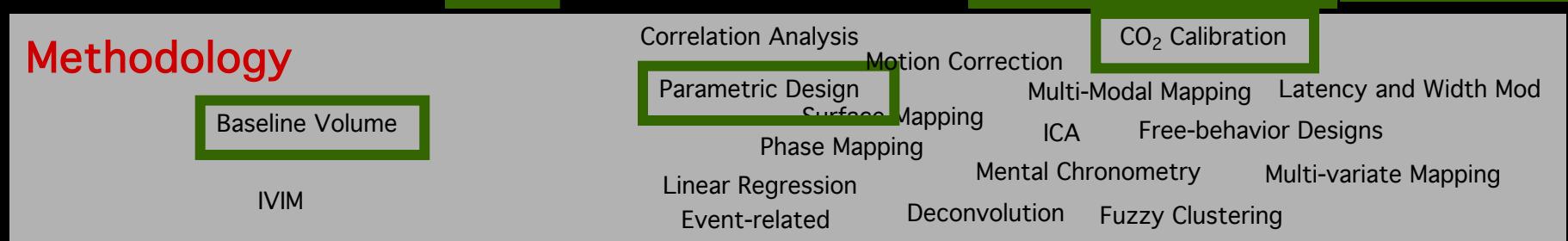
≈ 20 to 40 ms



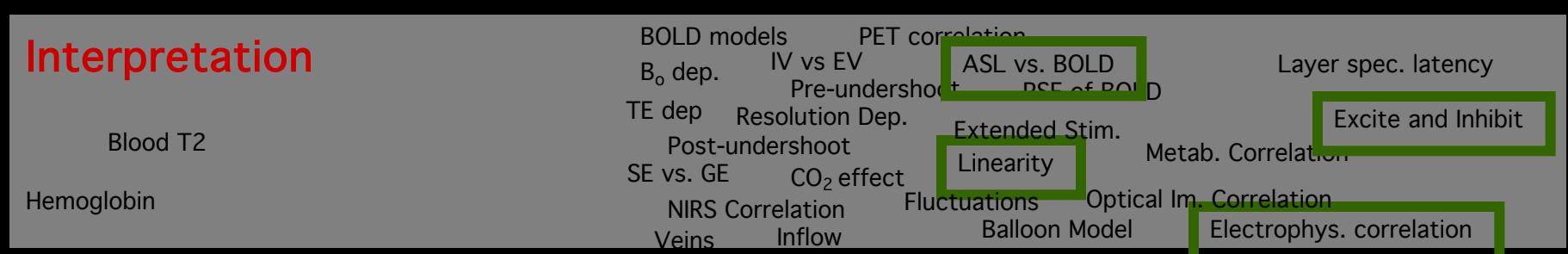
Technology



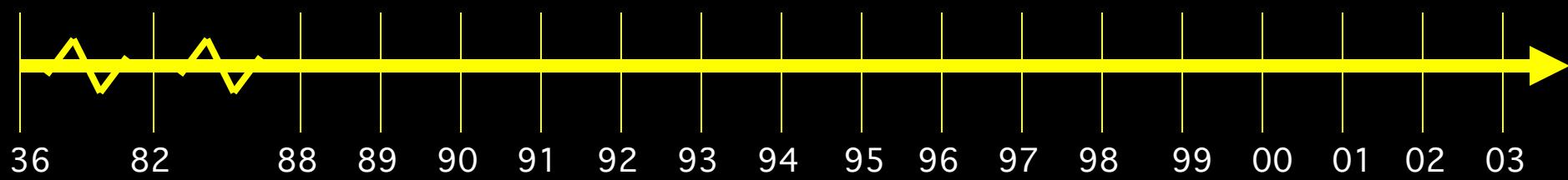
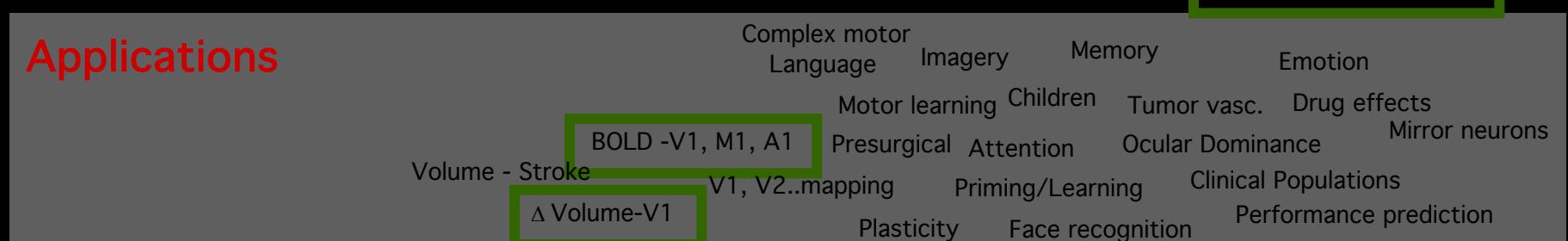
Methodology



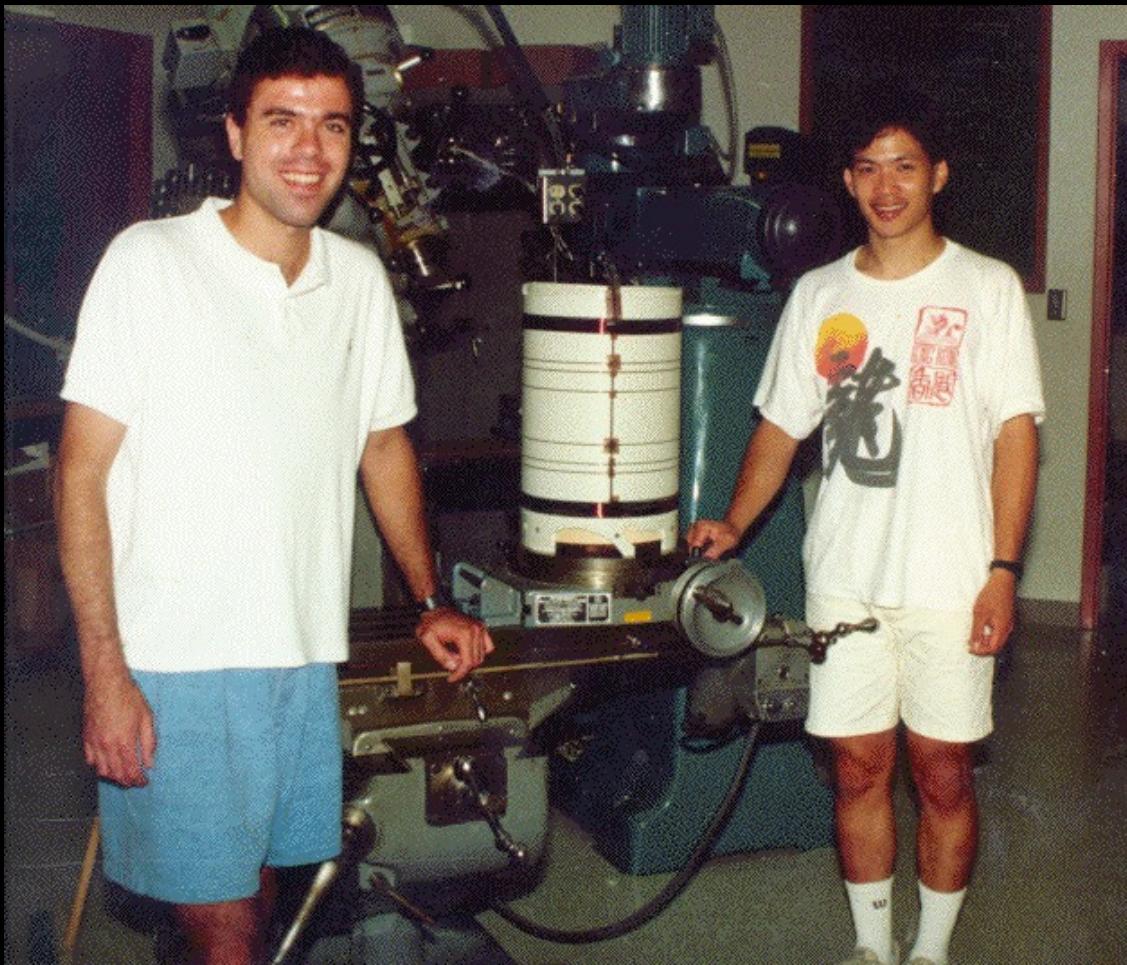
Interpretation



Applications



Local gradients solved the problem



August, 1991

1991-1992



1992-1999

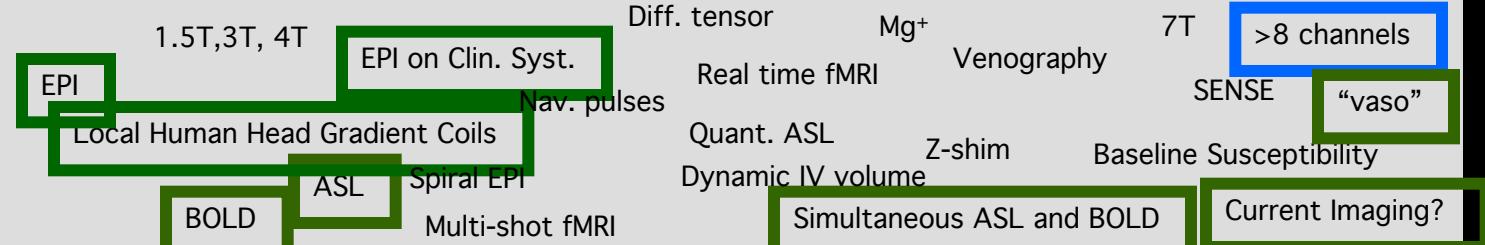


General Electric 3 Tesla Scanner



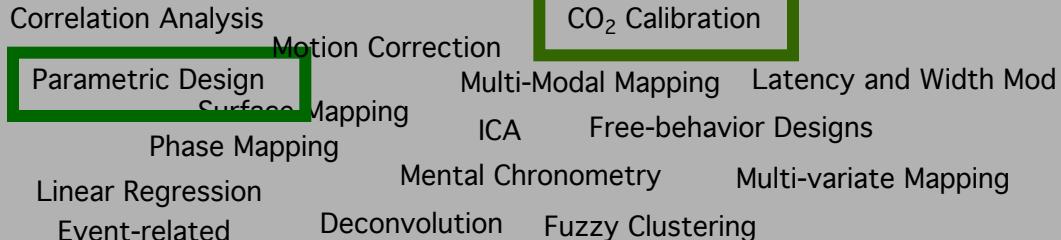
Technology

MRI



Methodology

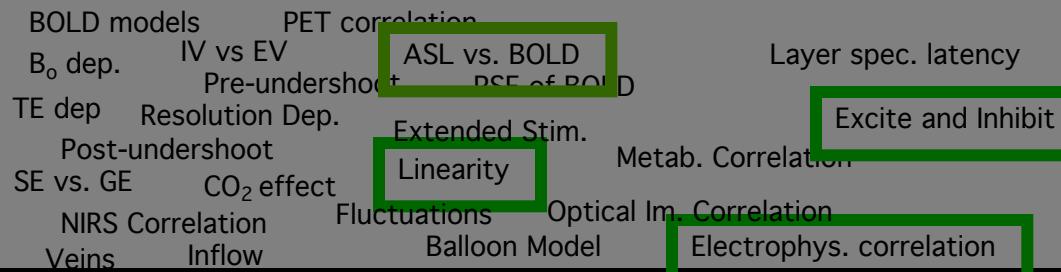
IVIM



Interpretation

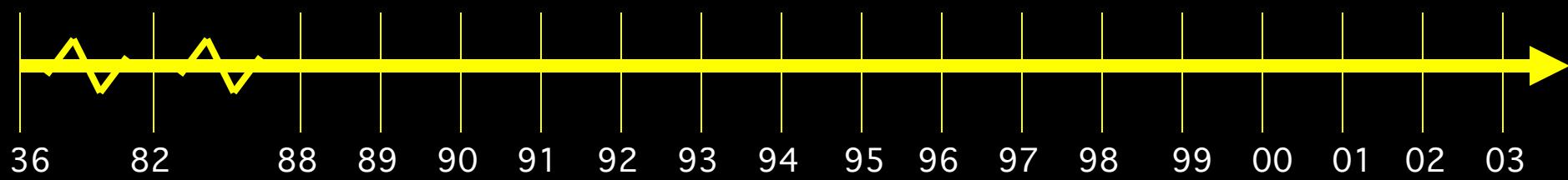
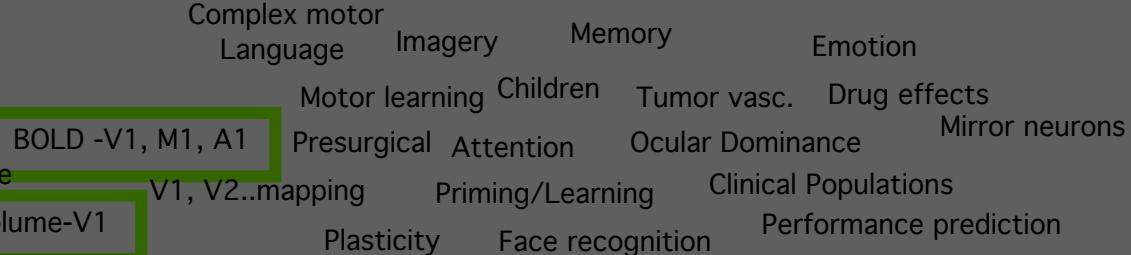
Blood T2

Hemoglobin



Applications

Volume - Stroke



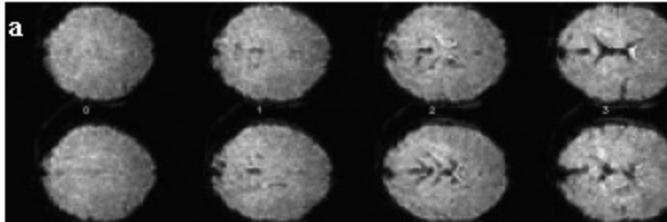
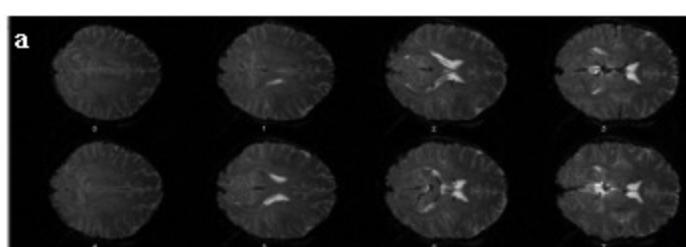
Single shot full k-space echo-planar-imaging with an eight-channel phase array coil at 3T.

Jerzy Bodurka¹, Peter van Gelderen², Patrick Ledden³, Peter Bandettini¹, Jeff Duyn²

¹Functional MRI Facility NIMH/NIH, ²Advance MRI NINDS/NIH, ³Nova Medical Inc.

Quadrature Head Coil

128 x 96



64 x 48

128 x 96

8 Channel Array

Figure 1

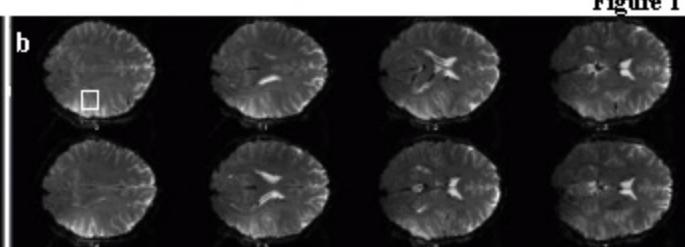
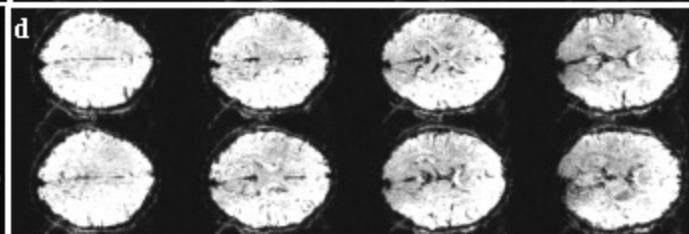
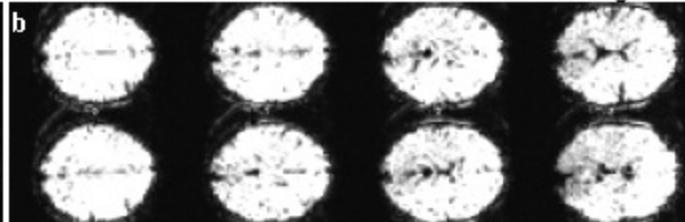


Figure 2

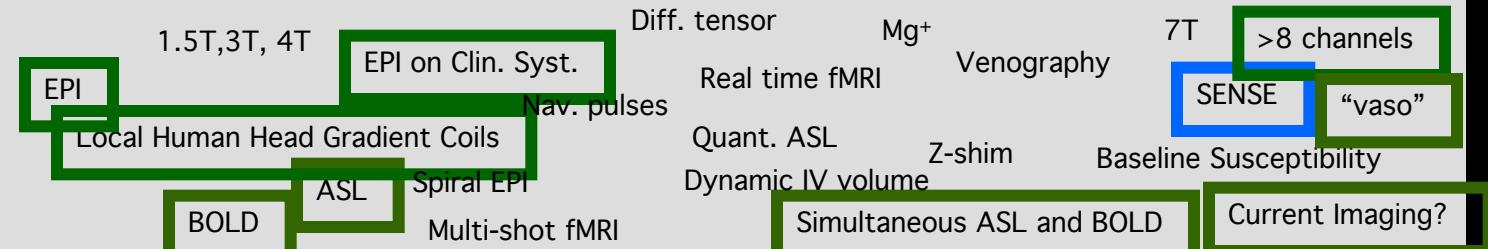


SNR

TSNR

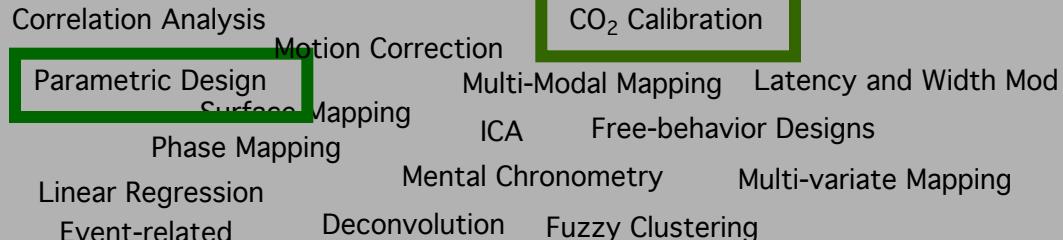
Technology

MRI



Methodology

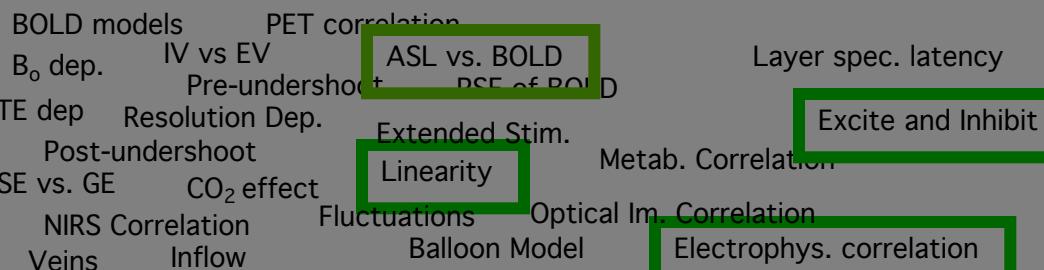
IVIM



Interpretation

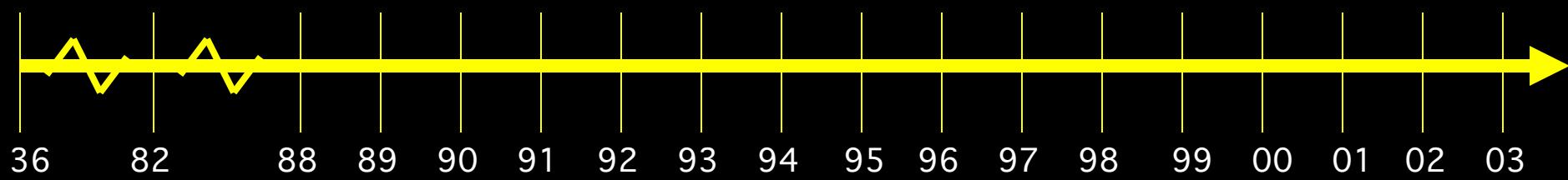
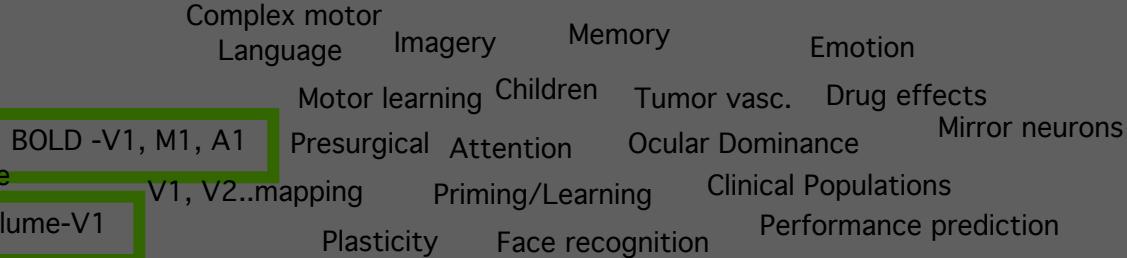
Blood T2

Hemoglobin

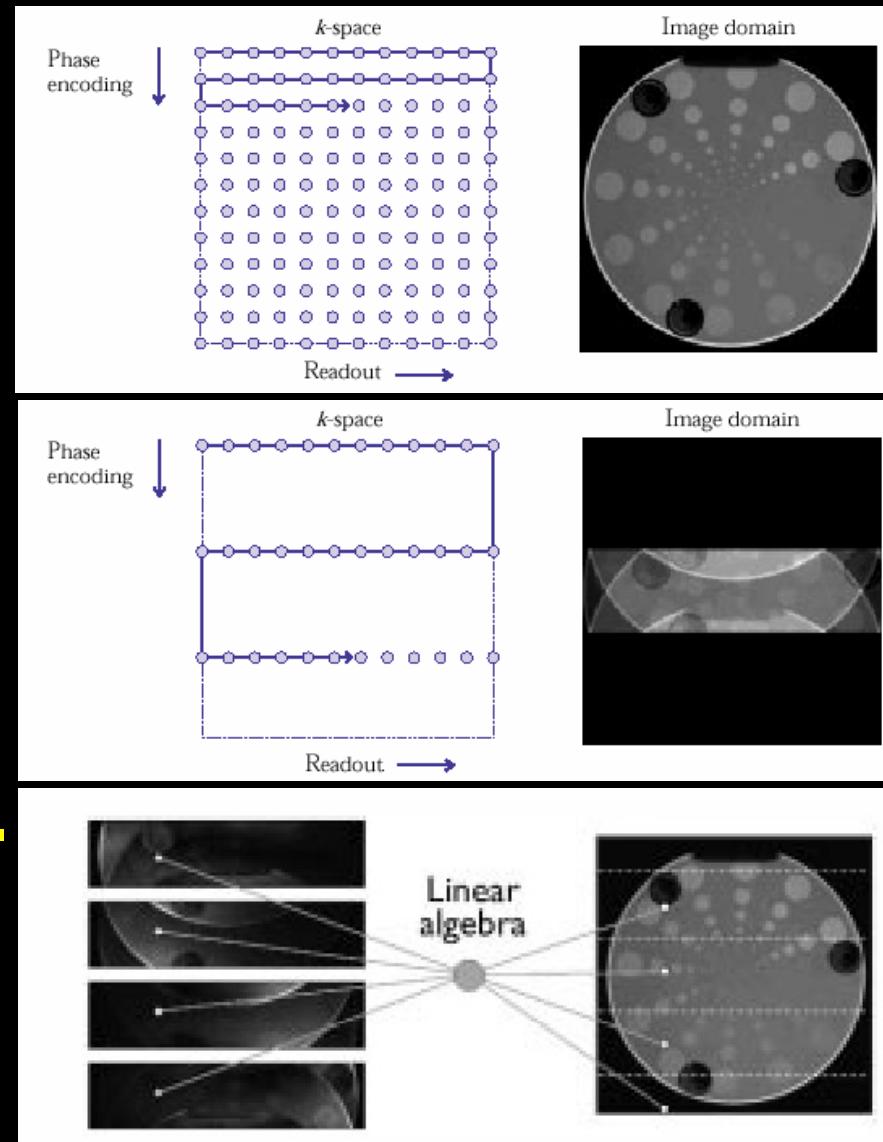


Applications

Volume - Stroke



SENSE Imaging



≈ 5 to 30 ms

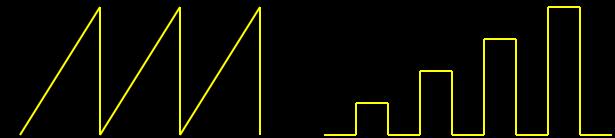
Pruessmann, et al.

- Functional contrast
- Signal interpretation
- Hardware and pulse sequences
- **Paradigm design and processing**

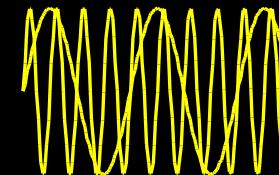
- Overview
- Current Limits
- Future Prospects

Neuronal Activation Input Strategies

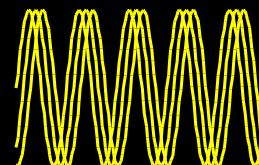
1. Block Design



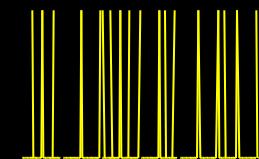
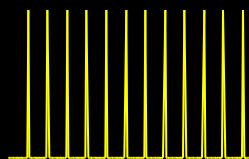
2. Parametric Design



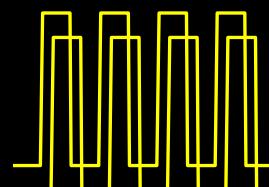
3. Frequency Encoding



4. Phase Encoding



5. Event Related

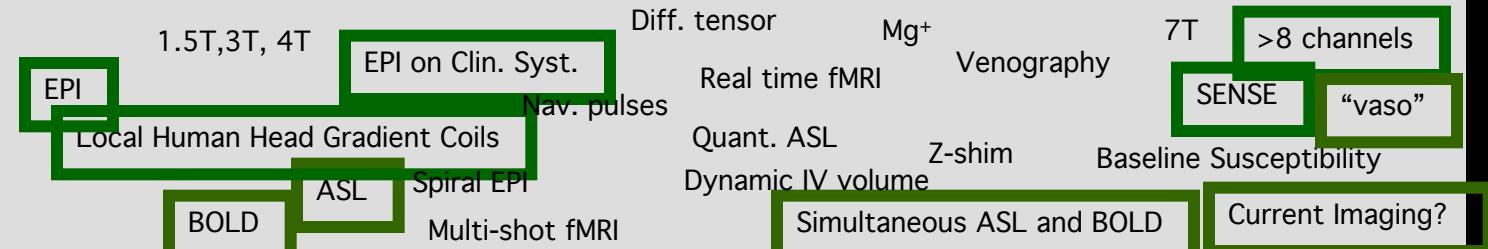


6. Orthogonal Design

7. Free Behavior Design

Technology

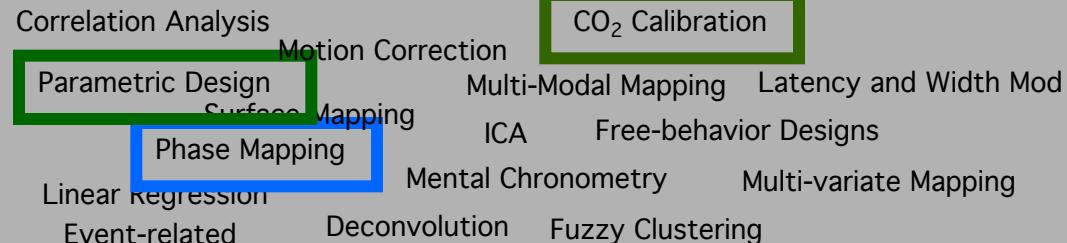
MRI



Methodology

Baseline Volume

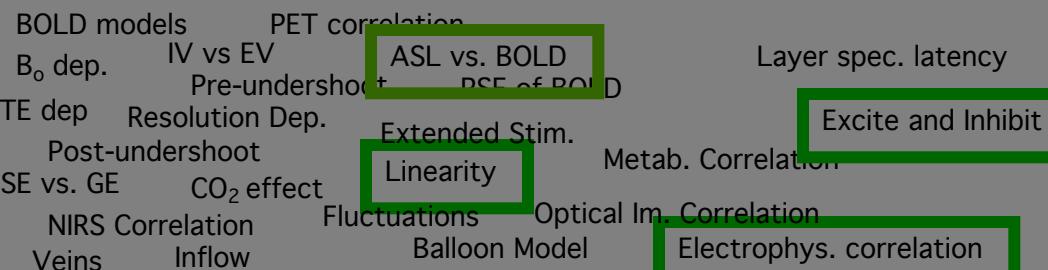
IVIM



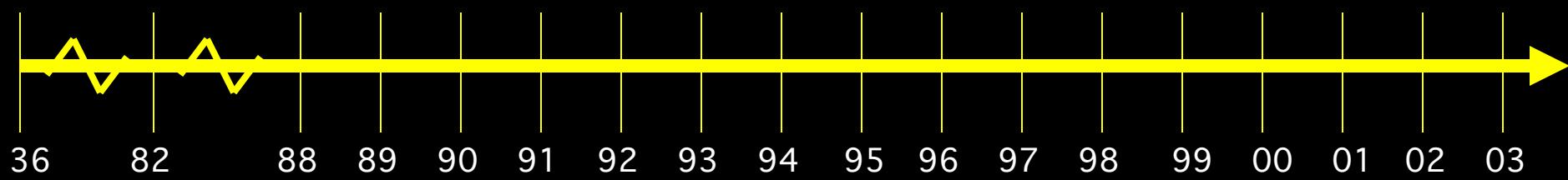
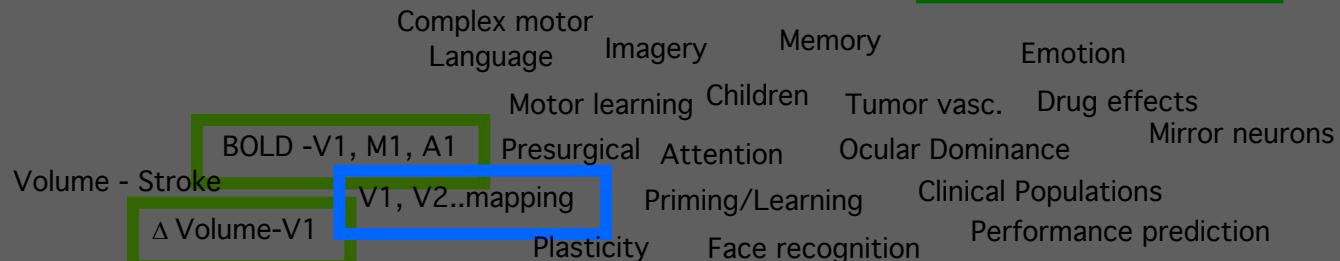
Interpretation

Blood T2

Hemoglobin

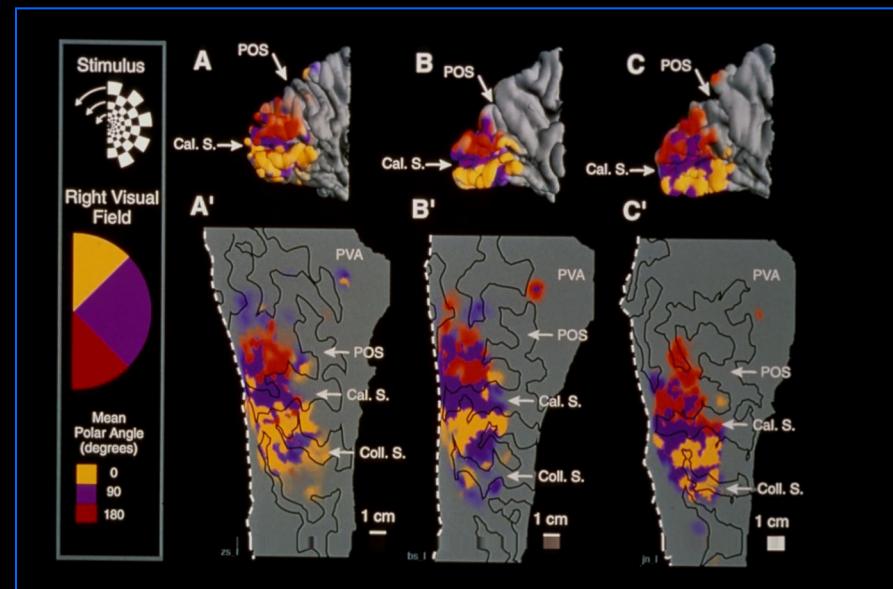
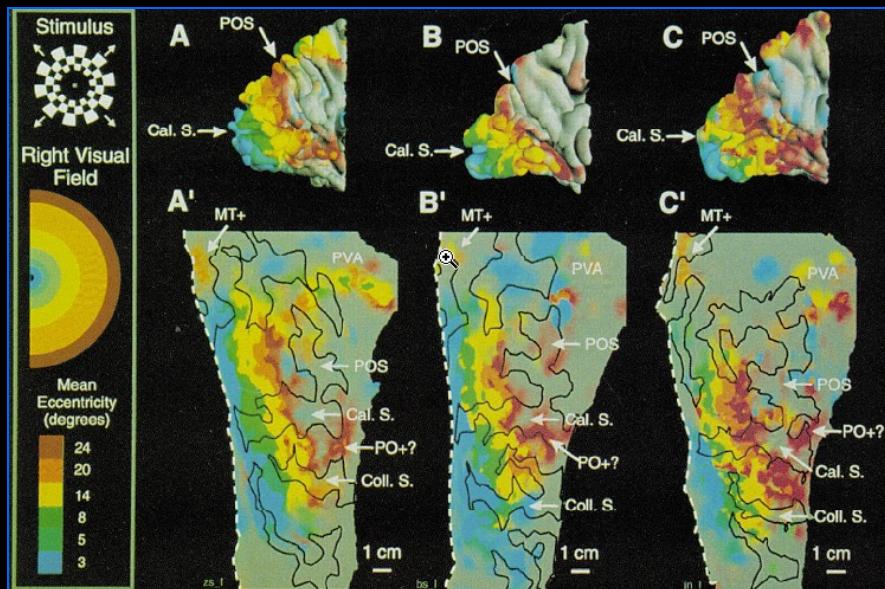


Applications



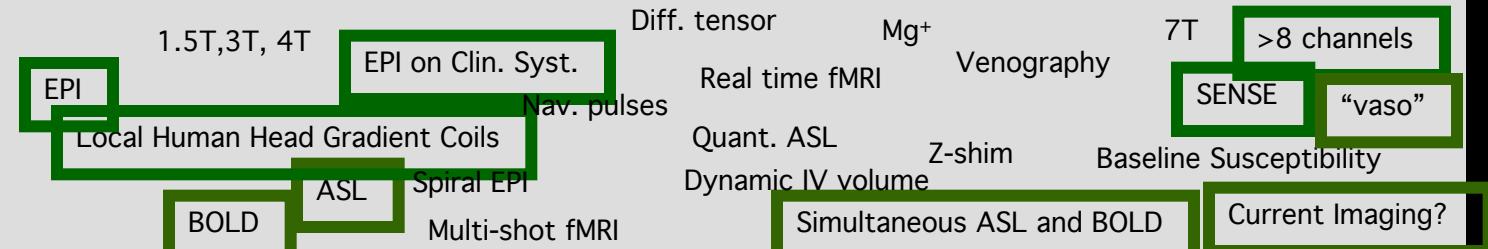
Mapping striate and extrastriate visual areas in human cerebral cortex

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



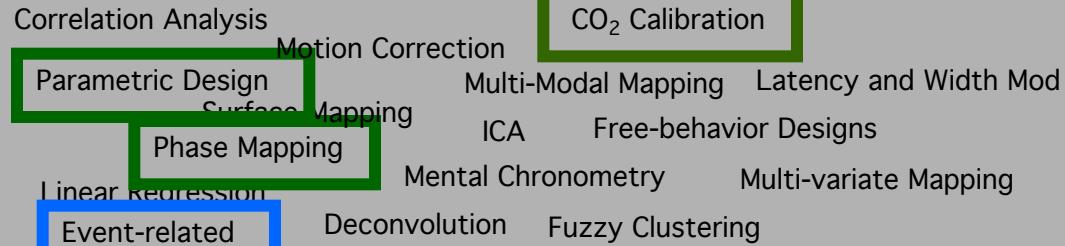
Technology

MRI



Methodology

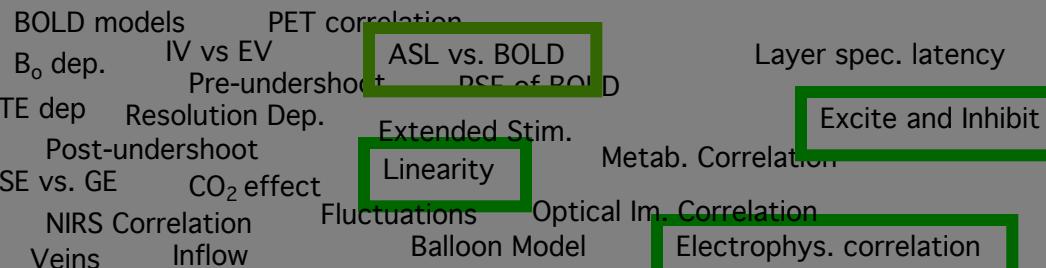
IVIM



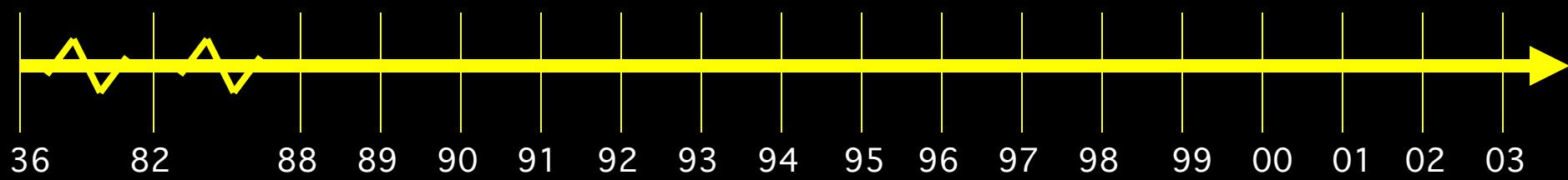
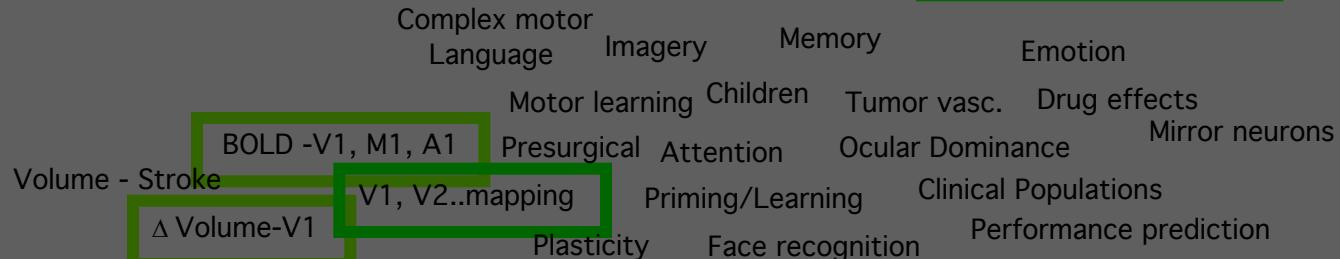
Interpretation

Blood T2

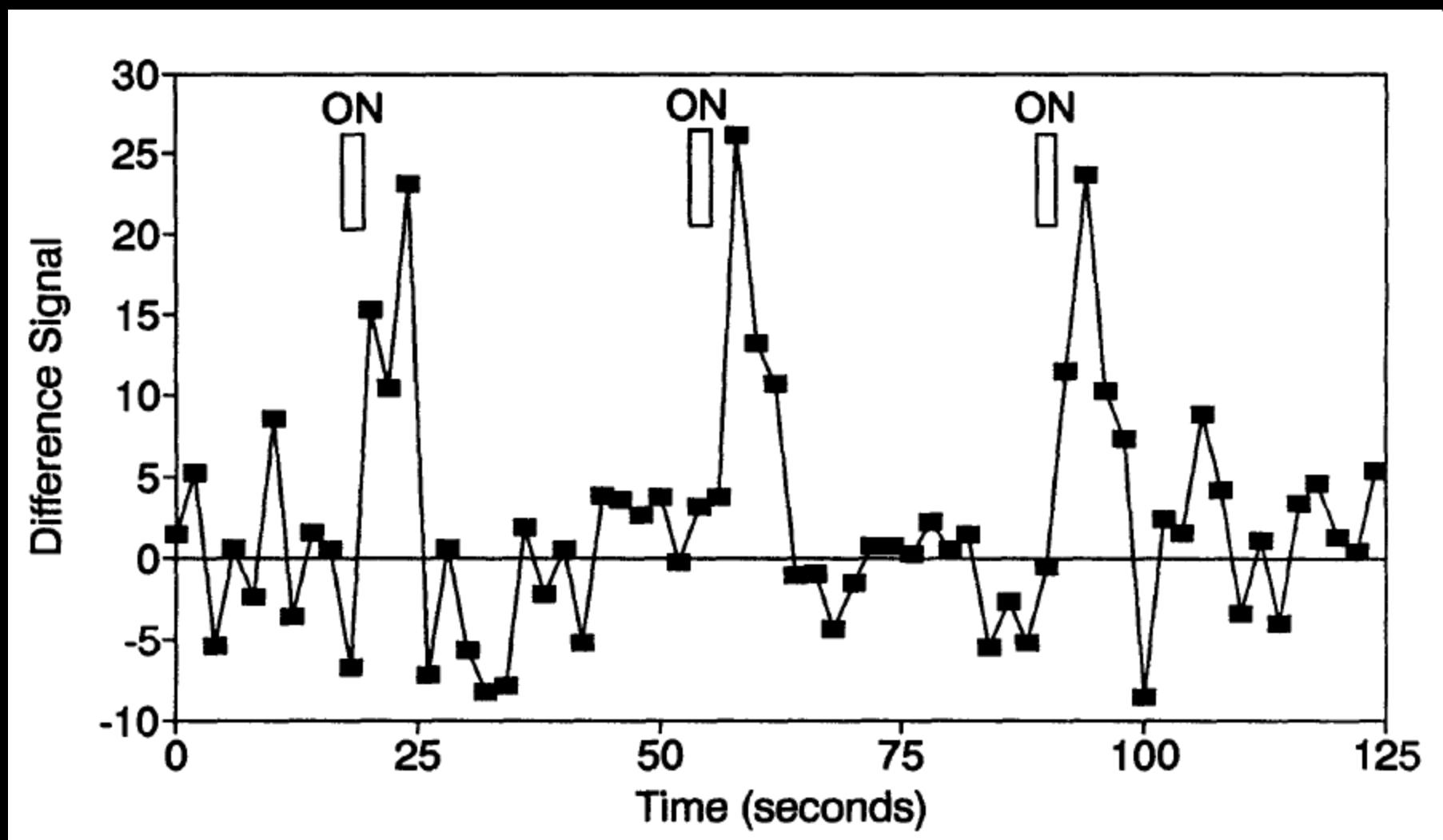
Hemoglobin



Applications



First Event-related fMRI Results

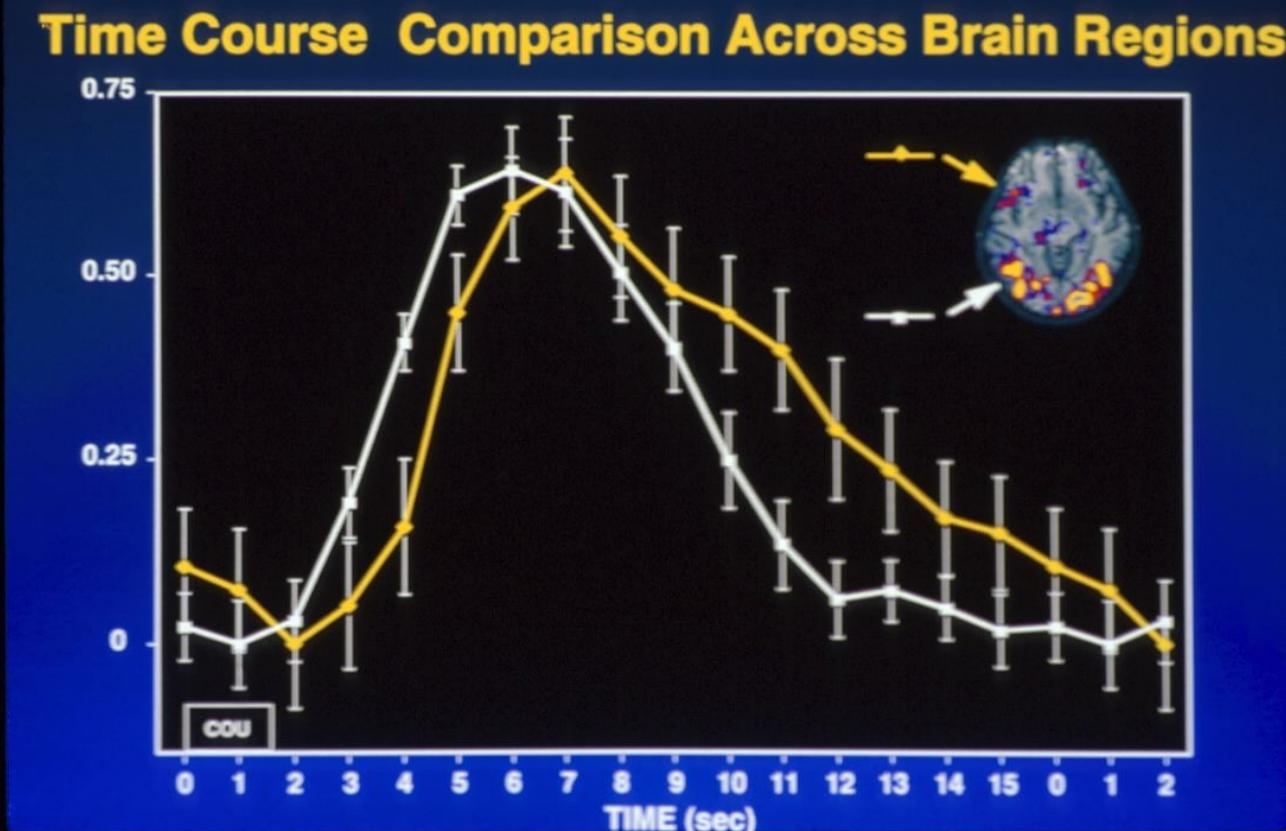


Blamire, A. M., et al. (1992). "Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging." Proc. Natl. Acad. Sci. USA 89: 11069-11073.

Detection of cortical activation during averaged single trials of a cognitive task using functional magnetic resonance imaging

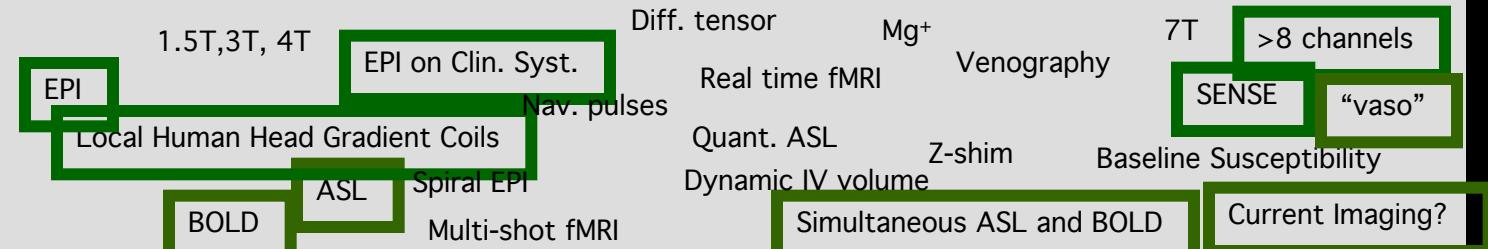
(neuroimaging/single trial/language/prefrontal)

RANDY L. BUCKNER^{†‡§¶||}, PETER A. BANDETTINI^{†‡}, KATHLEEN M. O'CRAVEN^{†||}, ROBERT L. SAVOY^{†||},
STEVEN E. PETERSEN^{*++††}, MARCUS E. RAICHLE^{§++††}, AND BRUCE R. ROSEN^{†‡}



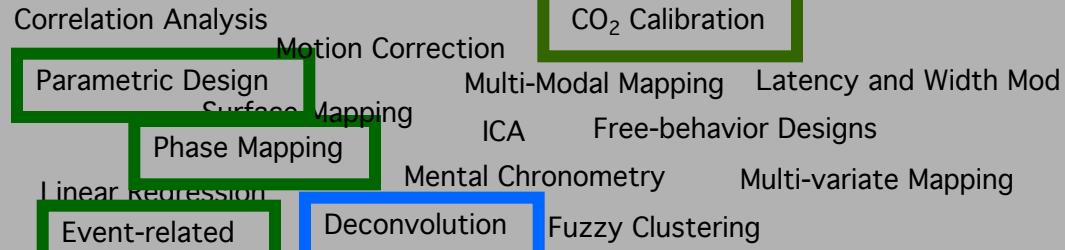
Technology

MRI



Methodology

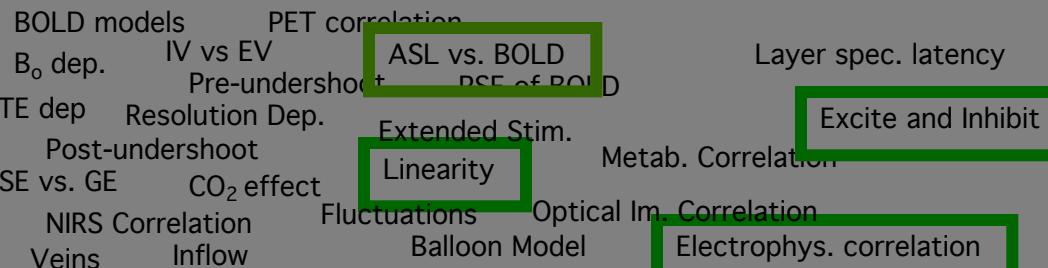
IVIM



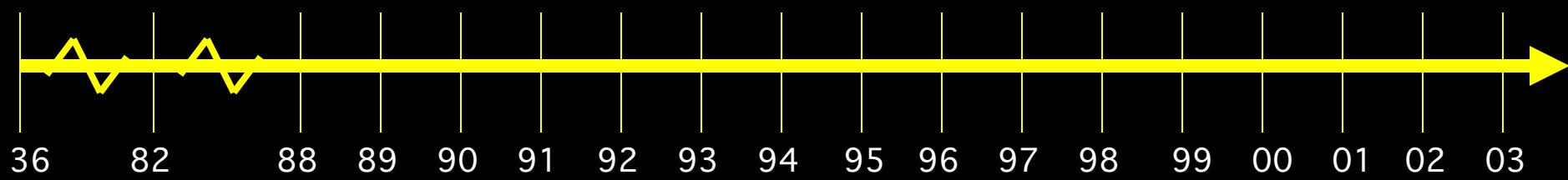
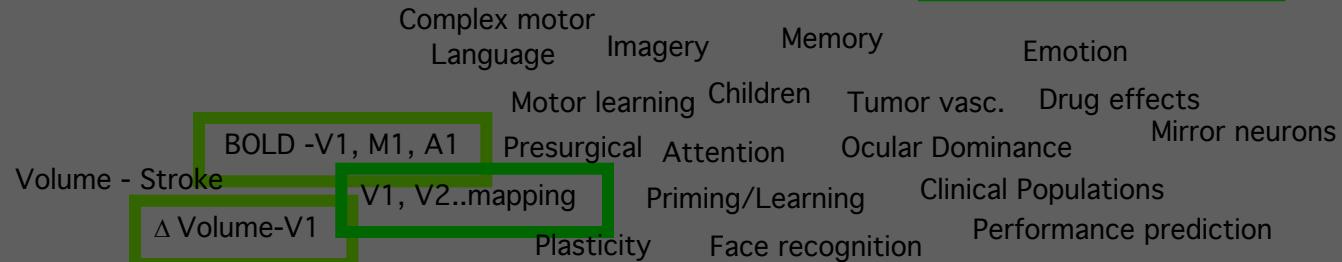
Interpretation

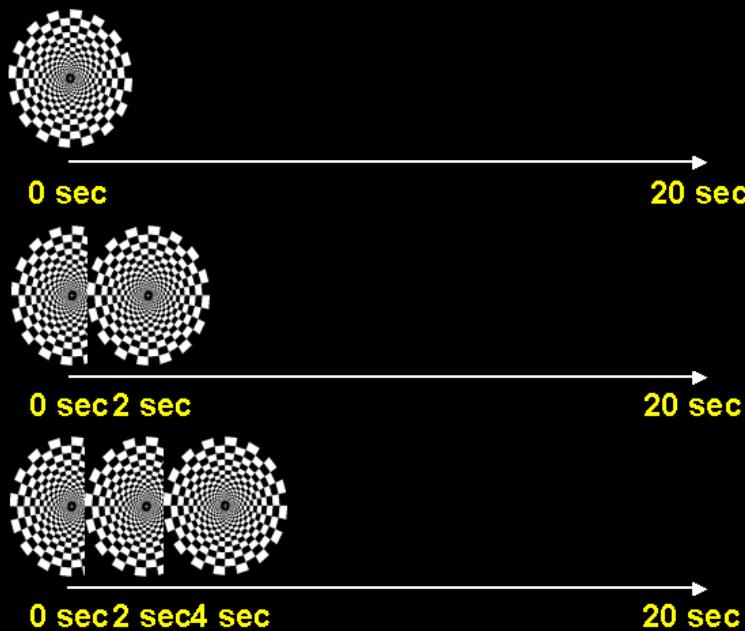
Blood T2

Hemoglobin



Applications



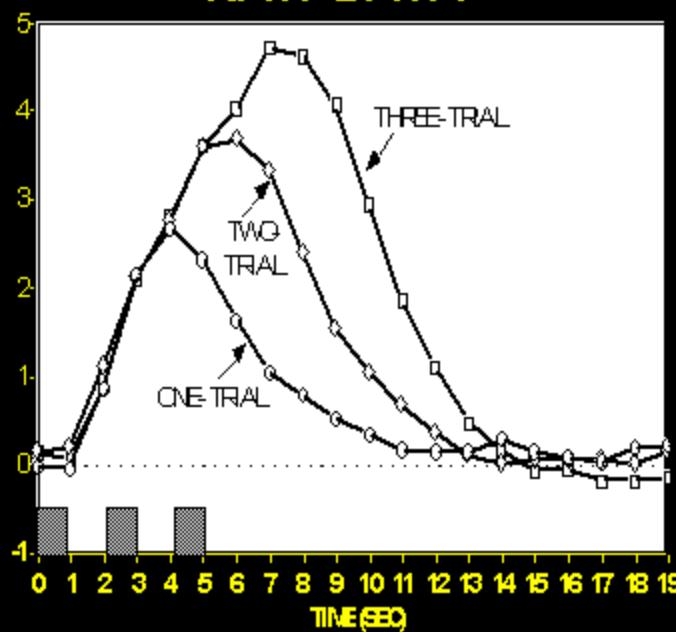


♦ Human Brain Mapping 5:329–340(1997) *

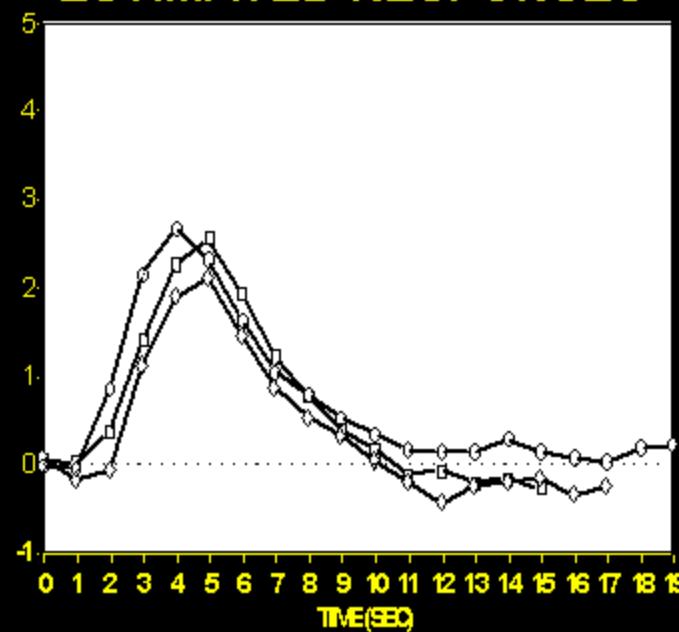
Selective Averaging of Rapidly Presented Individual Trials Using fMRI

Anders M. Dale* and Randy L. Buckner

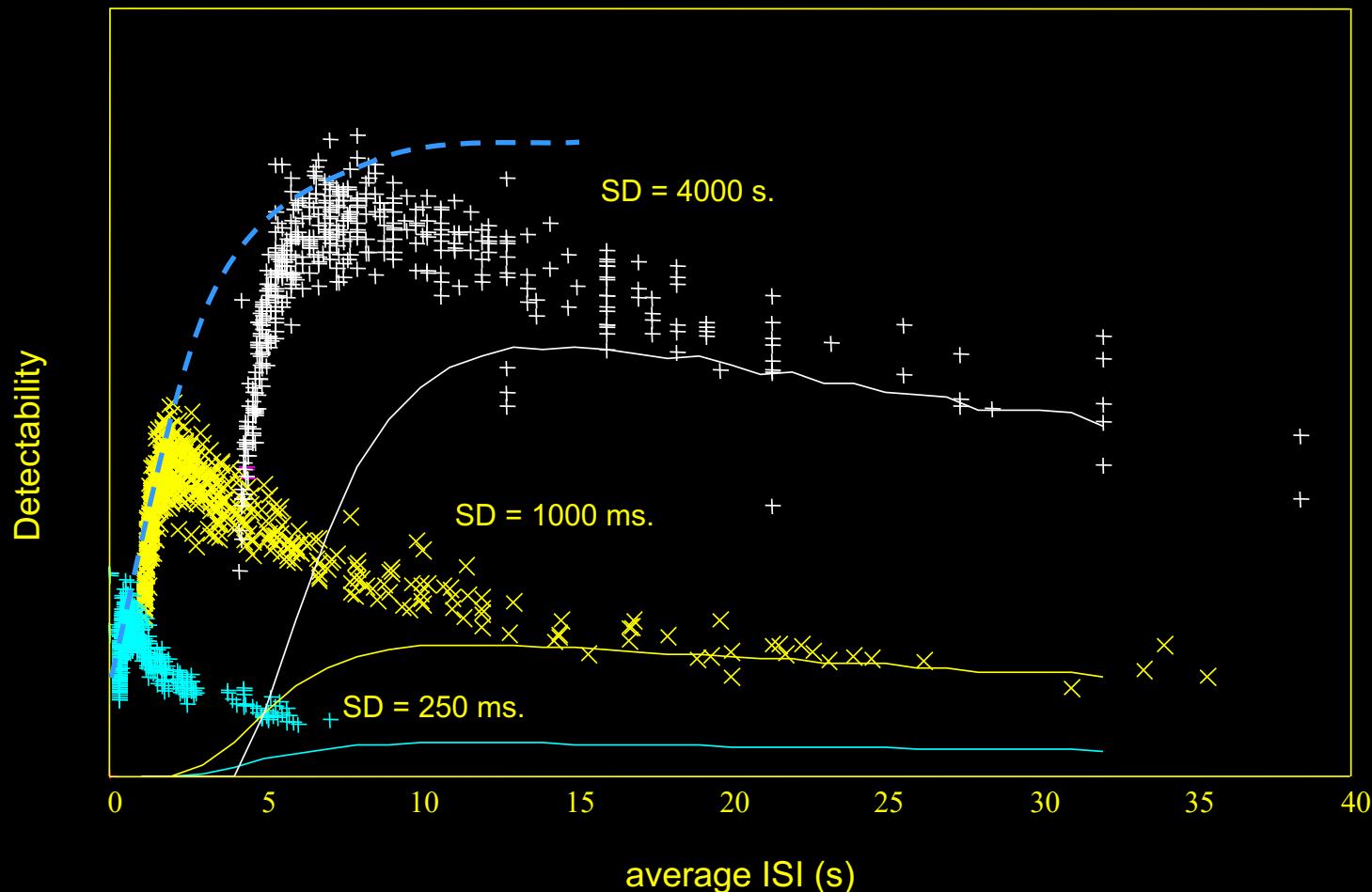
RAW DATA



ESTIMATED RESPONSES



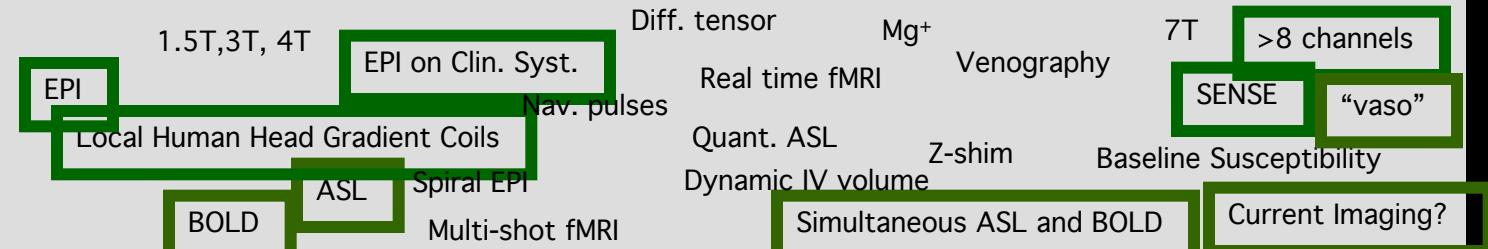
Detectability vs. Average ISI



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).

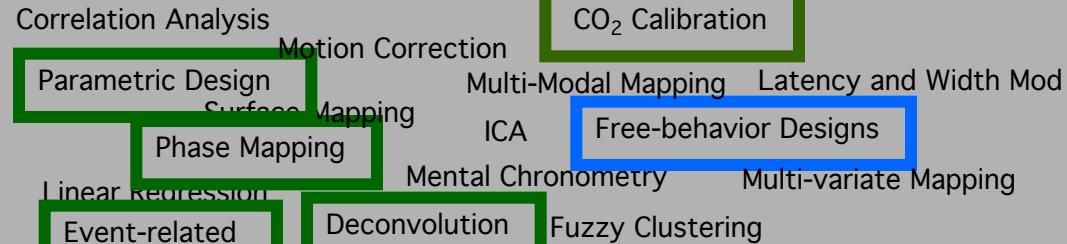
Technology

MRI



Methodology

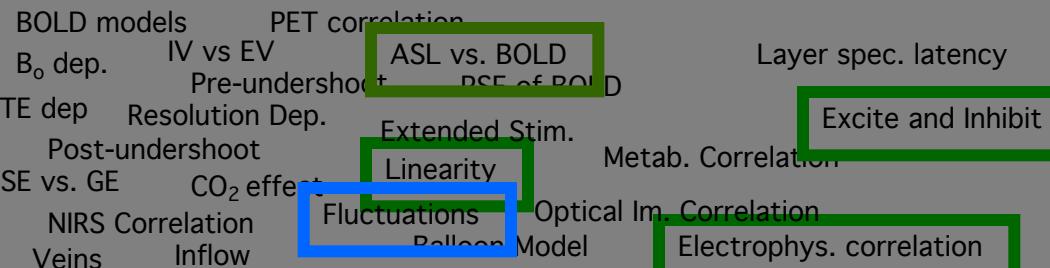
IVIM



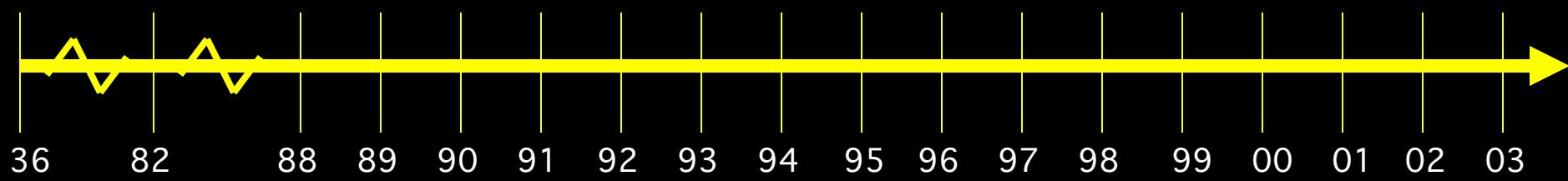
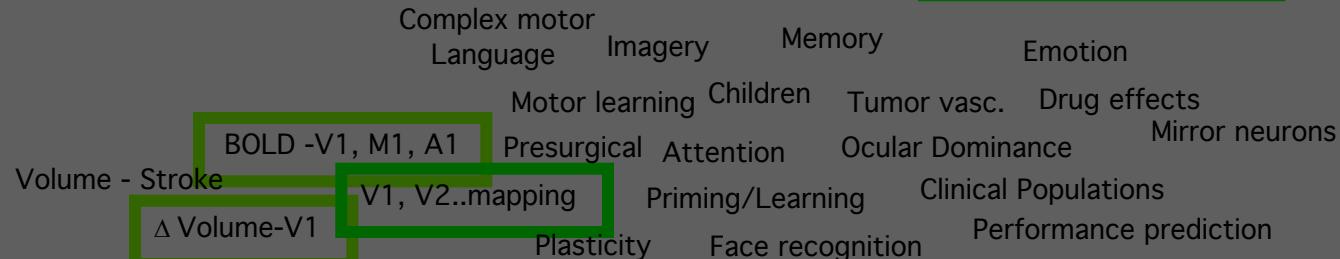
Interpretation

Blood T2

Hemoglobin



Applications

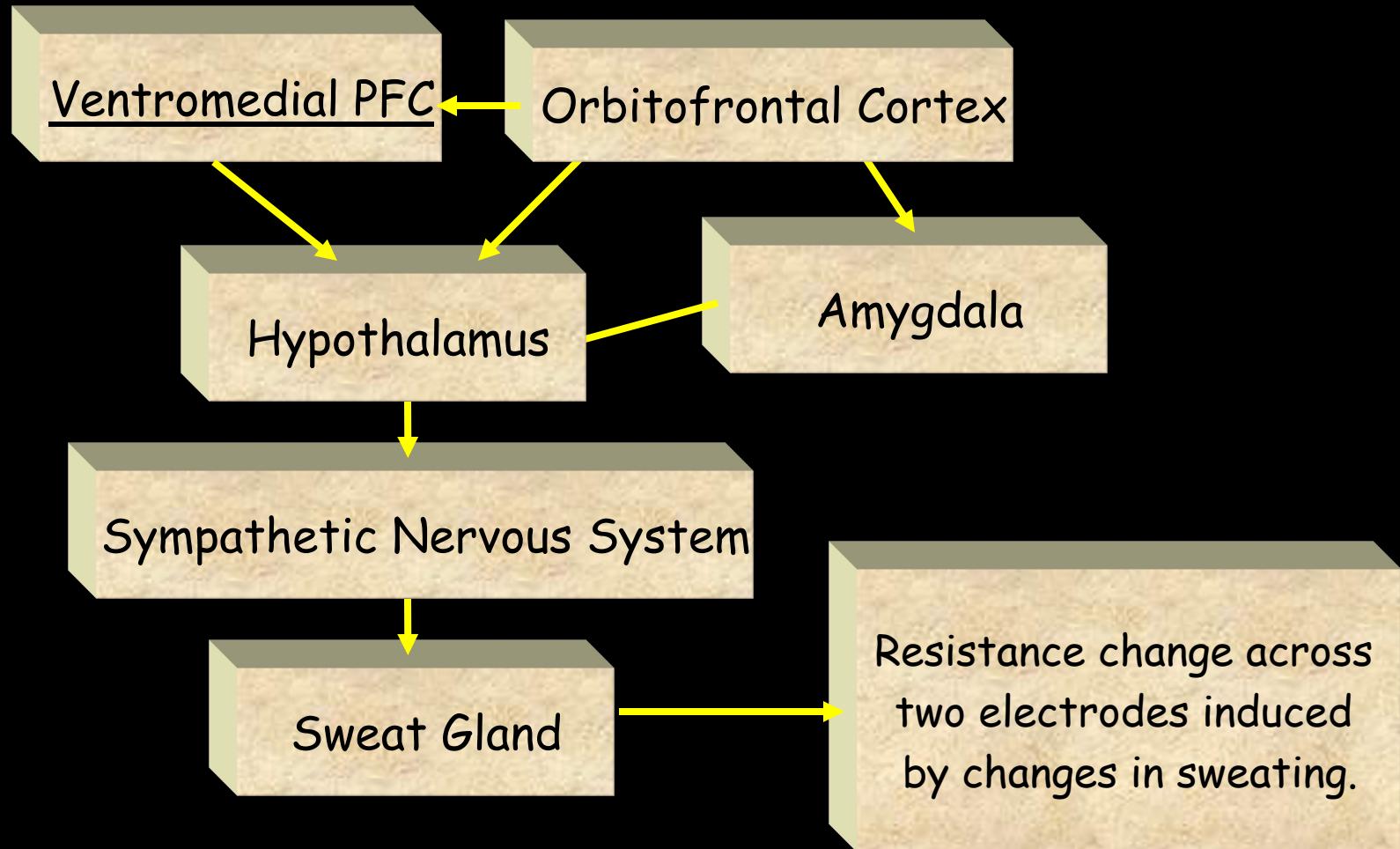


Free Behavior Design

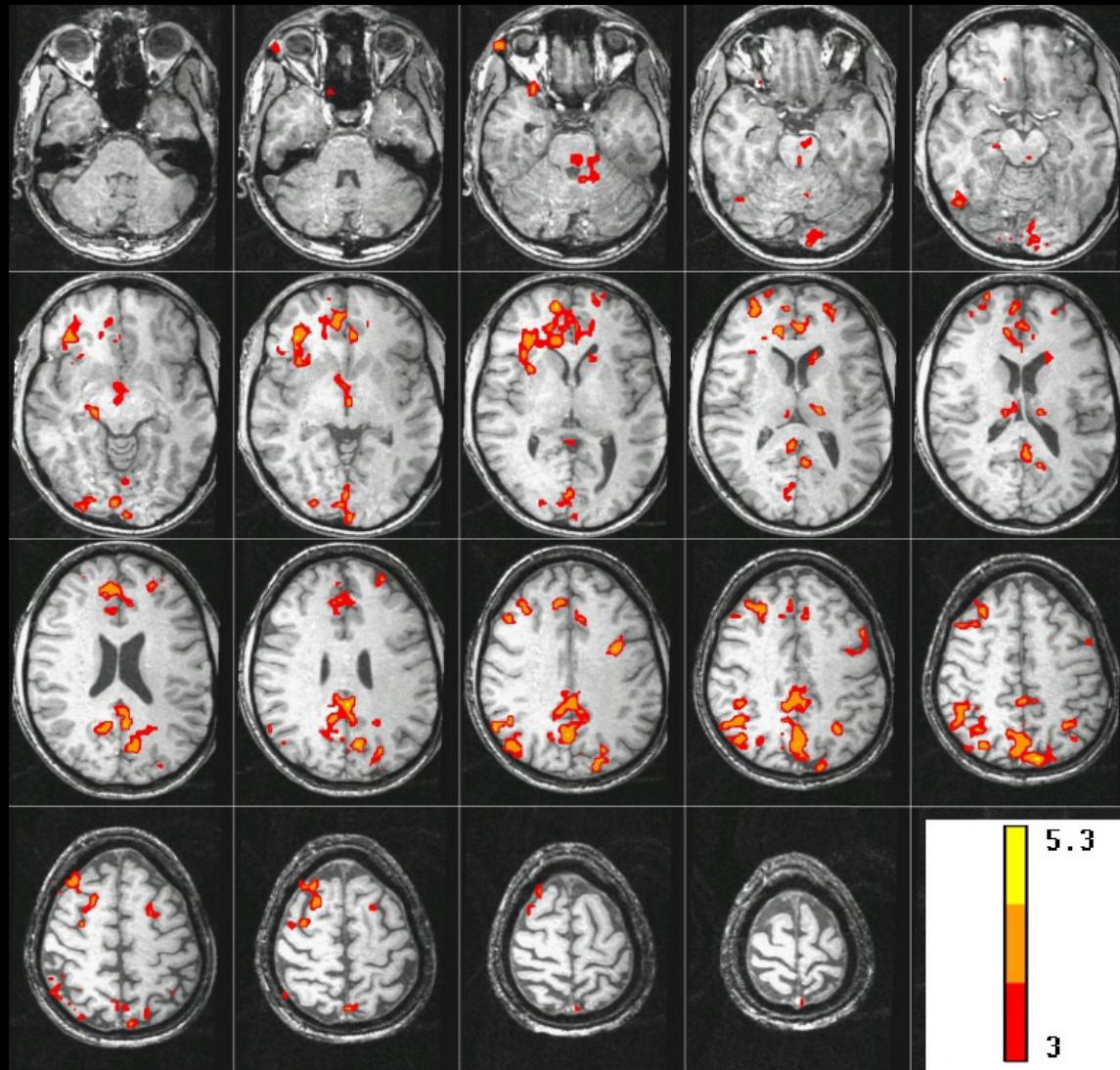
Use a continuous measure as a reference function:

- 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* 17: 1787-1806, (2002).

Simultaneous EEG and fMRI of the alpha rhythm

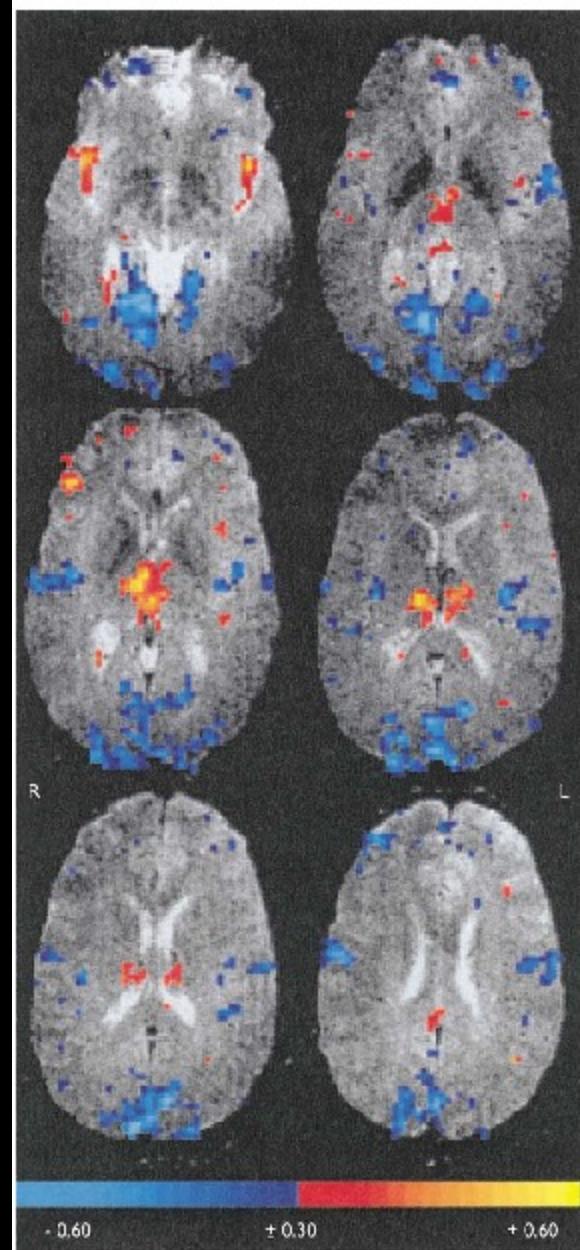
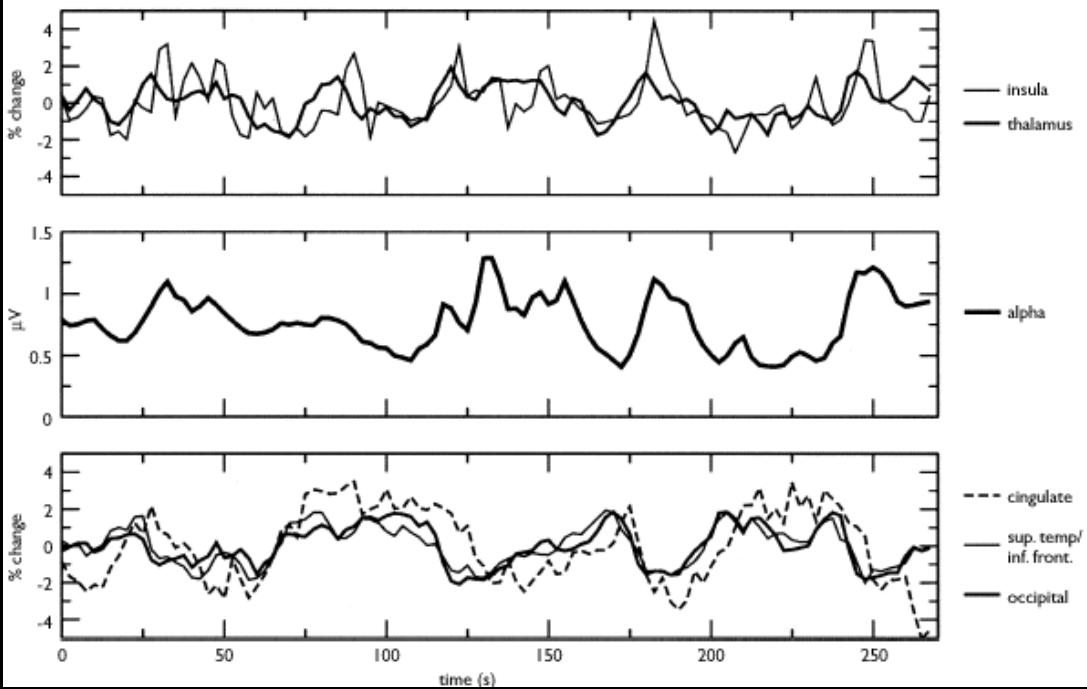
Robin I. Goldman,^{2,CA} John M. Stern,¹ Jerome Engel Jr¹ and Mark S. Cohen

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

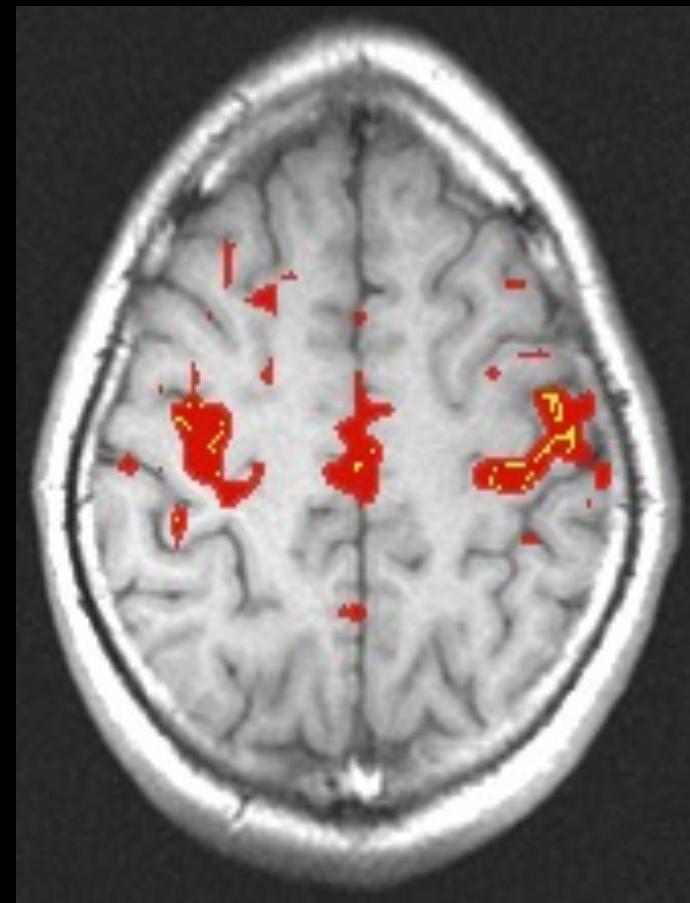
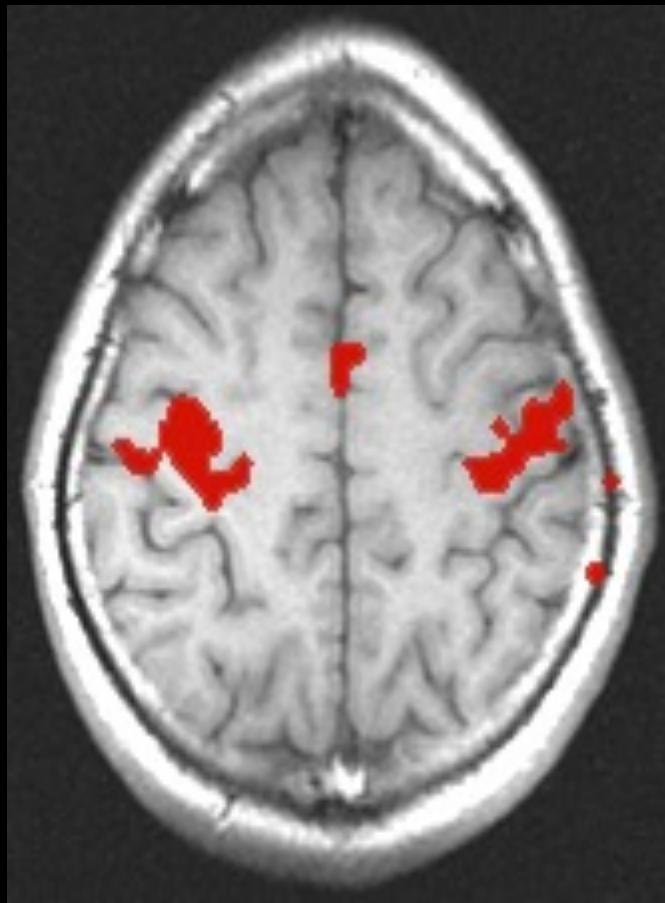
CA,²Corresponding Author and Address: rg2146@columbia.edu

Received 28 October 2002; accepted 30 October 2002

DOI: 10.1097/01.wnr.0000047685.08940.d0



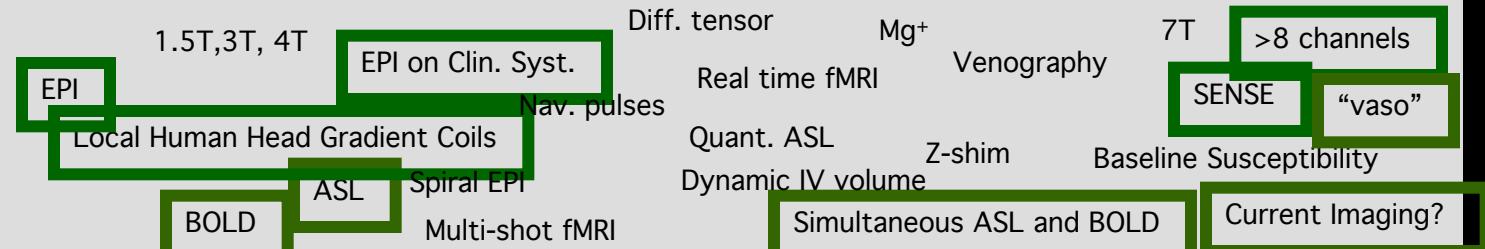
Resting State Fluctuations



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

Technology

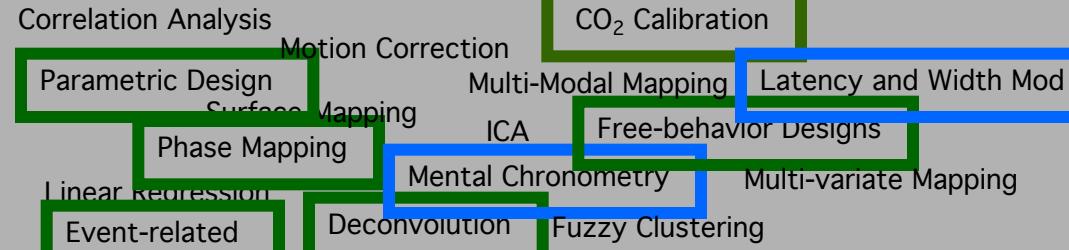
MRI



Methodology

Baseline Volume

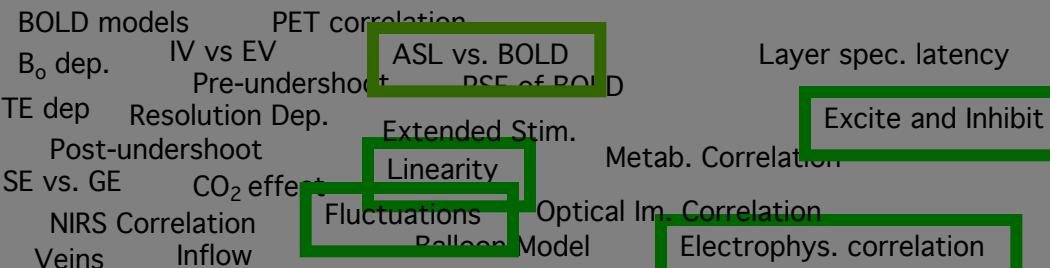
IVIM



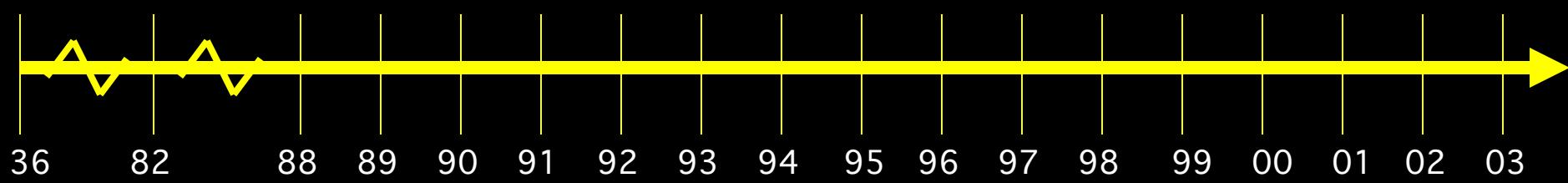
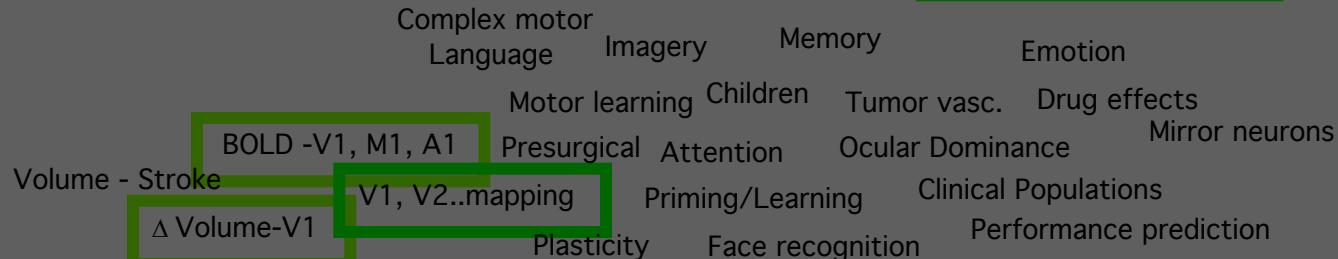
Interpretation

Blood T2

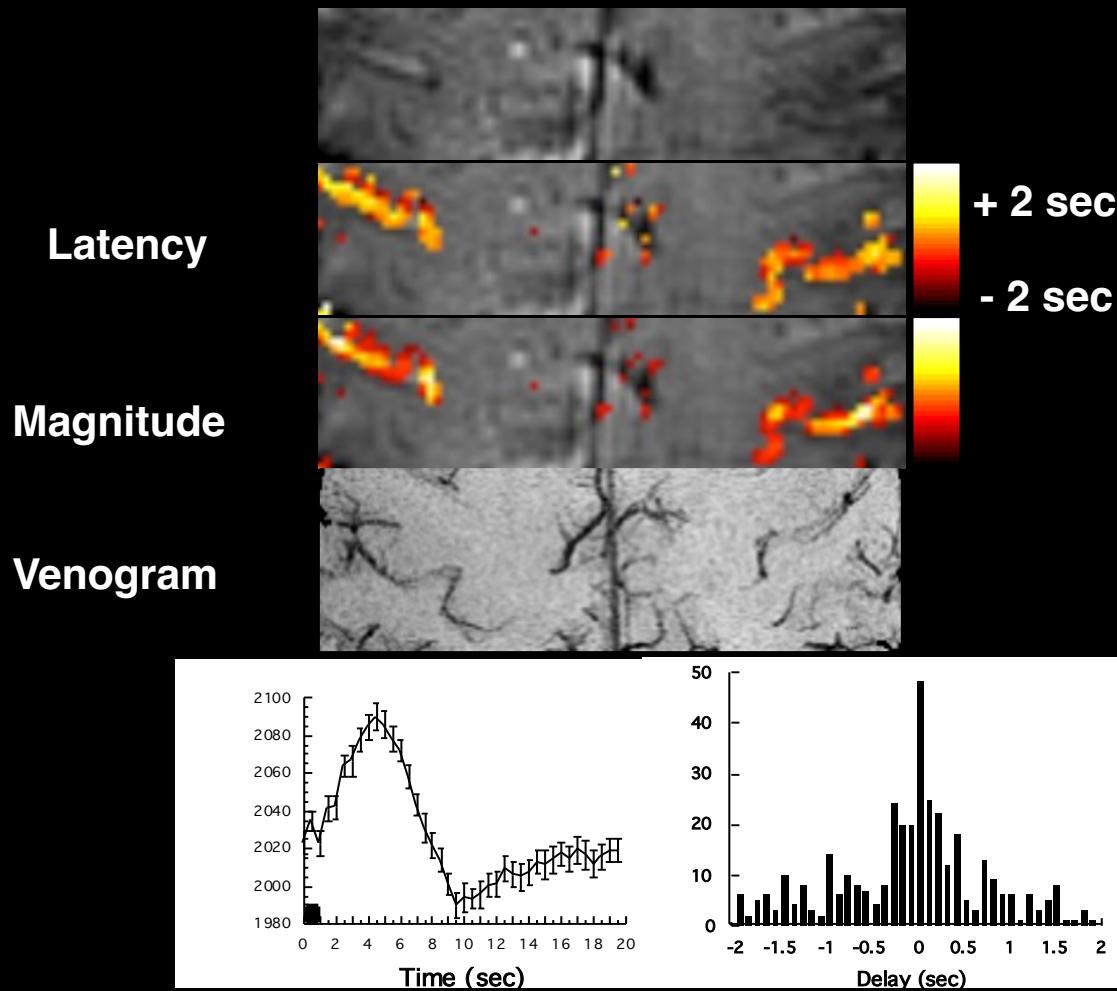
Hemoglobin



Applications



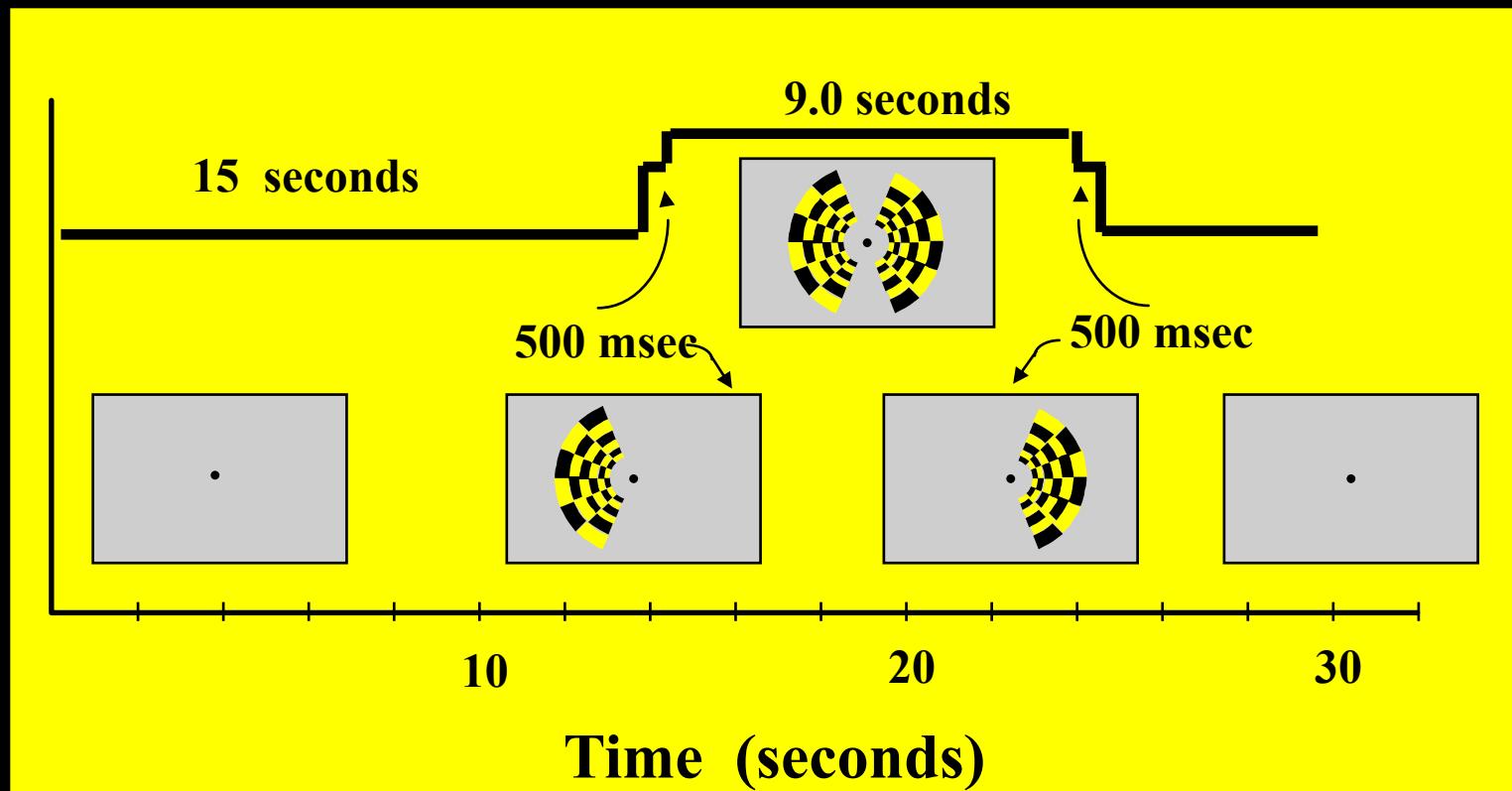
Latency and Width



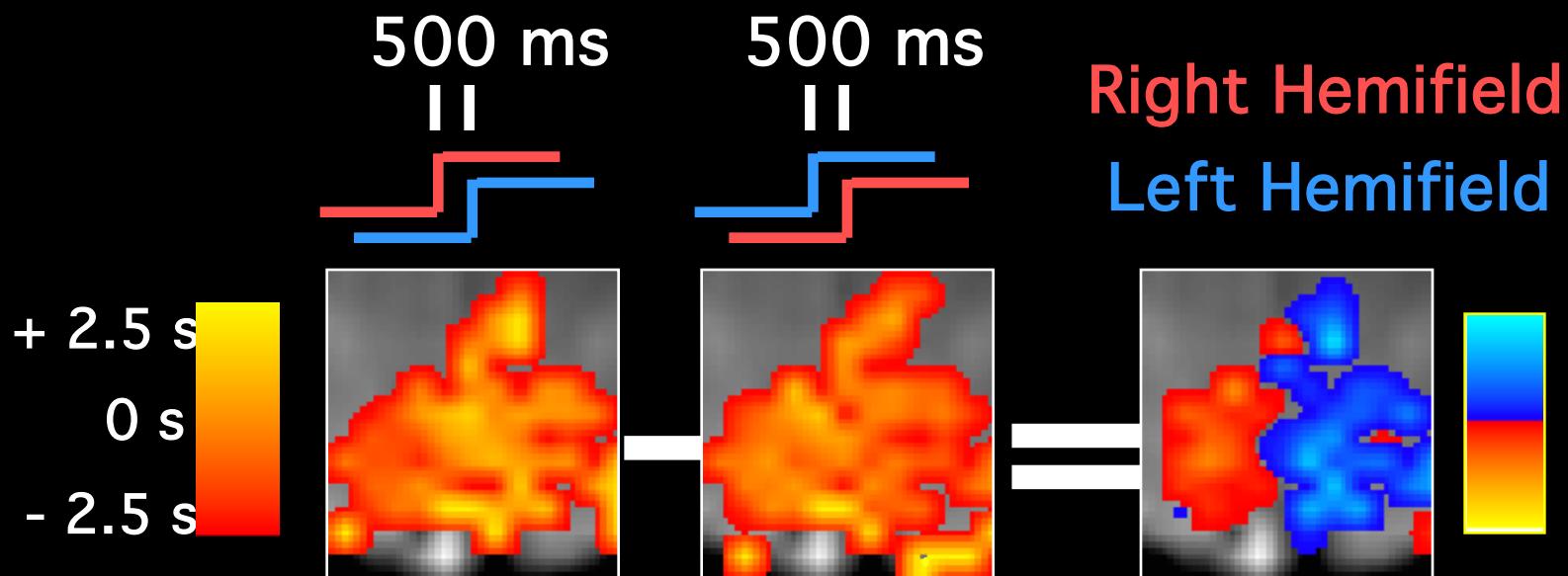
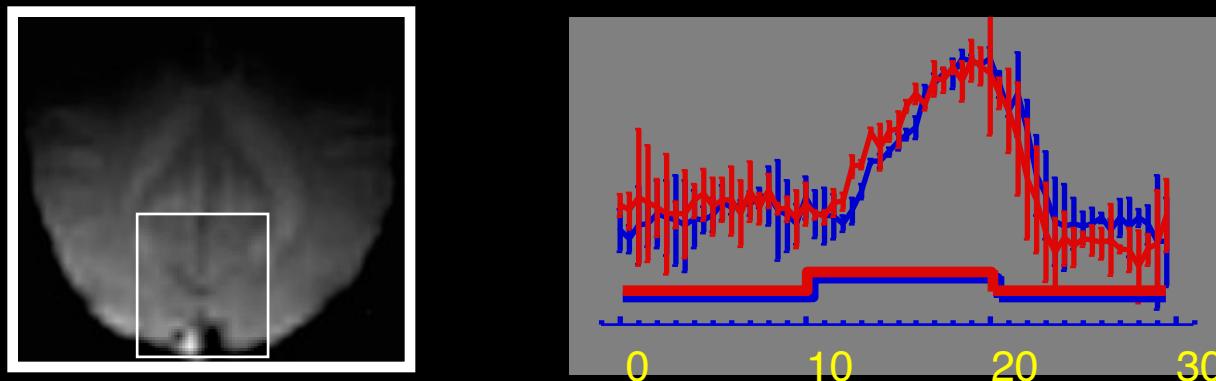
Hemi-Field Experiment

**Left
Hemisphere**

**Right
Hemisphere**



Timing Modulation (calibration)



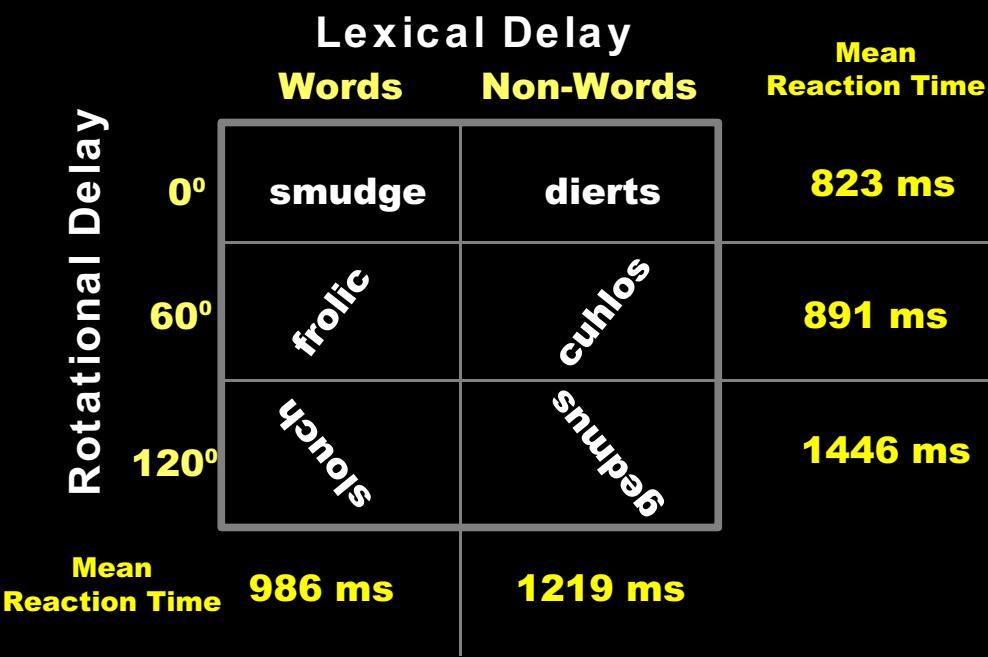
Understanding neural system dynamics through task modulation and measurement of functional MRI amplitude, latency, and width

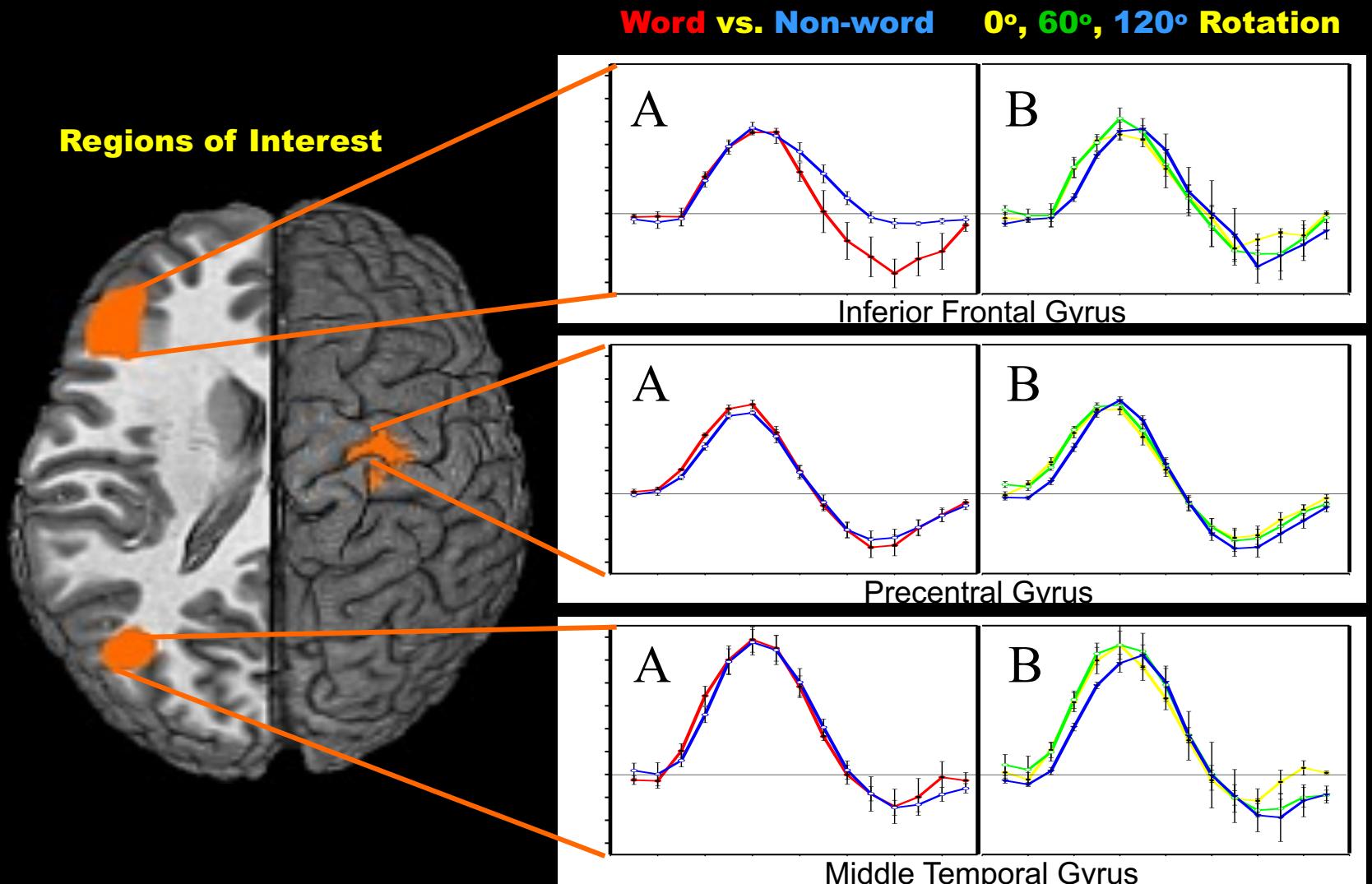
P. S. F. Bellgowan^{*†}, Z. S. Saad[‡], and P. A. Bandettini^{*}

^{*}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)

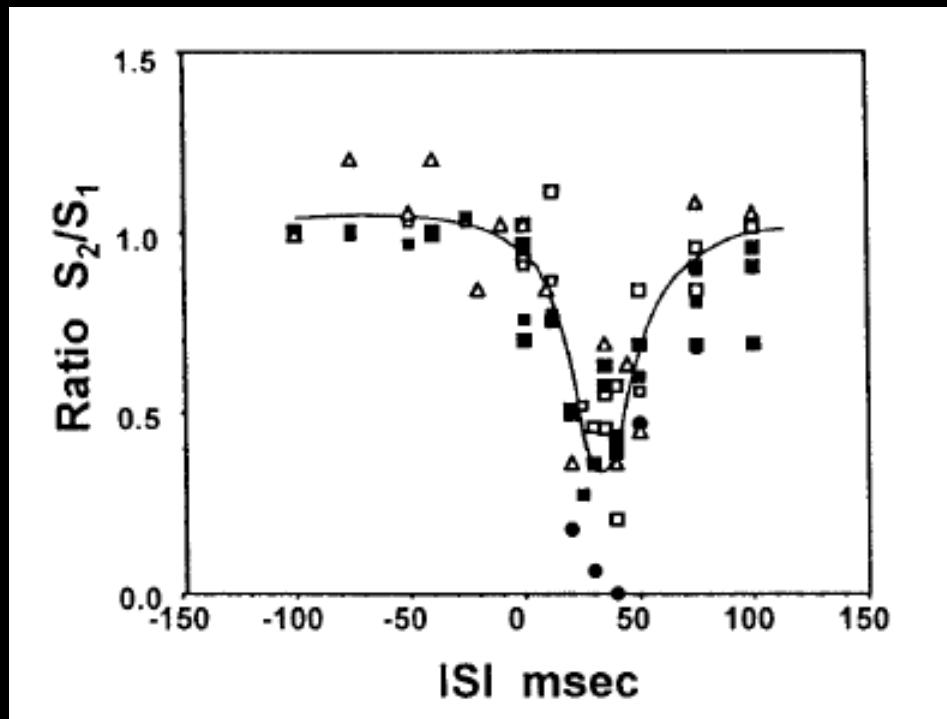
Proc. Nat'l. Acad. Sci. USA **100**, 1415-1419 (2003).





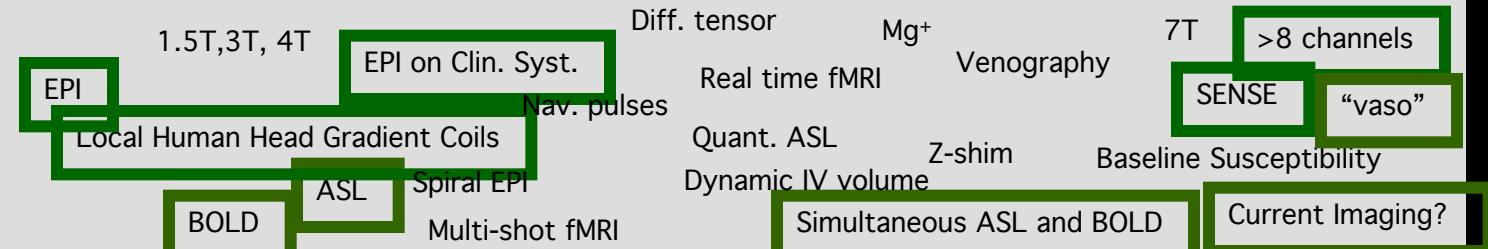
An approach to probe some neural systems interaction by functional MRI at neural time scale down to milliseconds

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



Technology

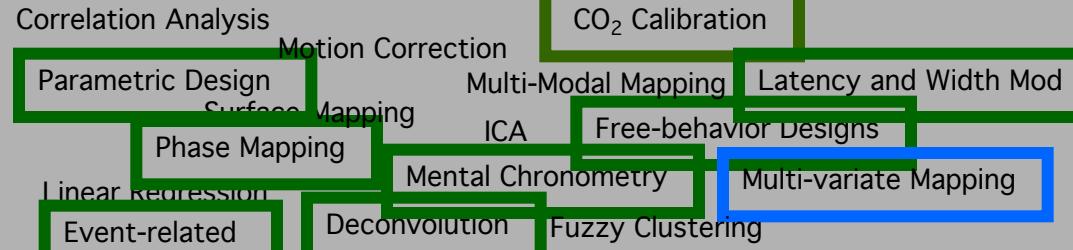
MRI



Methodology

Baseline Volume

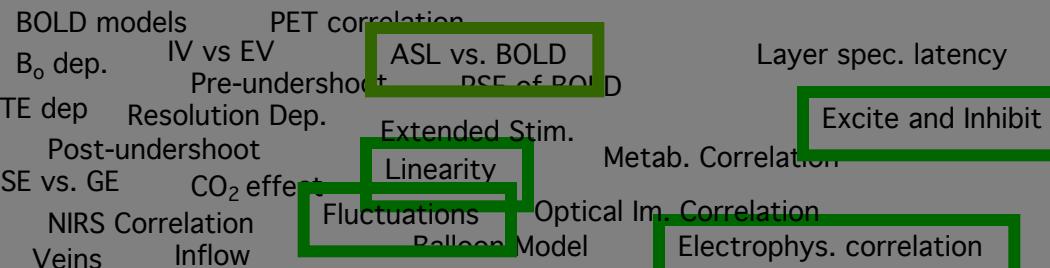
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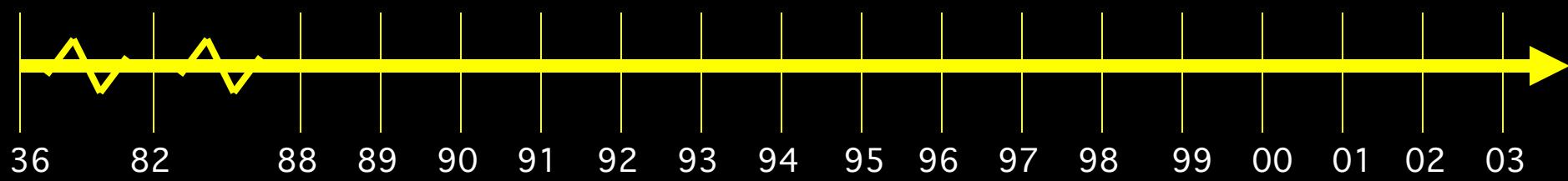
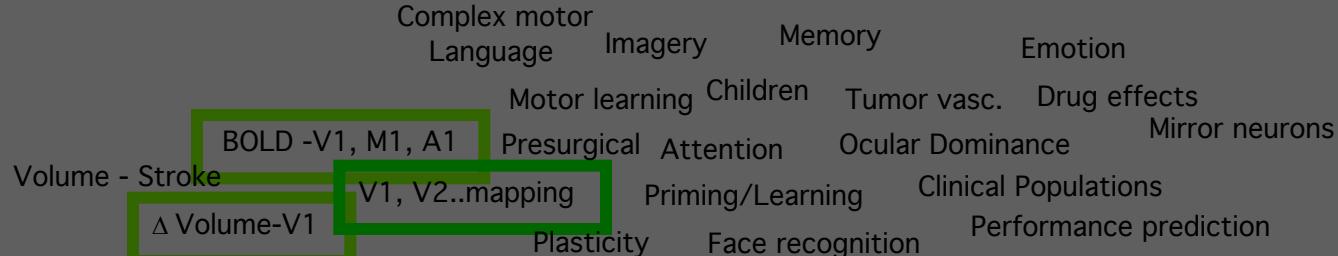
Interpretation

Blood T2

Hemoglobin



Applications



Functional magnetic resonance imaging (fMRI) "brain reading":
detecting and classifying distributed patterns of fMRI activity
in human visual cortex

David D. Cox^{a,b,*} and Robert L. Savoy^{a,b,c}

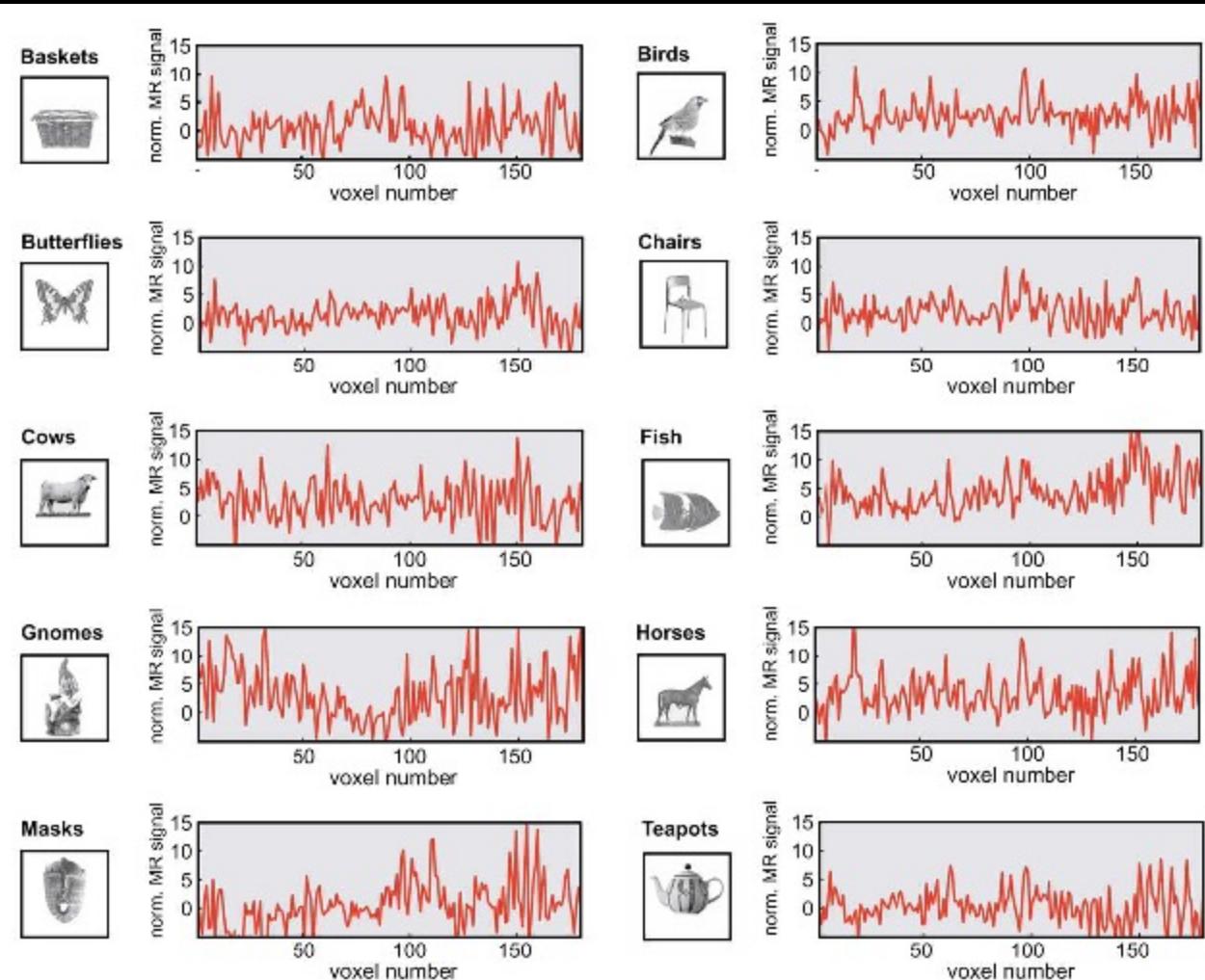
^a Rowland Institute for Science, Cambridge, MA 02142, USA

^b Athinoula A. Martinos Center for Structural and Functional Biomedical Imaging, Charlestown, MA 02129, USA

^c HyperVision, Inc., P.O. Box 158, Lexington, MA 02420, USA

Received 15 July 2002; accepted 10 December 2002

NEUROIMAGE 19 (2): 261-270 Part 1 JUN 2003



The Future

Sensitivity
Resolution
Calibration
Integration
Correlation

FIM Unit & FMRI Core Facility

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

Anthony Boemio

Patrick Bellgowan

Ziad Saad

Graduate Student:

Natalia Petridou

Post-Back. IRTA Students:

Hanh Ngyun

Ilana Levy

Elisa Kapler

August Tuan

Dan Kelley

Visiting Fellows:

Sergio Casciaro

Marta Maierov

Guosheng Ding

Clinical Fellow:

James Patterson

Psychologist:

Julie Frost

Summer Students:

Allison Sanders

Julia Choi

Thomas Gallo

Jenna Gelfand

Hannah Chang

Courtney Kemps

Douglass Ruff

Carla Wettig

Kang-Xing Jin

Program Assistant:

Kay Kuhns

Scanning Technologists:

Karen Bove-Bettis

Paula Rowser

Alda Ottley