Functional MRI Contrast, Resolution, Paradigms, and Processing

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Section on Functional Imaging Methods

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&

Functional MRI Facility

http://fmrif.nimh.nih.gov

Contrast
Resolution
Paradigms
Processing

Contrast

Resolution

Paradigms

Processing

Functional Contrast

- Volume (gadolinium)
- BOLD
- Perfusion (ASL)
- $\Delta CMRO_2$
- ΔVolume (VASO)
- Neuronal Currents
- Diffusion coefficient
- Temperature

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- **BOLD**
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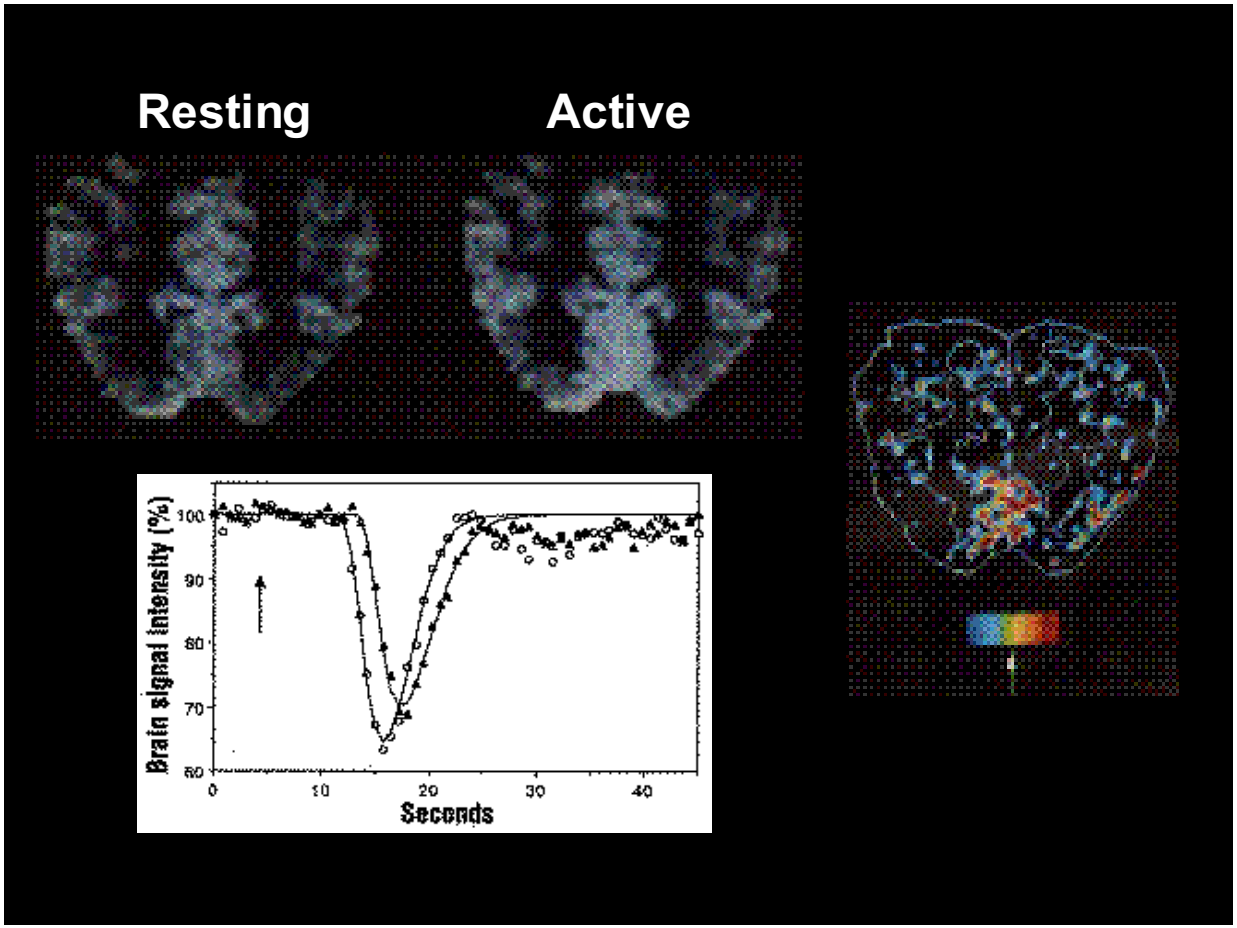
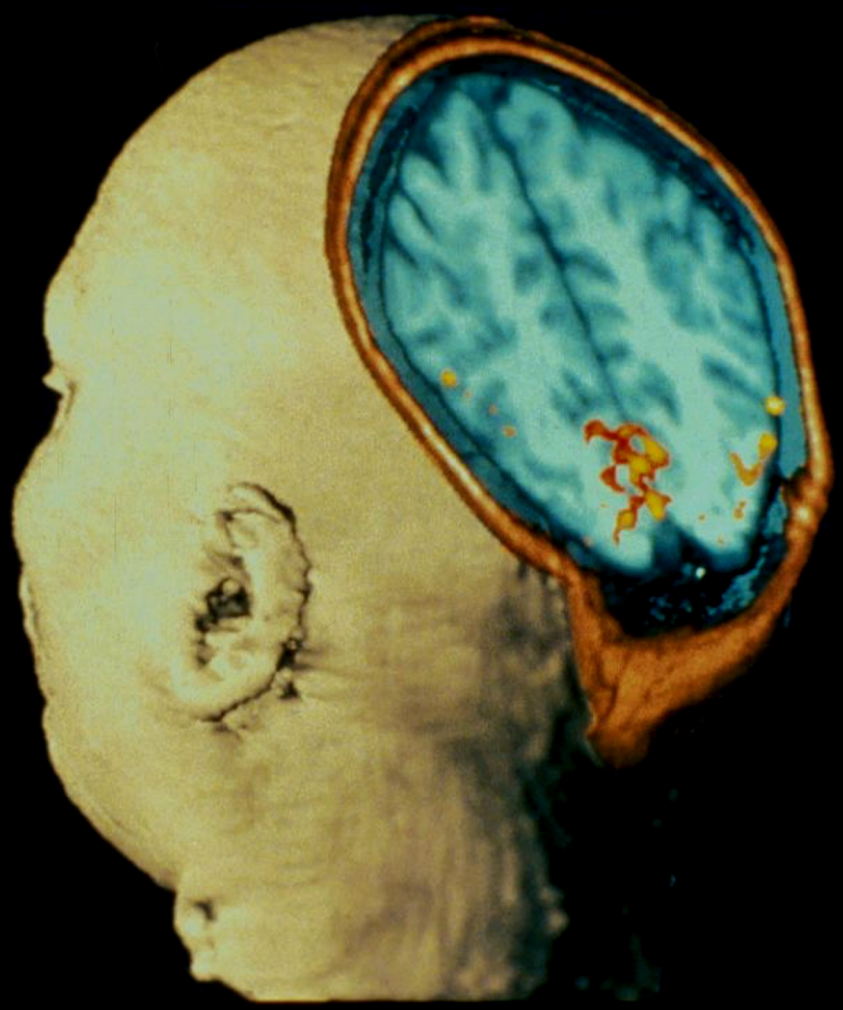
- **Diffusion coefficient**
- **Temperature**

Blood Volume Imaging

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



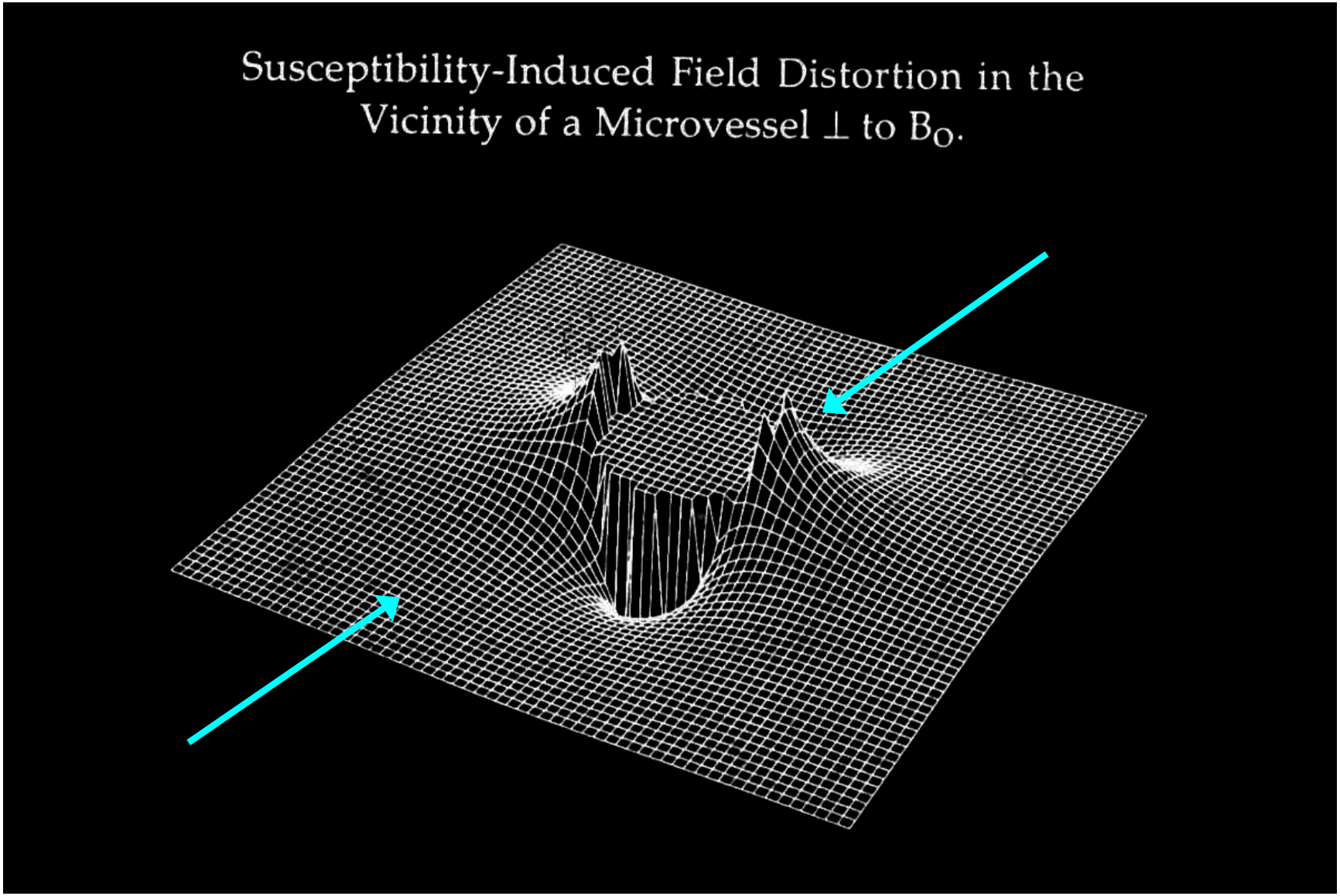
Photic Stimulation



MRI Image showing activation of the Visual Cortex

From Belliveau, et al. Science Nov 1991

Susceptibility Contrast



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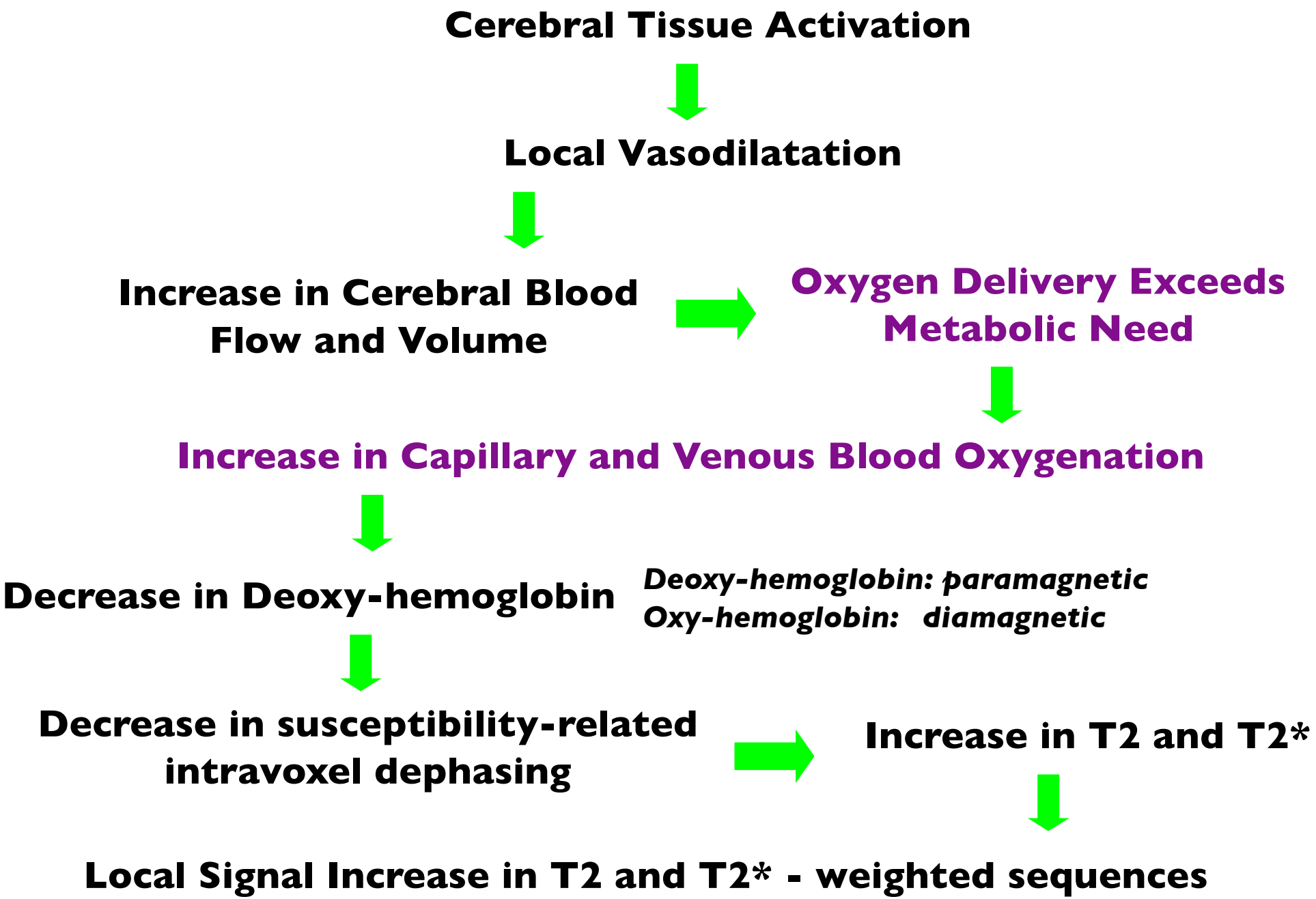
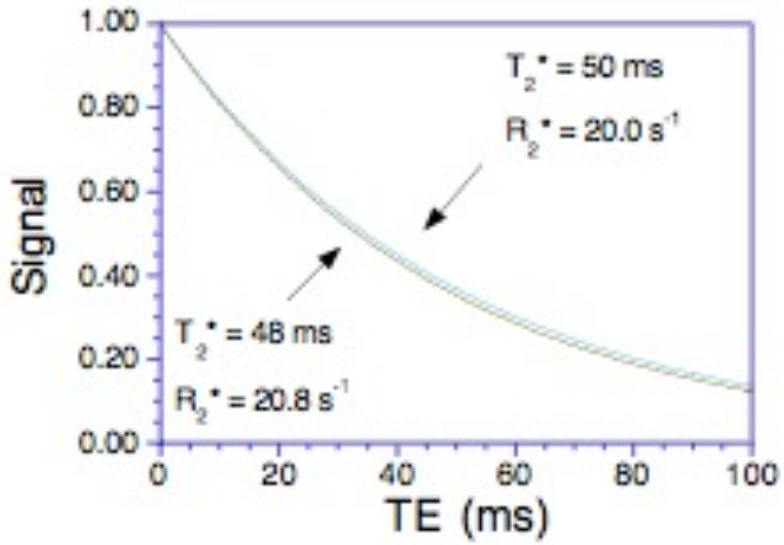
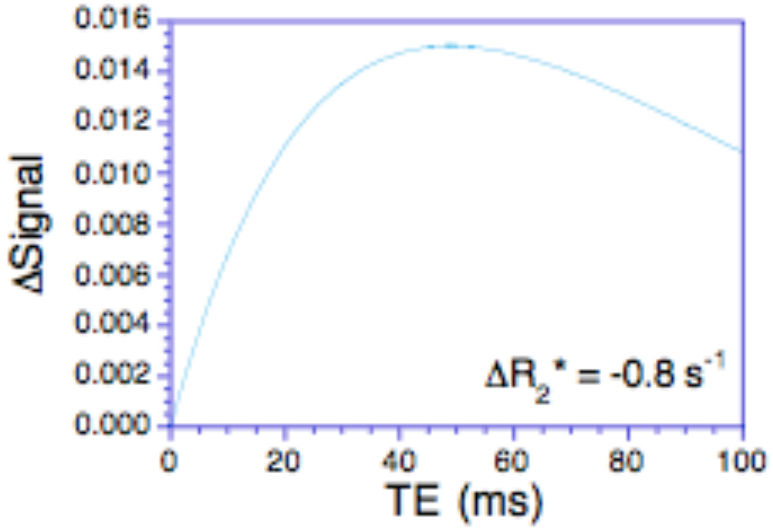
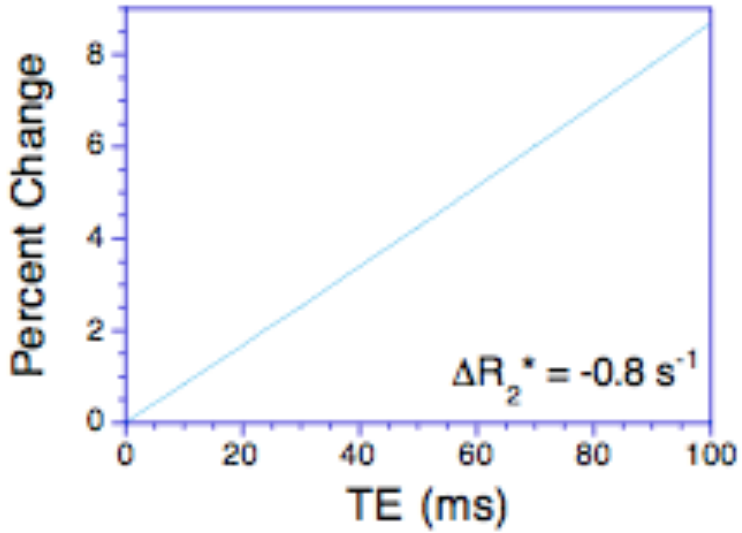

Cerebral Tissue Activation
Local Vasodilatation
Increase in Cerebral Blood Flow and Volume
Oxygen Delivery Exceeds Metabolic Need
Increase in Capillary and Venous Blood Oxygenation
Decrease in Deoxy-hemoglobin
Deoxy-hemoglobin: paramagnetic
Oxy-hemoglobin: diamagnetic
Decrease in susceptibility-related intravoxel dephasing
Increase in T2 and T2*
Local Signal Increase in T2 and T2* - weighted sequences

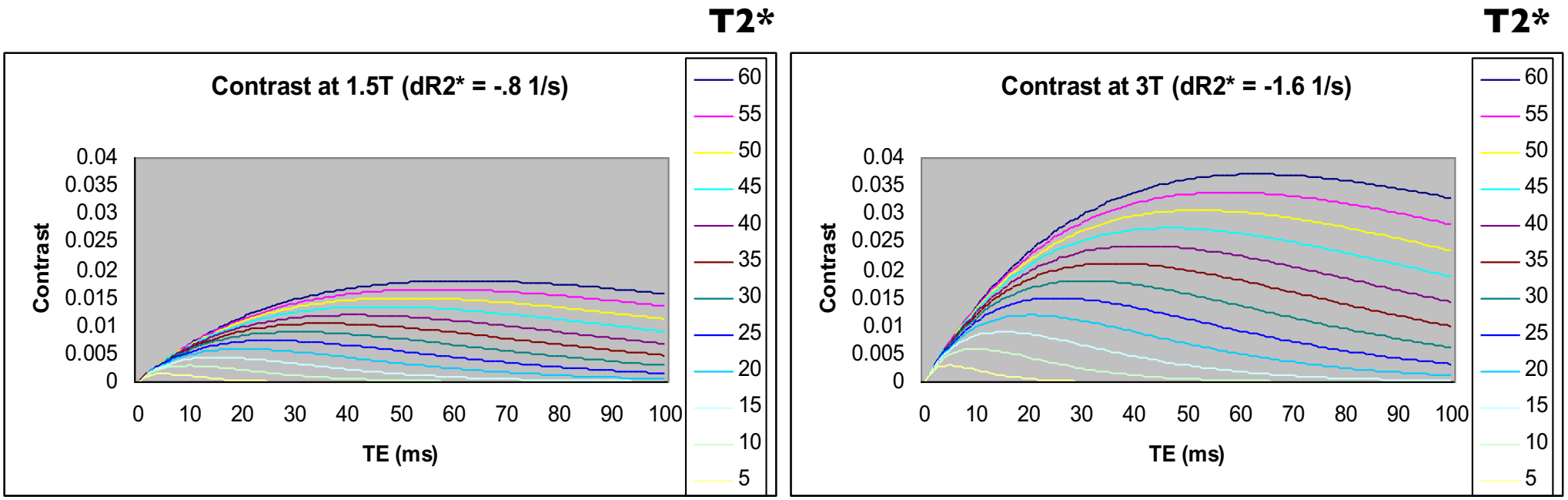
Characteristics of the BOLD signal: T2* effect.

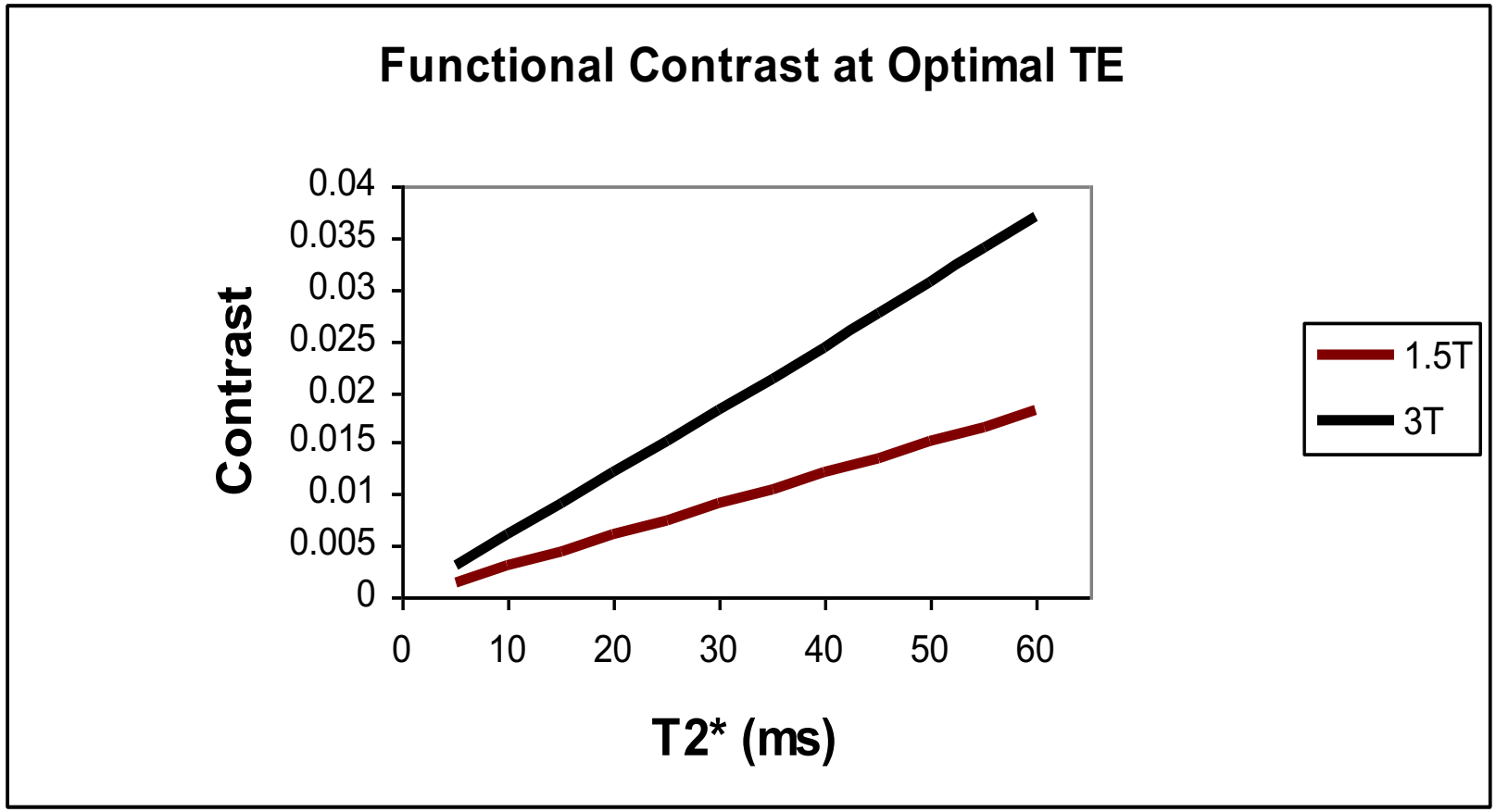






Contrast depends on:
activation-induced changes in T2* *and* resting T2*

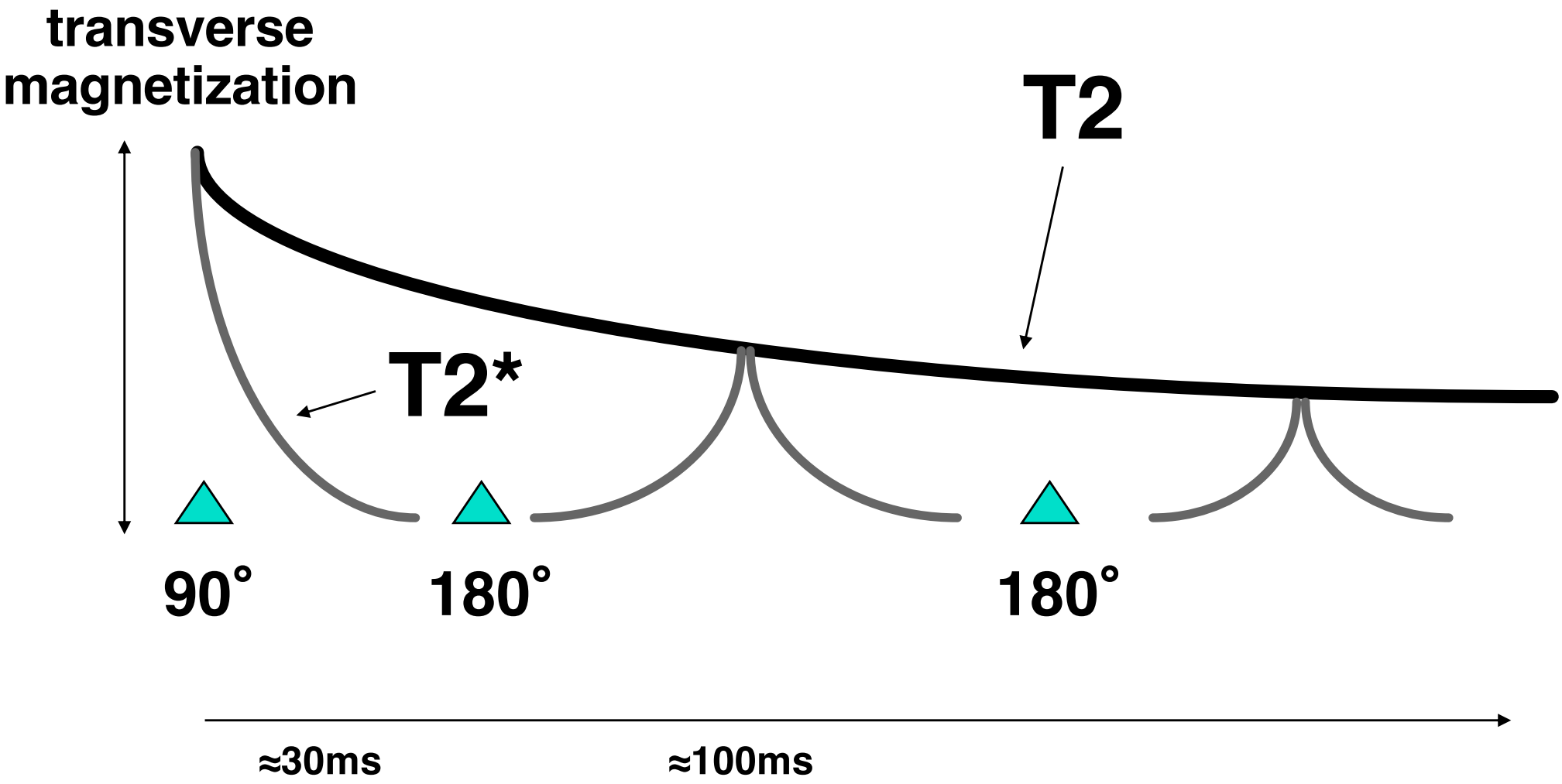



Functional Contrast at Optimal TE
Contrast
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
10
20
30
40
50
60
T2* (ms)
1.5T
3T

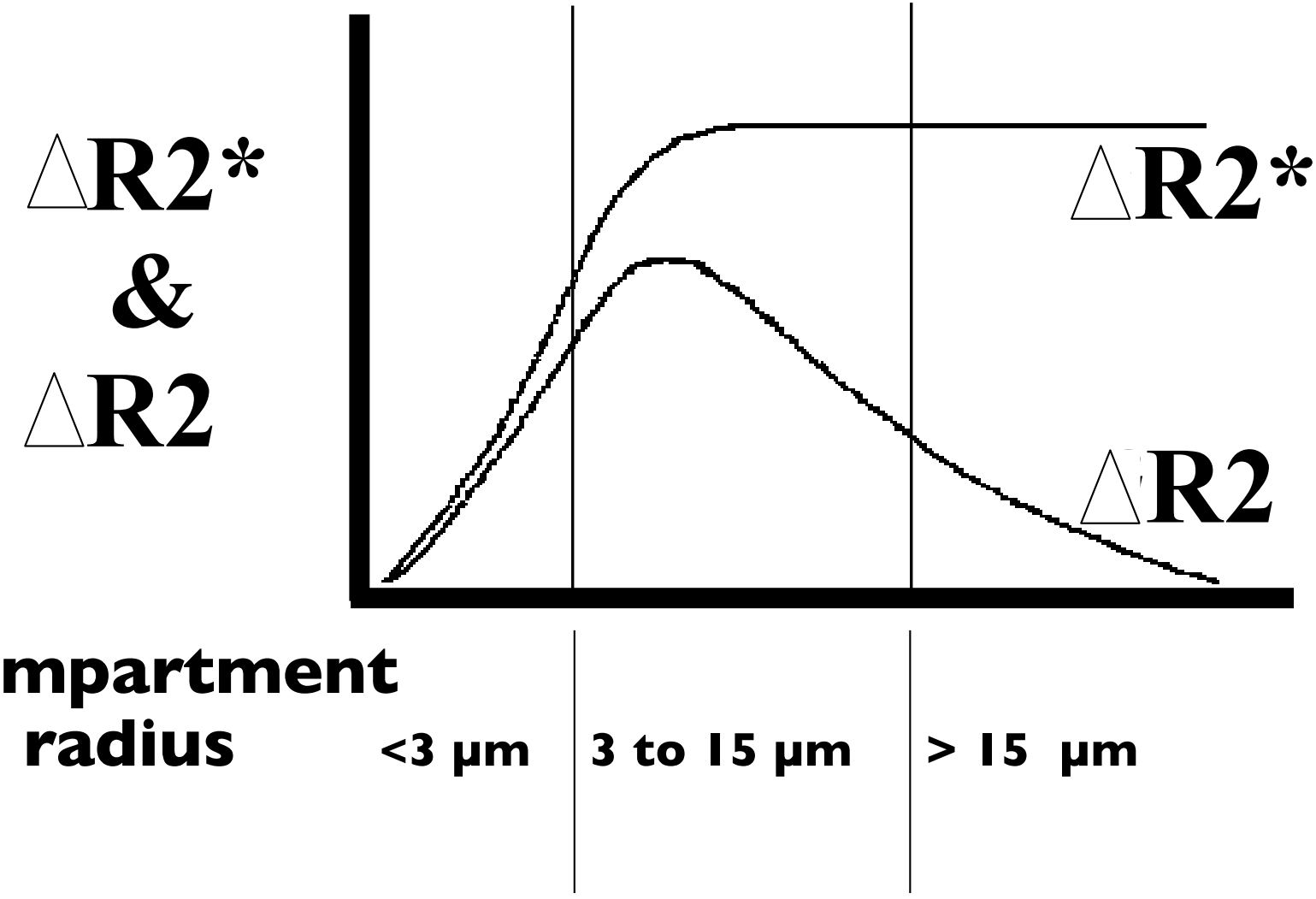
Spin-Echo vs. Gradient-Echo

fMRI

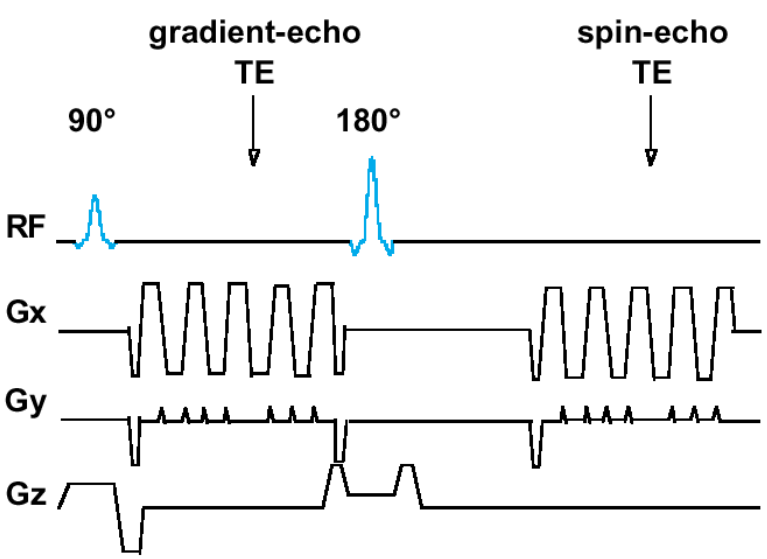
Transverse Relaxation

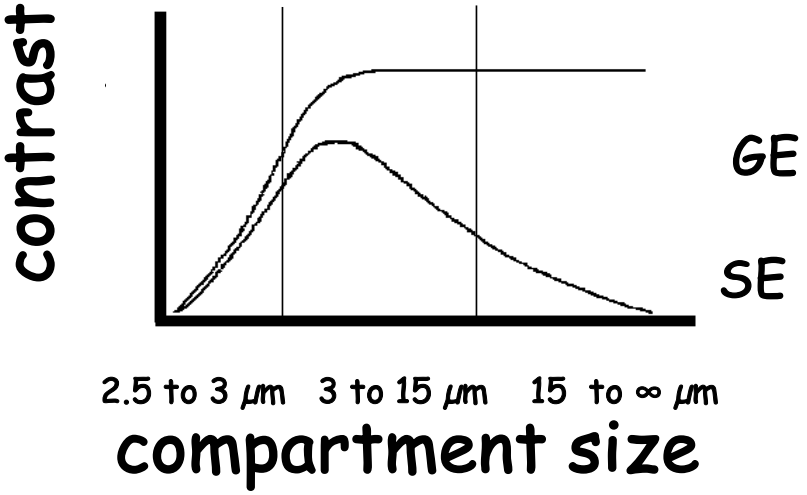


Spin echo vs. Gradient echo



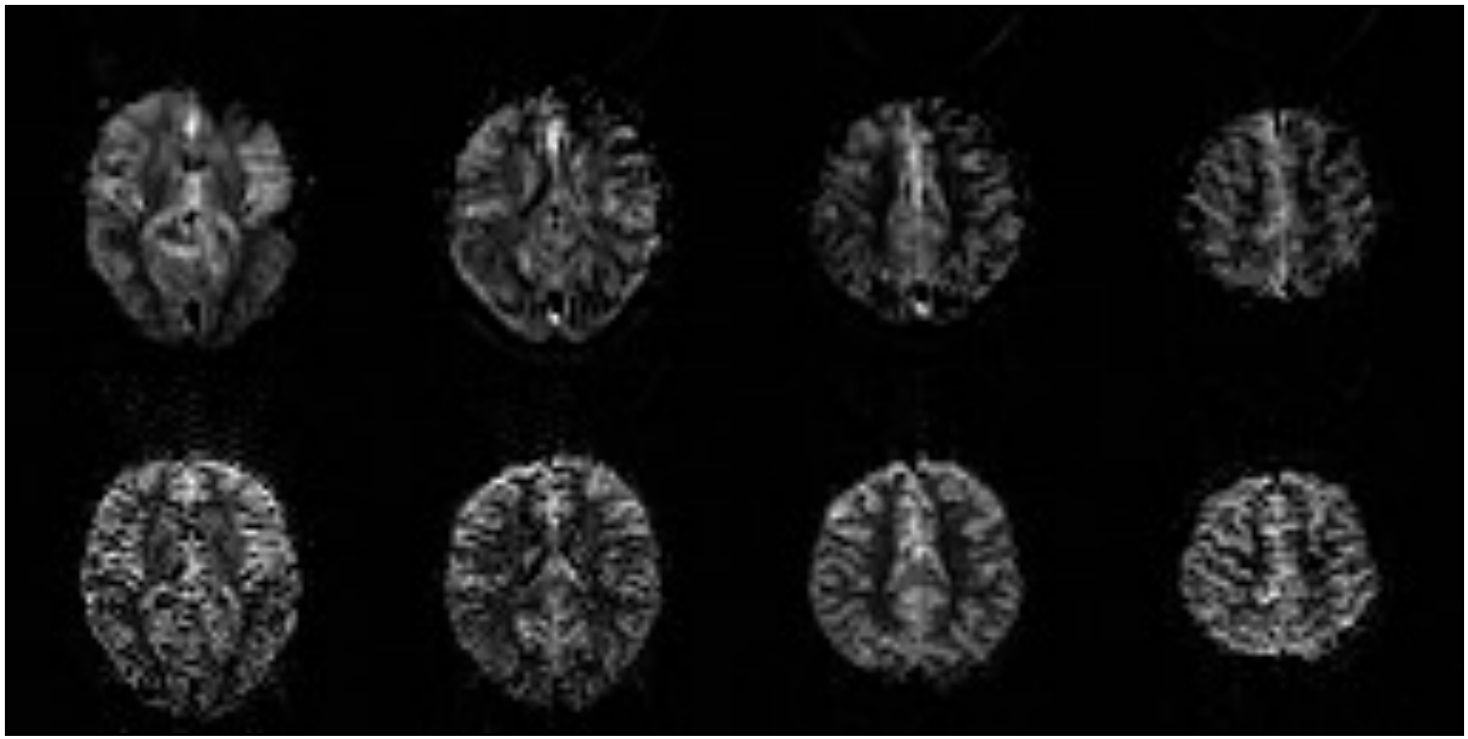
Bolus Injection of Gadolinium





GE
TE = 30 ms

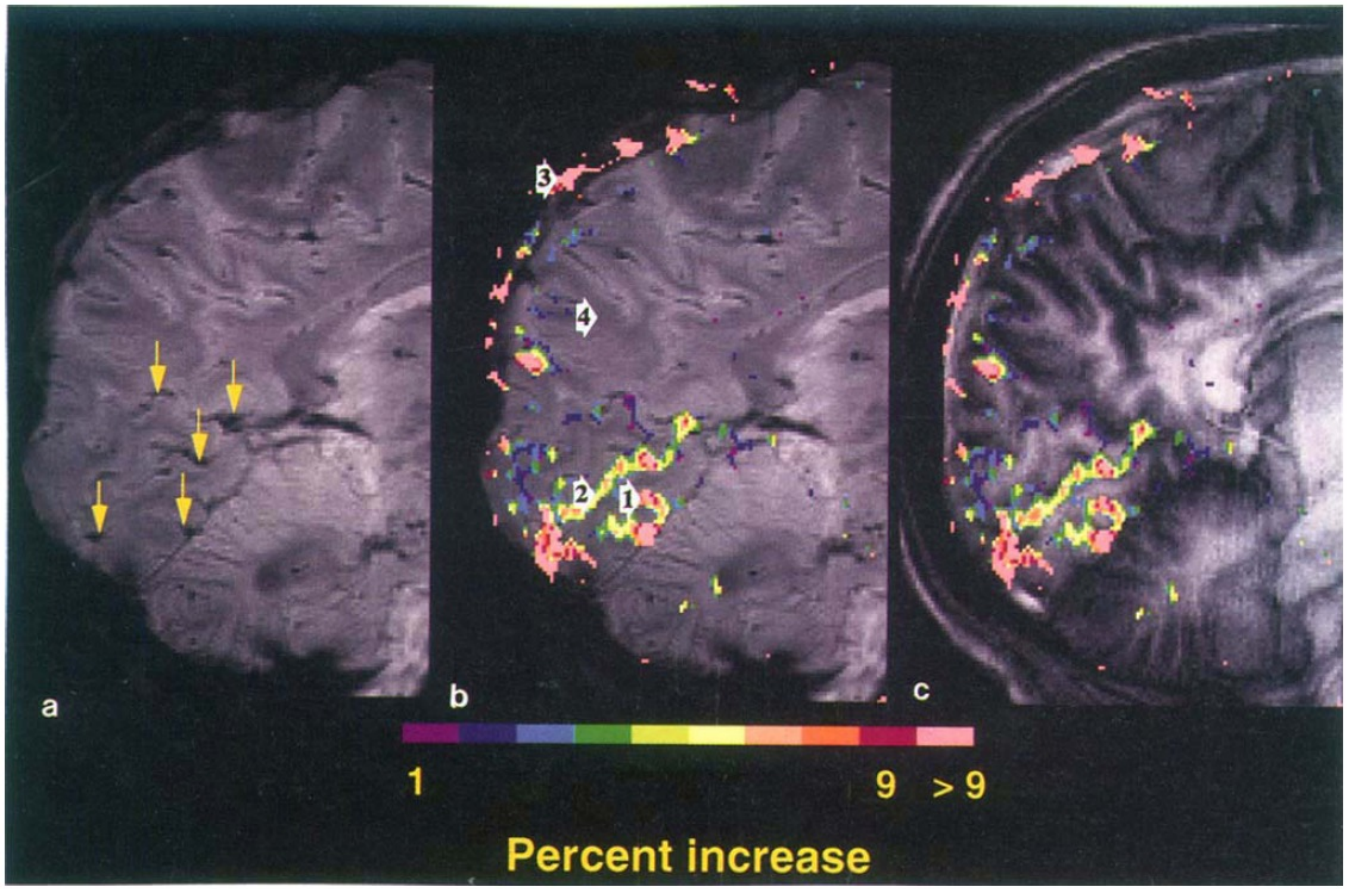
SE
TE = 110 ms

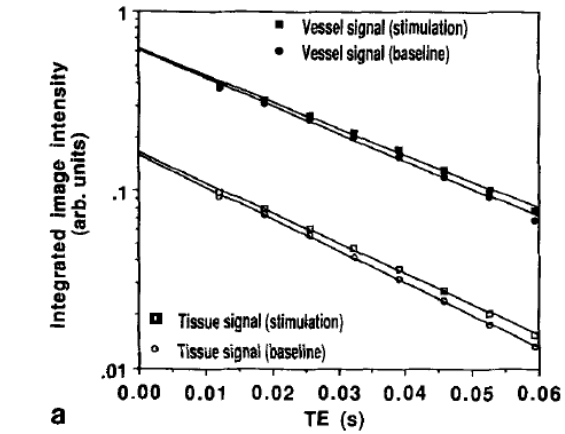


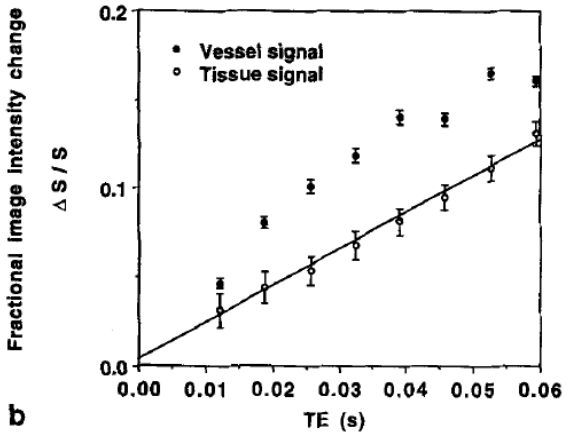
MRM 30:380-386 (1993)

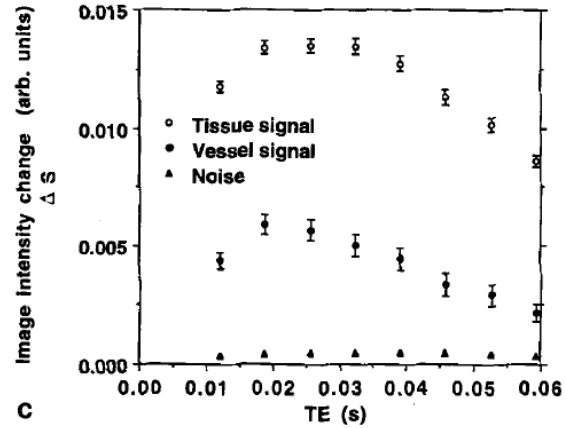
4 Tesla Gradient Recalled Echo Characteristics of Photic Stimulation-Induced Signal Changes in the Human Primary Visual Cortex

Ravi S. Menon, Seiji Ogawa, David W. Tank, Kâmil Uğurbil





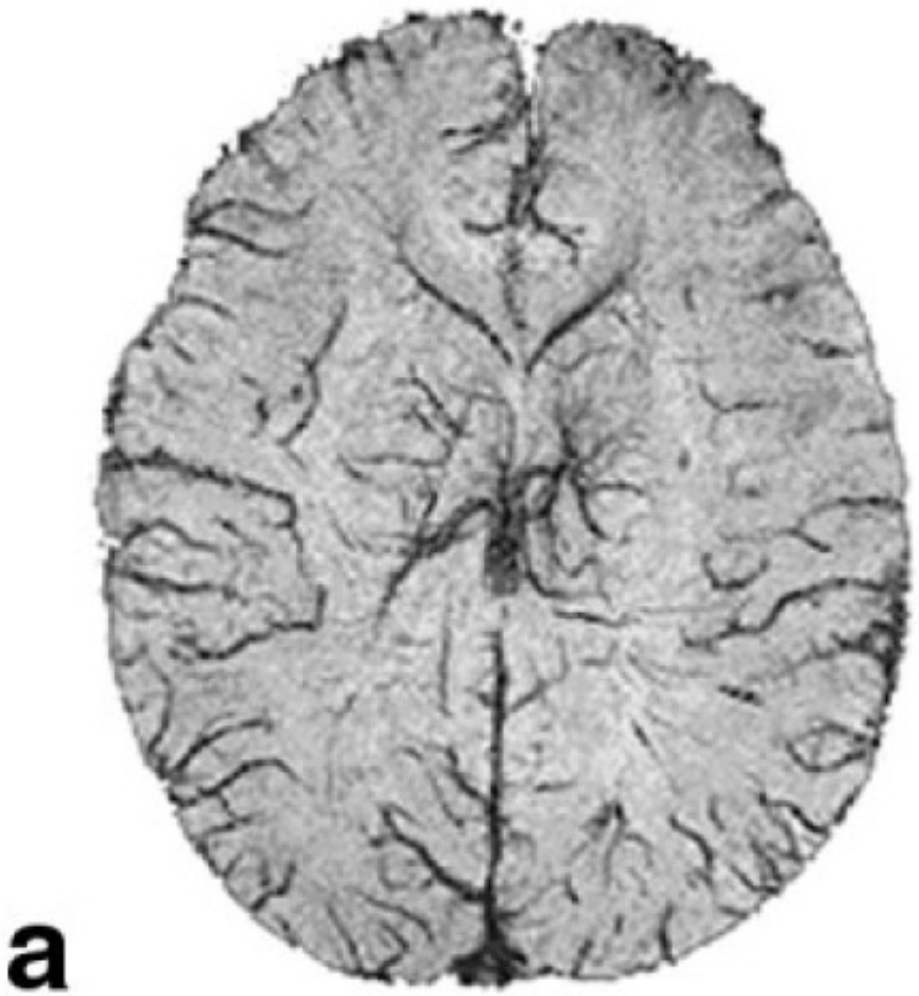




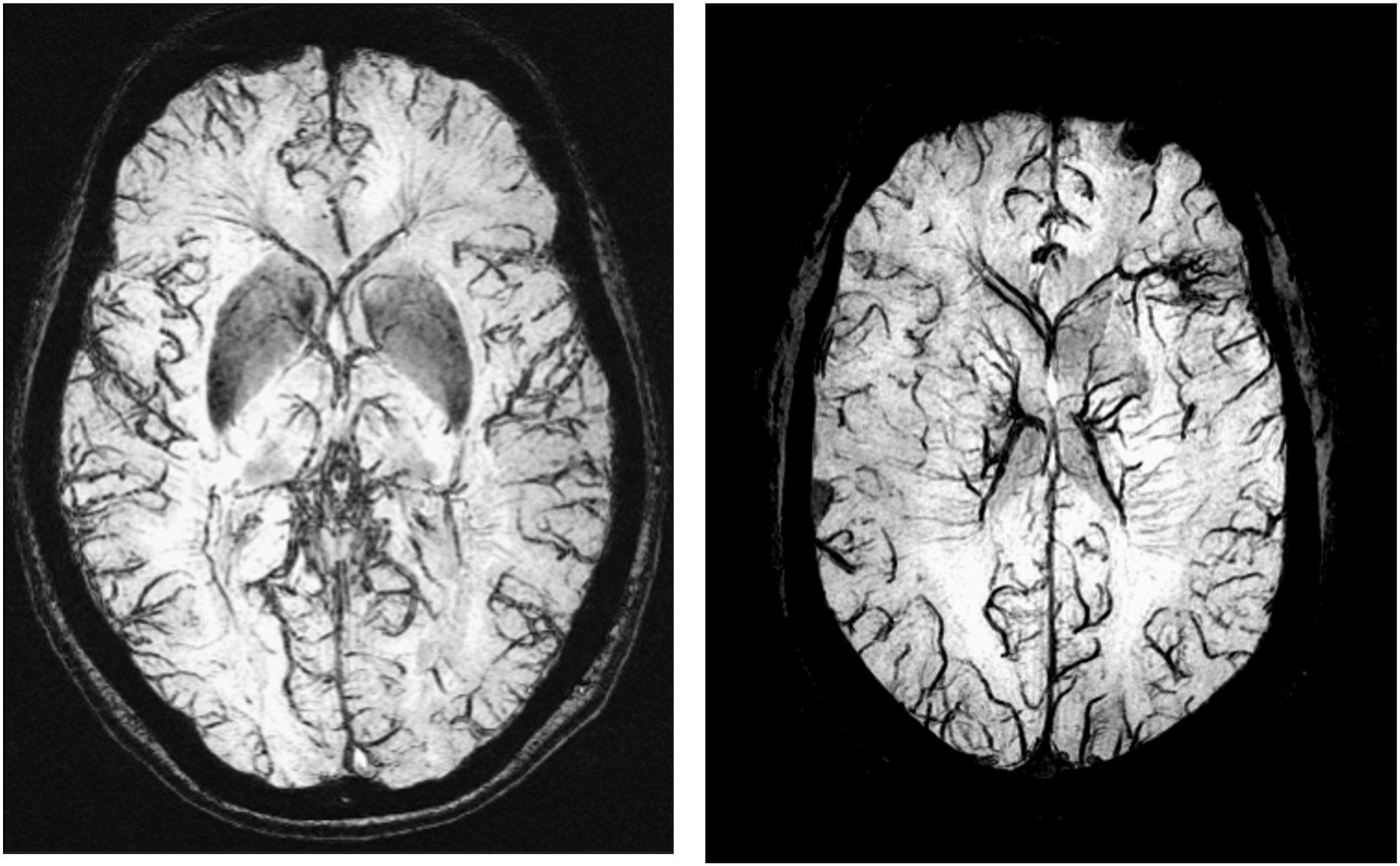
Magnetic Resonance in Medicine 52:612–618 (2004)

Susceptibility Weighted Imaging (SWI)

E. Mark Haacke,[1-4*] Yingbiao Xu,[1,2] Yu-Chung N. Cheng,[1] and Jürgen R. Reichenbach[5]



BOLD effect to highlight veins: 3 Tesla



Bove-Bettis, et al (2004), SMRT

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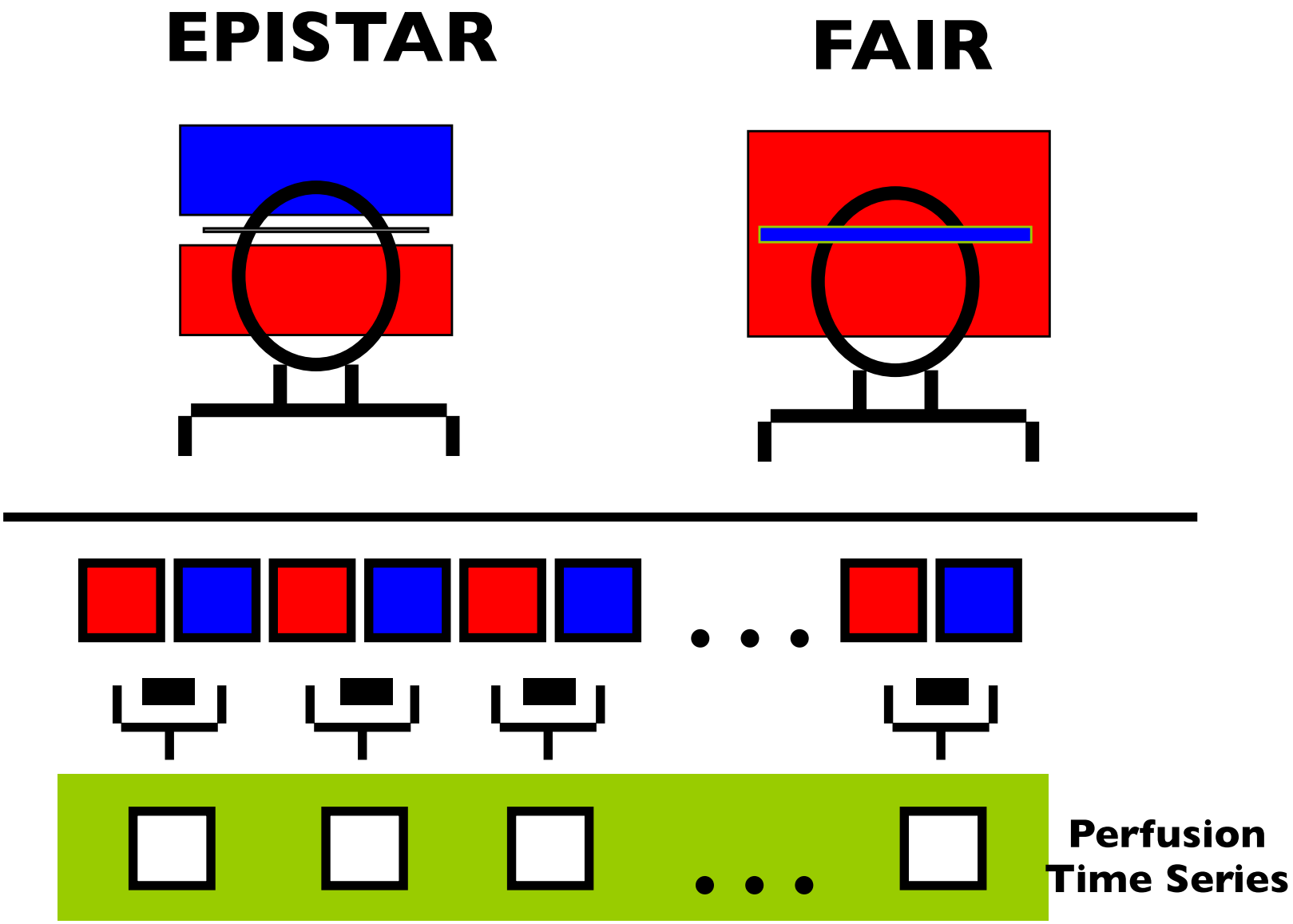
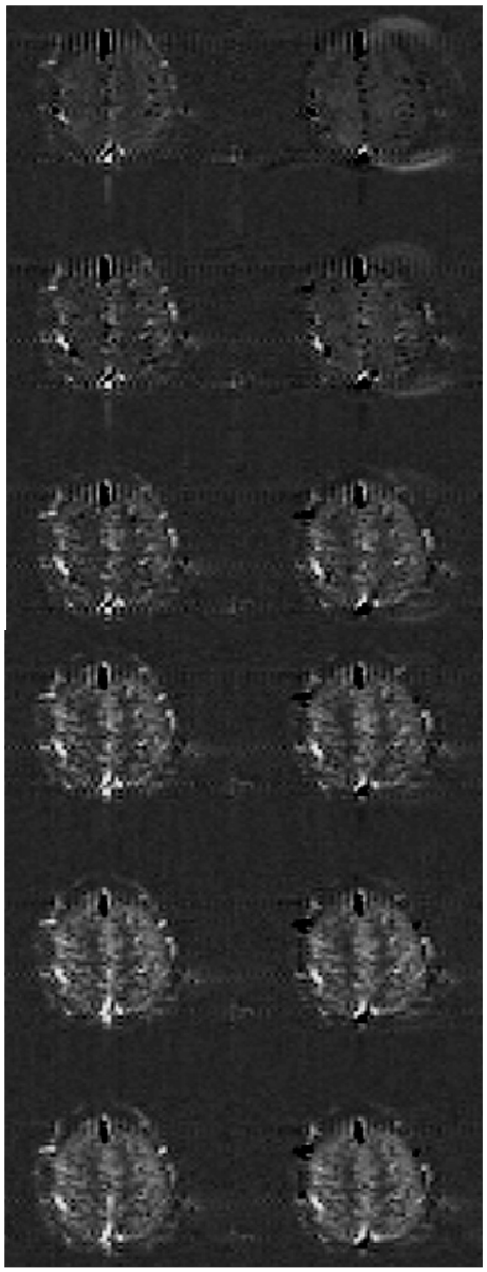
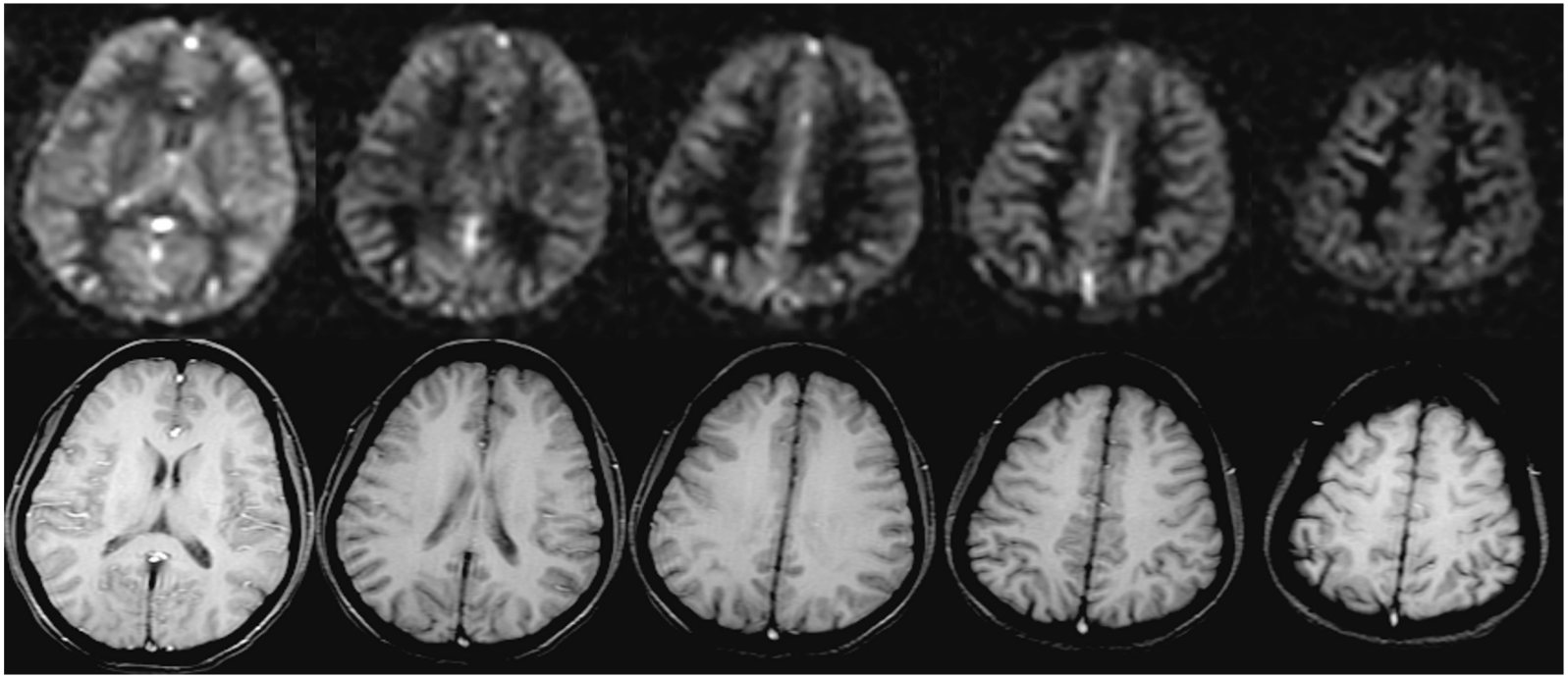
Perfusion Contrast



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

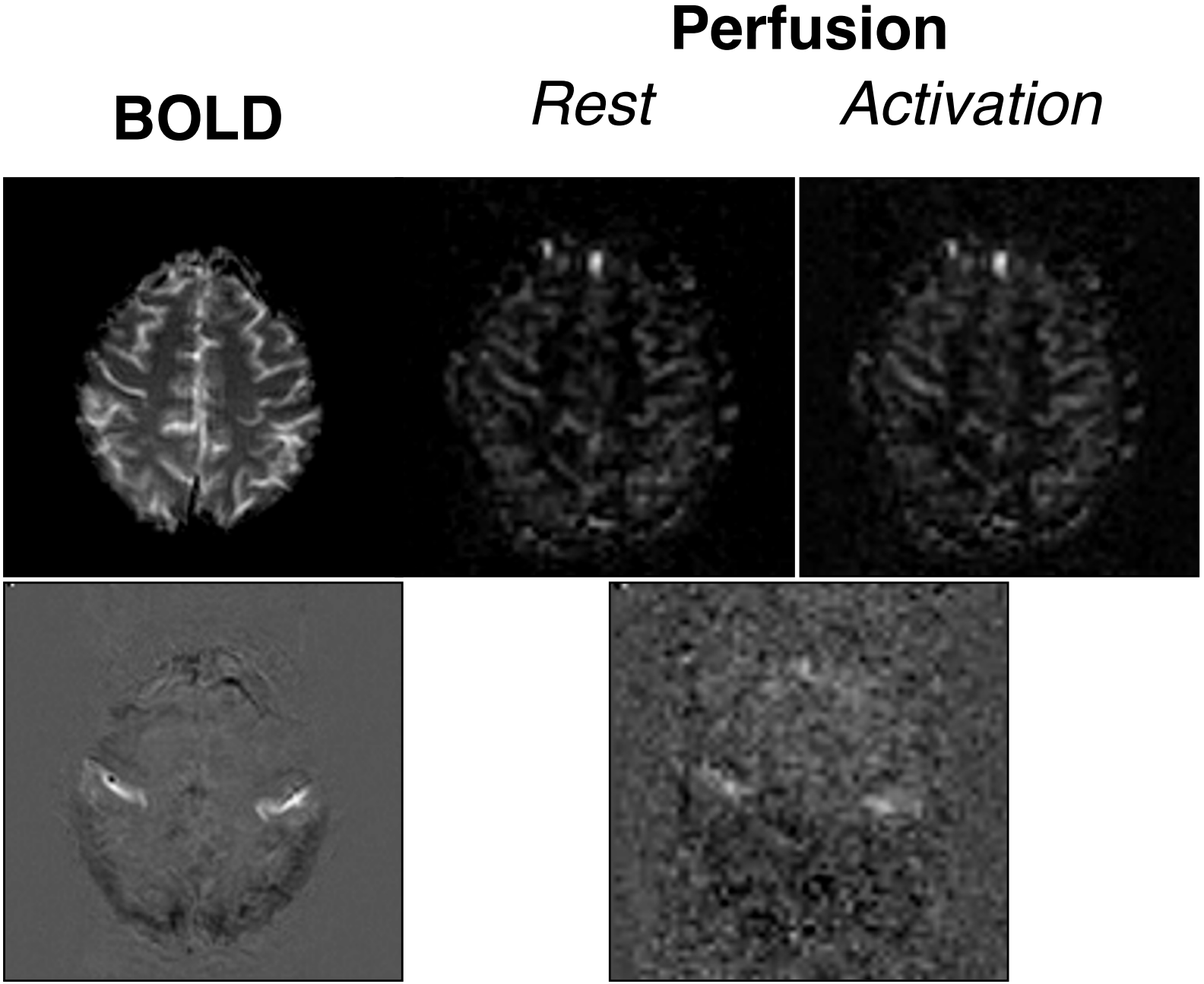


Williams, D. S., Detre, J. A., Leigh, J. S. & Koretsky, A. S. (1992) "Magnetic resonance imaging of perfusion using spin-inversion of arterial water." **Proc. Natl. Acad. Sci. USA 89, 212-216.**

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.**

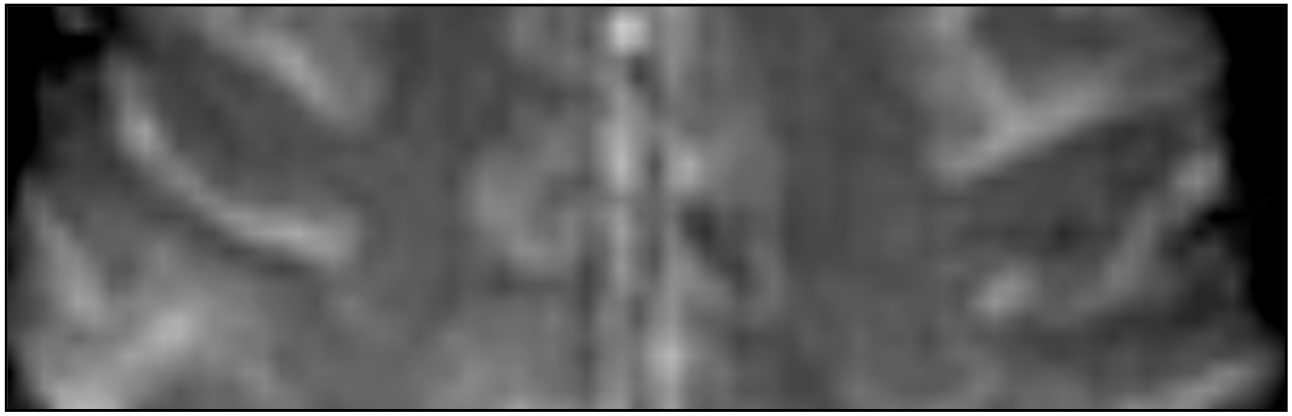
Kim, S.-G. (1995) "Quantification of relative cerebral blood flow change by flow-sensitive alternating inversion recovery (FAIR) technique: application to functional mapping." **Magn. Reson. Med. 34, 293-301**.

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

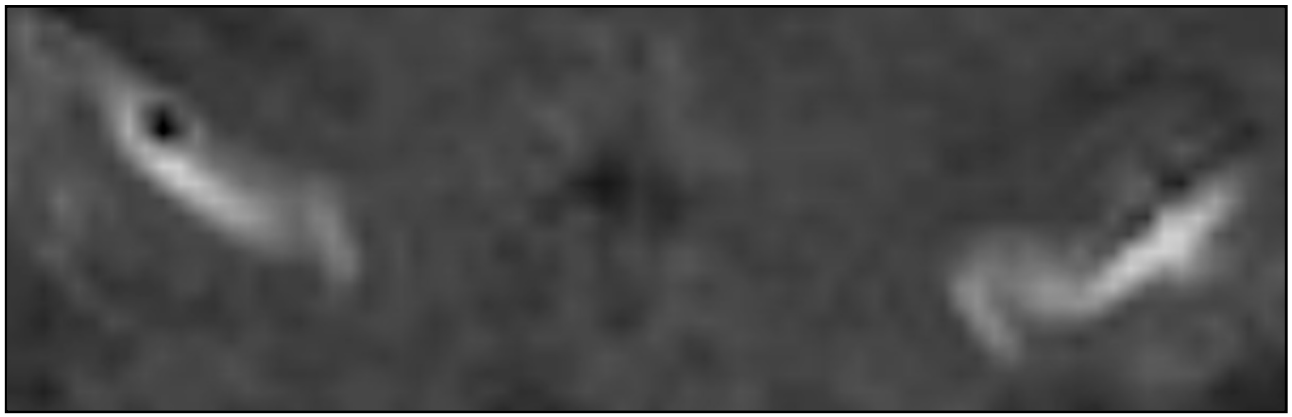


P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

Anatomy



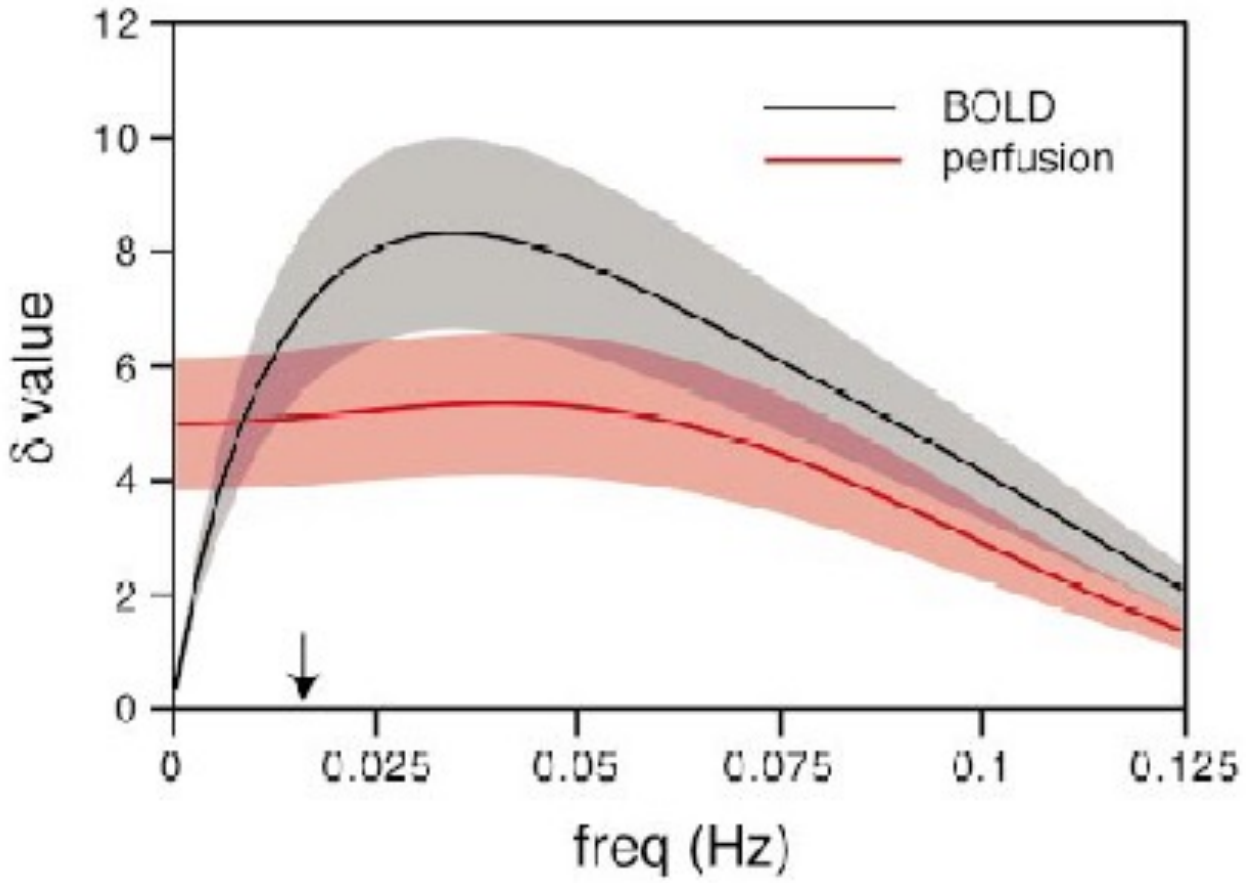
BOLD



Perfusion

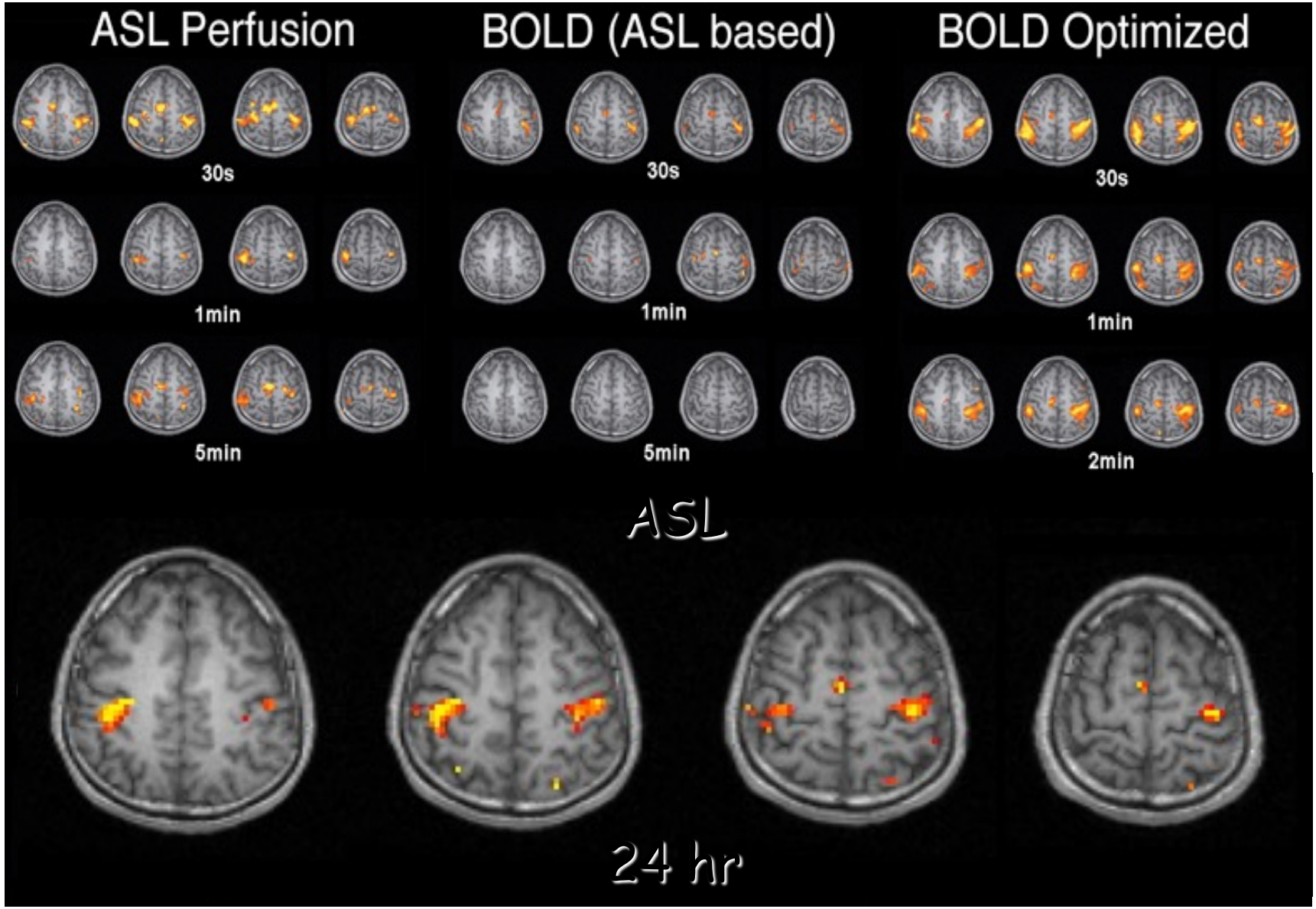
P. A. Bandettini, E. C. Wong, Magnetic resonance imaging of human brain function: principles, practicalities, and possibilities, *in* "Neurosurgery Clinics of North America: Functional Imaging" (M. Haglund, Ed.), p.345-371, W. B. Saunders Co., 1997.

Better than BOLD for long duration activation…



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

Perfusion vs. BOLD: Low Task Frequency



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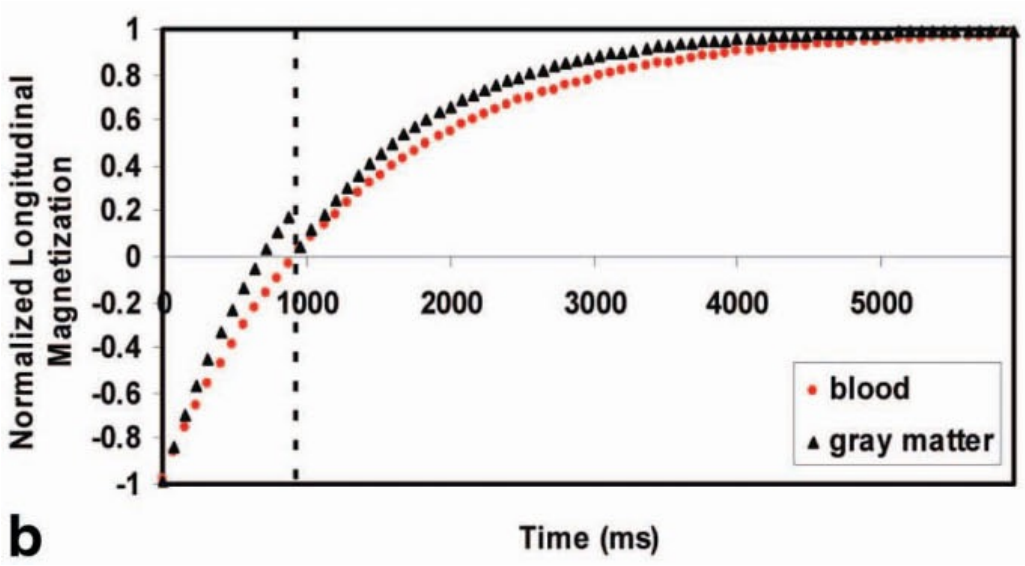
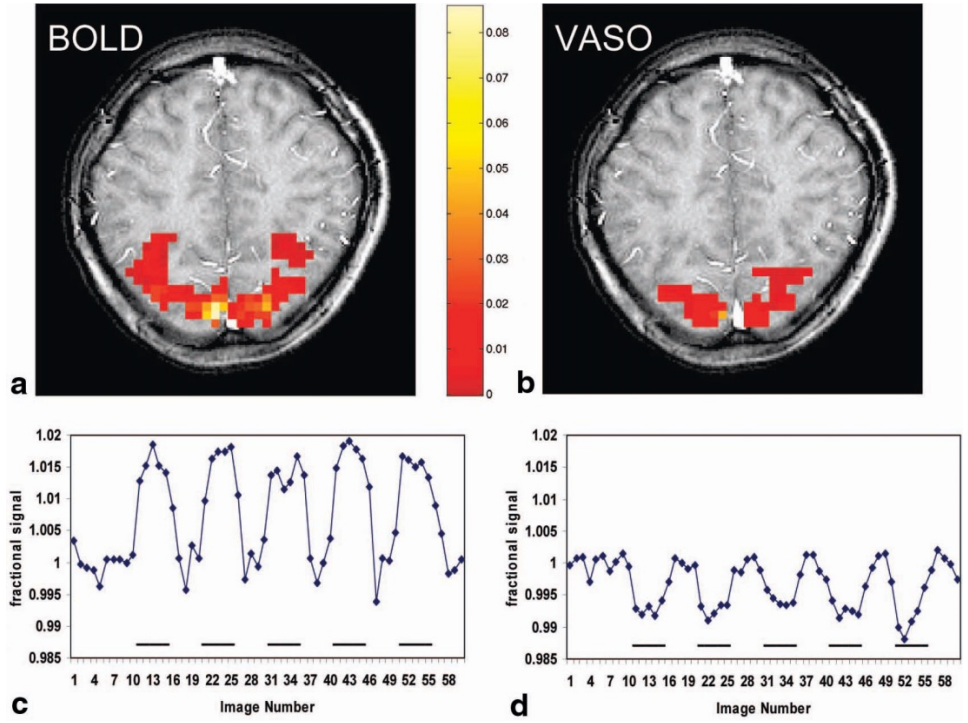
Activation-induced Blood Volume Changes: "VASO"

H. Lu, et al, MRM 50: 263-274, 2003





Null blood based on T1 difference between blood and tissue
..more blood -> less signal.

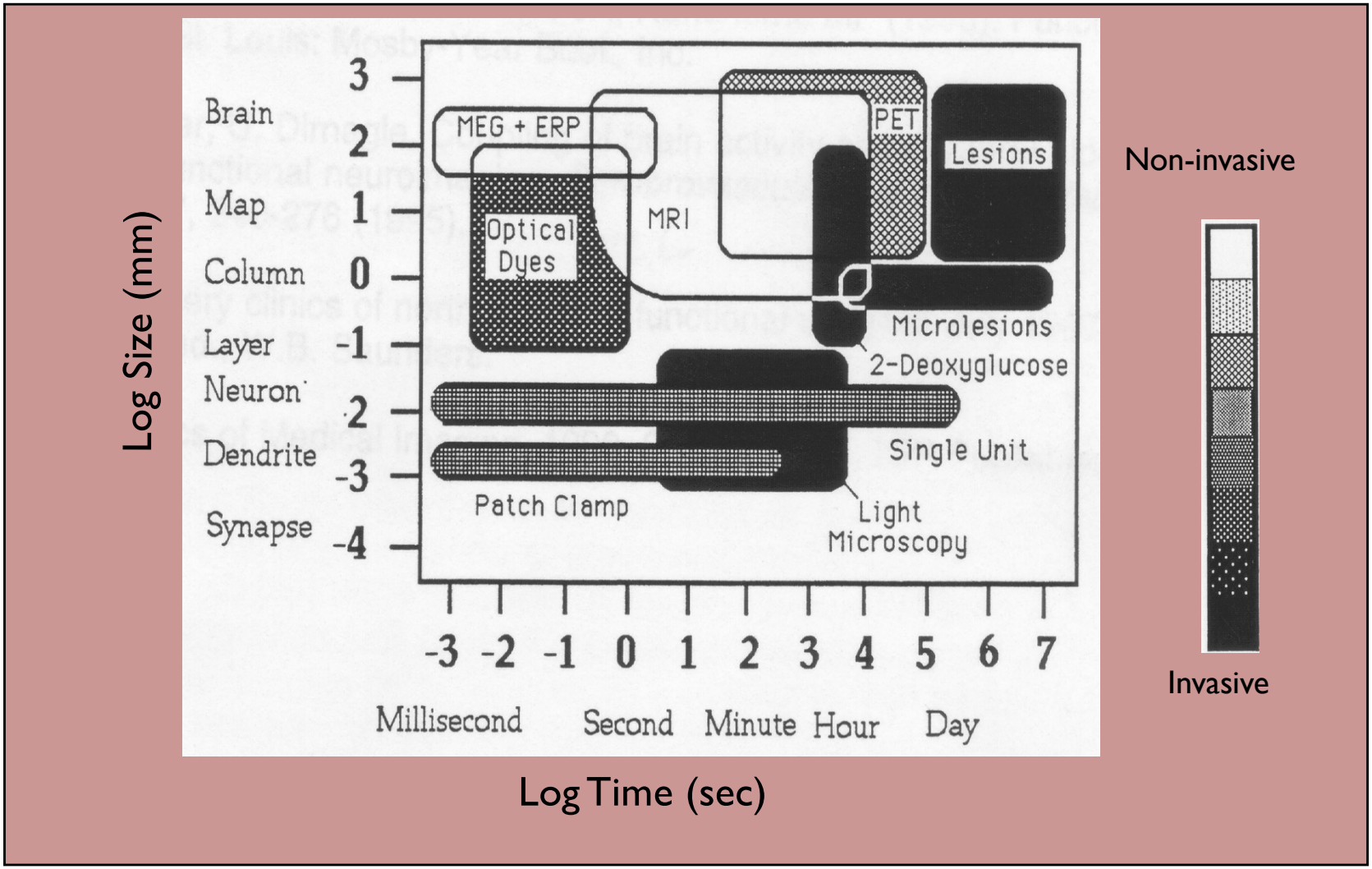
Contrast

Resolution

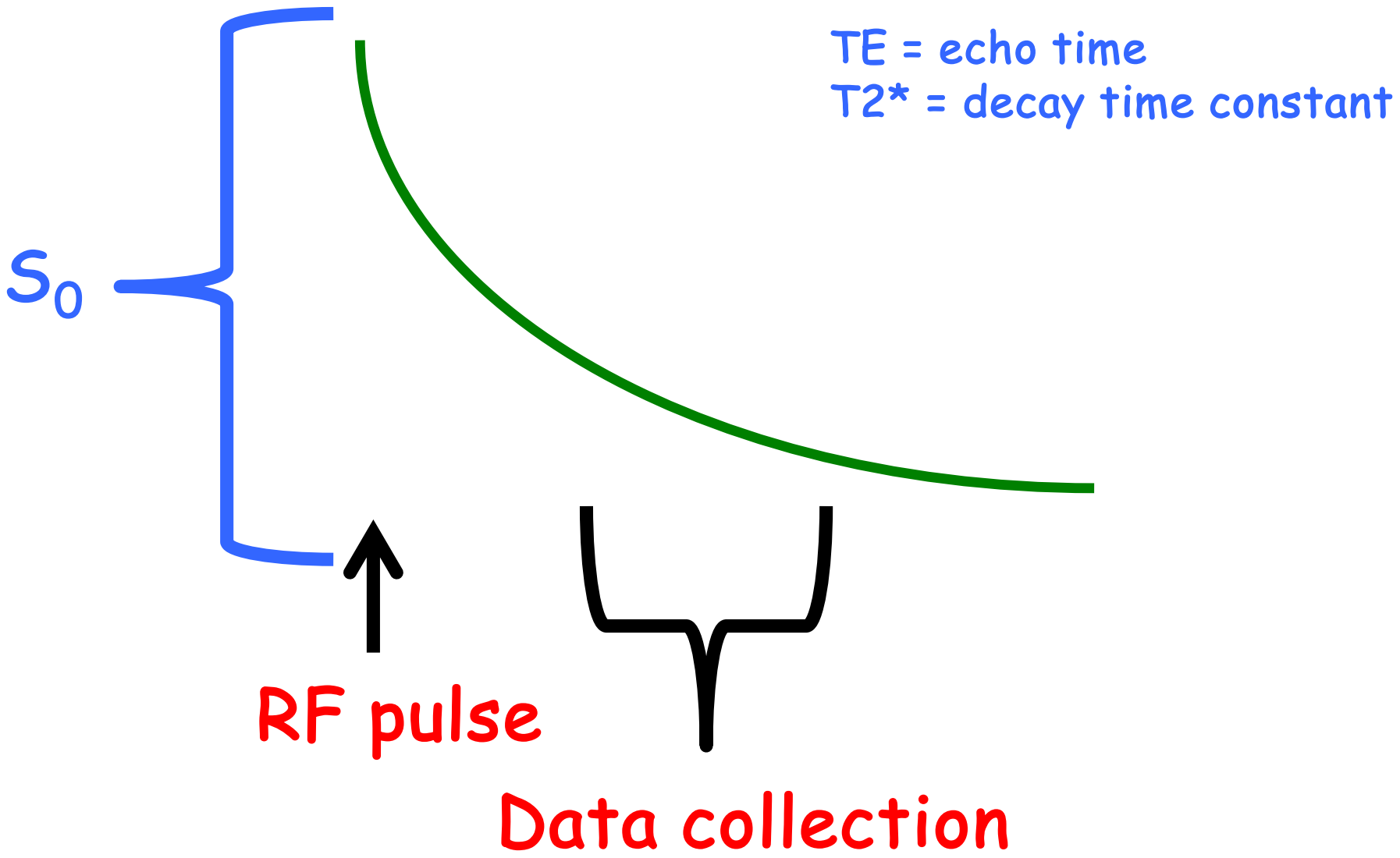
Paradigms

Processing

Functional Neuroimaging Techniques



$$\text{Signal} = S_0 \, e^{-TE/T2^*}$$



Neuronal Activation

?

Measured Signal

?

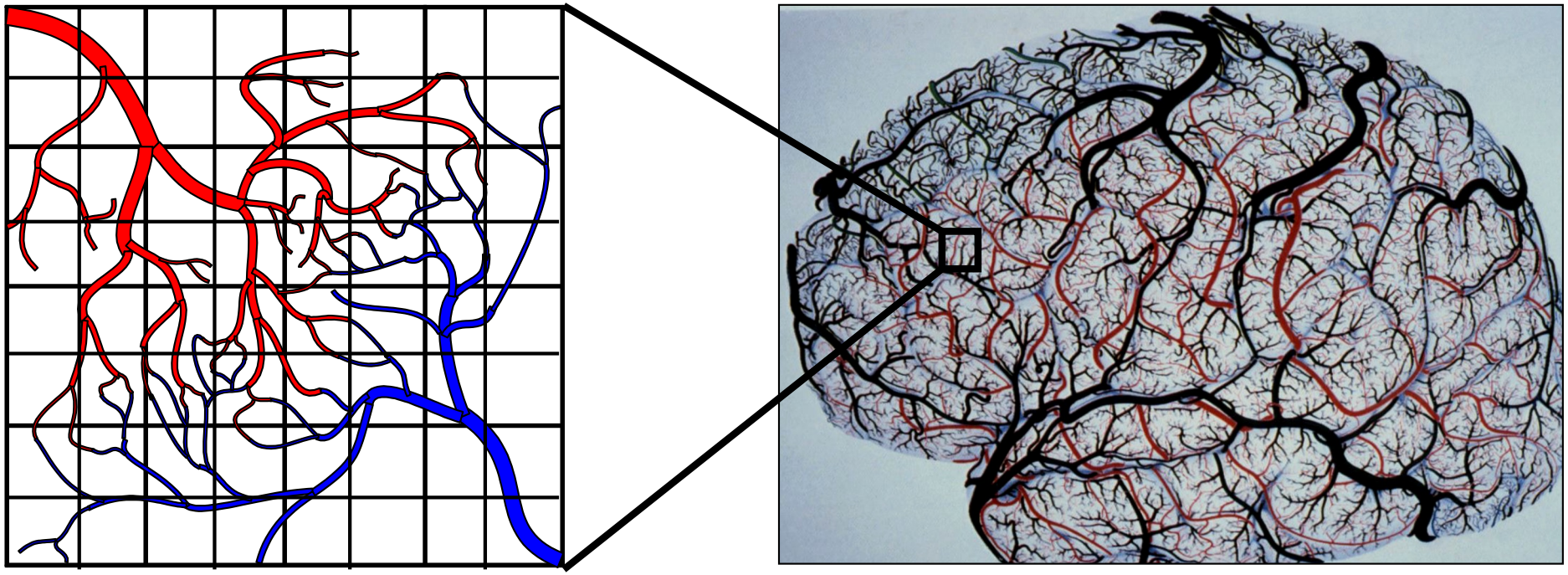
?

Hemodynamics

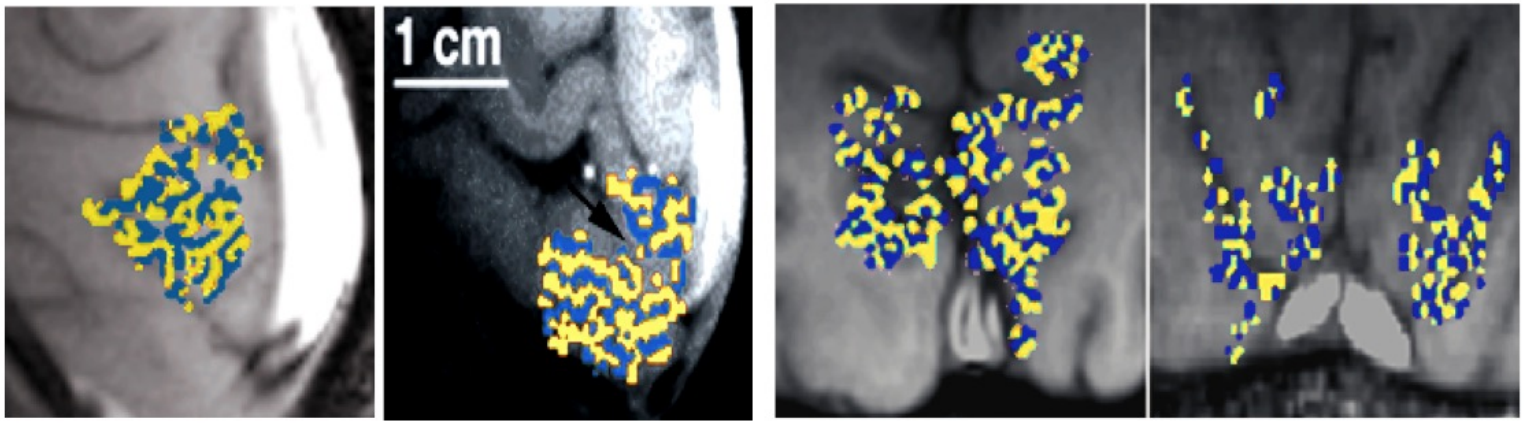
?

?

Noise



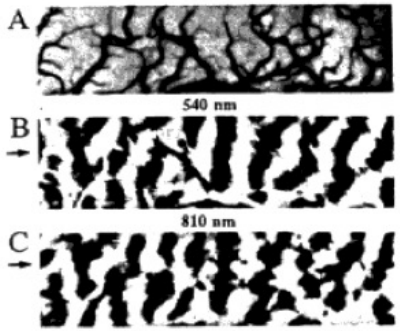
Ocular Dominance Column Mapping



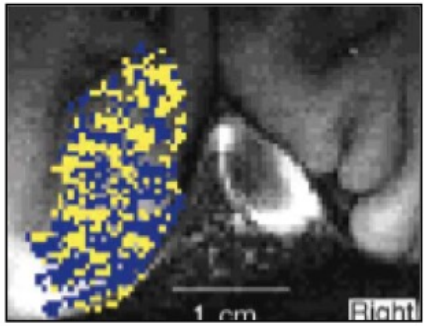
Menon, R. S., S. Ogawa, et al. (1997). J Neurophysiol 77(5): 2780-7.

0.54 x 0.54 in plane resolution

Optical Imaging



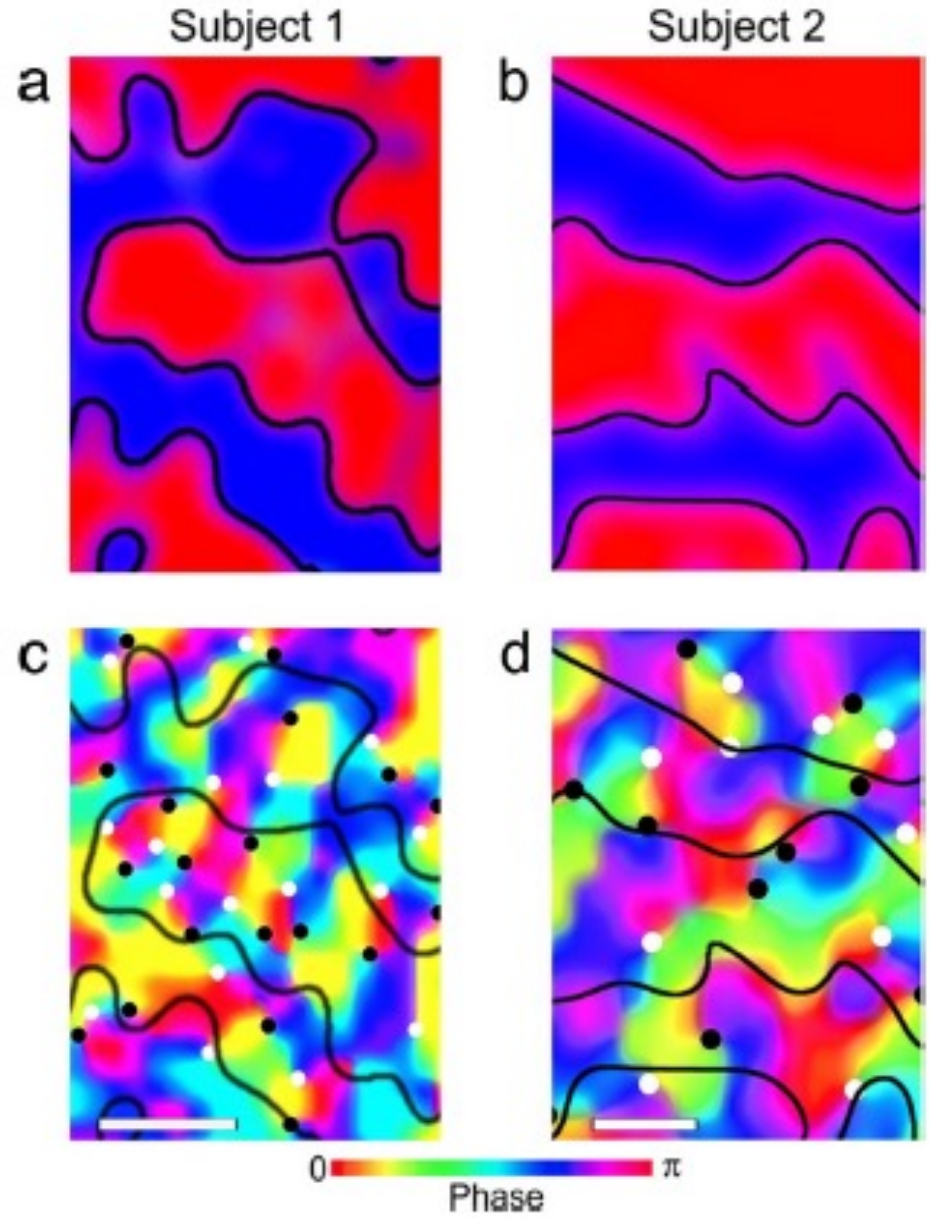
R. D. Frostig et. al, PNAS
87: 6082-6086, (1990).



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

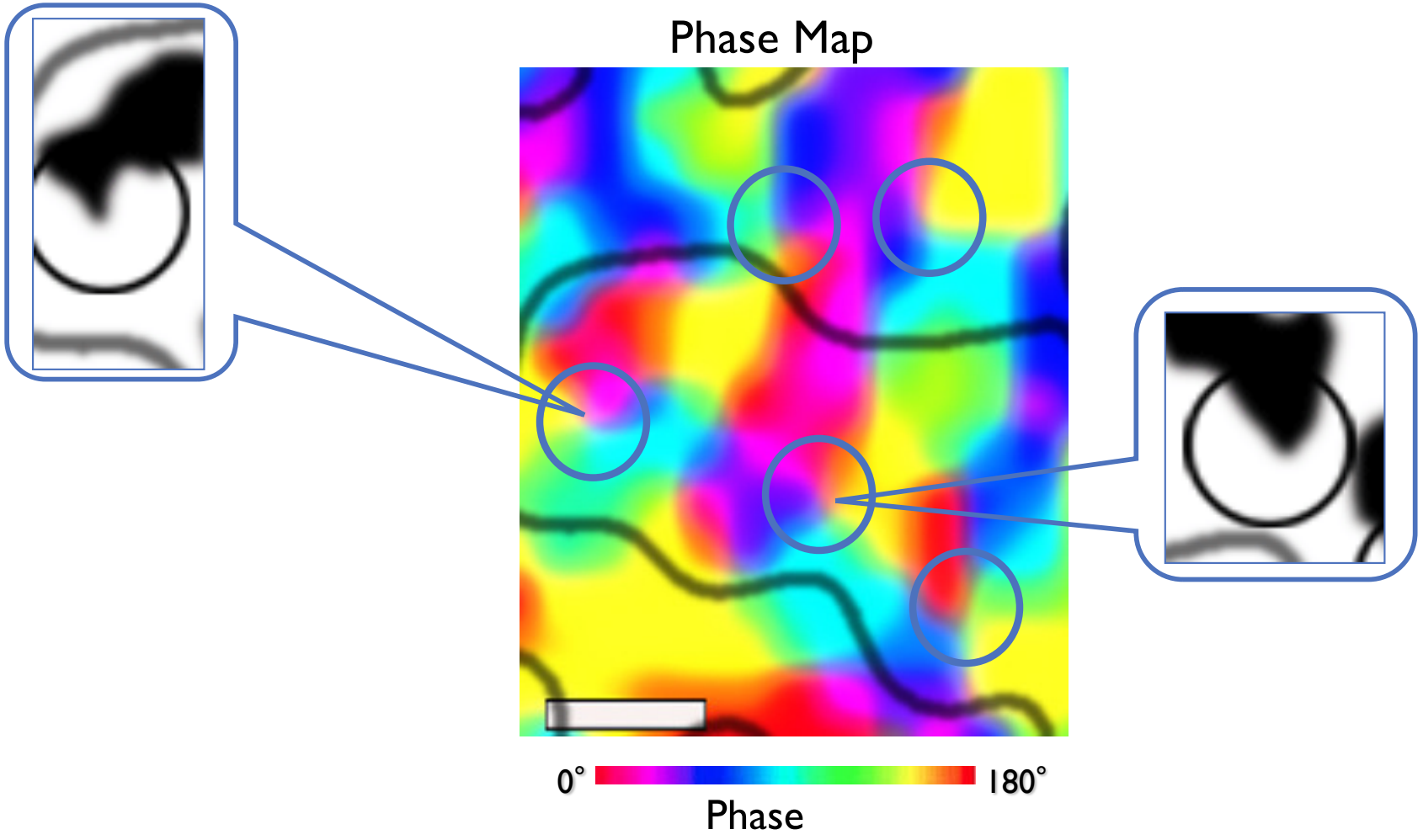
0.47 x 0.47 in plane resolution

3.5mm at 1.5T (S. Engel et al - 1994)
3.9mm (GE), 3.4mm (SE) at 3T (L. Parkes et al - 2005)
2.3 mm at 7T (A. Schmuel et al - 2007)



Yacoub et al. PNAS 2008

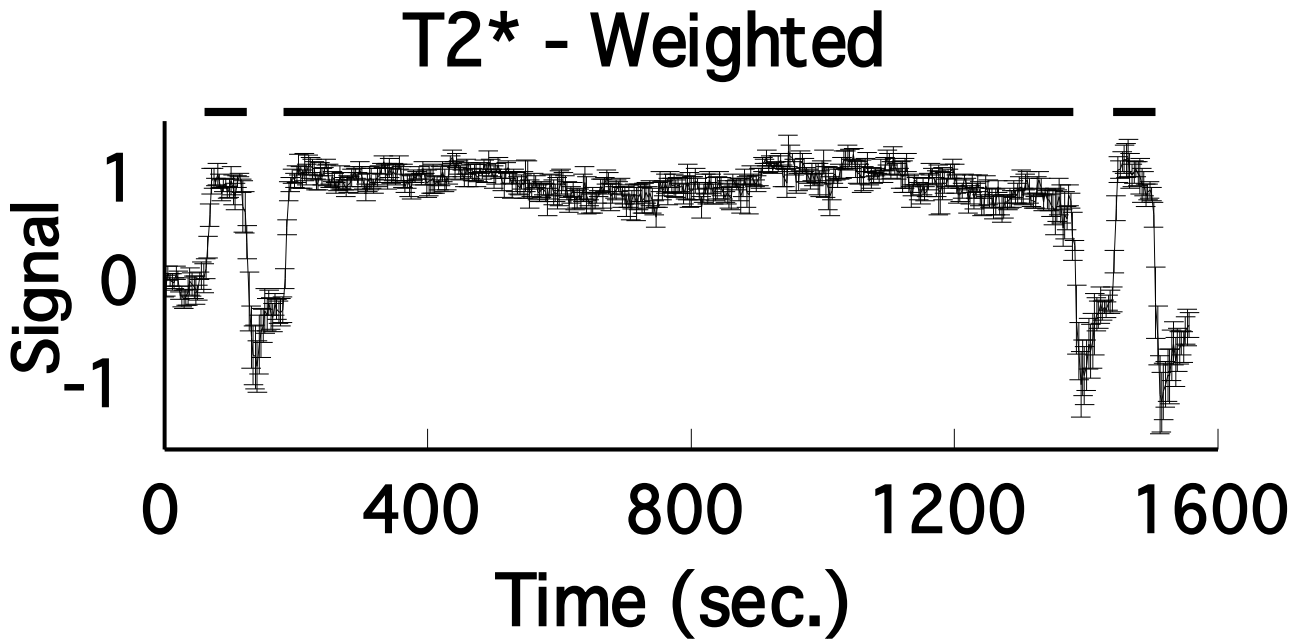
Orientation Columns in Human V1 as Revealed by fMRI at 7T



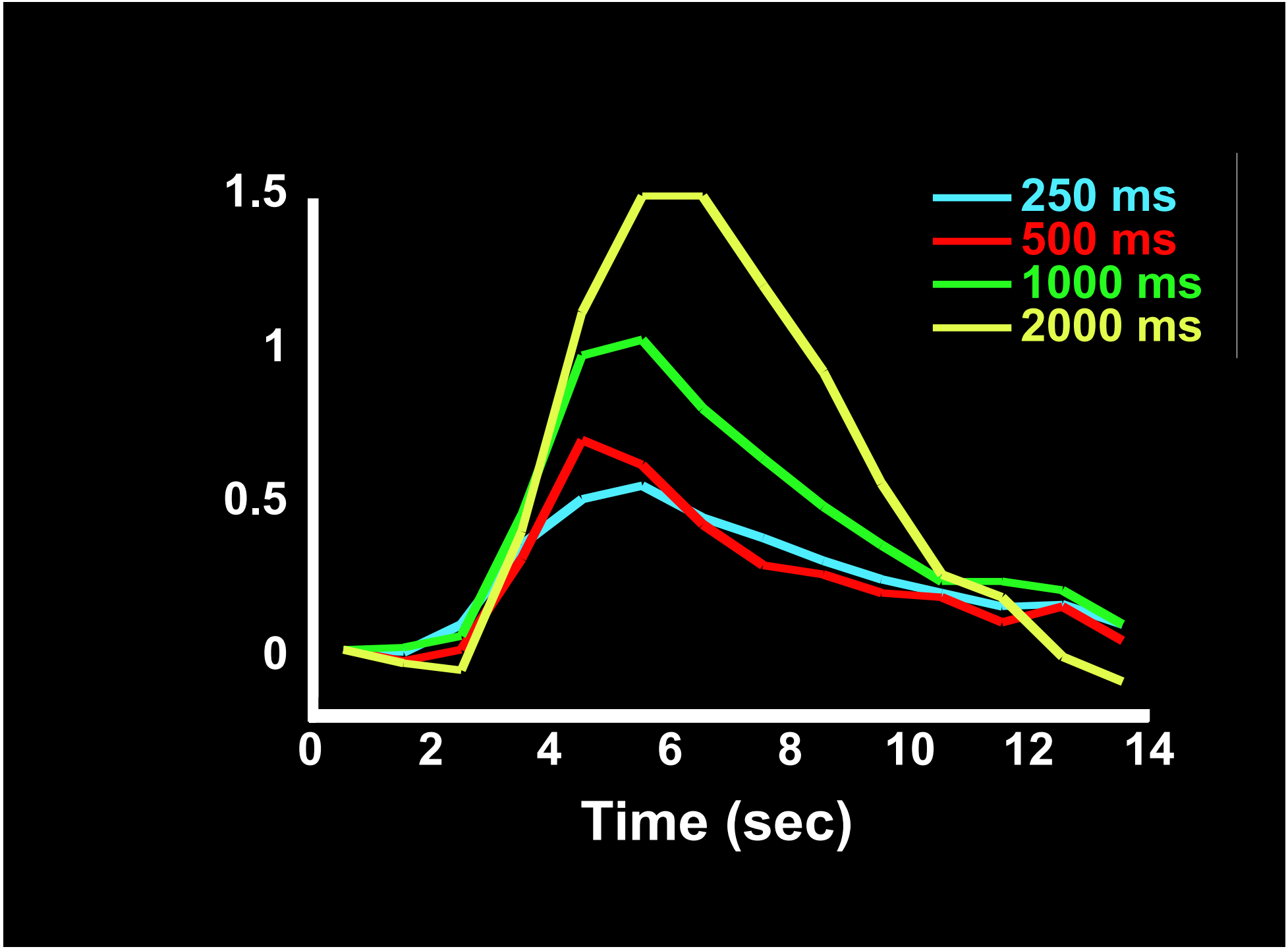
Scalebar = 0.5 mm

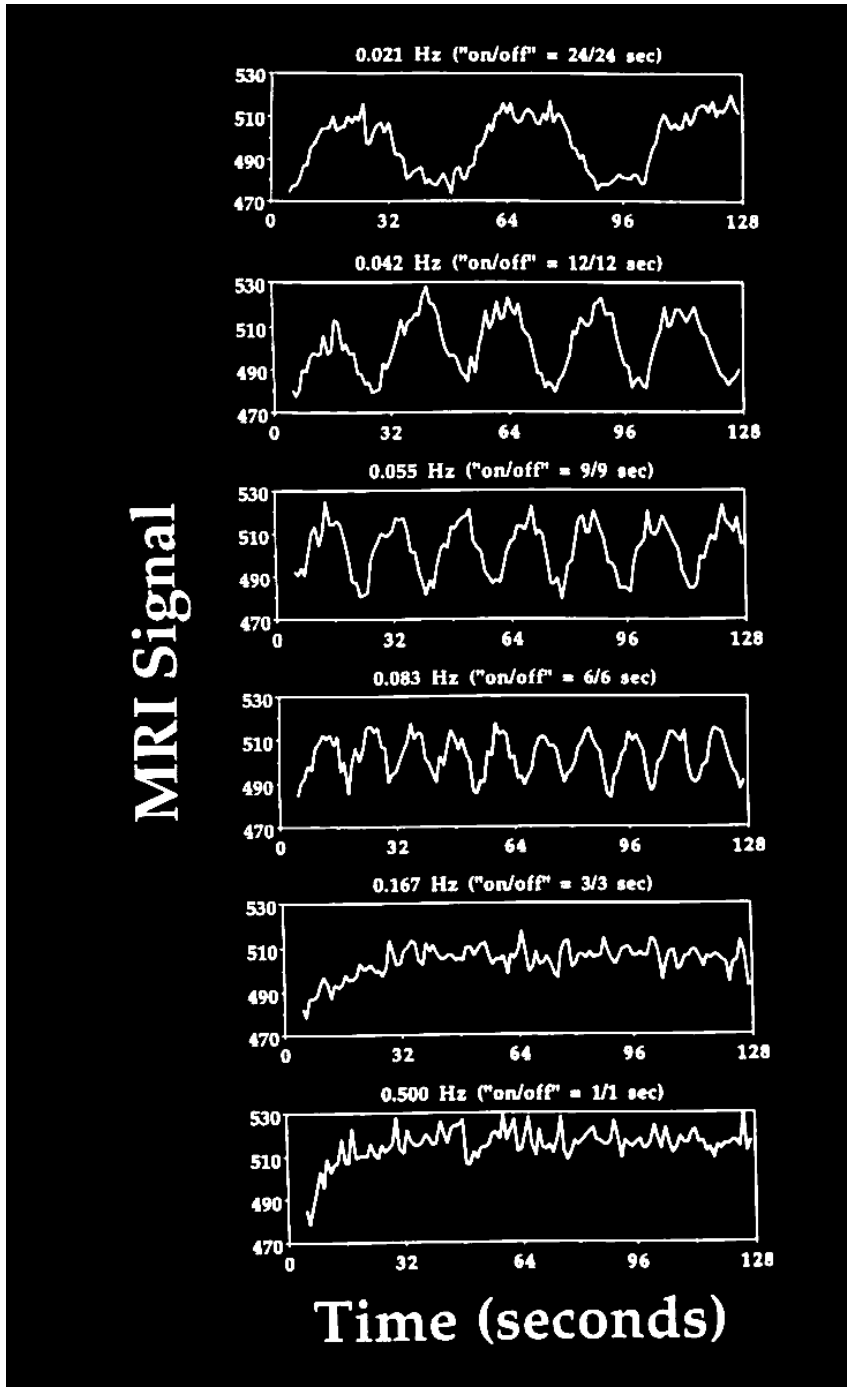
Yacoub et al. PNAS 2008

20 minutes continuous activation

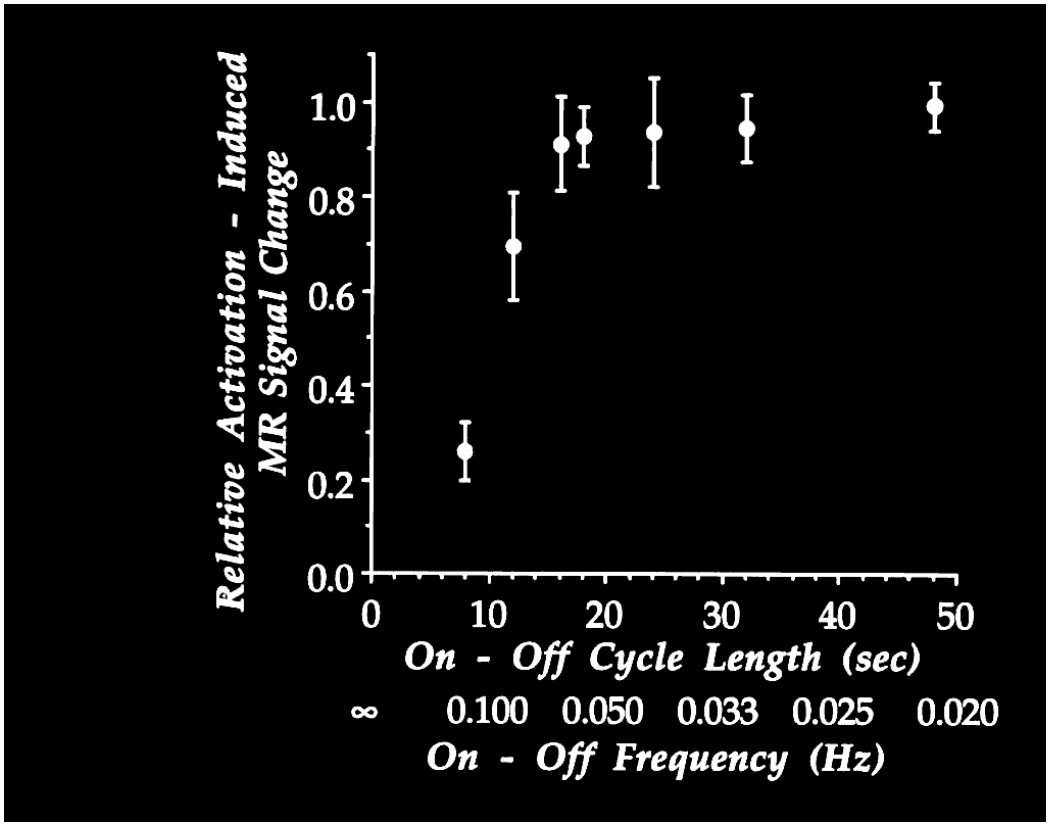


P. A. Bandettini, K. K. Kwong, T. L. Davis, R. B. H. Tootell, E. C. Wong, P. T. Fox, J. W. Belliveau, R. M. Weisskoff, B. R. Rosen, (1997). "Characterization of cerebral blood oxygenation and flow changes during prolonged brain activation." *Human Brain Mapping* 5, 93-109.


1.5
1
0.5
0
0
2
4
6
8
10
12
14
Time (sec)
250 ms
500 ms
1000 ms
2000 ms



How rapidly can one switch on and off?

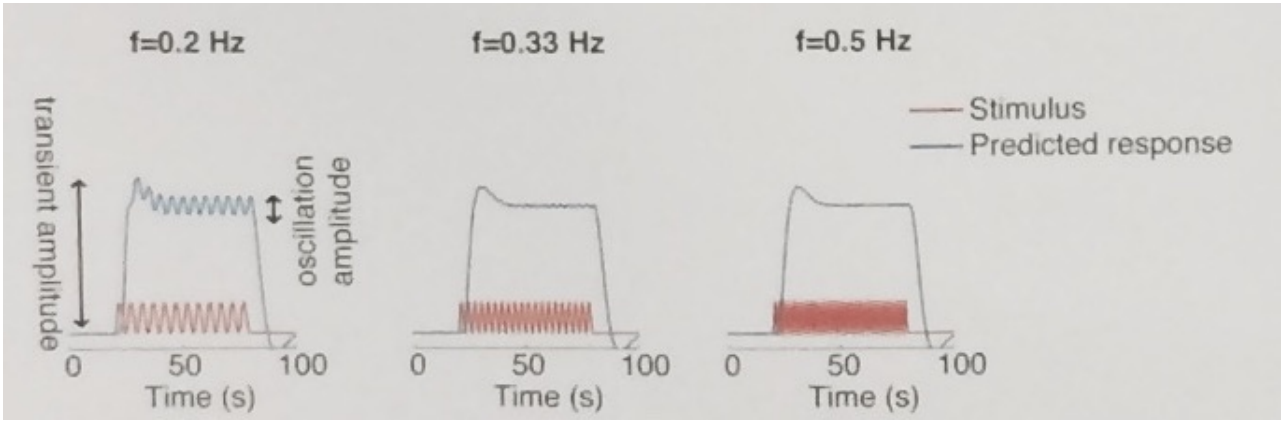


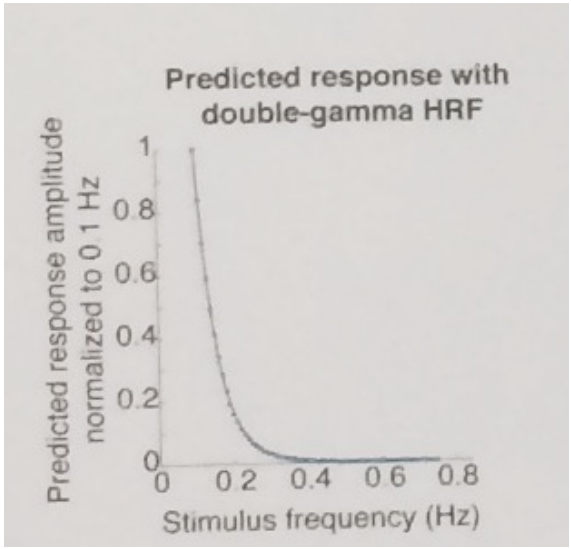
P. A. Bandettini,, Functional MRI using the BOLD approach: dynamic characteristics and data analysis methods, in "Diffusion and Perfusion: Magnetic Resonance Imaging" (D. L. Bihan, Ed.), p.351-362, Raven Press, New York, 1995.

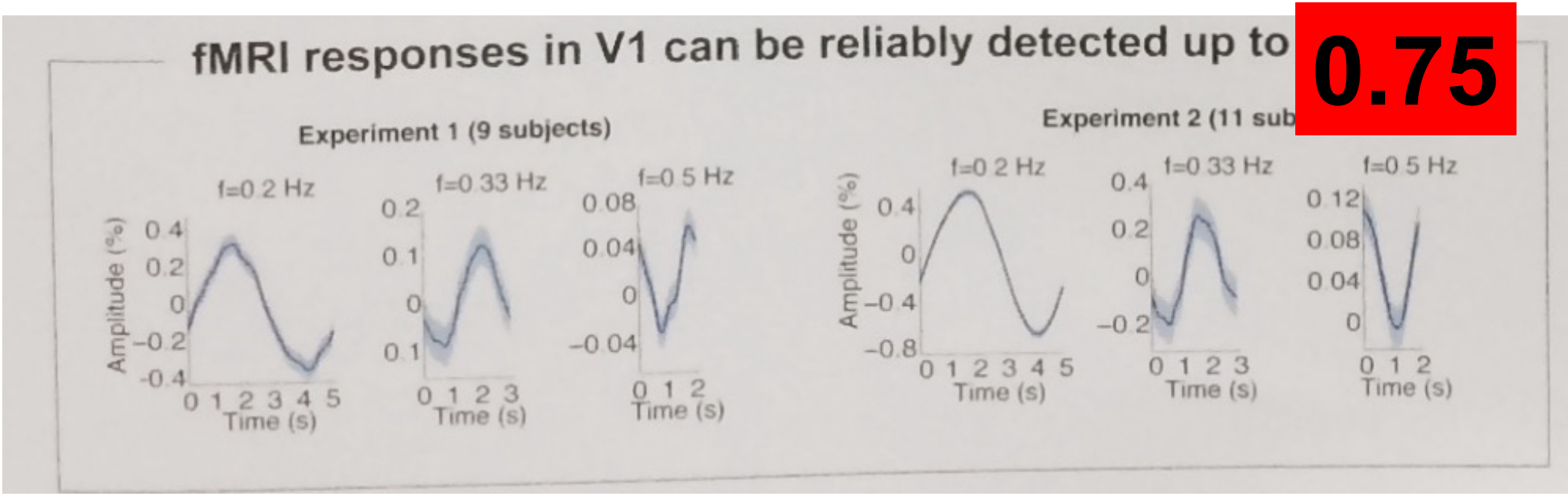
Detection of delta-band oscillations in visual cortex using fast fMRI and simultaneous EEG-fMRI

Laura D. Lewis, Kawin Setsompop, Bruce R. Rosen, Jonathan R. Polimeni

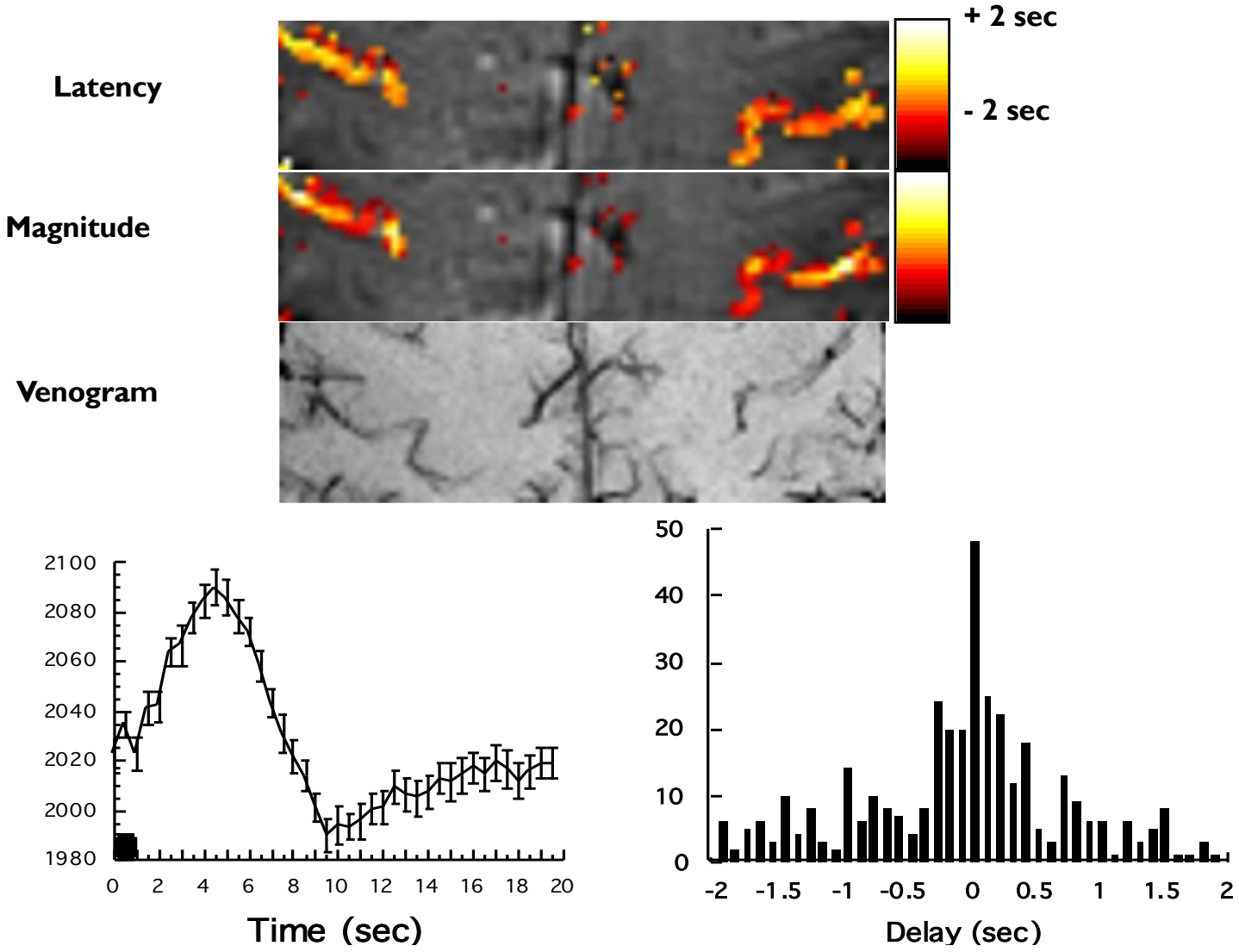
OHBM 2015







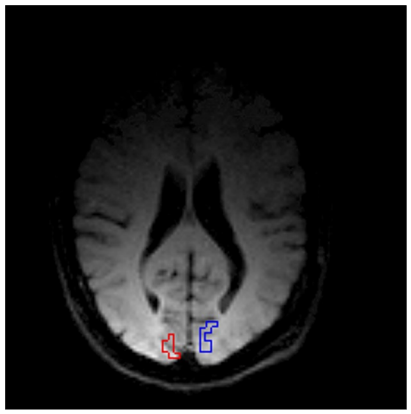
Latency Variation…



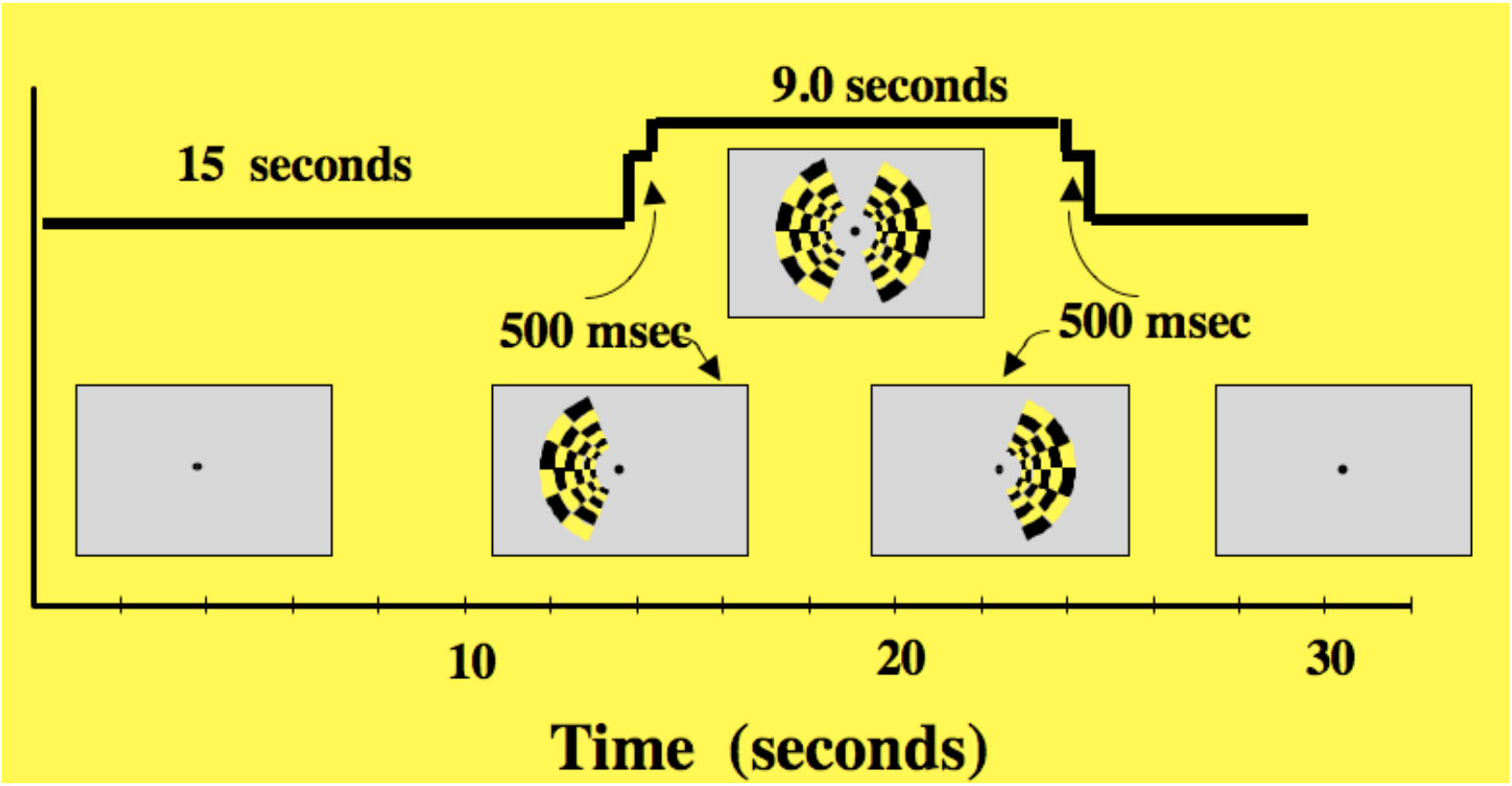
P.A. Bandettini, (1999) "Functional MRI" 205-220.

Hemi-Field Experiment

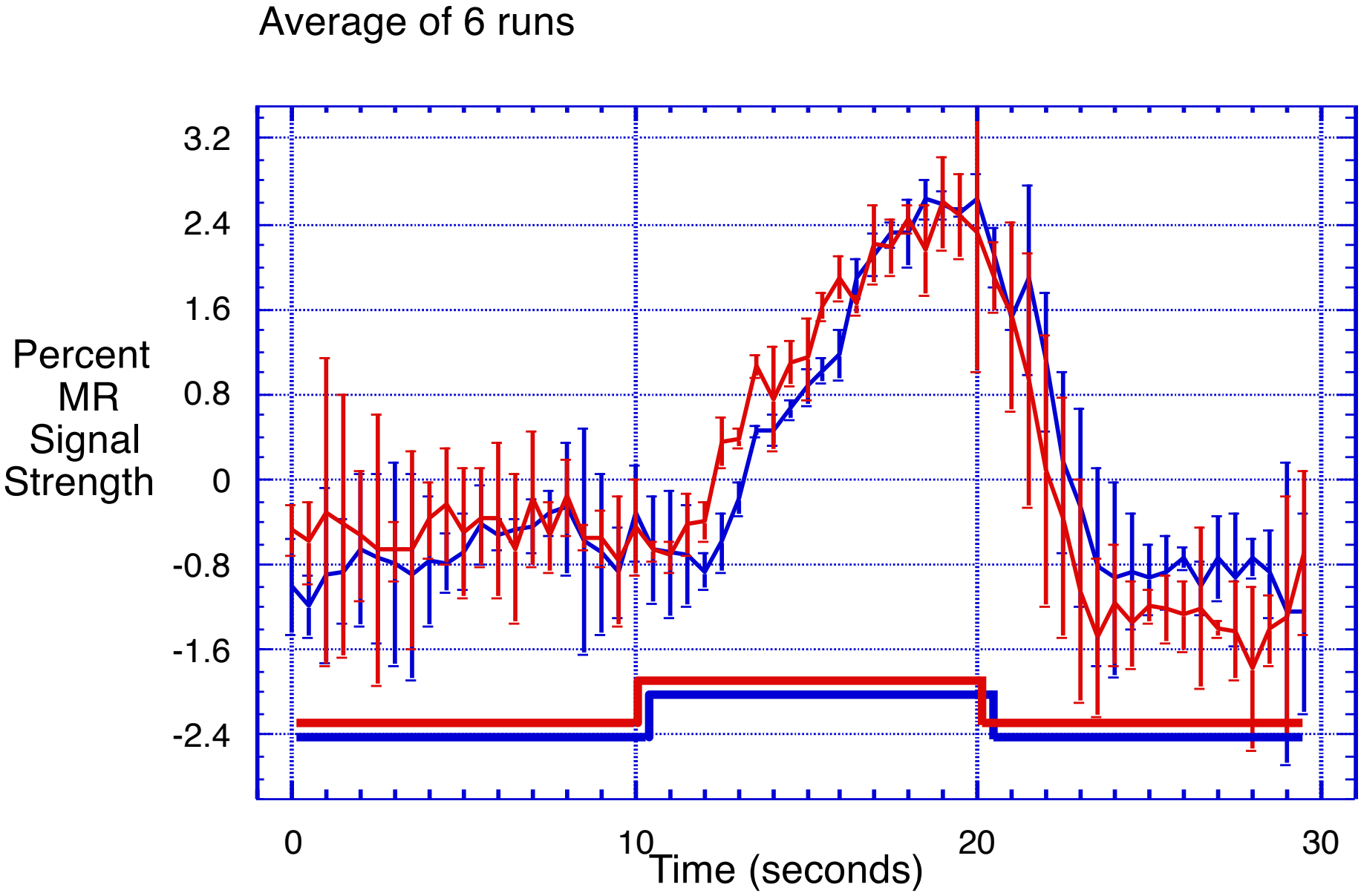
Right Hemisphere

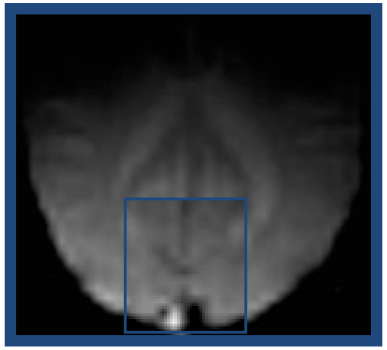


Left Hemisphere



Hemi-field with 500 msec asynchrony





Timing

500 ms

500 ms

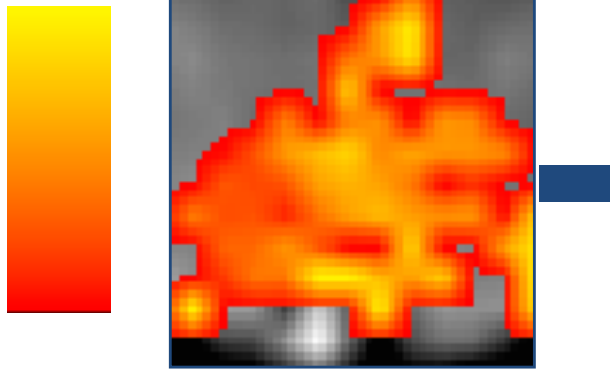
Right Hemifield

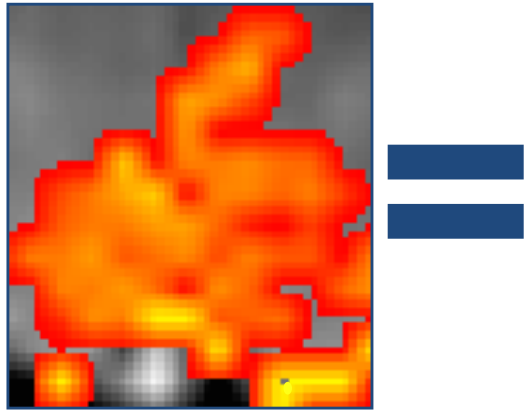
Left Hemifield

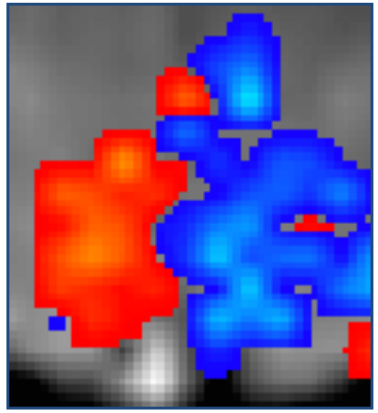
+ 2.5 s

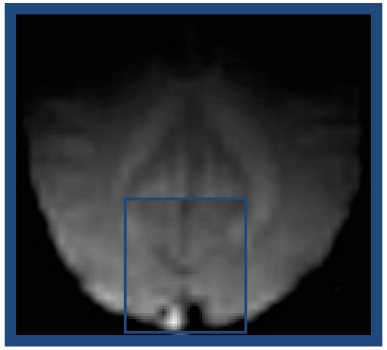
0 s

- 2.5 s









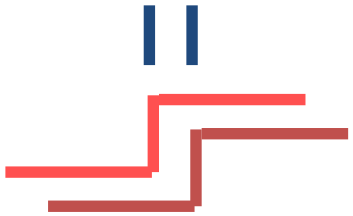
Timing

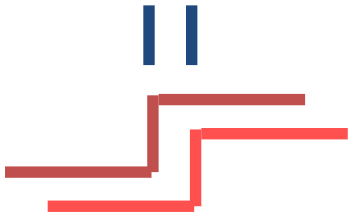
250 ms

250 ms

Right Hemifield

Left Hemifield

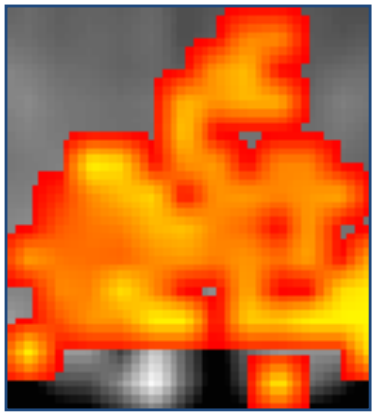


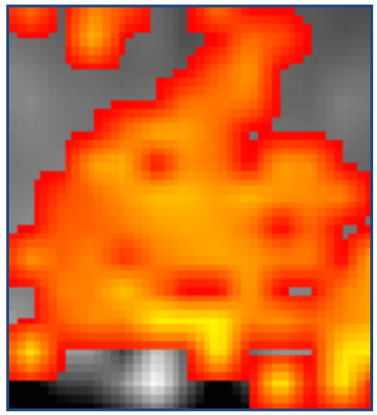


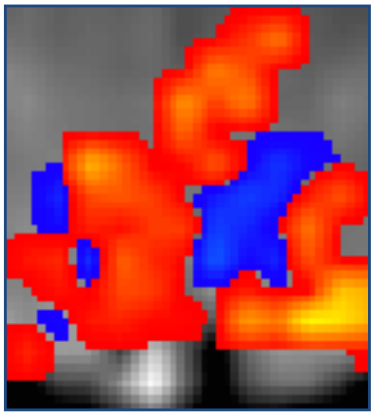
+ 2.5 s

0 s

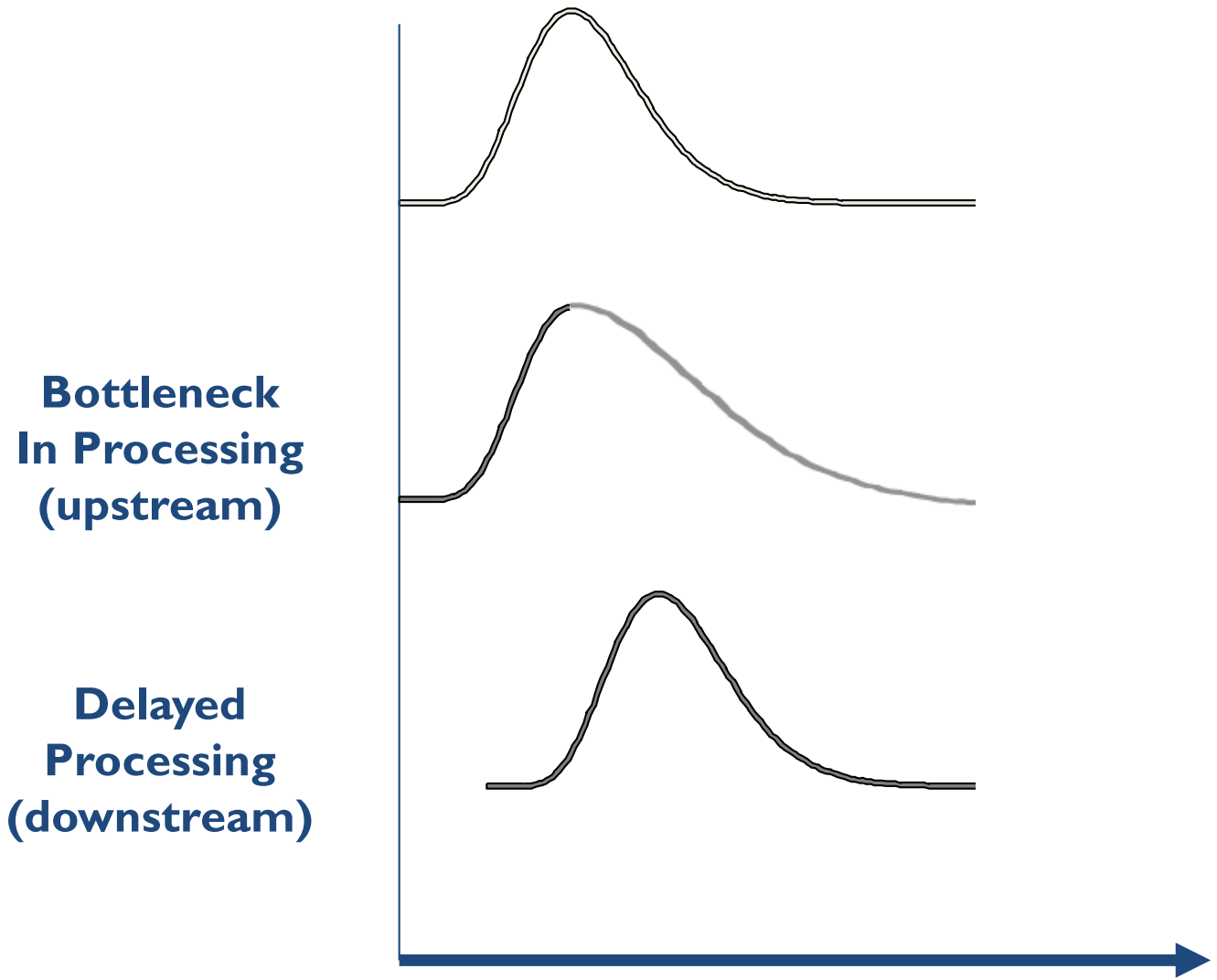
- 2.5 s







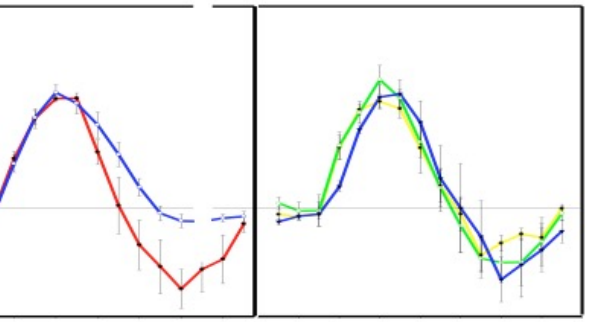
Hemodynamic Response Modulation

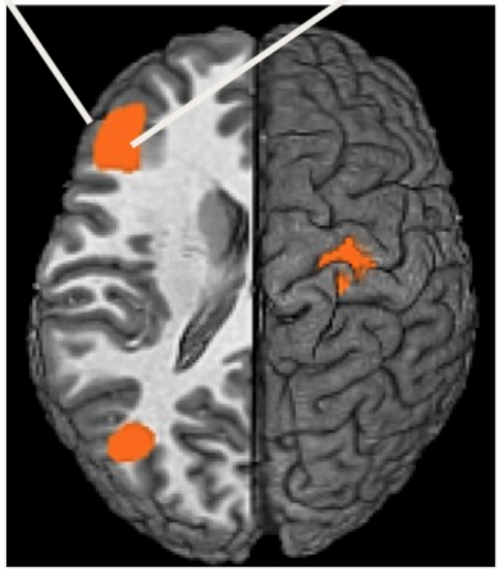


Word vs. Non-word

0°, 60°, 120° Rotation

Rotational Delay	Lexical Delay: Words	Lexical Delay: Non-Words	Mean Reaction Time
0°	smudge	dierts	823 ms
60°	frolic	cuhlos	891 ms
120°	slouch	yeamus	1446 ms
Mean Reaction Time	986 ms	1219 ms	



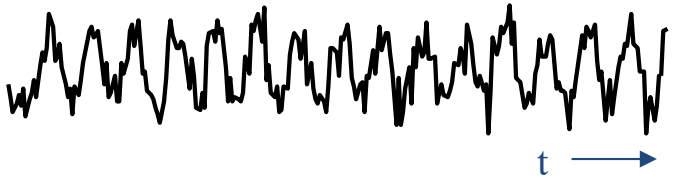


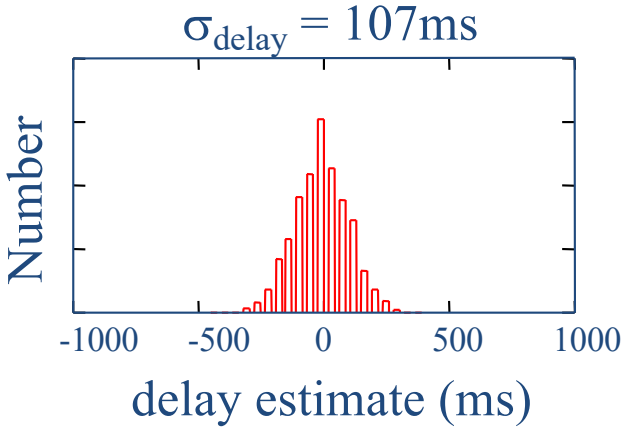
Bellgowan, et al (2003), PNAS 100, 15820–15283

Even if no hemodynamic variability exists…

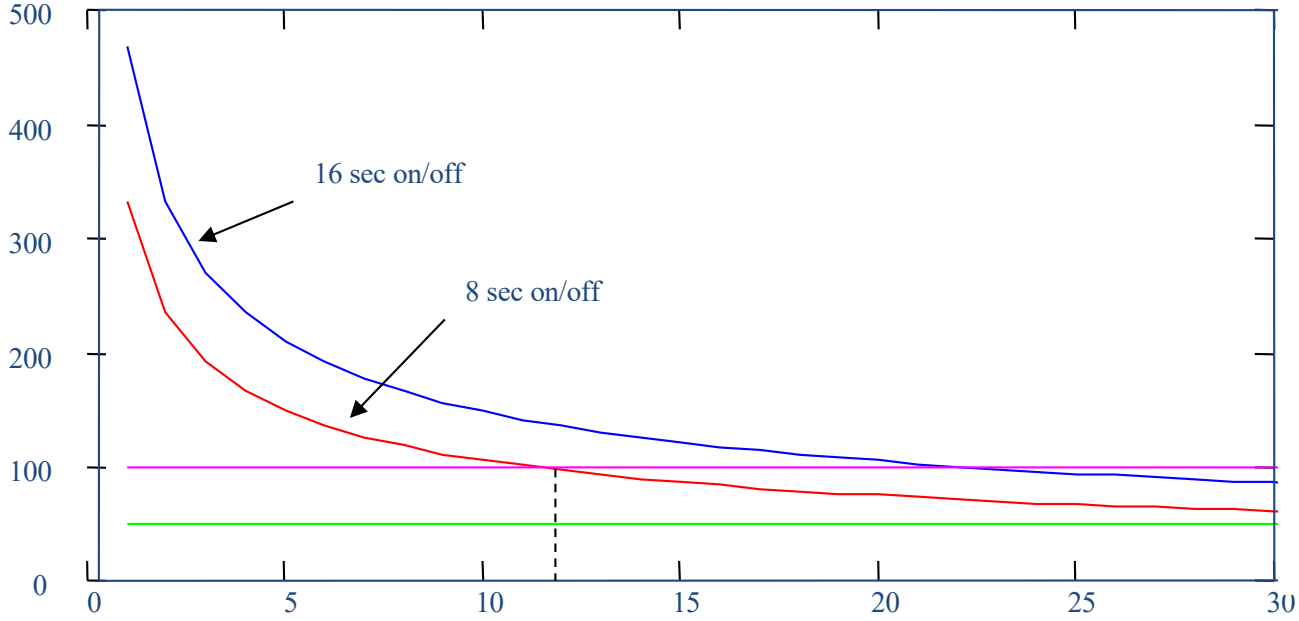
1 run:

1% Noise
4% BOLD
256 time pts /run
1 second TR



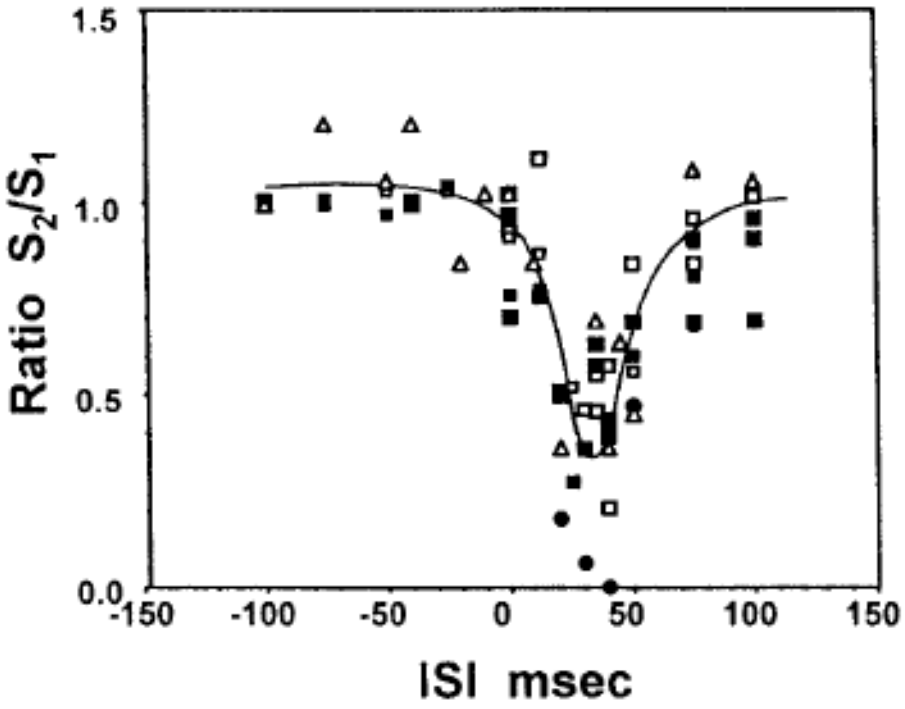


Smallest latency
Variation Detectable
(ms) (p < 0.001)



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

Contrast

Resolution

Paradigms

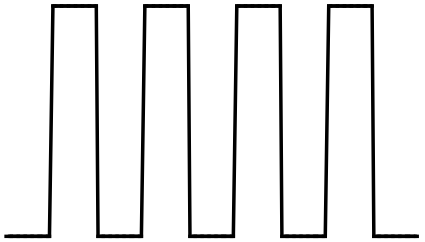
Processing

fMRI Paradigm Designs and Processing Strategies

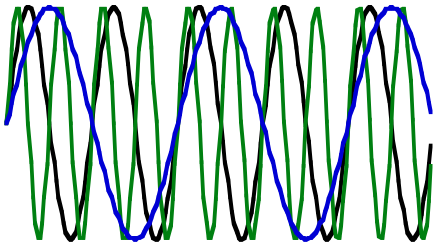
1. Neuronal Activation Input Strategies
2. Resting State fMRI
3. fMRI Decoding

Neuronal Activation Input Strategies

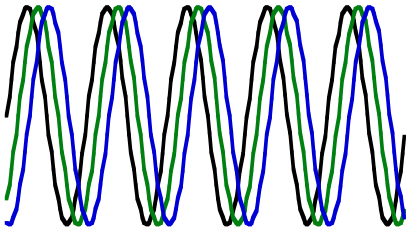
1. Block Design



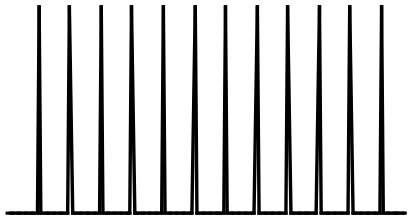
2. Frequency Encoding



3. Phase Encoding

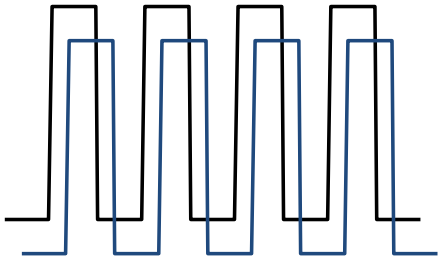


4. Event-Related



5. fMRI adaptation

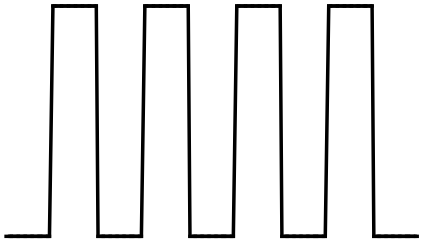
6. Orthogonal Block Design



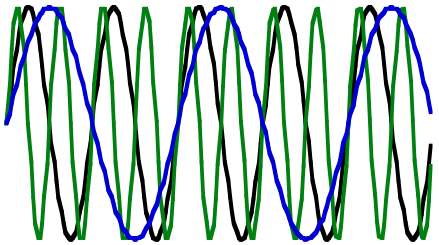
7. Free Behavior Design.

Neuronal Activation Input Strategies

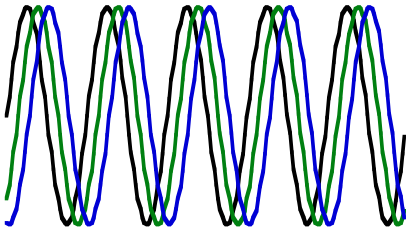
1. Block Design



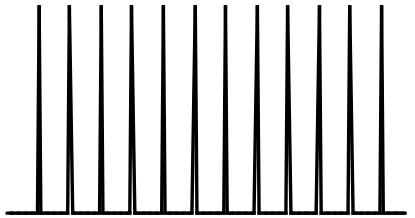
2. Frequency Encoding



3. Phase Encoding

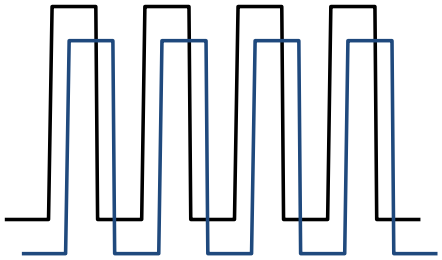


4. Event-Related

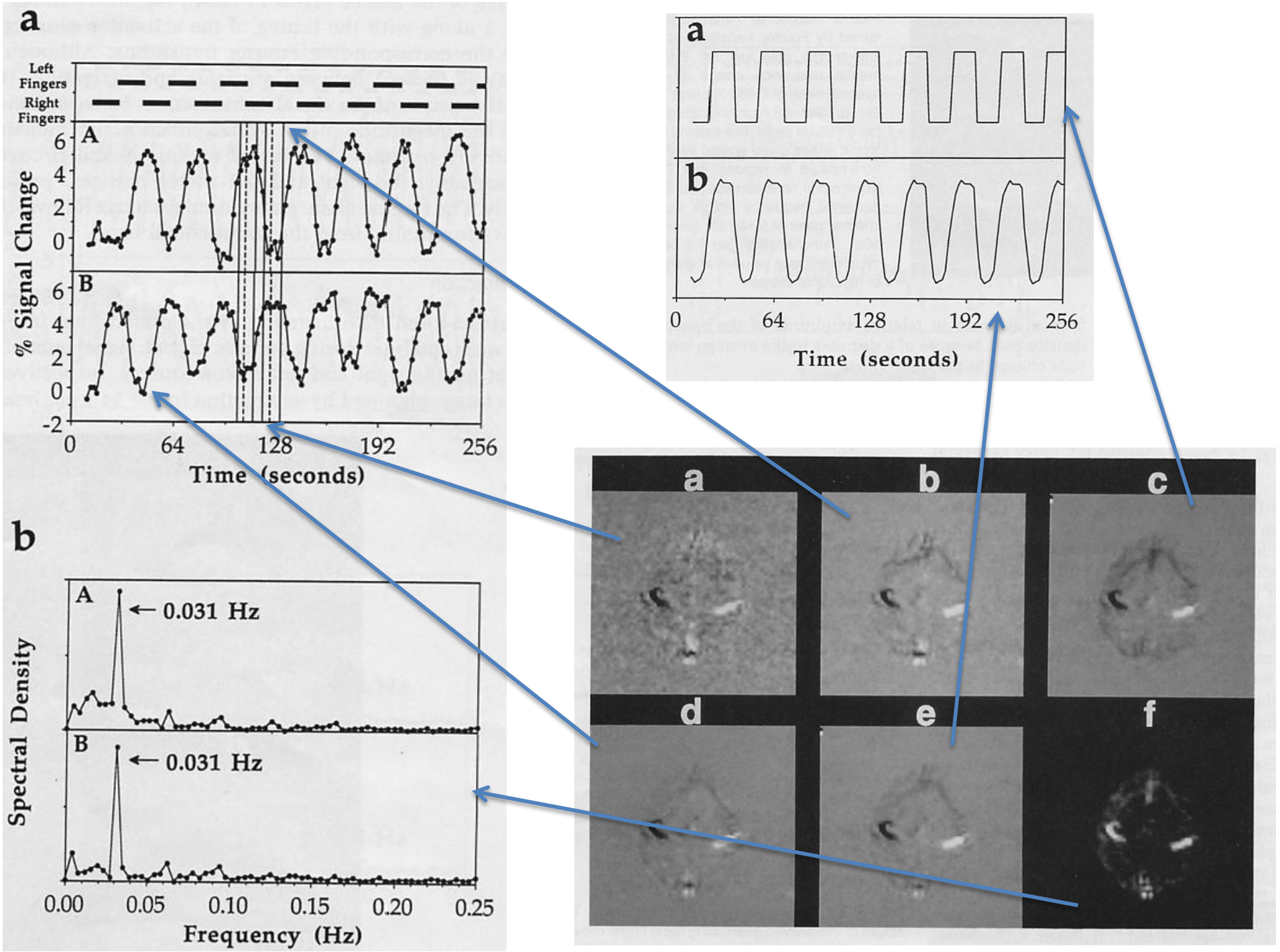


5. fMRI adaptation

6. Orthogonal Block Design

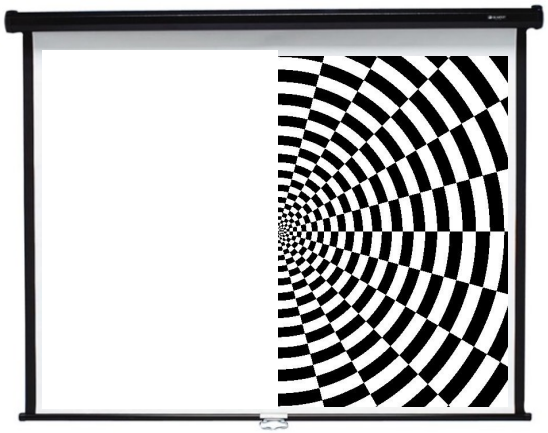


7. Free Behavior Design.

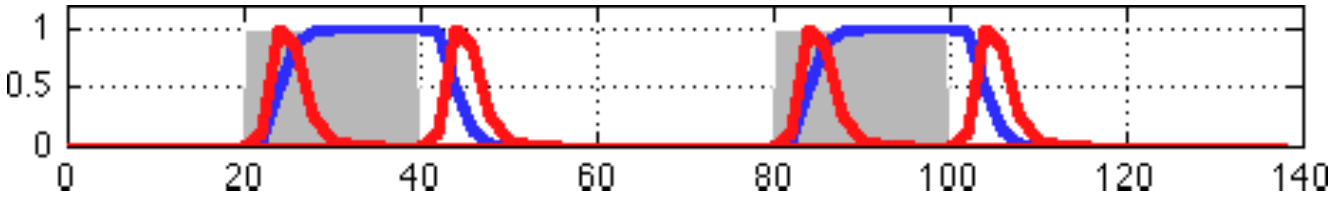


P. A. Bandettini, A. Jesmanowicz, E. C. Wong, J. S. Hyde, Processing strategies for time-course data sets in functional MRI of the human brain. *Magn. Reson. Med.* 30, 161-173 (1993).

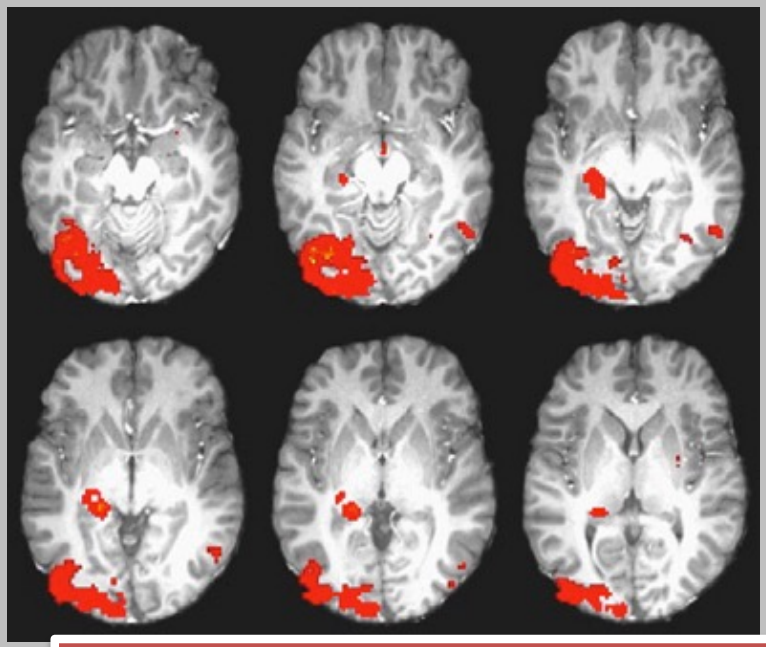
Predictive Response Model effect on fMRI Results (III)



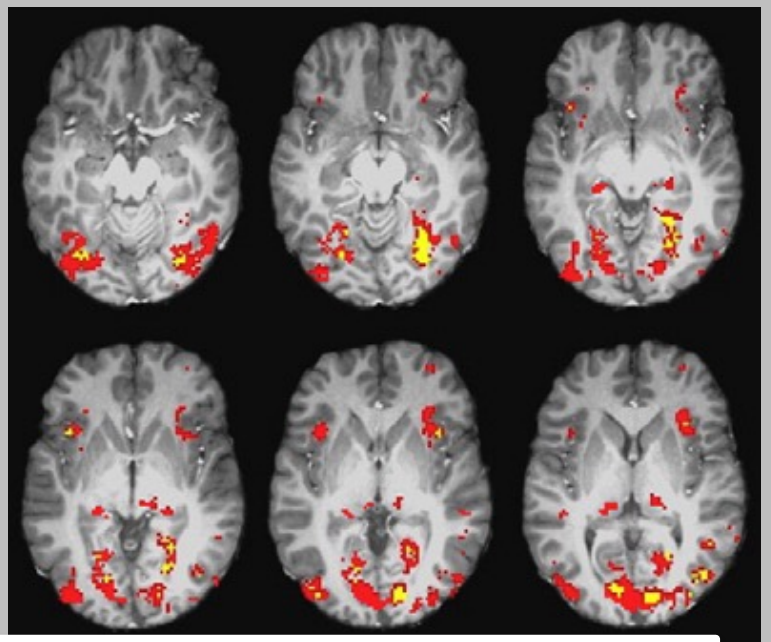
BLOCK DESIGN & HEMIFIELD VISUAL STIMULATION



SUSTAINED RESPONSE MODEL

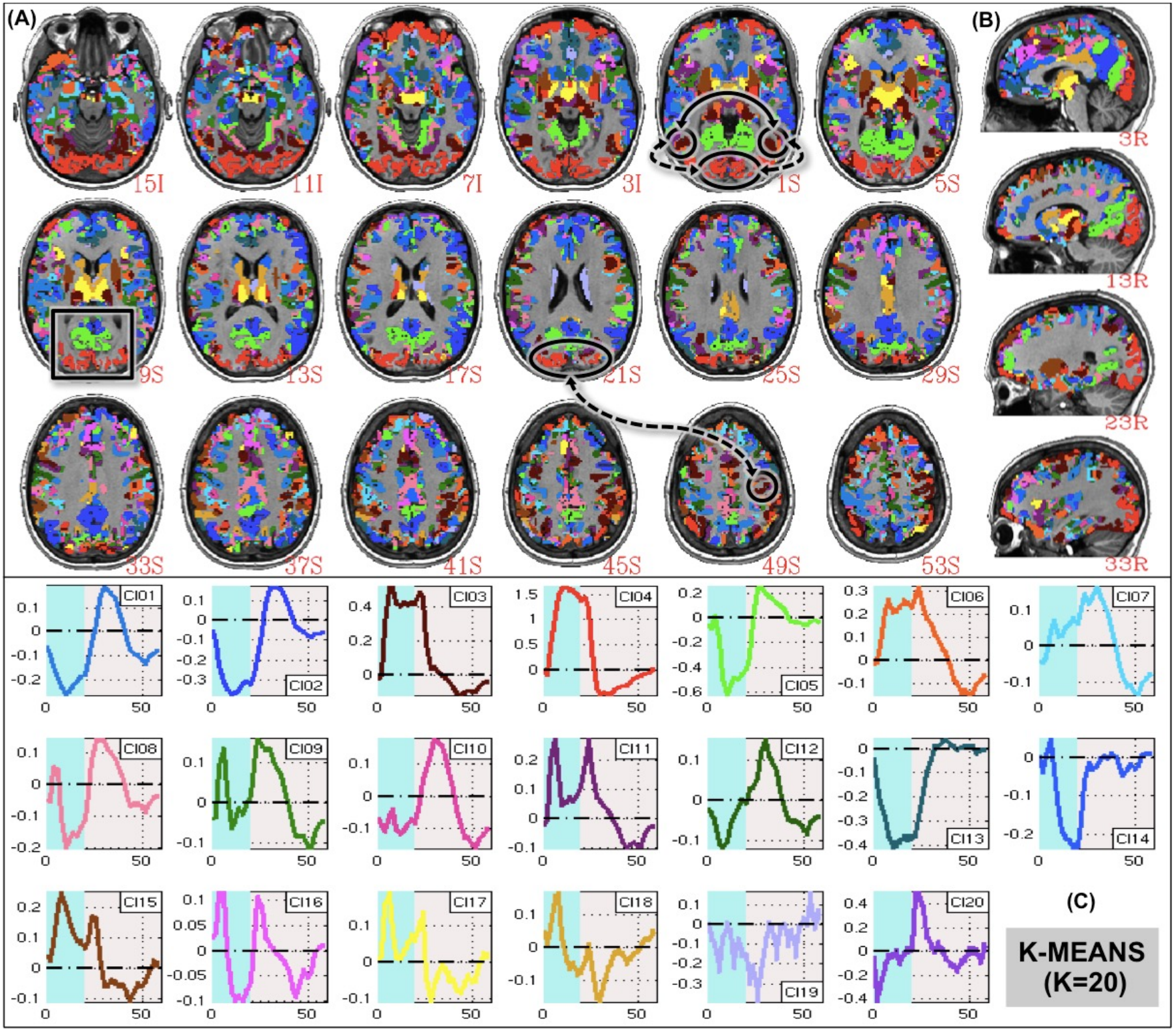


ONSET/OFFSET RESPONSE MODEL



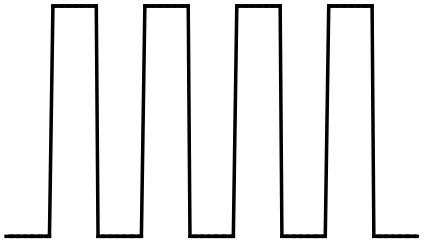
DIFFERENT RESPONSE SHAPES ARE PRESENT ACROSS DIFFERENT REGIONS OF THE BRAIN FOR A SINGLE STIMULUS TYPE

Uludag et al. Magn Reson Imaging. 2008 Sep;26(7):863-9.

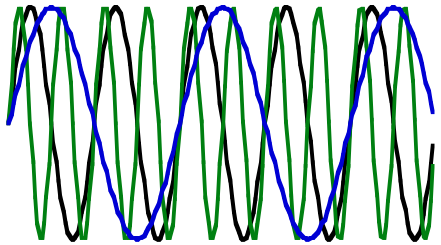

(A)
15I
11I
7I
3I
1I
5S
9S
13S
17S
21S
25S
29S
33S
37S
41S
45S
49S
53S
(B)
3R
13R
23R
33R
CI01
CI02
CI03
CI04
CI05
CI06
CI07
CI08
CI09
CI10
CI11
CI12
CI13
CI14
CI15
CI16
CI17
CI18
CI19
CI20
(C)
K-MEANS
(K=20)

Neuronal Activation Input Strategies

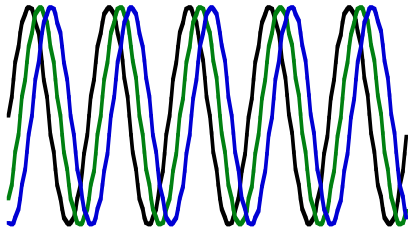
1. Block Design



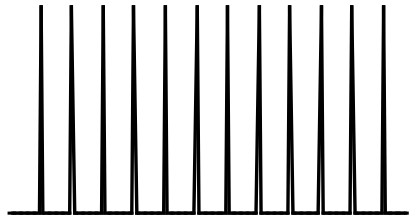
2. Frequency Encoding



3. Phase Encoding

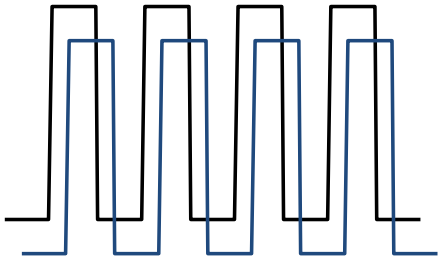


4. Event-Related

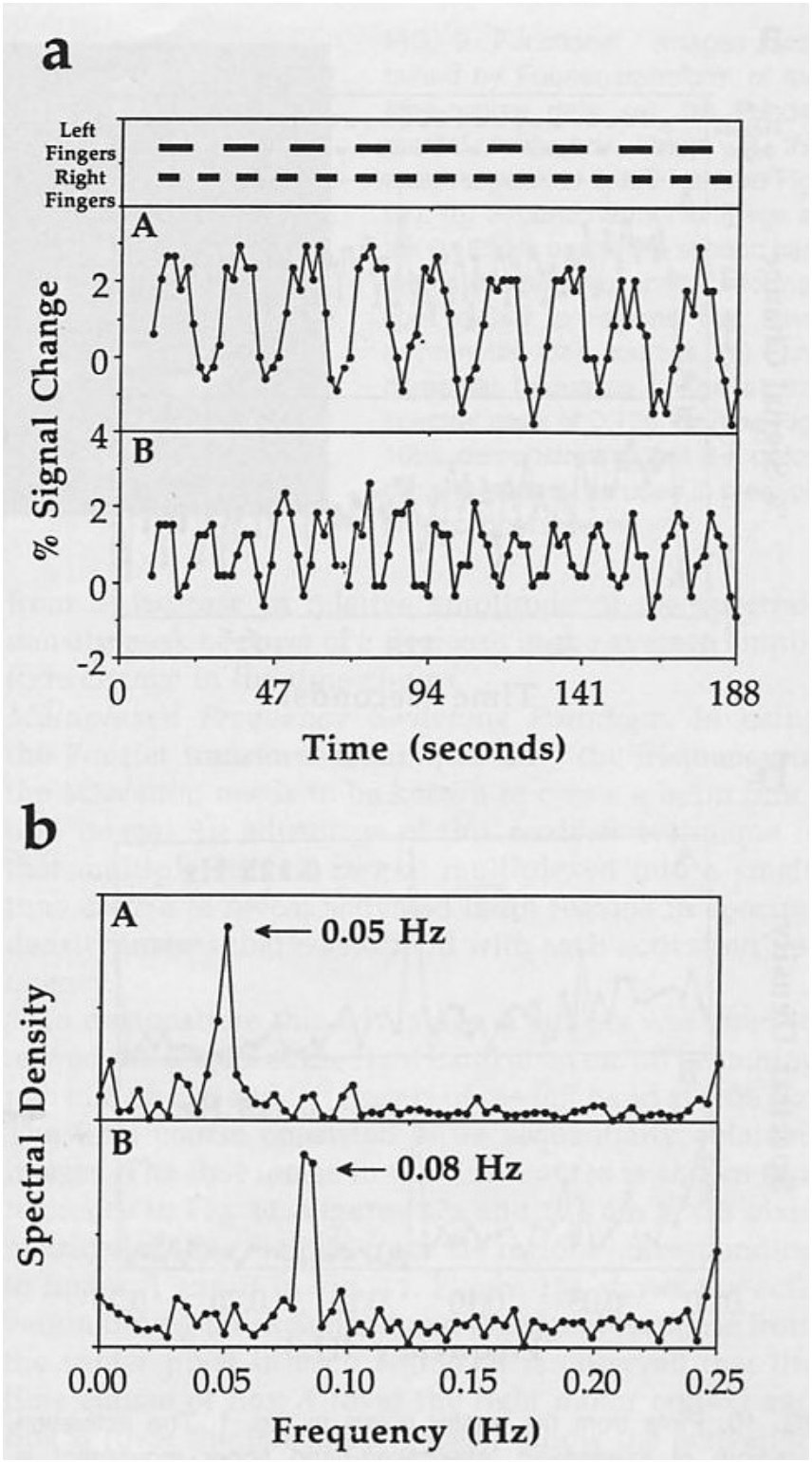


5. fMRI adaptation

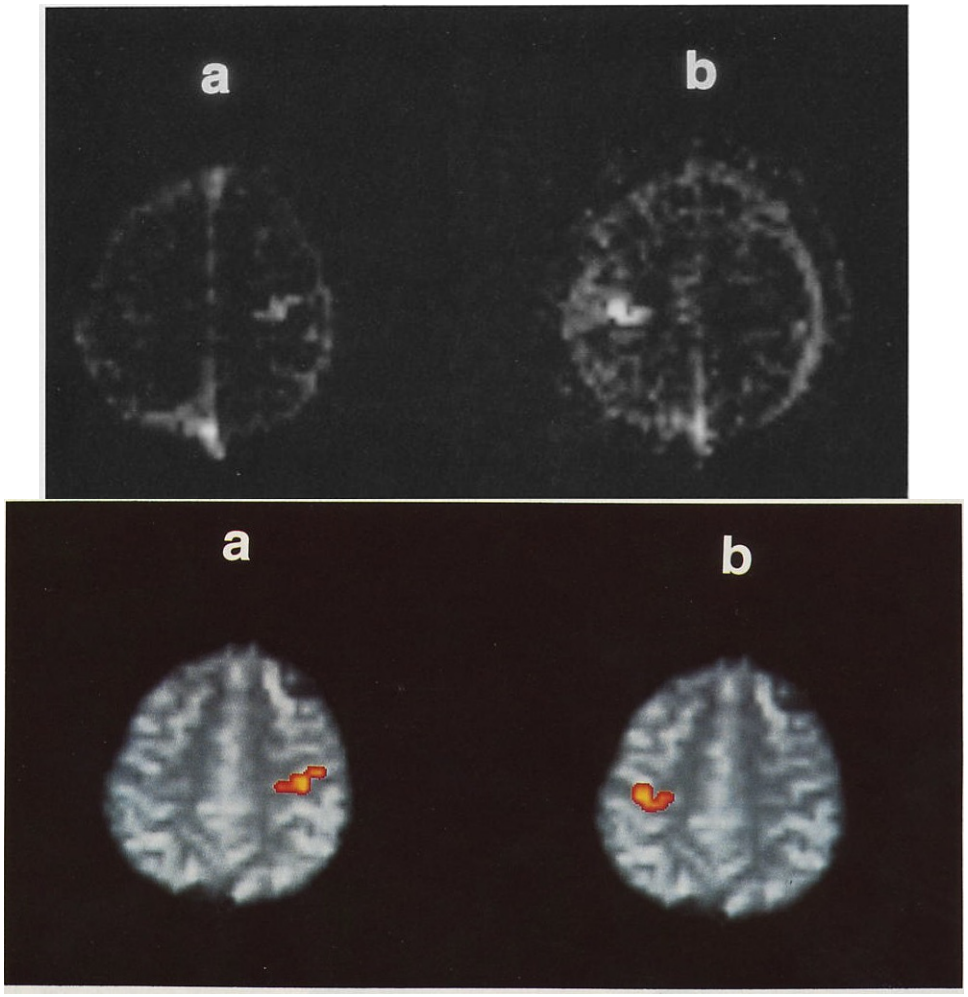
6. Orthogonal Block Design



7. Free Behavior Design.



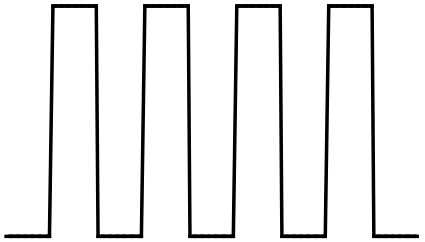
Tapping left and right fingers at two different "on/off" frequencies



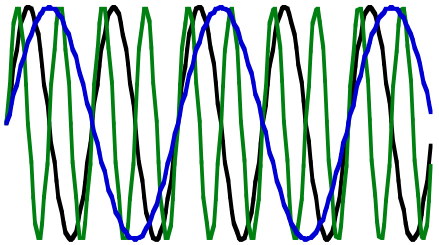
P. A. Bandettini, A. Jesmanowicz, E. C. Wong, J. S. Hyde, Processing strategies for time-course data sets in functional MRI of the human brain. *Magn. Reson. Med.* 30, 161-173 (1993).

Neuronal Activation Input Strategies

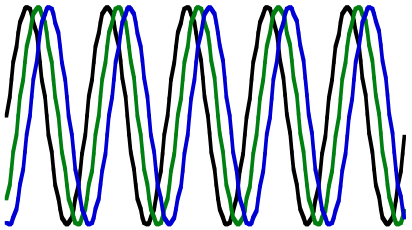
1. Block Design



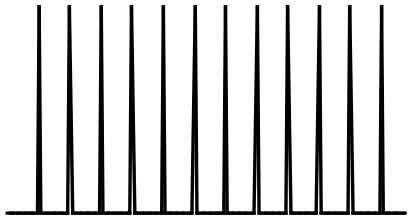
2. Frequency Encoding



3. Phase Encoding

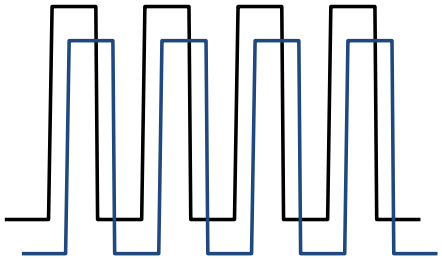


4. Event-Related

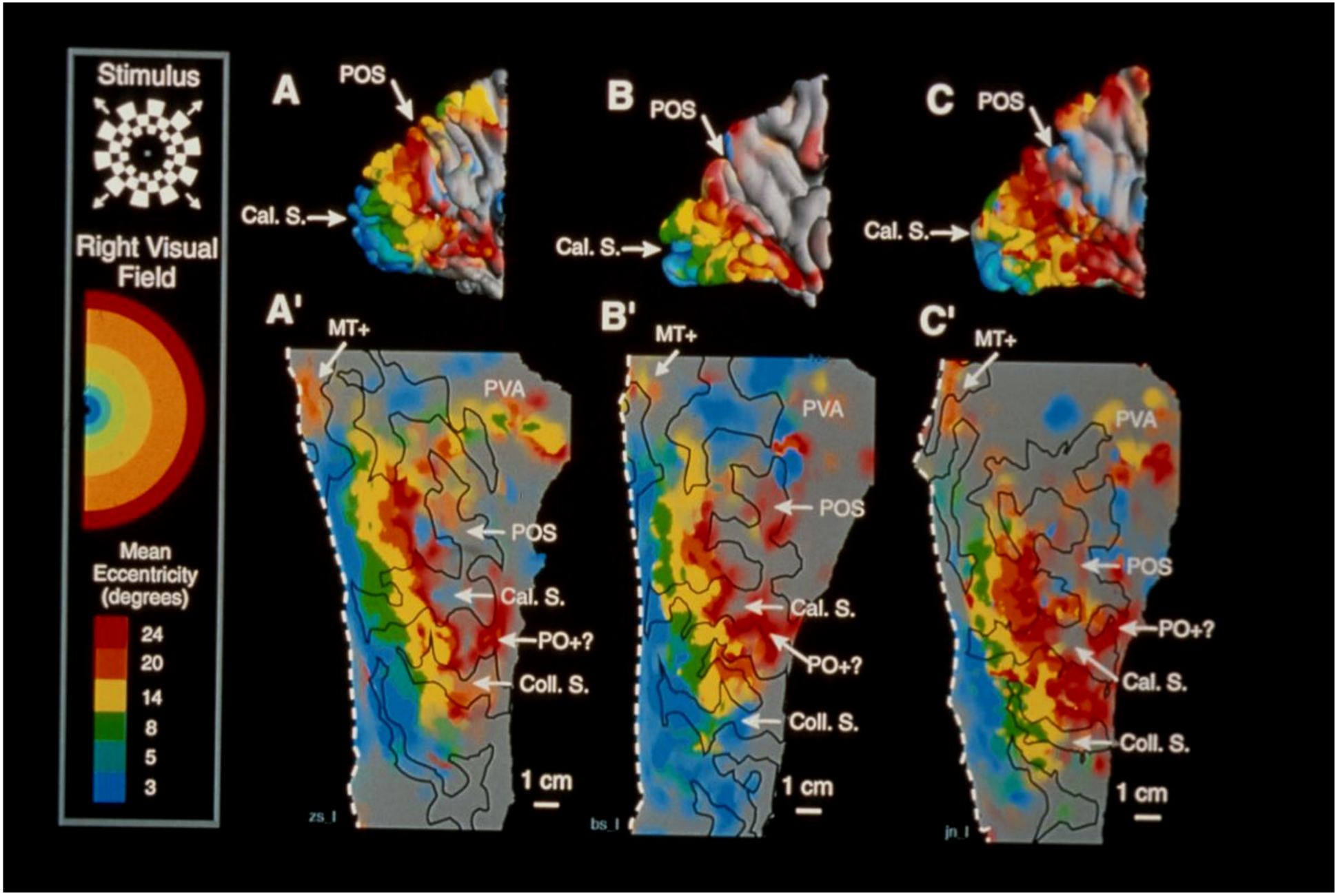


5. fMRI adaptation

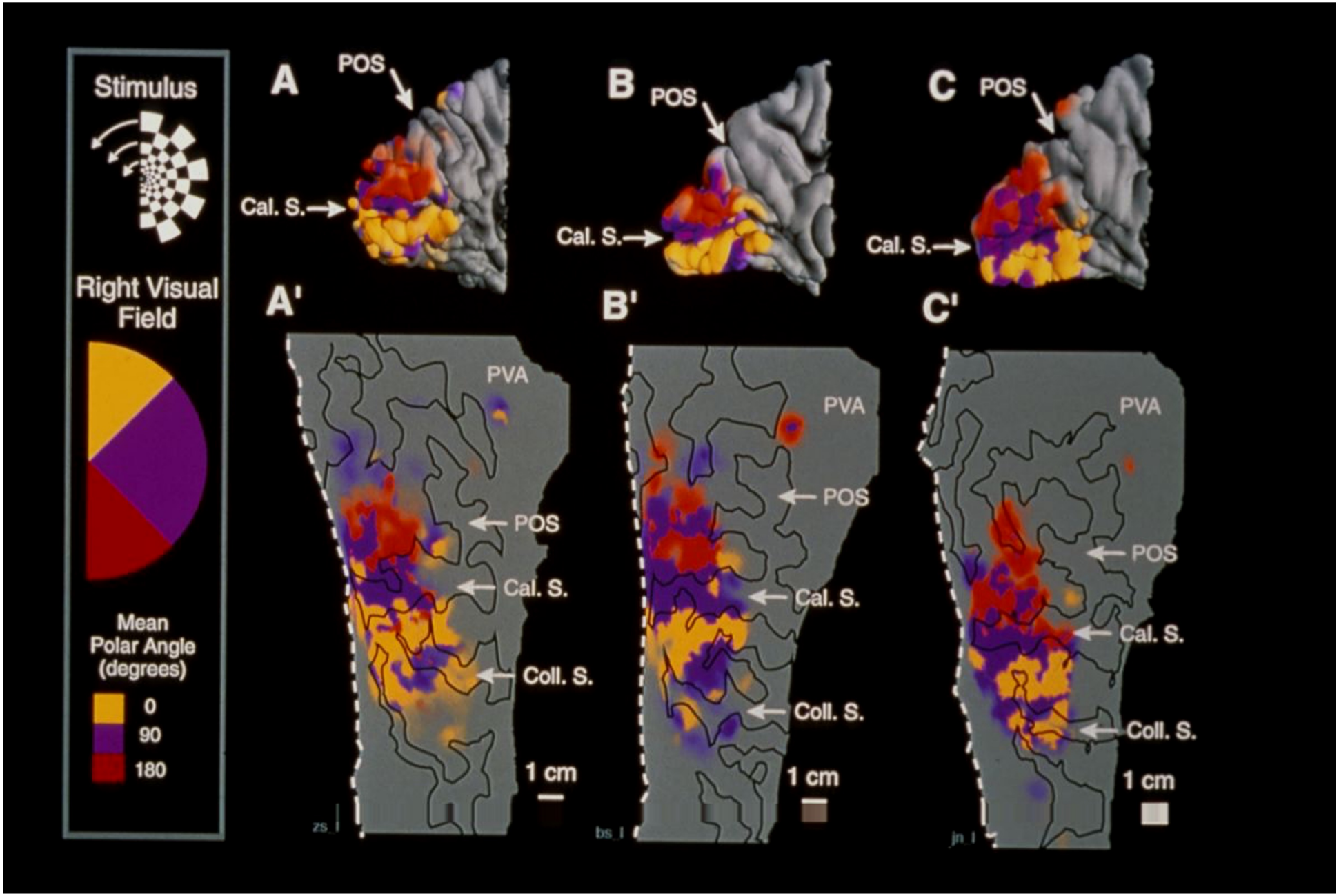
6. Orthogonal Block Design



7. Free Behavior Design.



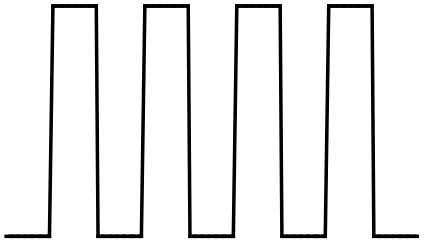
E. A. DeYoe, G. Carman, P. Bandettini, G. S., W. J., R. Cox, D. Miller, J. Neitz, Mapping striate and extrastriate visual areas in human cerebral cortex. *Proc. Nat'l. Acad. Sci.* 93, 2282-2386 (1996).



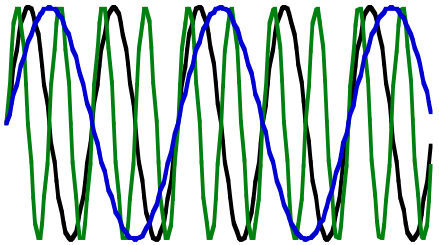
E. A. DeYoe, G. Carman, P. Bandettini, G. S., W. J., R. Cox, D. Miller, J. Neitz, Mapping striate and extrastriate visual areas in human cerebral cortex. *Proc. Nat'l. Acad. Sci.* 93, 2282-2386 (1996).

Neuronal Activation Input Strategies

1. Block Design



2. Frequency Encoding



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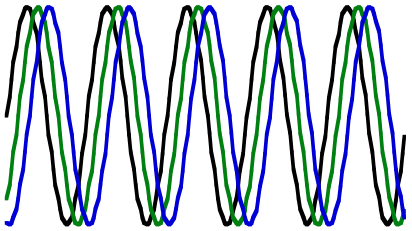
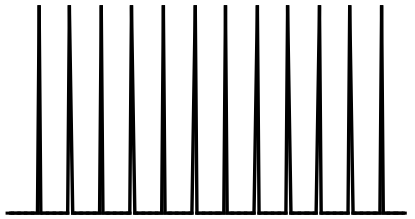
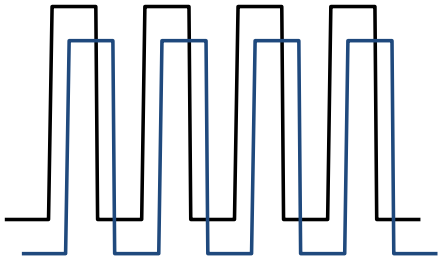


4. Event-Related



5. fMRI adaptation

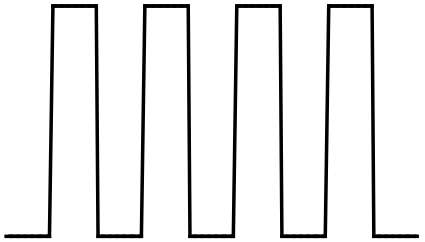
6. Orthogonal Block Design



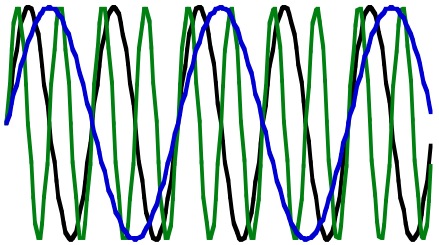
7. Free Behavior Design.

Neuronal Activation Input Strategies

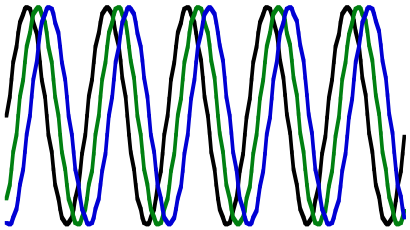
1. Block Design



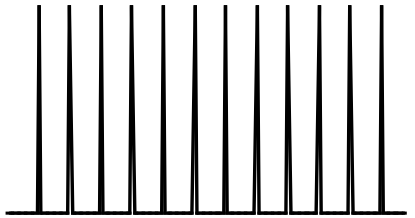
2. Frequency Encoding



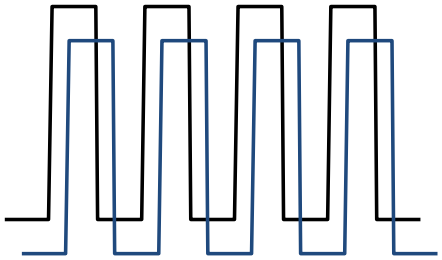
3. Phase Encoding



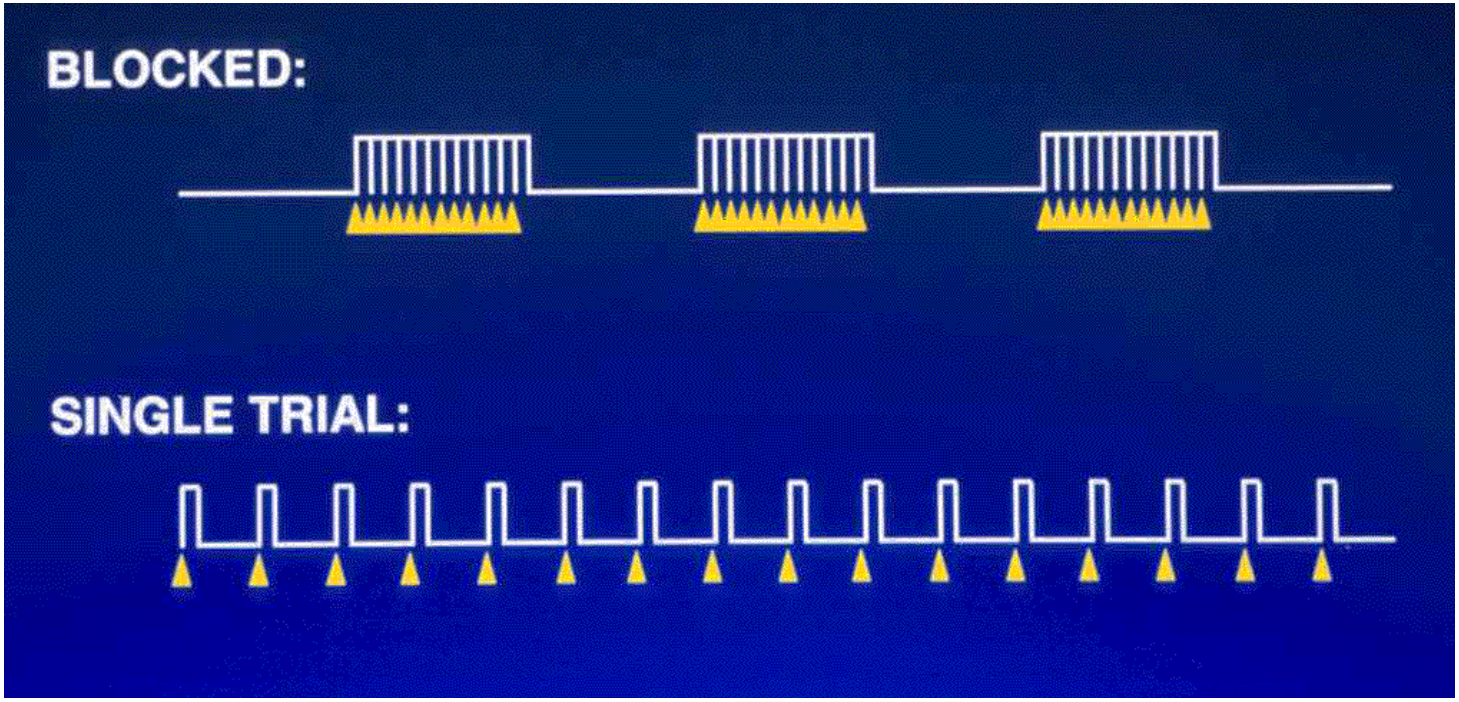
4. Event-Related

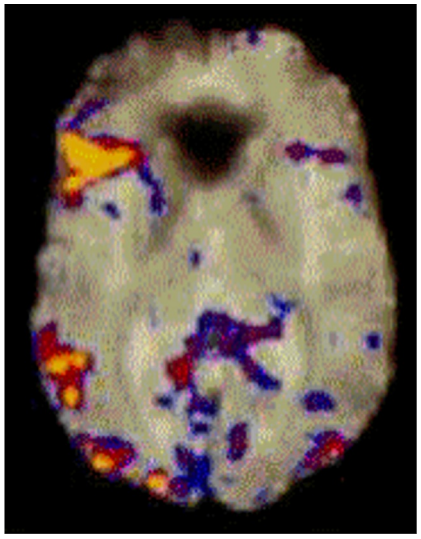


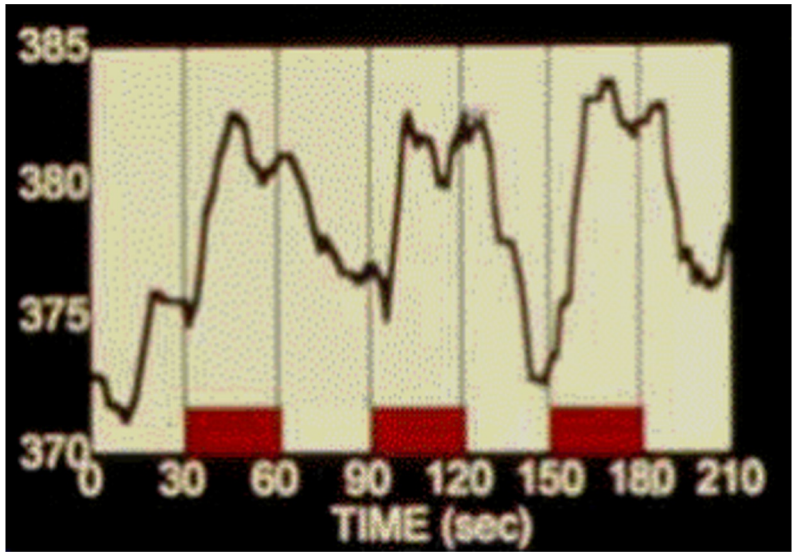
5. Orthogonal Block Design

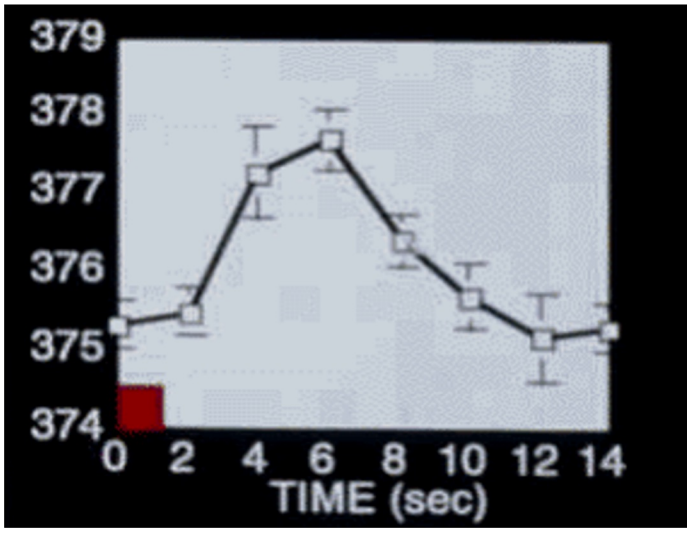


6. Free Behavior Design.

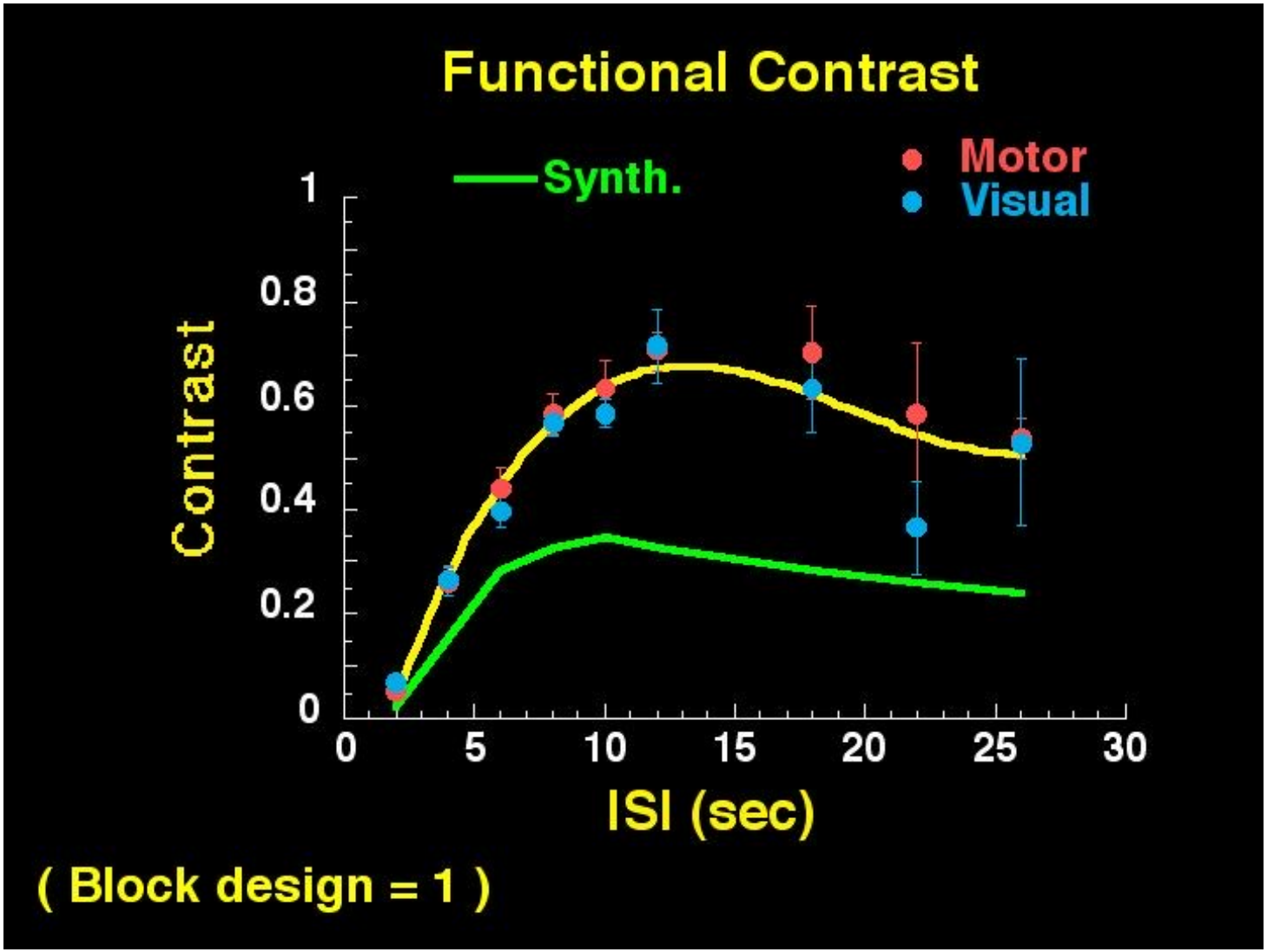






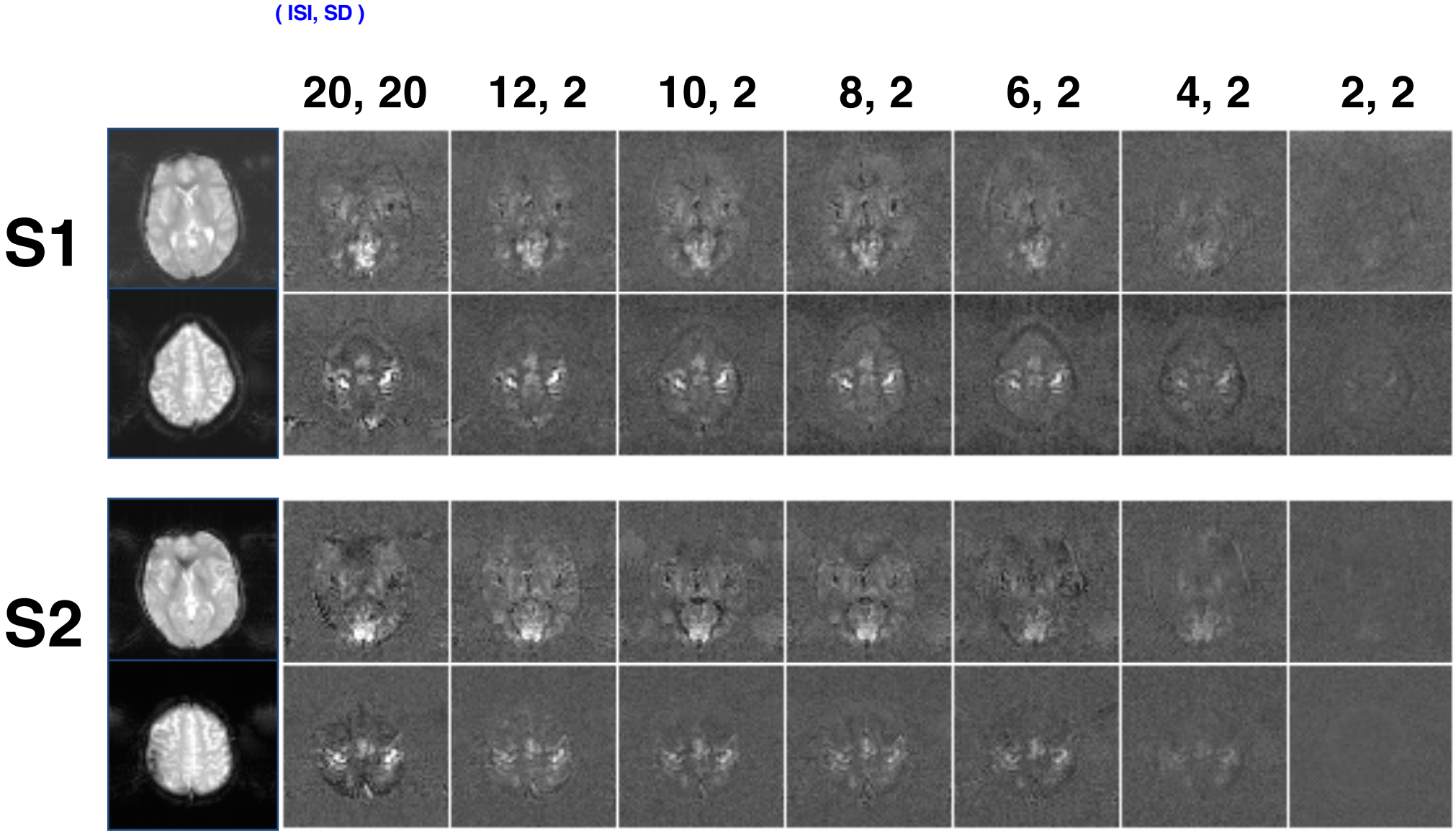


R. L. Buckner, P. A. Bandettini, K. M. O'Craven, R. L. Savoy, S. E. Peterson, M. E. Raichle, T. L. Brady, B. R. Rosen, fMRI detection and time course of distributed cortical activations during single trials of a cognitive task. *Proc. Nat'l. Acad. Sci. USA* 93, 14878-14883 (1996).



P. A. Bandettini, R. W. Cox. Functional contrast in constant interstimulus interval event - related fMRI: theory and experiment. *Magn. Reson. Med.* 43: 540-548 (2000).

Contrast to Noise Images



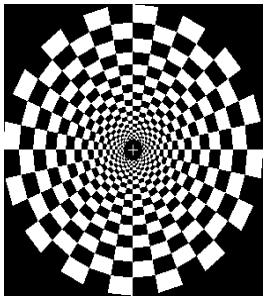
P. A. Bandettini, R. W. Cox. Functional contrast in constant interstimulus interval event - related fMRI: theory and experiment. *Magn. Reson. Med.* 43: 540-548 (2000).

◆ Human Brain Mapping 5:329–340(1997) ◆

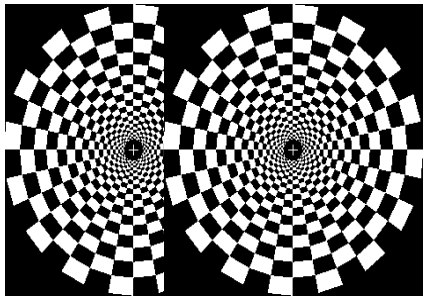
Selective Averaging of Rapidly Presented Individual Trials Using fMRI

Anders M. Dale* and Randy L. Buckner

Massachusetts General Hospital Nuclear Magnetic Resonance Center and the Department of Radiology, Harvard Medical School, Boston, Massachusetts 02129



0 sec 20 sec



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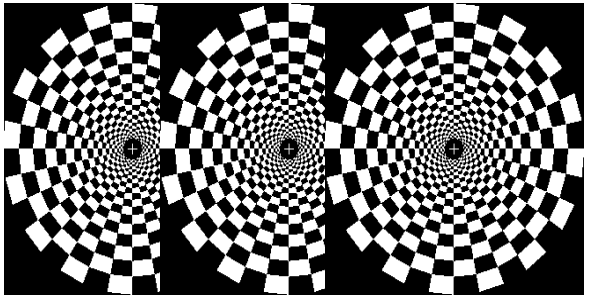
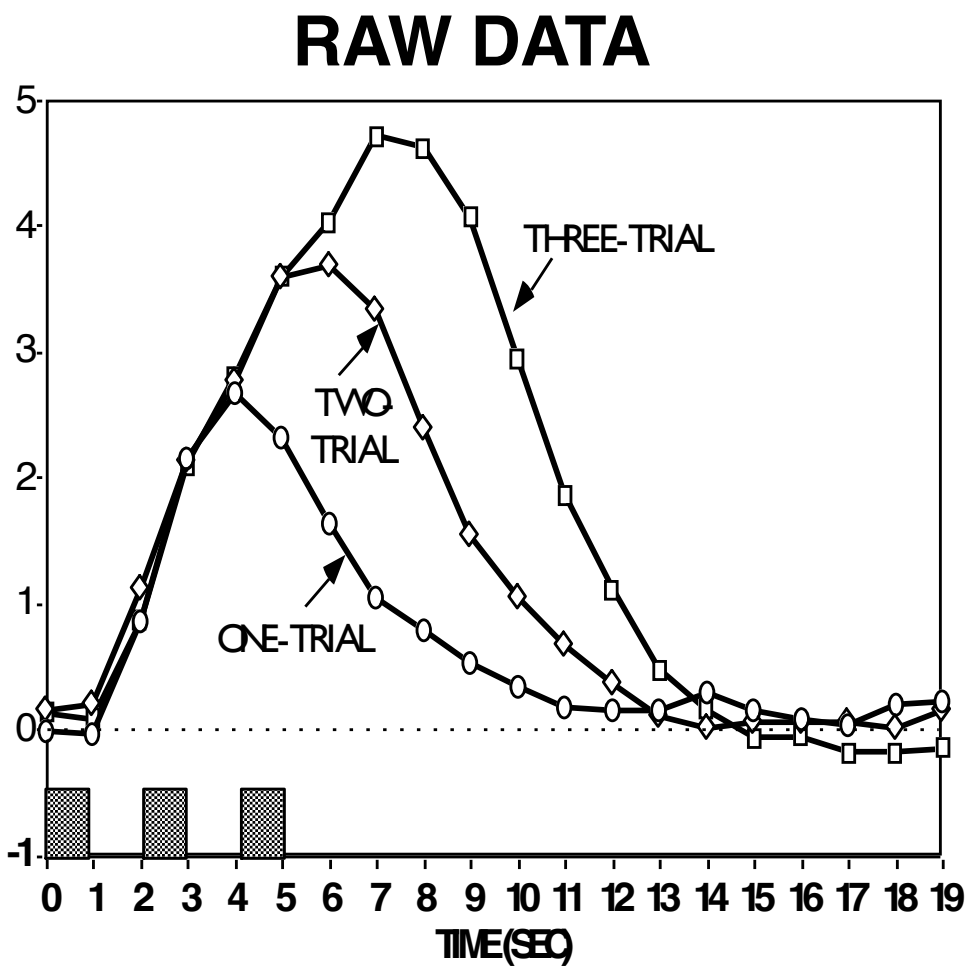
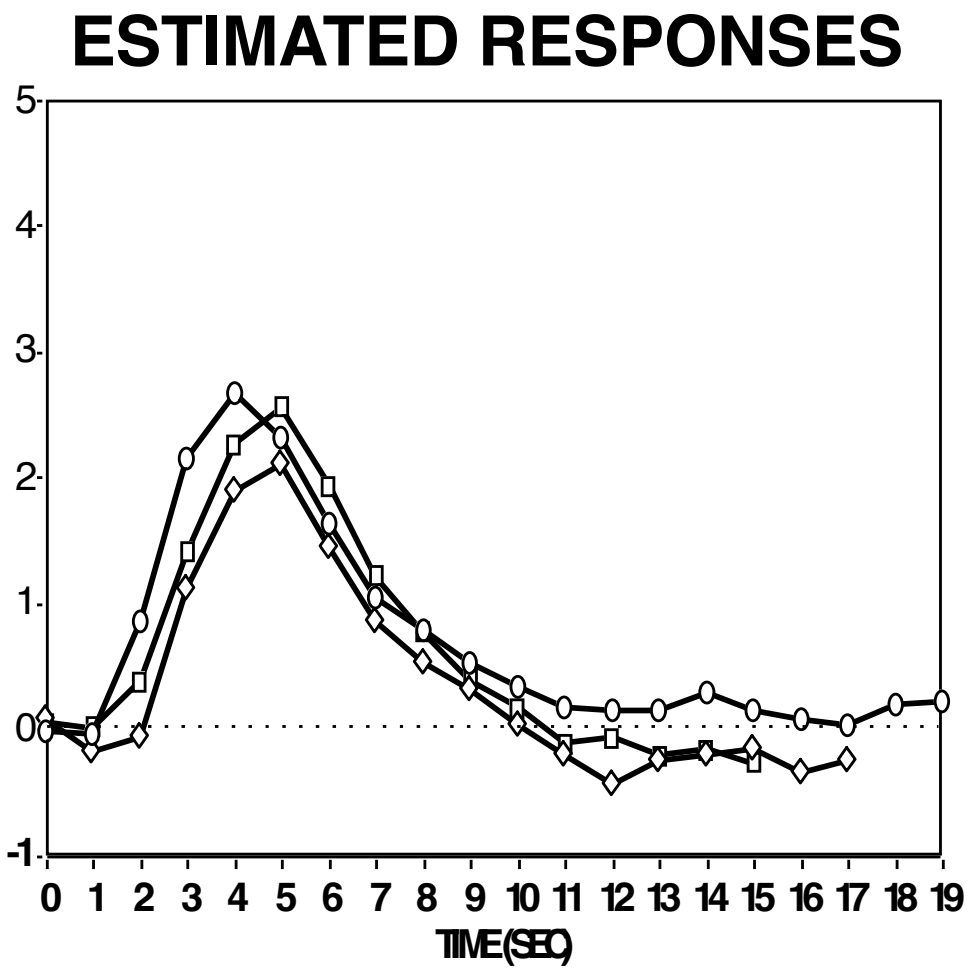
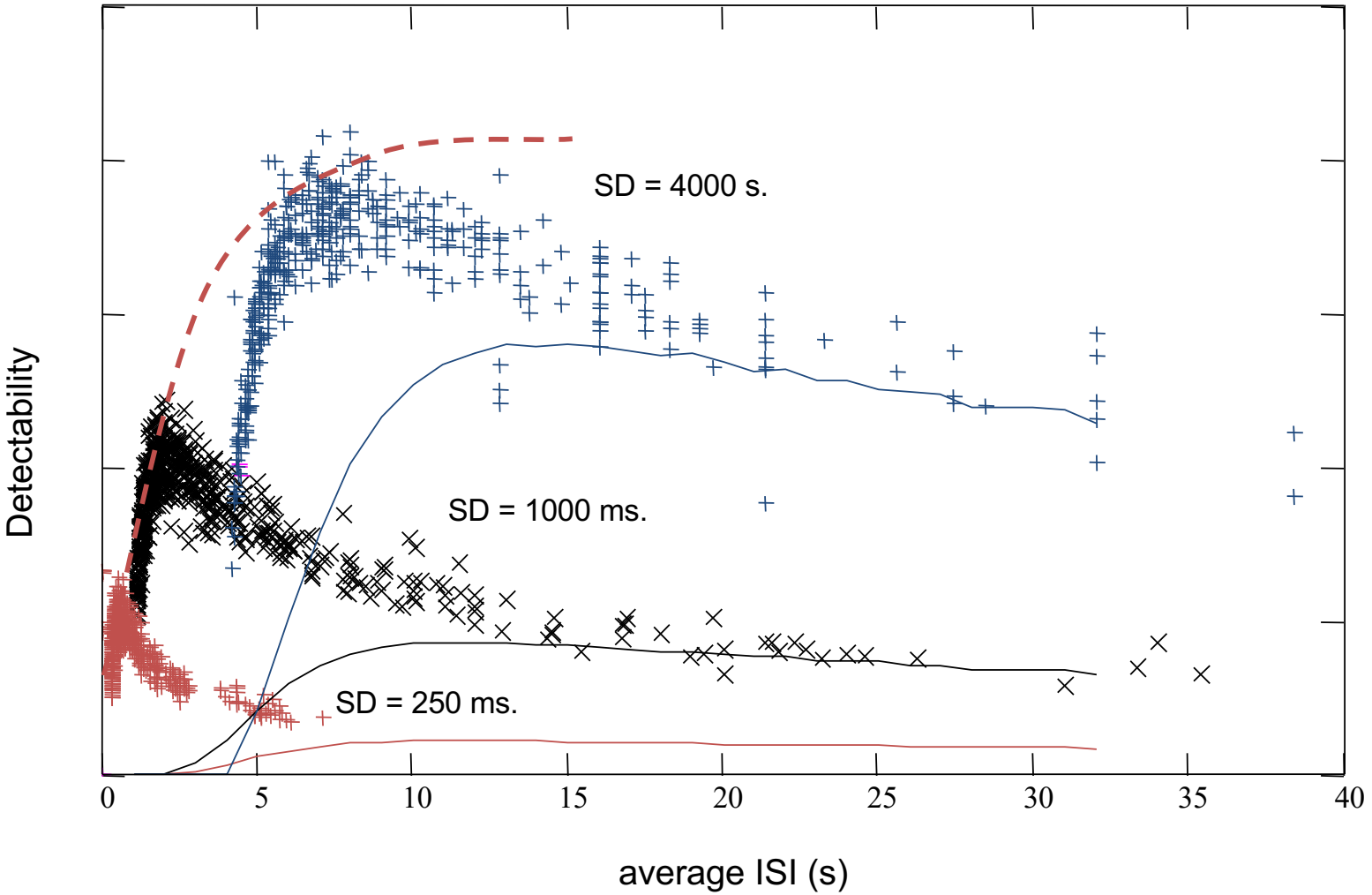


0 sec2 sec4 sec 20 sec


RAW DATA
5
4
3
2
1
0
-1
THREE-TRIAL
TWO-TRIAL
ONE-TRIAL
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
TIME(SEC)

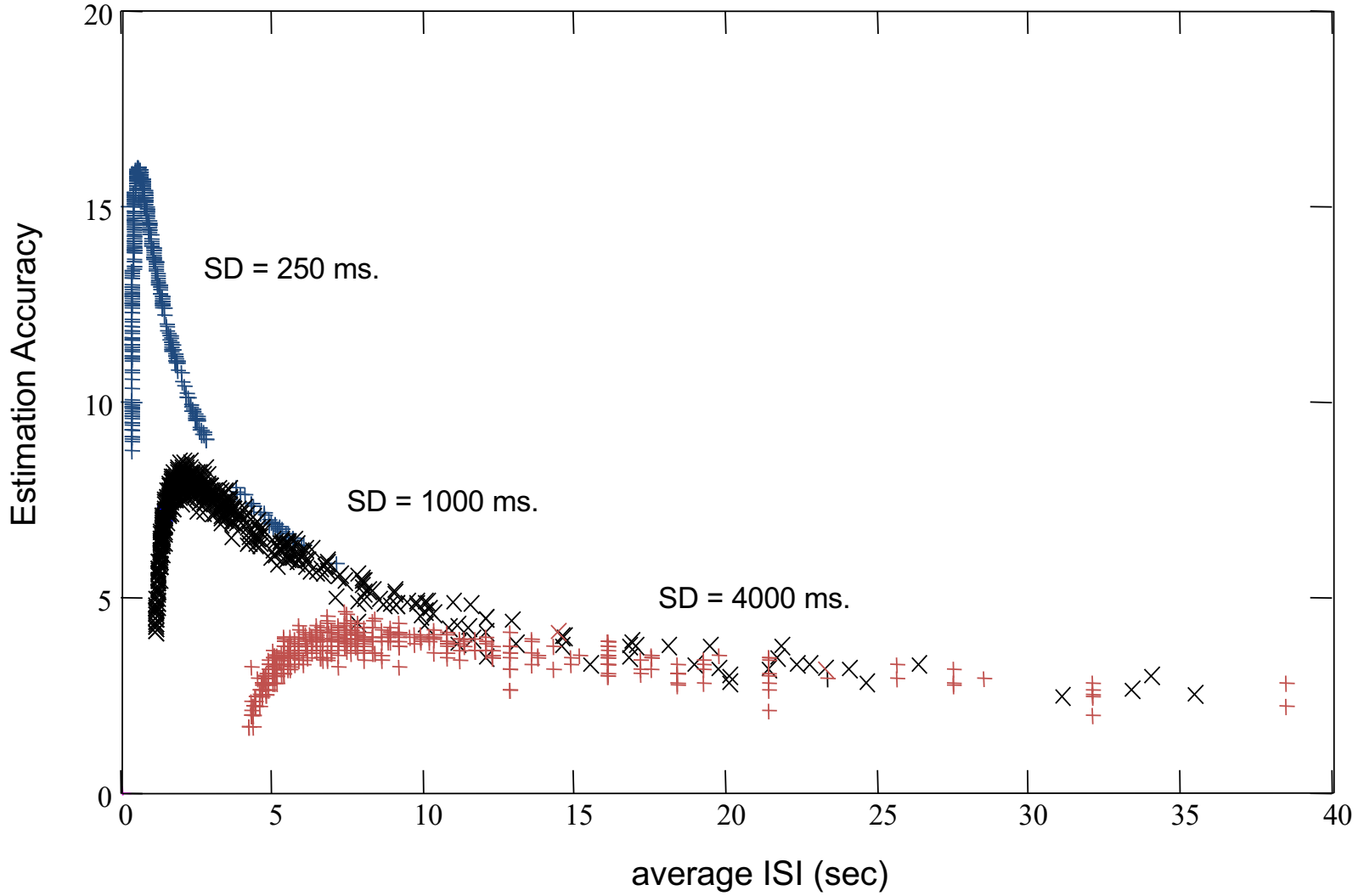

ESTIMATED RESPONSES
5
4
3
2
1
0
-1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
TIME(SEC)

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).

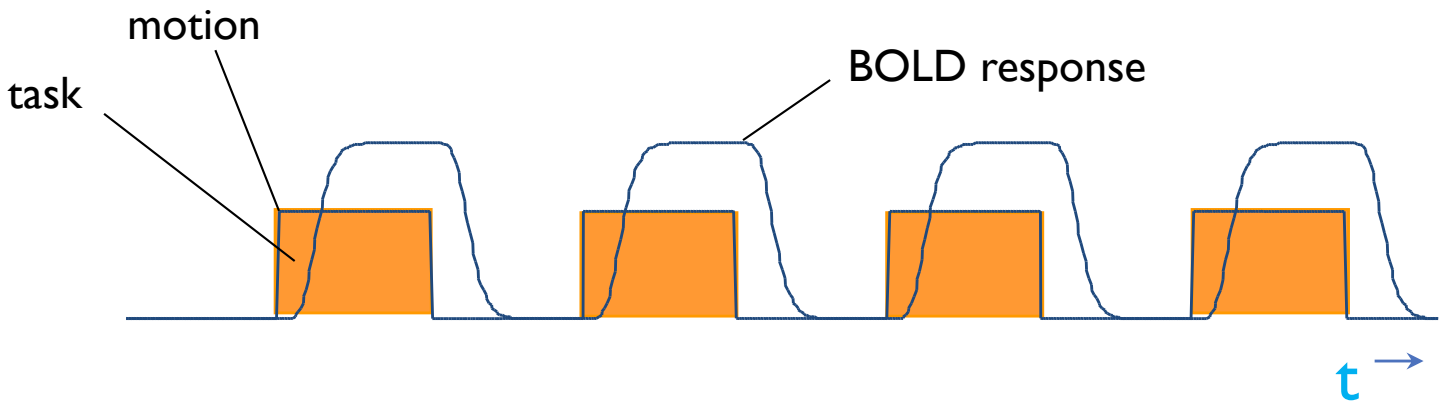
Estimation accuracy vs. average ISI



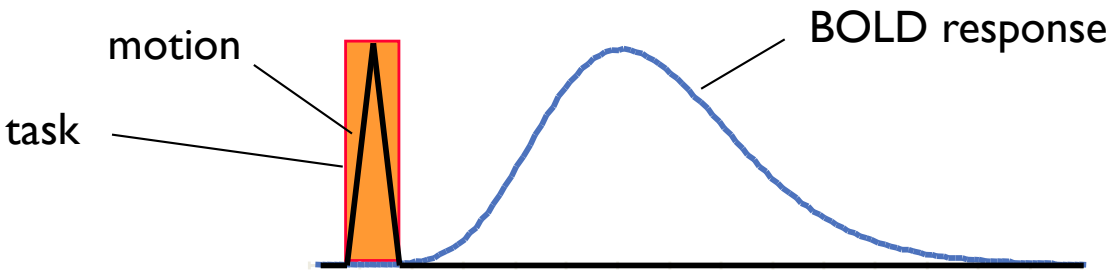
R. M. Birn, R. W. Cox, P. A. Bandettini, Detection versus estimation in Event-Related fMRI: choosing the optimal stimulus timing. *NeuroImage* 15: 262-264, (2002).

fMRI during tasks that involve brief motion

Blocked Design

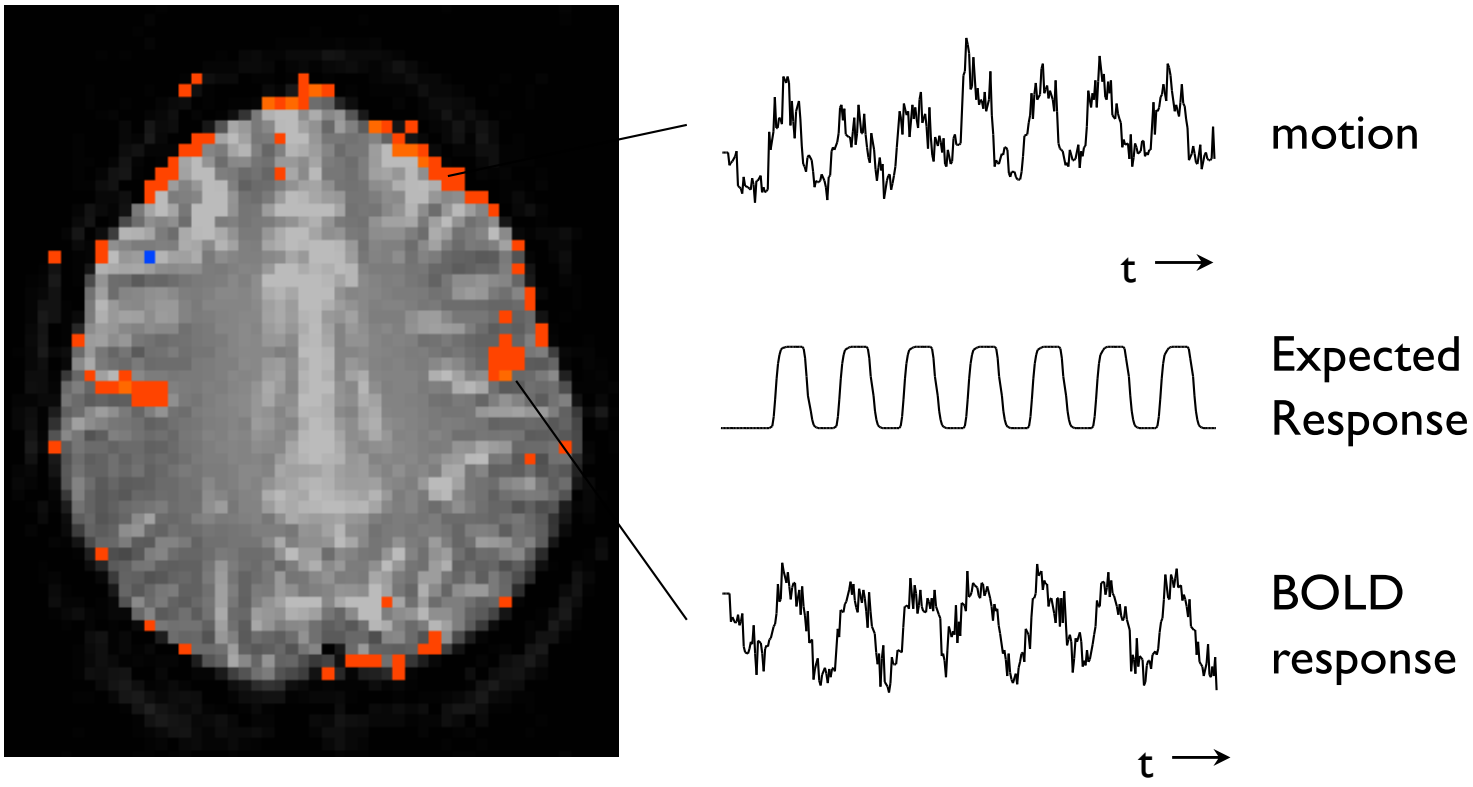


Event-Related Design



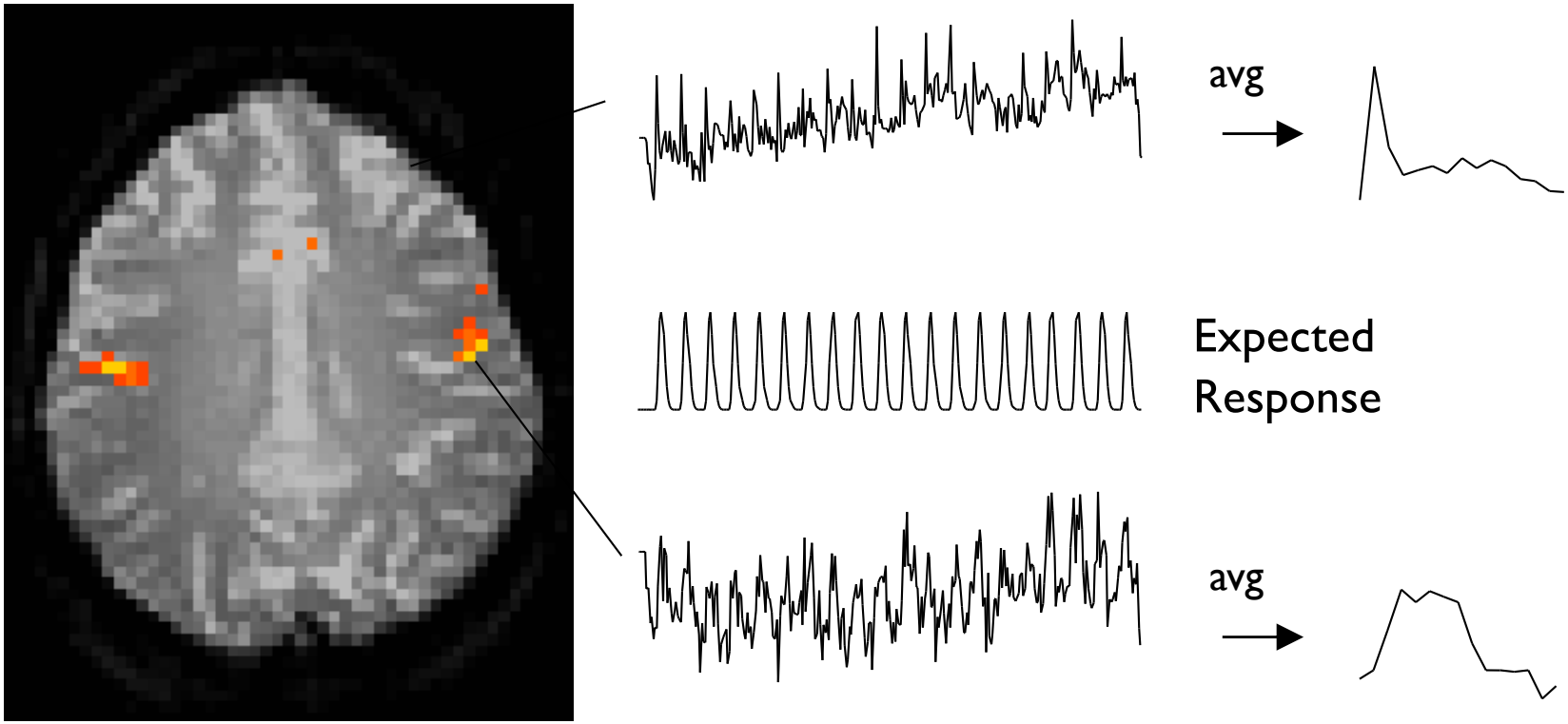
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Speaking - Blocked Trial



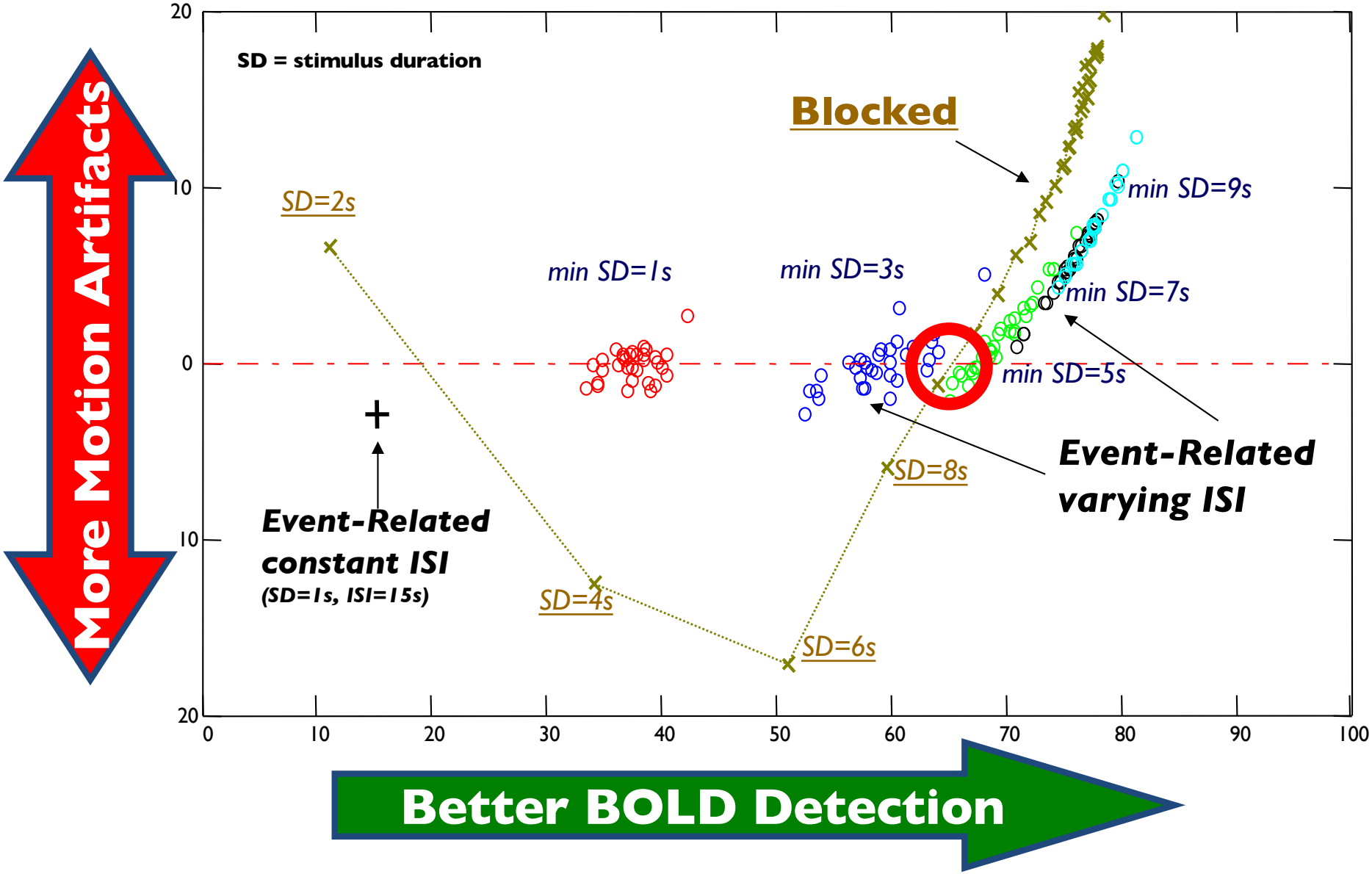
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Speaking - ER-fMRI



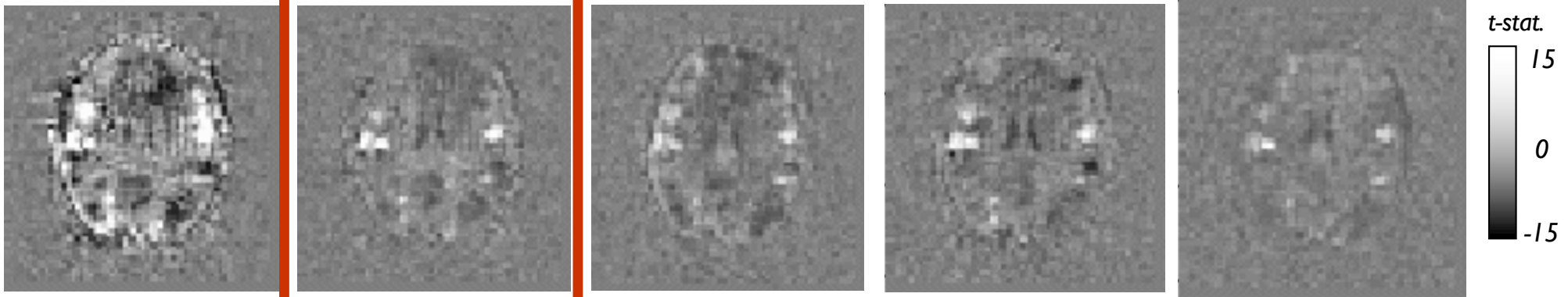
R. M. Birn, P. A. Bandettini, R. W. Cox, R. Shaker, Event - related fMRI of tasks involving brief motion. *Human Brain Mapping* 7: 106-114 (1999).

Overt Responses - Simulations



R.M. Birn, R.W. Cox, P.A. Bandettini, *NeuroImage,* 23, 1046-1058 (2004)

Overt Responses



Blocked design (30s/30s)

Blocked design (10s/10s)

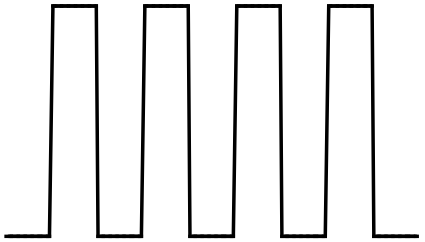
Event-related Varying ISI (1s min. SD)

Event-related Varying ISI (5s min. SD)

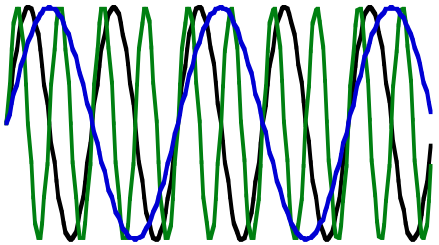
Event-related constant ISI (1s. SD, 15sISI)

Neuronal Activation Input Strategies

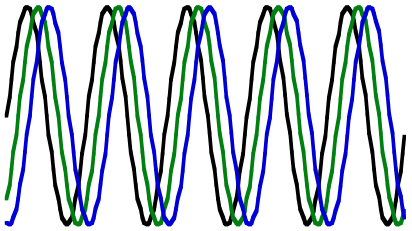
1. Block Design



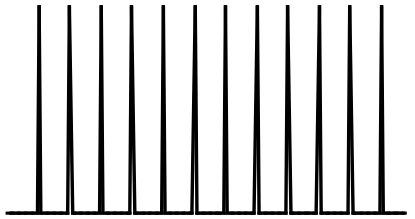
2. Frequency Encoding



3. Phase Encoding

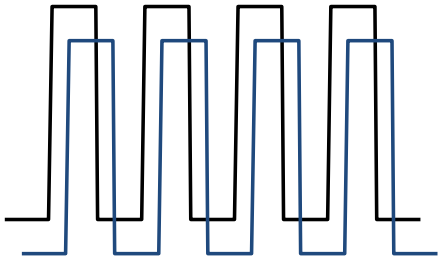


4. Event-Related



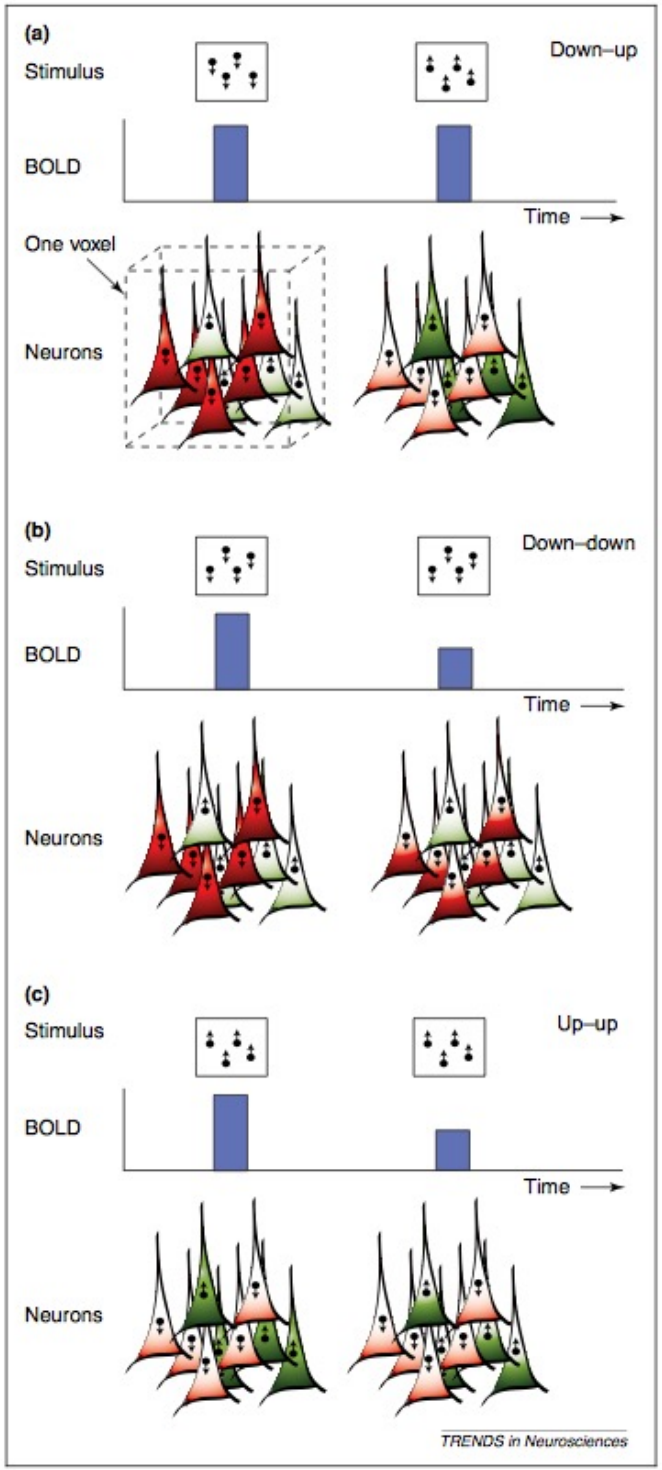
5. fMRI adaptation

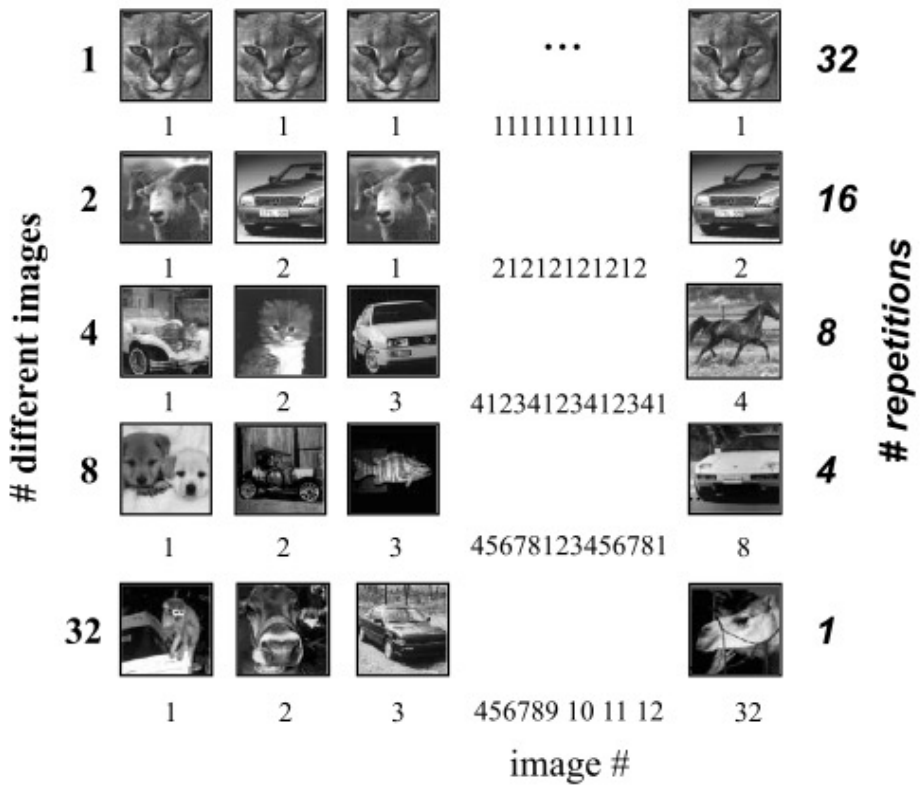
6. Orthogonal Block Design



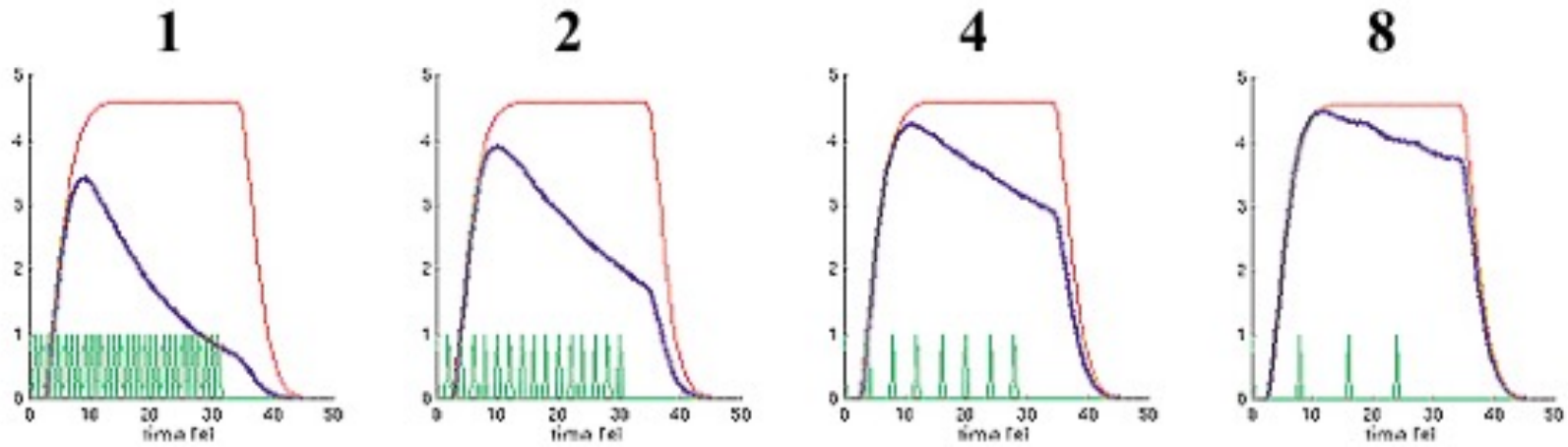
7. Free Behavior Design.

Adaptation: from single cells to BOLD signals, Bart Krekelberg, Geoffrey M. Boynton, and Richard J.A. van Wezel, Trends in Neurosciences, 29, 5, 2006



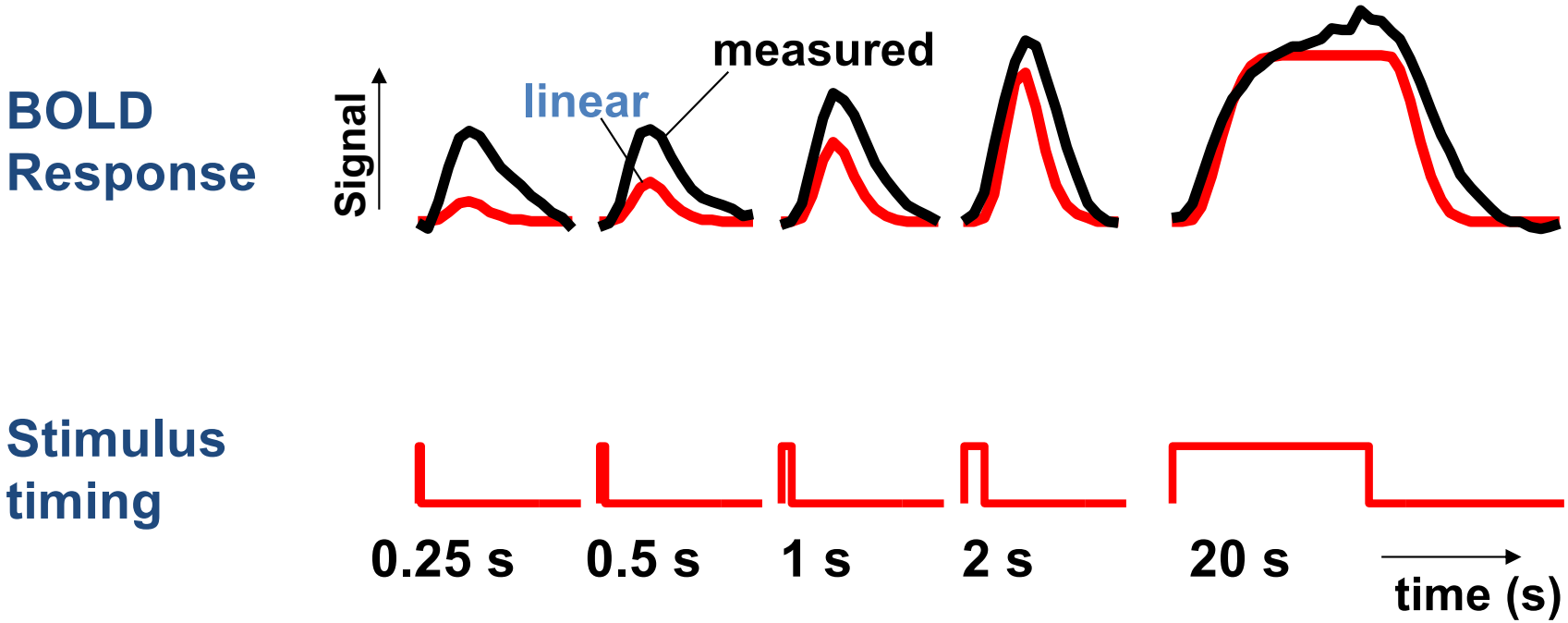


fMR-adaptation: a tool for studying the functional properties of human cortical neurons Kalanit Grill-Spector, Rafael Malach, Acta Psychologica, 107 (2001), 293-321



Dynamic Nonlinearity Assessment

Different stimulus "ON" periods

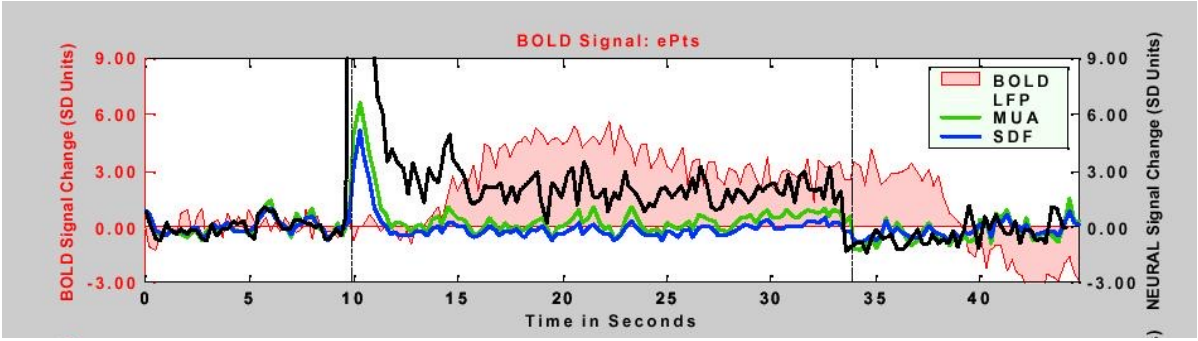


Brief stimuli produce larger responses than expected

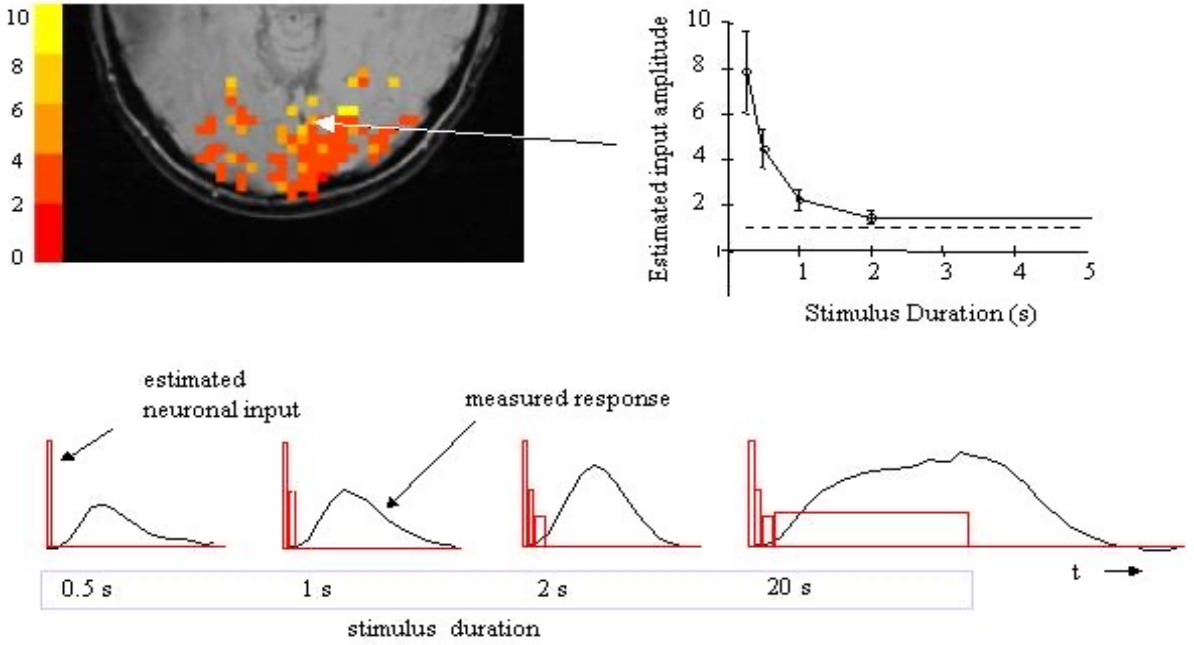
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." *NeuroImage*, 14: 817-826.

BOLD Correlation with Neuronal Activity

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

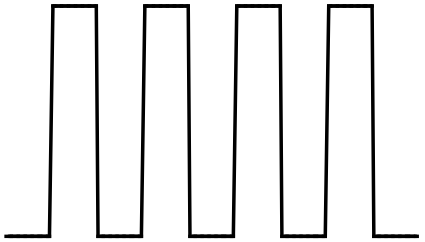


P. A. Bandettini and L. G. Ungerleider, (2001) "From neuron to BOLD: new connections." Nature Neuroscience, 4: 864-866.

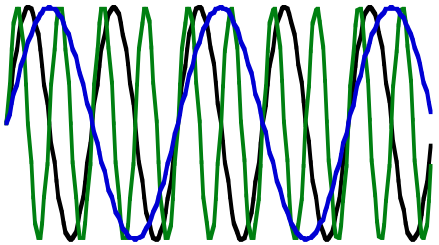


Neuronal Activation Input Strategies

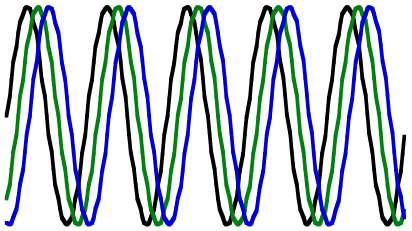
1. Block Design



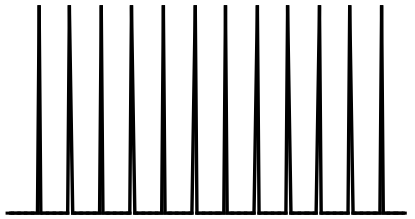
2. Frequency Encoding



3. Phase Encoding

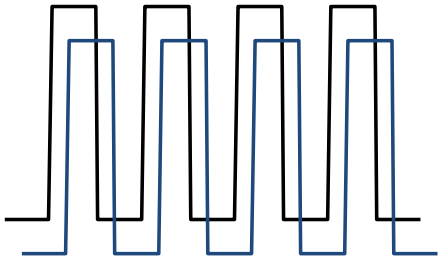


4. Event-Related



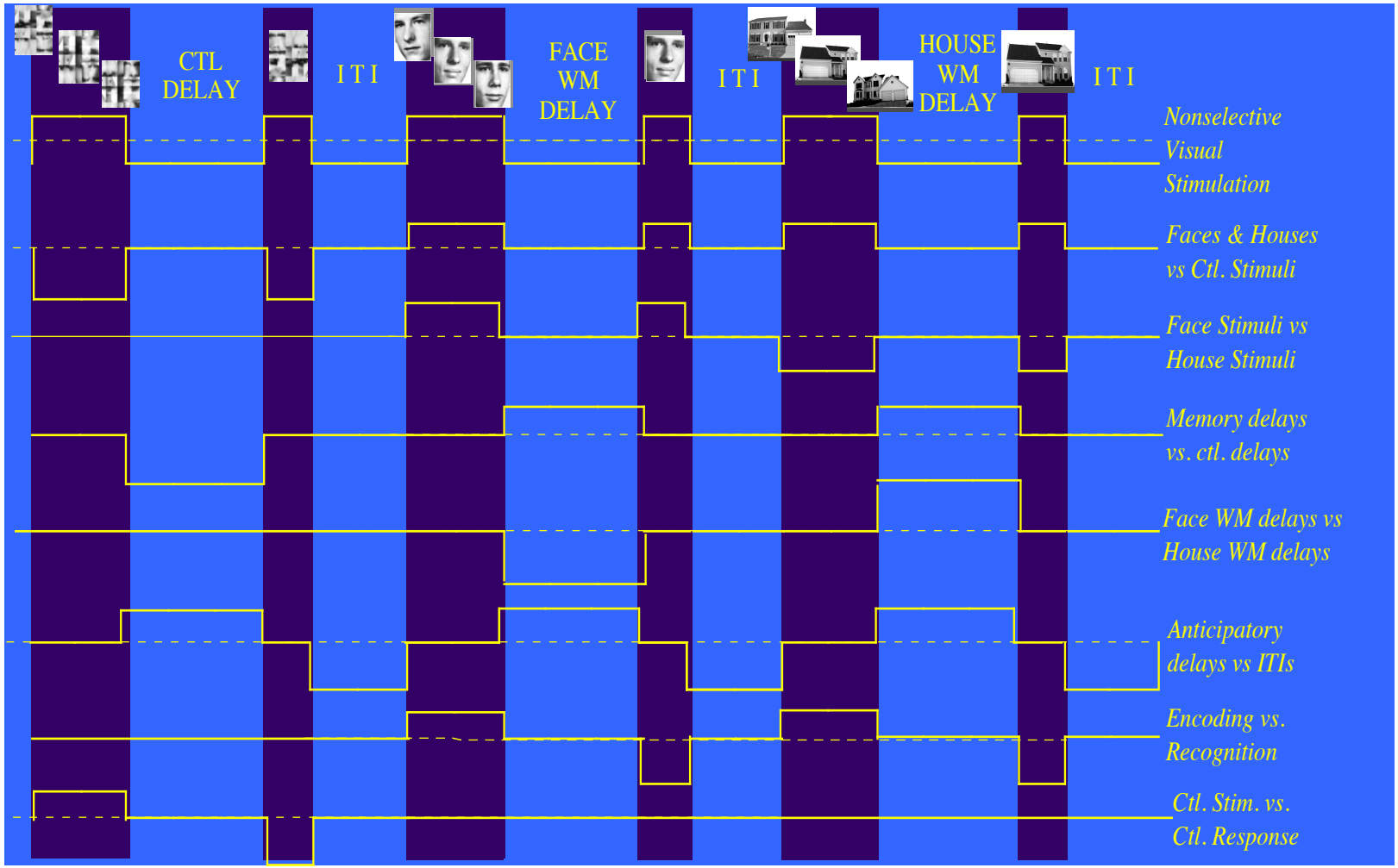
5. fMRI adaptation

6. Orthogonal Block Design



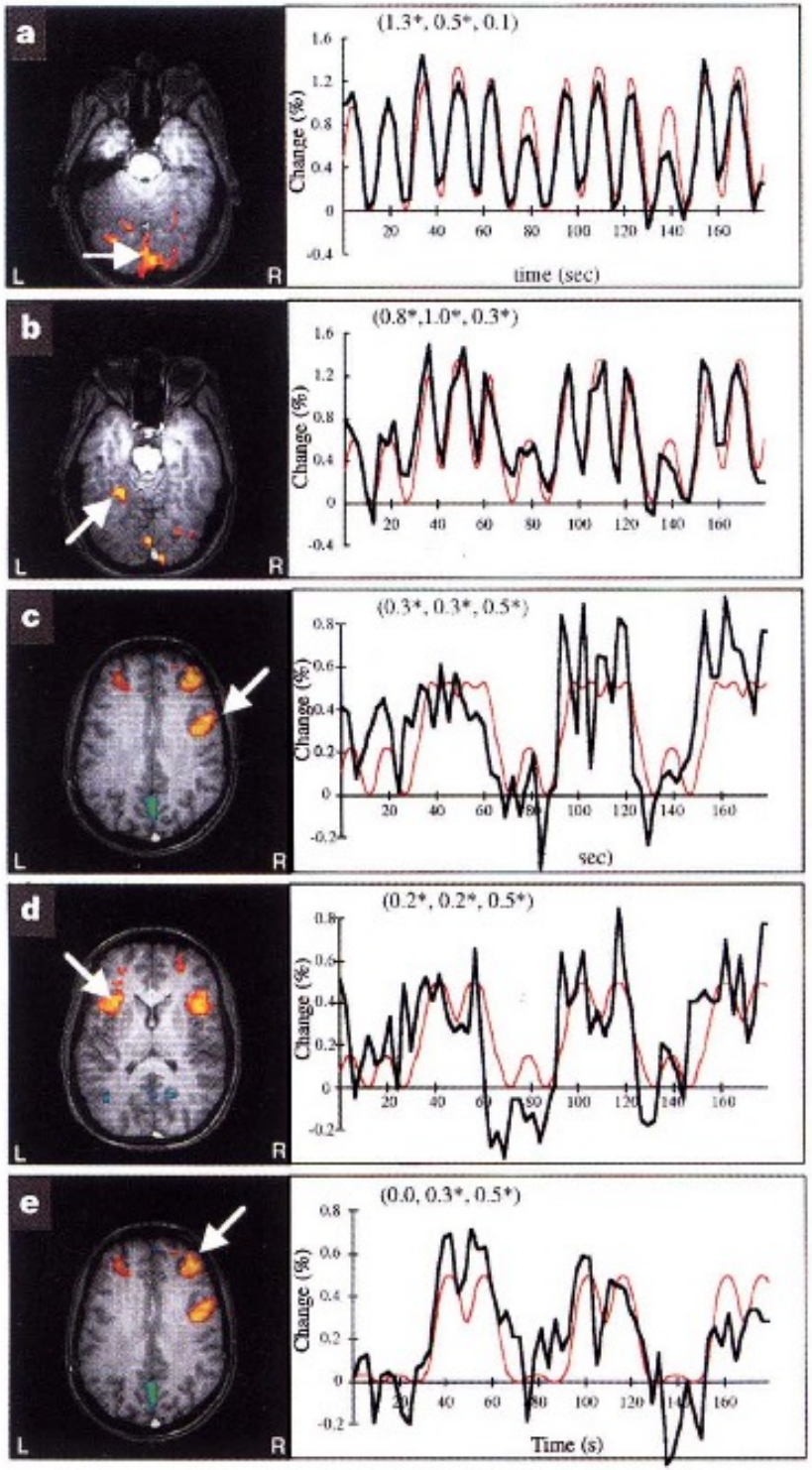
7. Free Behavior Design

Example of a Set of Orthogonal Contrasts for Multiple Regression



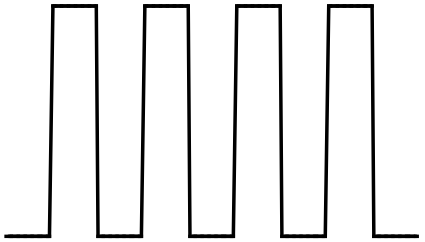
Transient and Sustained activity in a distributed neural system for human working memory, S. M. Courtney, L. G. Ungerleider, K. Keil, J. V. Haxby, Nature, 386, pp. 608-611

Transient and Sustained activity in a distributed neural system for human working memory, S. M. Courtney, L. G. Ungerleider, K. Keil, J. V. Haxby, Nature, 386, pp. 608-611

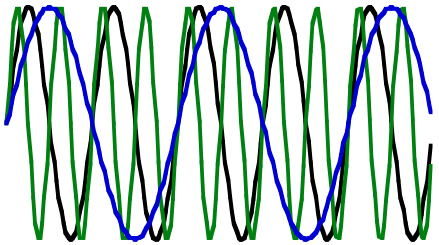


Neuronal Activation Input Strategies

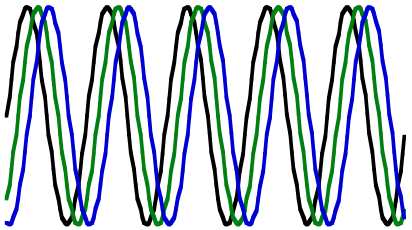
1. Block Design



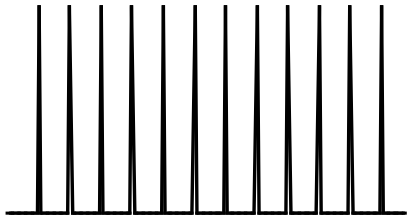
2. Frequency Encoding



3. Phase Encoding

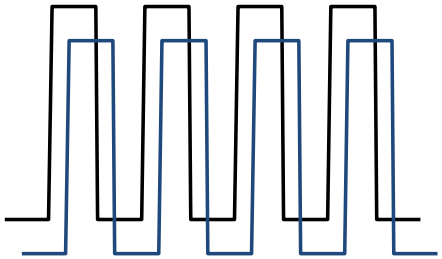


4. Event-Related



5. fMRI adaptation

6. Orthogonal Block Design

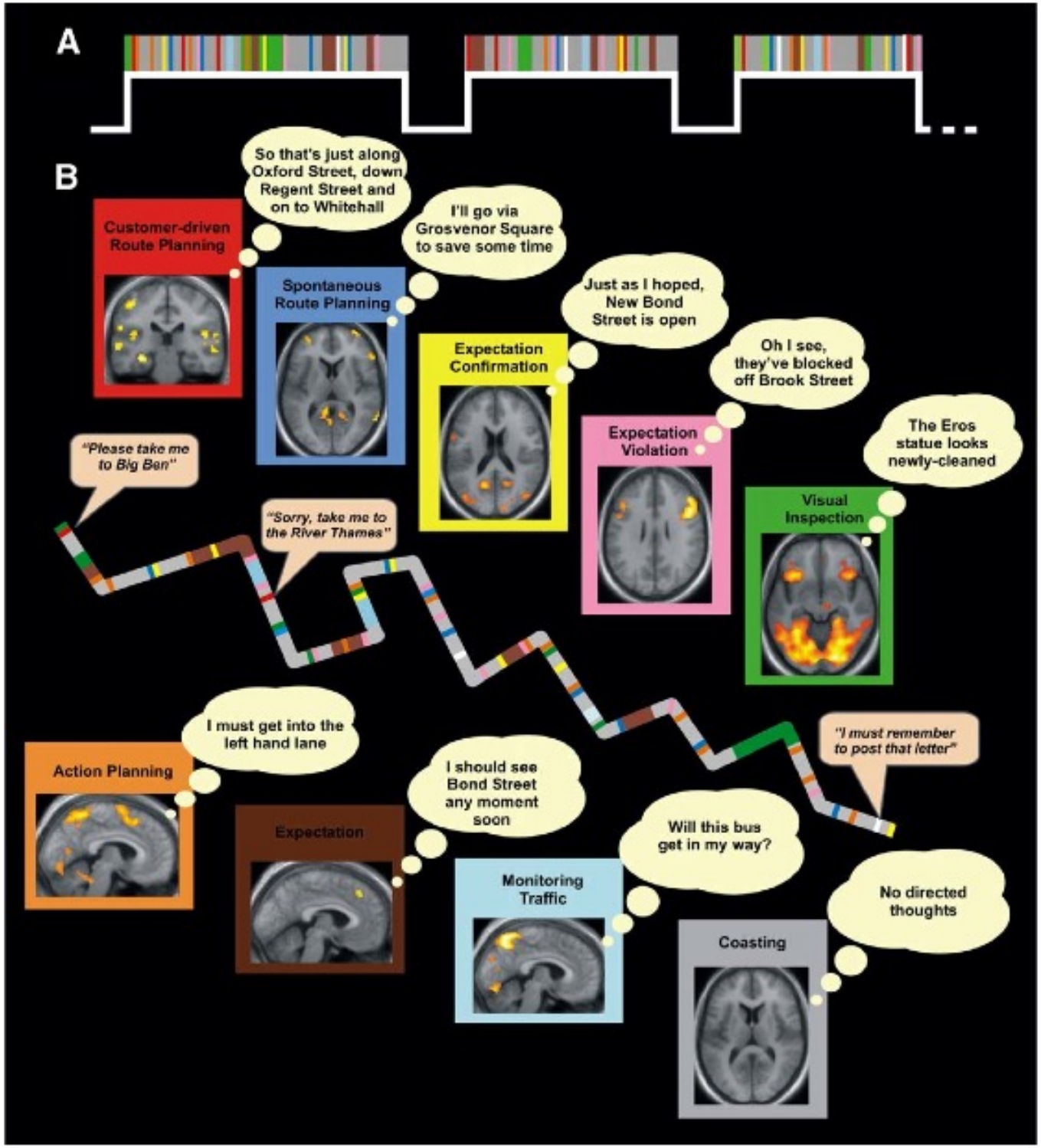


7. Free Behavior Design

Category	Definition	Mean number of occurrences (SD)
Customer-driven Route Planning	Planning a route to a given destination	16.6 (1.8)
Subtypes: Initial plan	Planning from the initial request	6.8 (0.8)
Change in plan	Planning after an en route request from a customer to alter the destination	9.8 (1.0)
Spontaneous Route Planning	Further planning en route, independent of customers	34.3 (10.9)
Subtypes: Filling in	Planning the next stage of the journey	17.7 (6.6)
Re-planning	Altering the current plan to adapt to the environment	16.7 (5.7)
Action Planning	Planning future movements with the vehicle	45.8 (15.1)
Expectation Confirmation	Detecting the presence of an expected environmental feature	28.6 (9.9)
Expectation Violation	Detecting the absence of an expected environmental feature	31.6 (10.5)
Expectation	Looking out for the next expected environmental feature	24.5 (8.5)
Visual Inspection	Visual inspection of an environmental feature	36.0 (11.8)
Monitoring Traffic	Watching moving traffic in the environment	11.4 (5.9)
Coasting	Navigating automatically without any directed thoughts	25.8 (7.5)
Customers' Navigationally-Irrelevant Statements	Navigationally-irrelevant statements by customers, (a control for Customer-driven Route Planning)	6.6 (0.9)

Thoughts, behaviour, and brain dynamics during navigation in the real world. Hugo J. Spiers and Eleanor A. Maguire, NeuroImage, 31 (2006), 1826-1840.

Thoughts, behaviour, and brain dynamics during navigation in the real world. Hugo J. Spiers and Eleanor A. Maguire, NeuroImage, 31 (2006), 1826-1840.

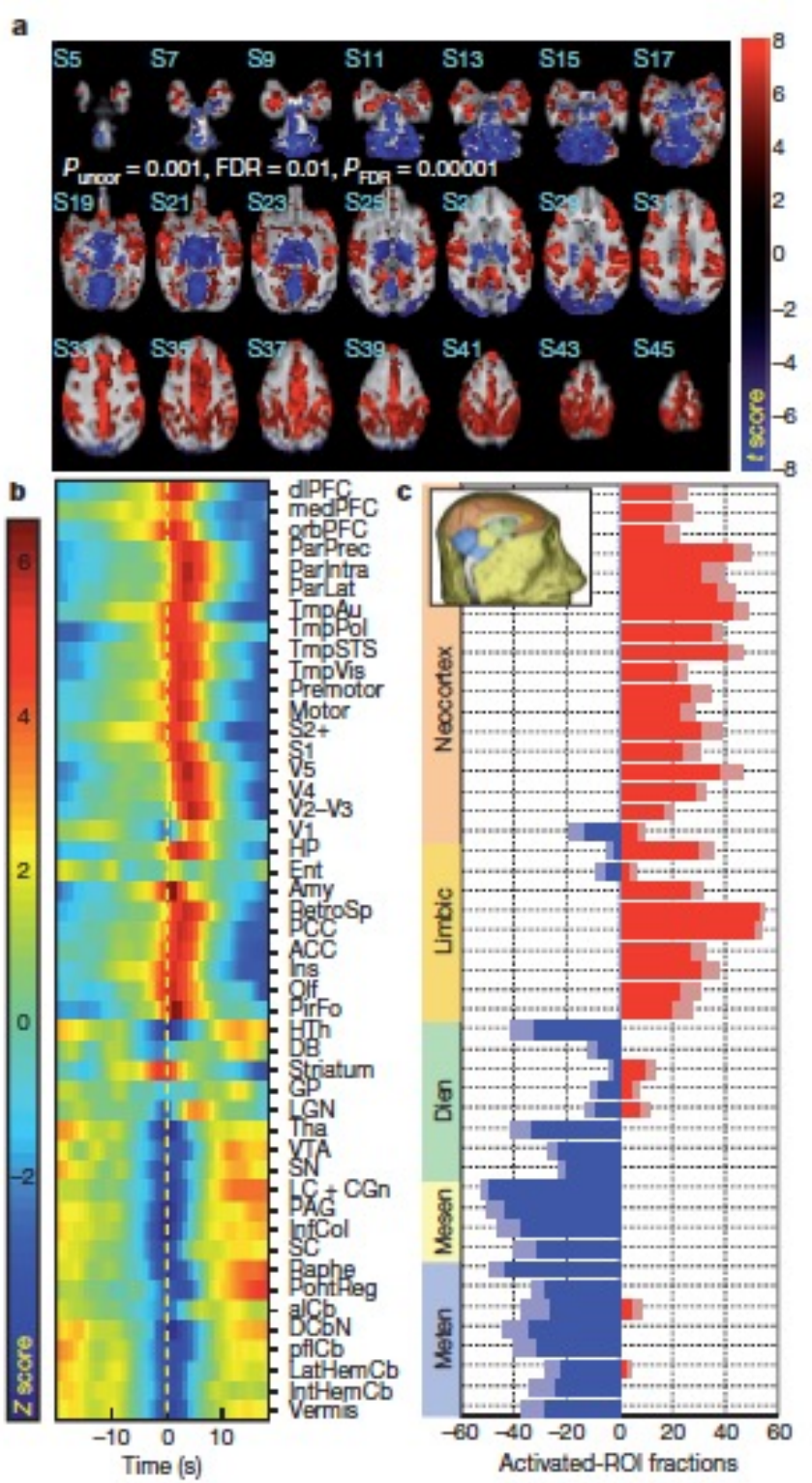


Multi-modal integration

Hippocampal–cortical interaction during periods of subcortical silence

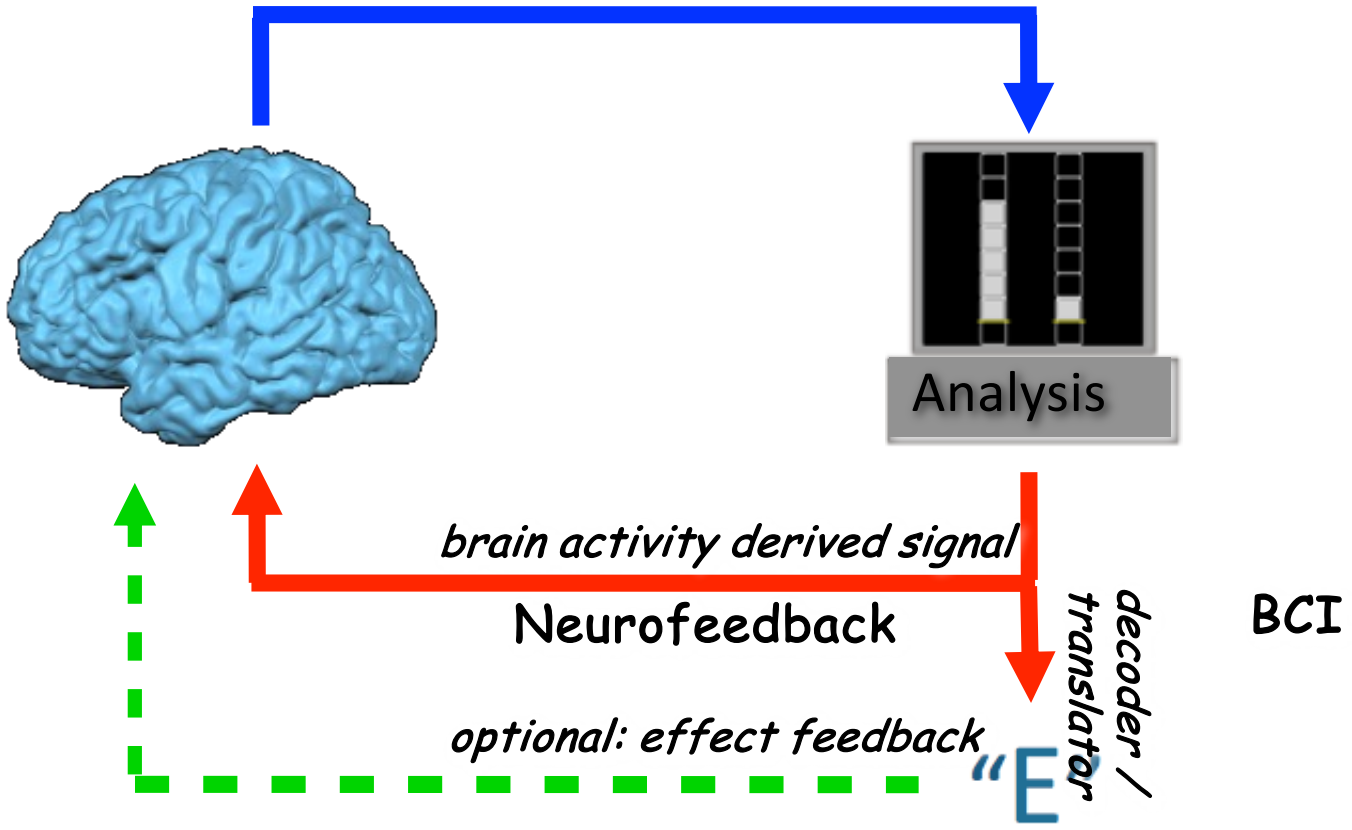
N. K. Logothetis[1,2], O. Eschenko[1], Y. Murayama[1], M. Augath[1], T. Steudel[1], H. C. Evrard[1], M. Besserve[1,3] & A. Oeltermann[1]

By combining electrophysiological recordings in hippocampus with ripple-triggered functional magnetic resonance imaging, here we show that most of the cerebral cortex is selectively activated during the ripples, whereas most diencephalic, midbrain and brainstem regions are strongly and consistently inhibited



Applications of Real-Time fMRI Data Analysis

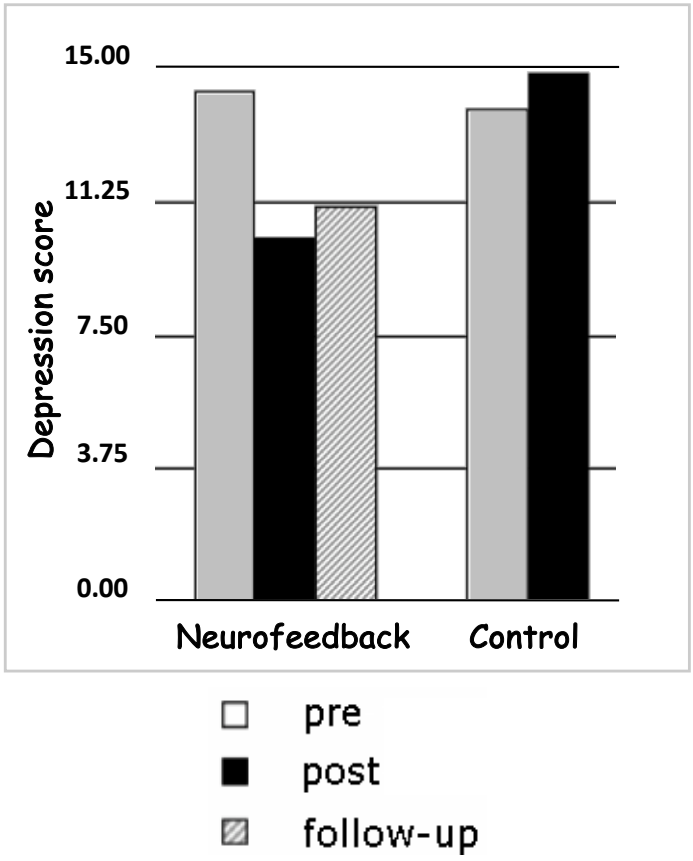
Online "brain reading" for neurofeedback and communication BCI



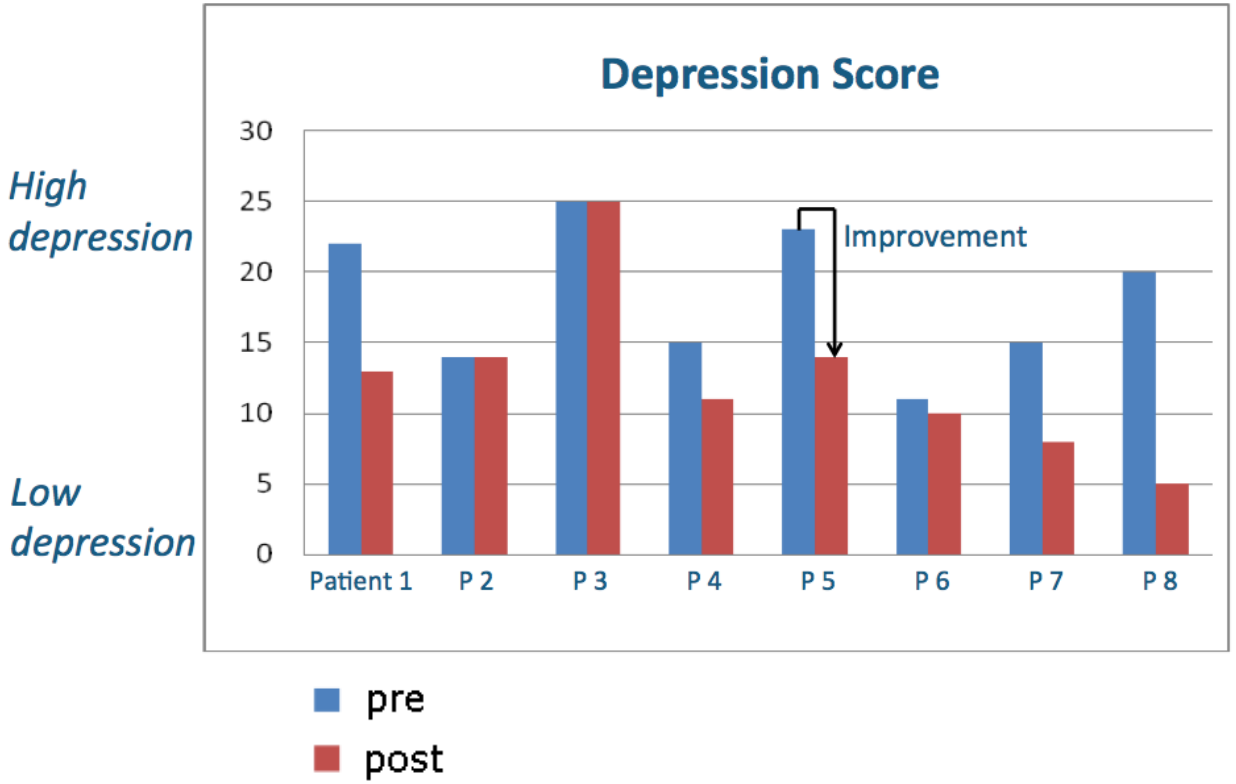
Neurofeedback Therapy for Patients with Depression

Behavioral effects of neurofeedback training after 4 sessions (HRSD score)

group results



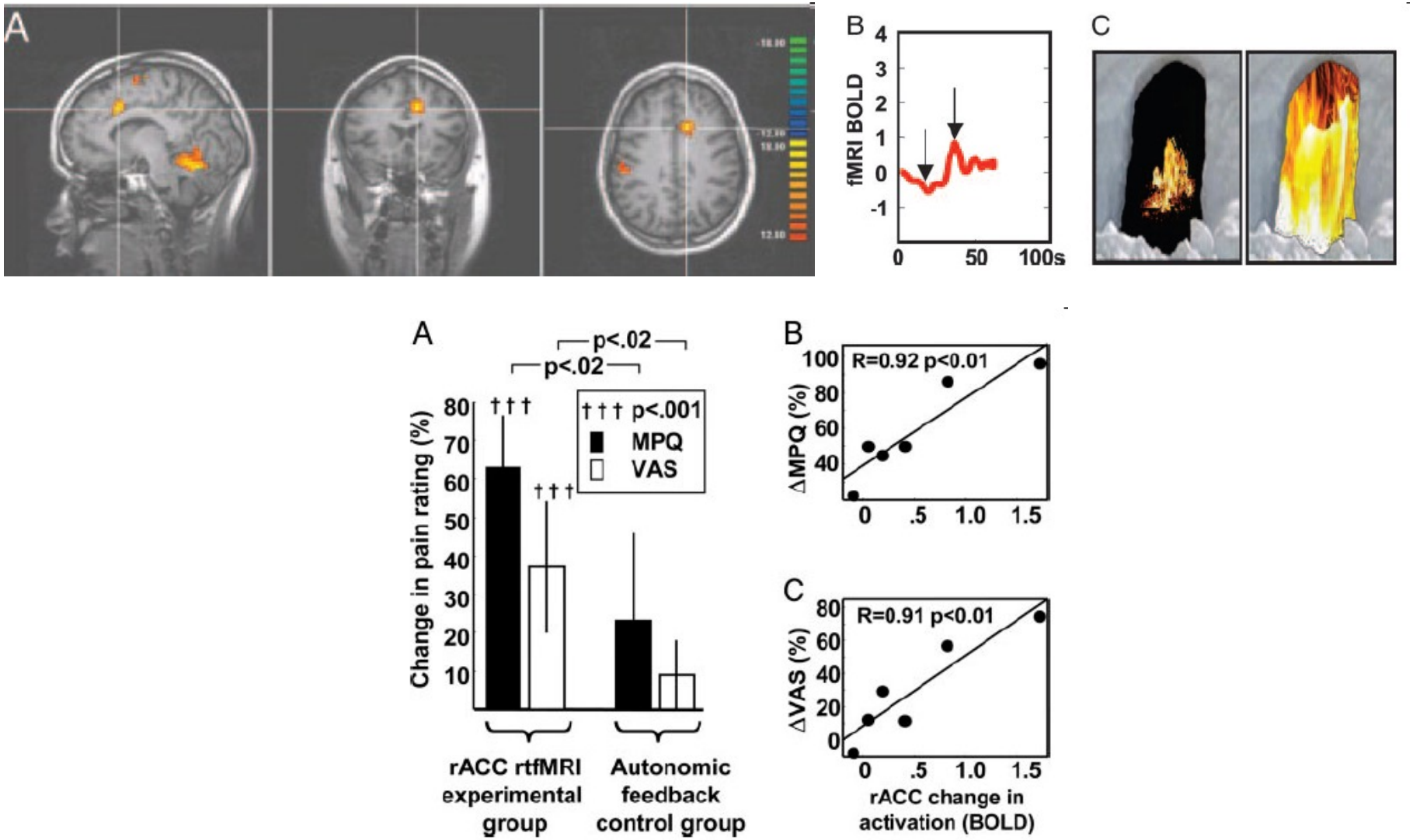
single-subject results



-> First clinical trial study in UK

Linden, D.E.J., Habes, I., Johnston, S.J., Linden, S., Tatineni, R., Subramanian L., Sorger, B., Healy, D., Goebel, R. (2012) Real-time Self-regulation of Emotion Networks in Patients with Depression. *PLOS One*, 7, e38115.

Real time fMRI feedback to reduce chronic pain

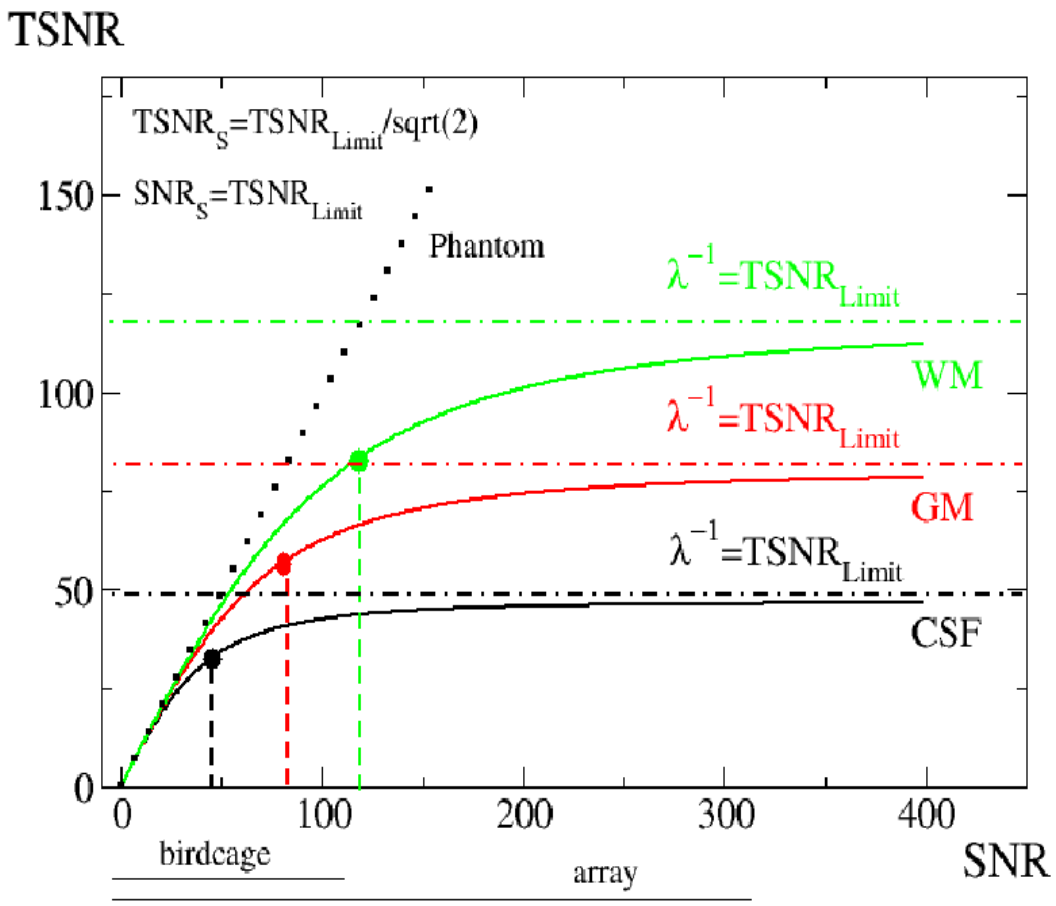


Control over brain activation and pain learned by using real-time functional MRI, R. C. deCharms, et al. PNAS, 102; 18626-18631 (2005)

fMRI Paradigm Designs and Processing Strategies

1. Neuronal Activation Input Strategies
2. Resting State fMRI
3. fMRI Decoding

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

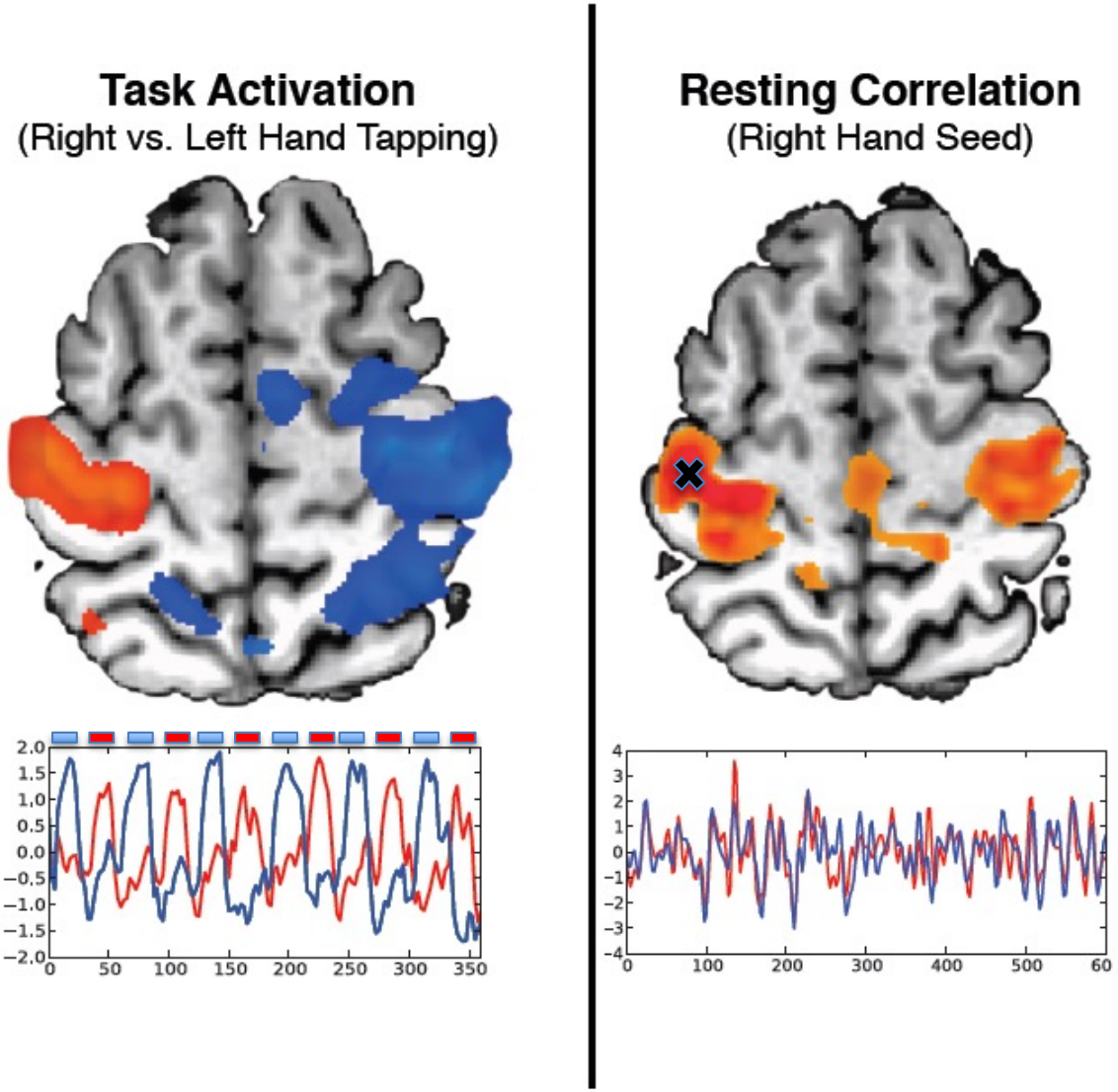


J. Bodurka, F.Ye, N Petridou, K. Murphy, P.A. Bandettini, *NeuroImage*, 34, 542-549 (2007)

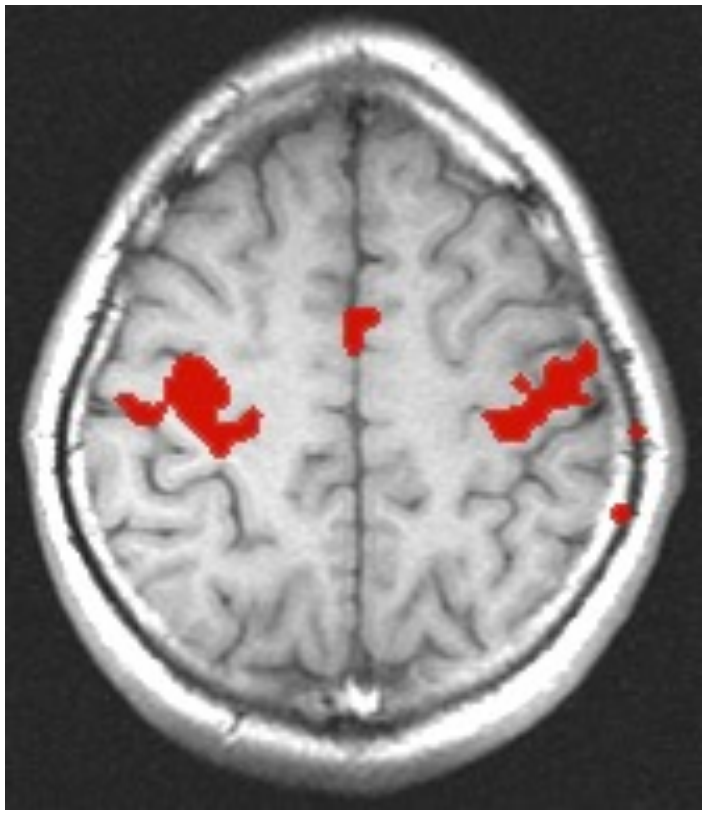
Sources of time series fluctuations:

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

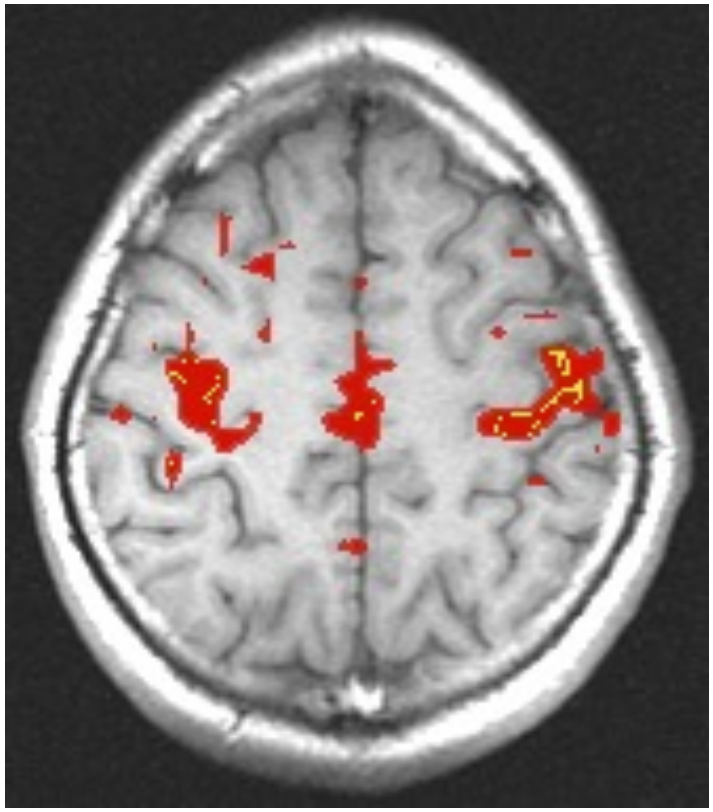
Activation-based fMRI and “resting state” fMRI



Resting State Correlations



Activation:
correlation with reference function

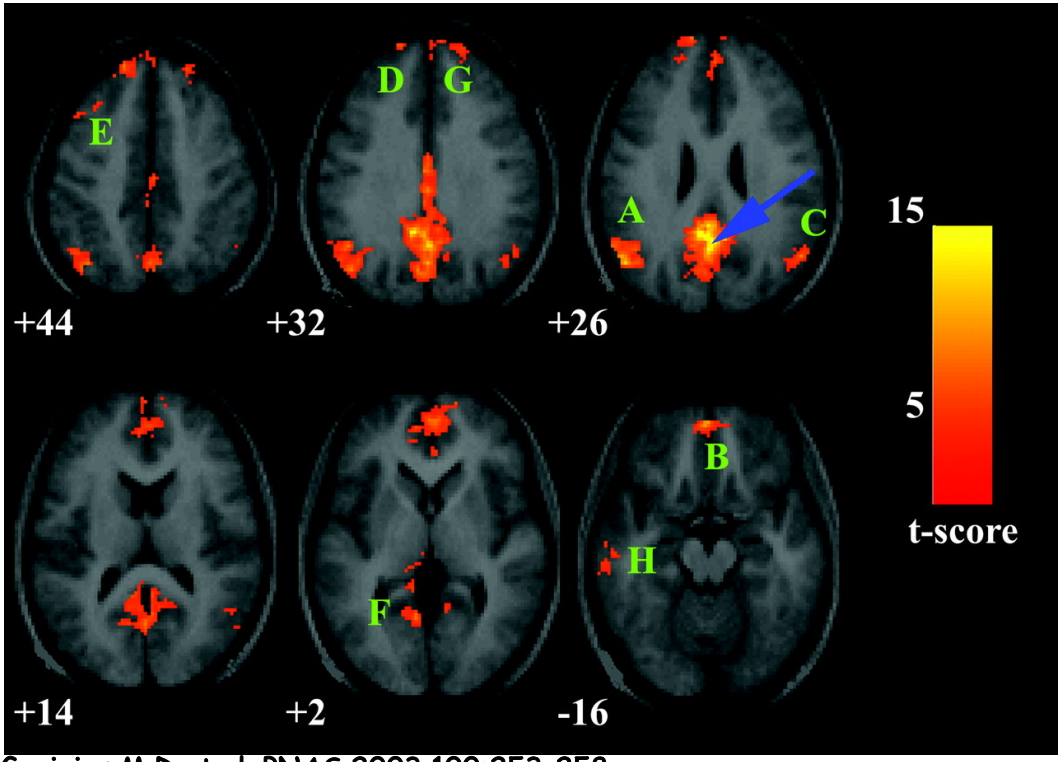


Rest:
seed voxel in motor cortex

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

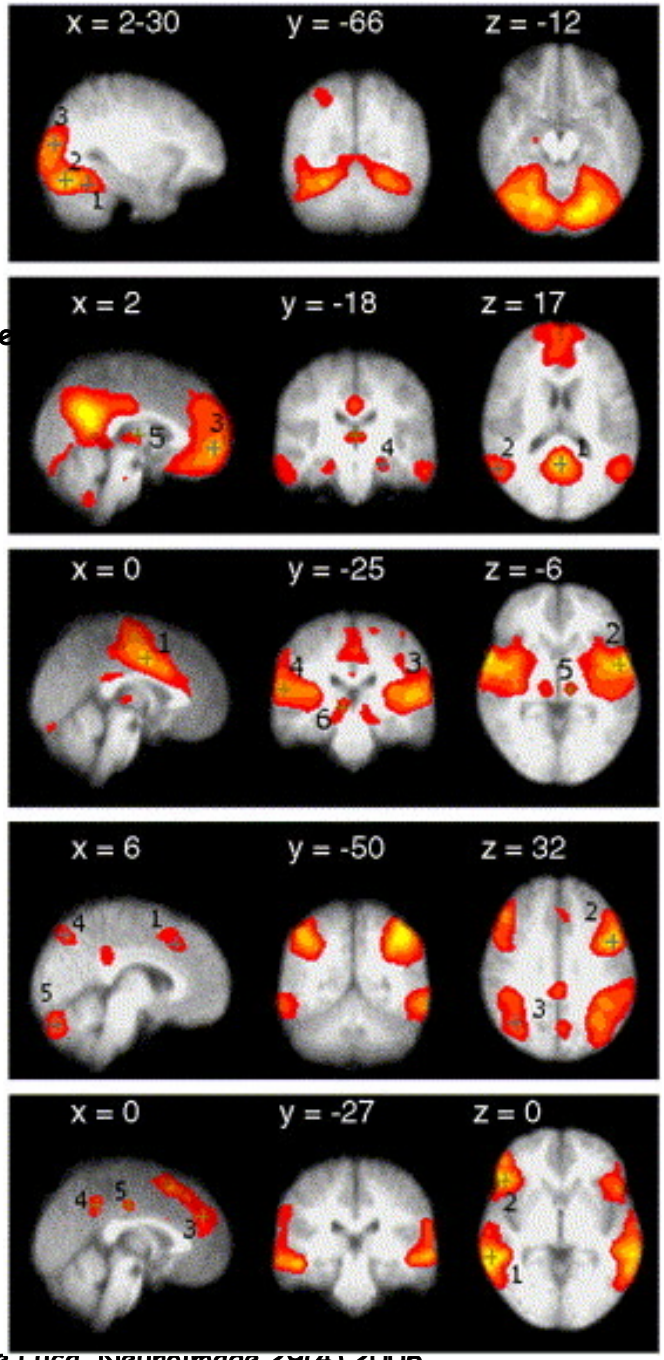
Seed Voxel

Seed Based Correlation from the Posterior Cingulate Cortex



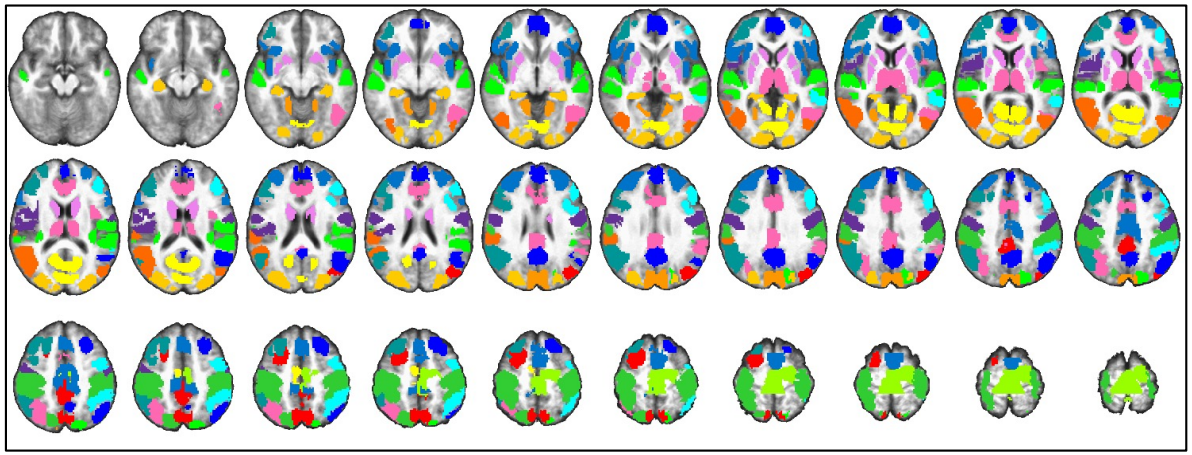
Greicius M D et al. PNAS 2003;100:253-258

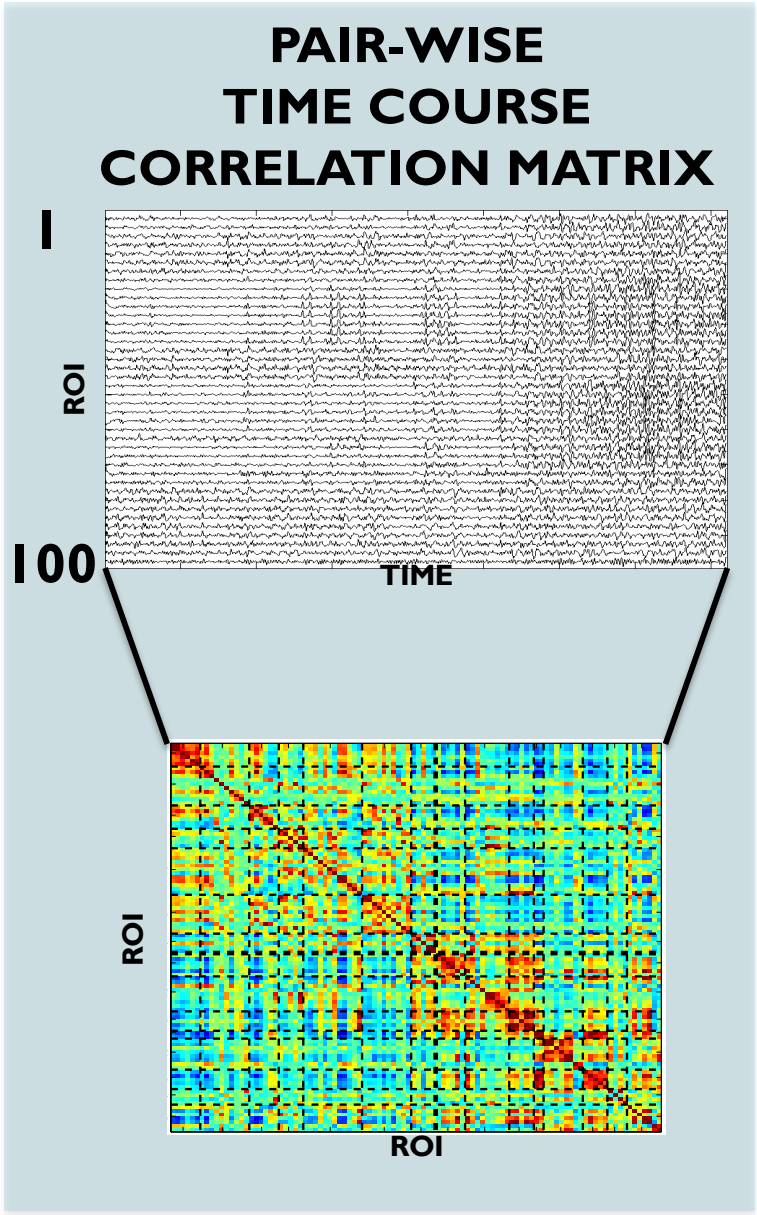
ICA

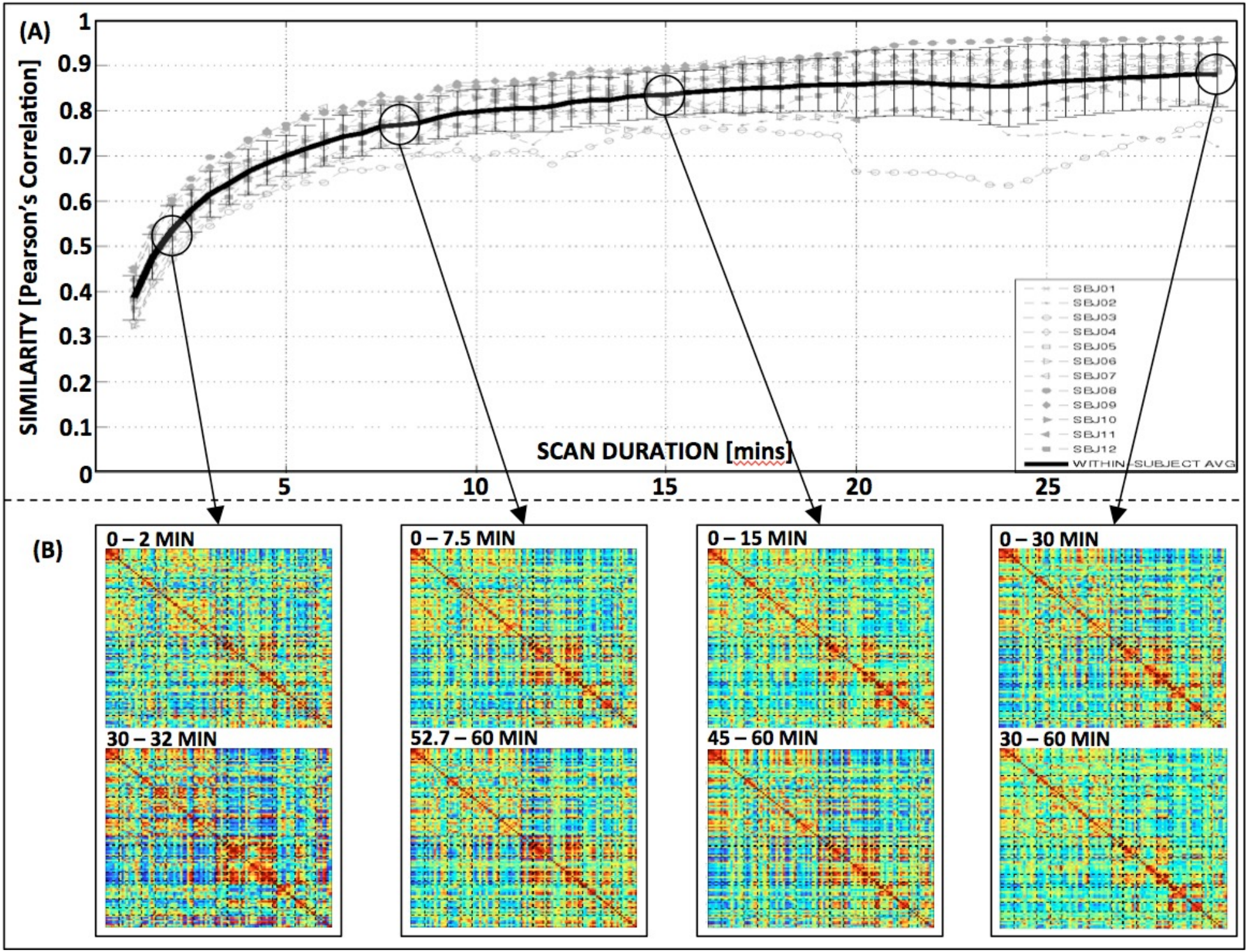


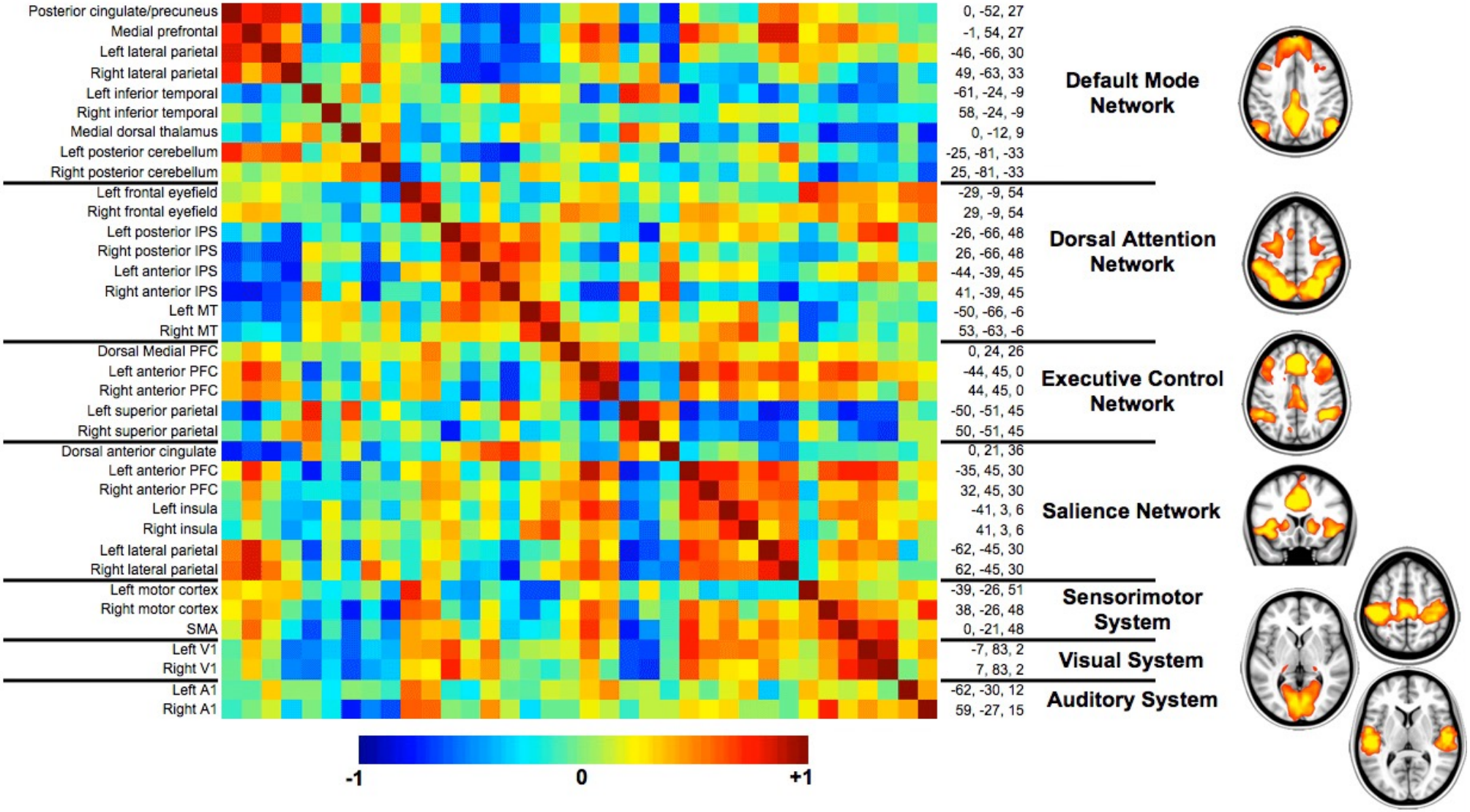
De Luca, Neuroimage 29(4) 2006

Time Course Correlation Matrix






(A)
SIMILARITY [Pearson's Correlation]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
SCAN DURATION [mins]
SBJ01
SBJ02
SBJ03
SBJ04
SBJ05
SBJ06
SBJ07
SBJ08
SBJ09
SBJ10
SBJ11
SBJ12
WITHIN-SUBJECT AVG
(B)
0 – 2 MIN
30 – 32 MIN
0 – 7.5 MIN
52.7 – 60 MIN
0 – 15 MIN
45 – 60 MIN
0 – 30 MIN
30 – 60 MIN



http://www.nil.wustl.edu/labs/raichle/images/Restless_Brain/correlation_matrix.html

fMRI Paradigm Designs and Processing Strategies

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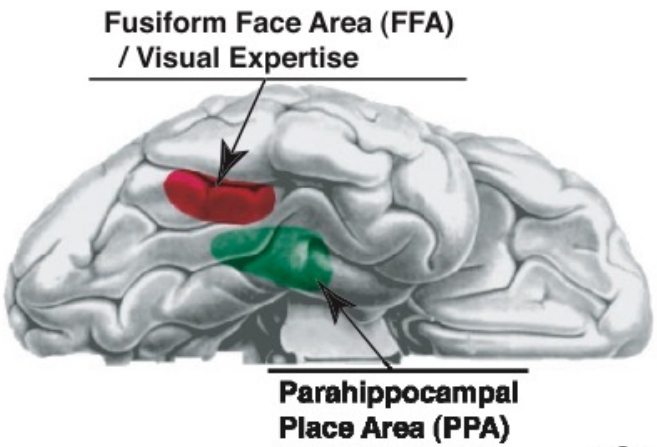
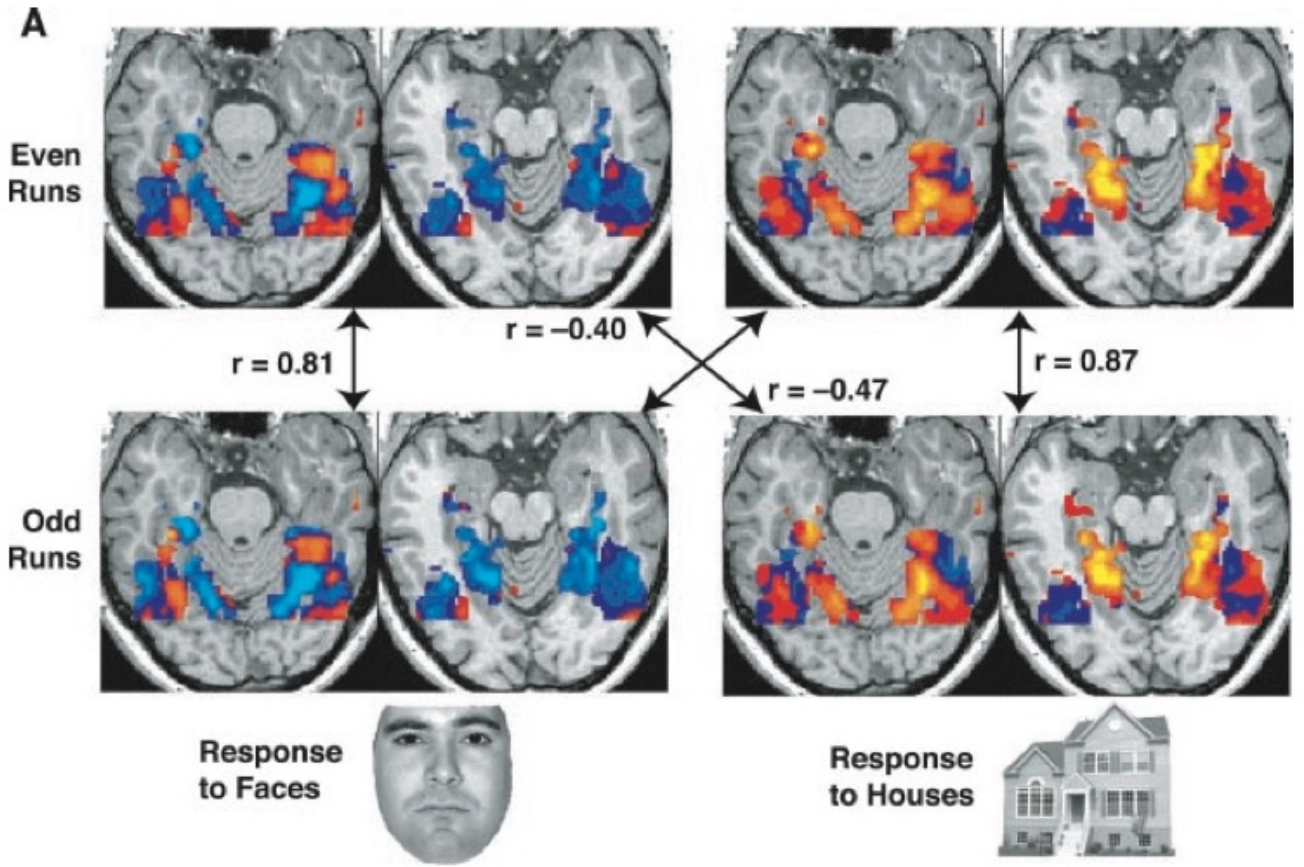
3. fMRI Decoding

Brain Reading



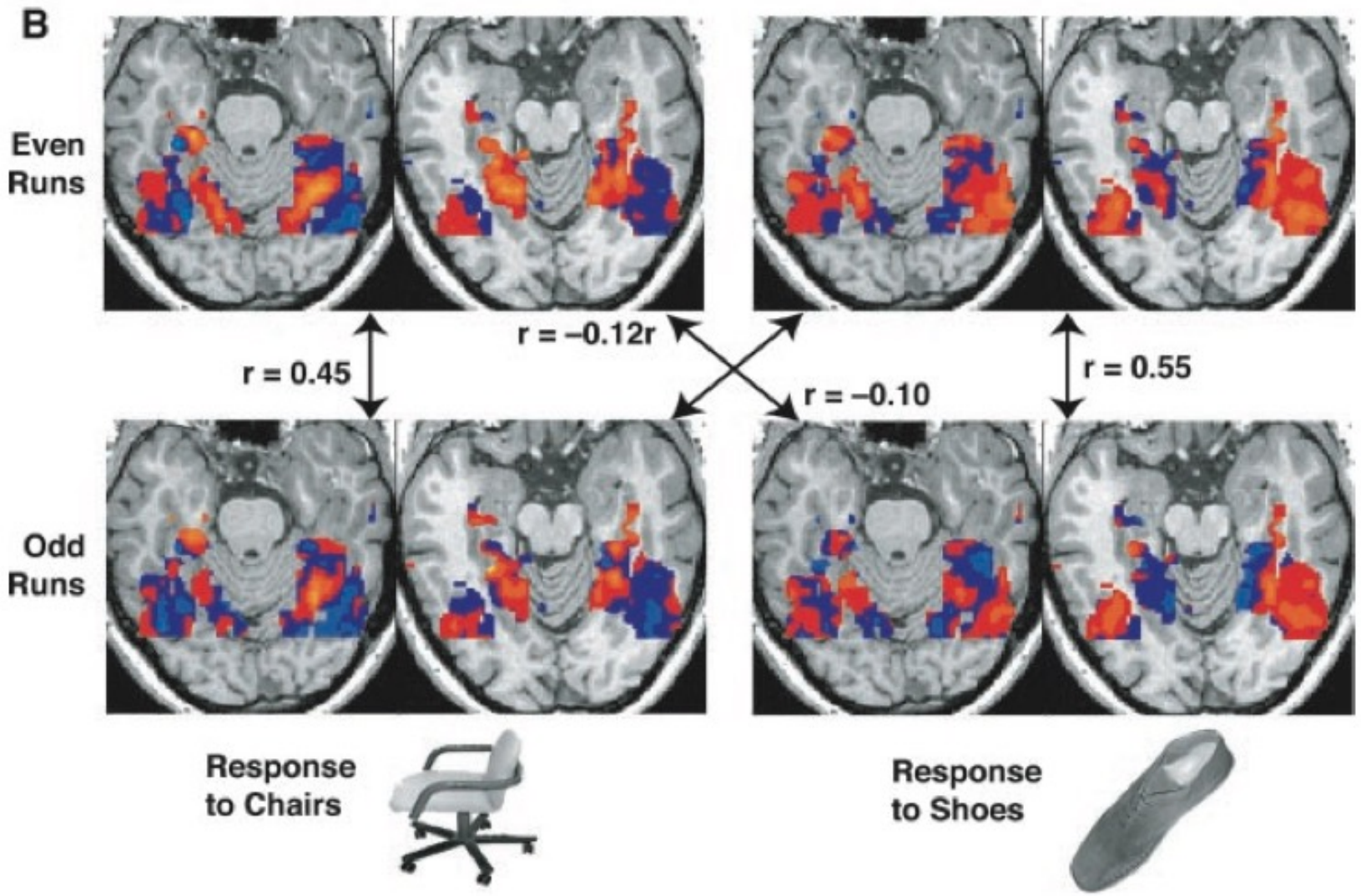
Face Area vs House Area



Haxby, J. V. et al. Distributed and Overlapping Representations in Ventral Temporal Cortex, Science 293, 2425-2429, (2001)

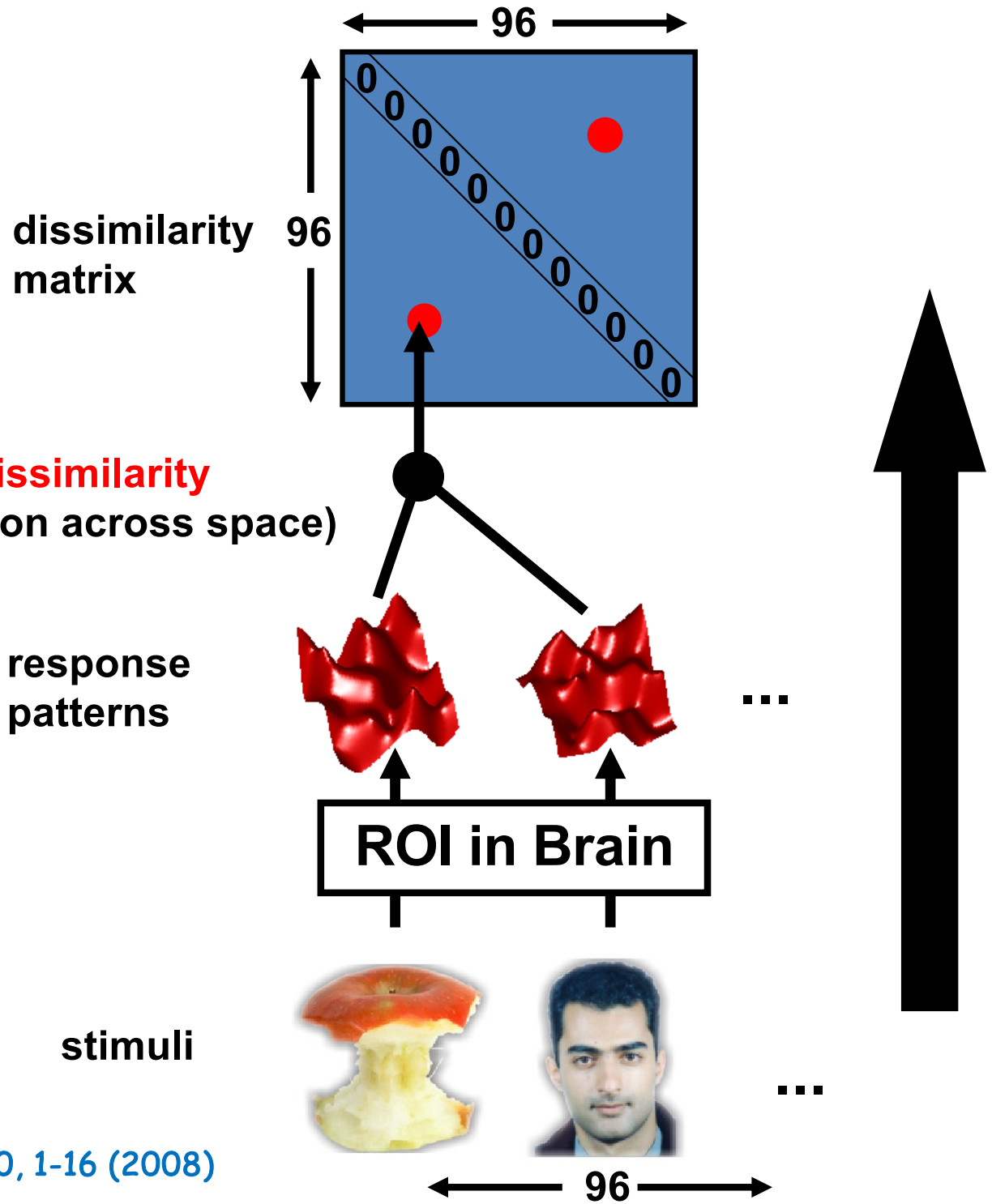
Brain Reading

Decoding more complex activity where obvious blobs don't appear



Haxby, J. V. et al. Distributed and Overlapping Representations in Ventral Temporal Cortex, Science 293, 2425-2429, (2001)

Dissimilarity Matrix Creation

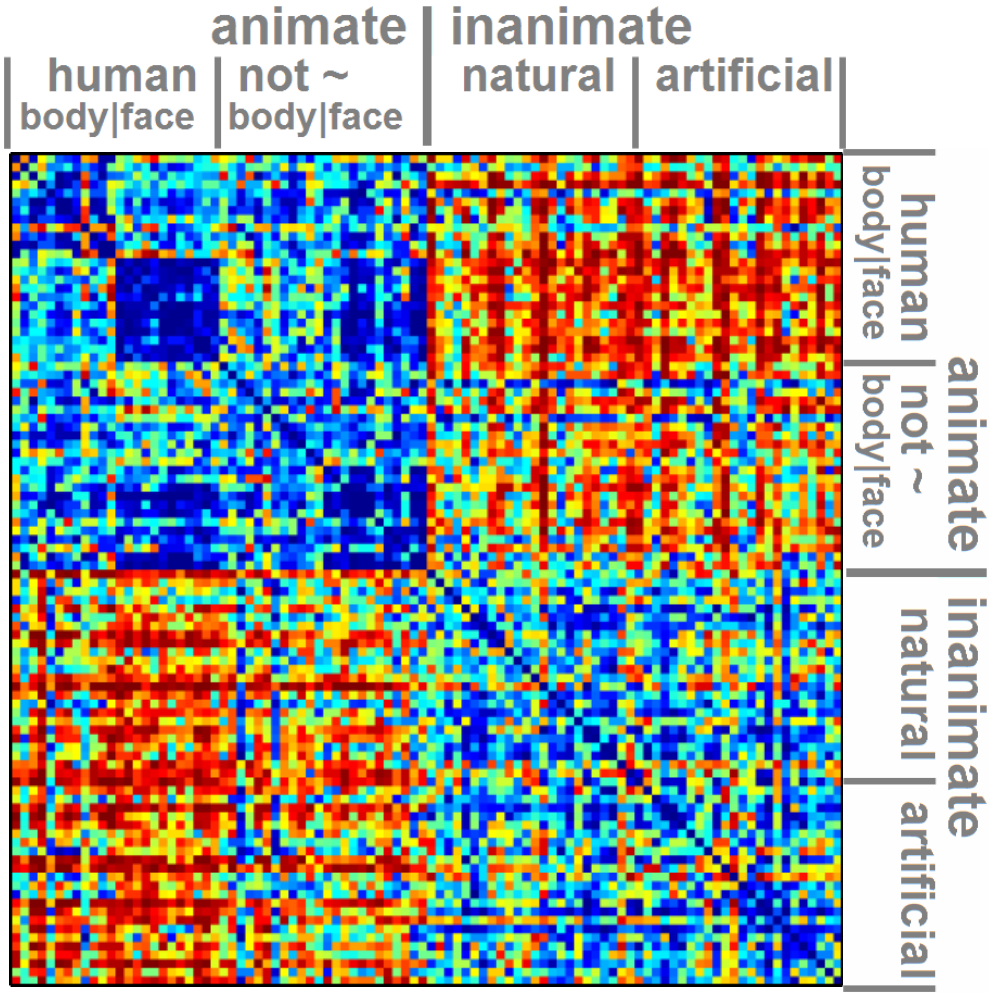


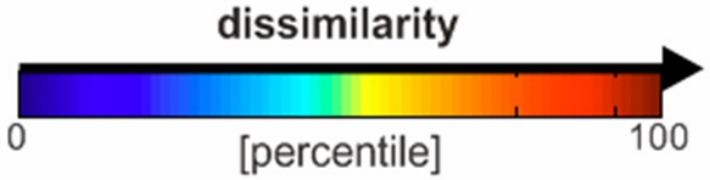
N. Kriegeskorte, et al, Neuron 60, 1-16 (2008)

Visual Stimuli

Human IT

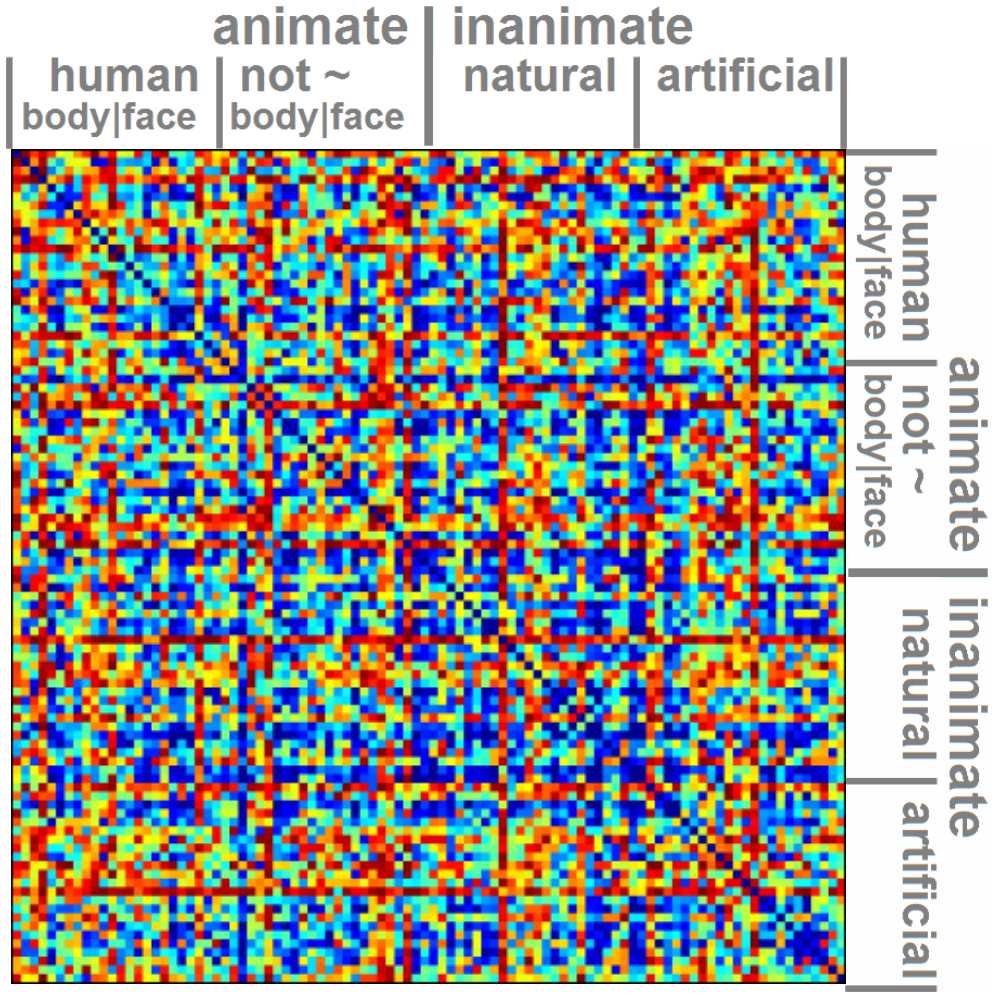
(1000 visually most responsive voxels)

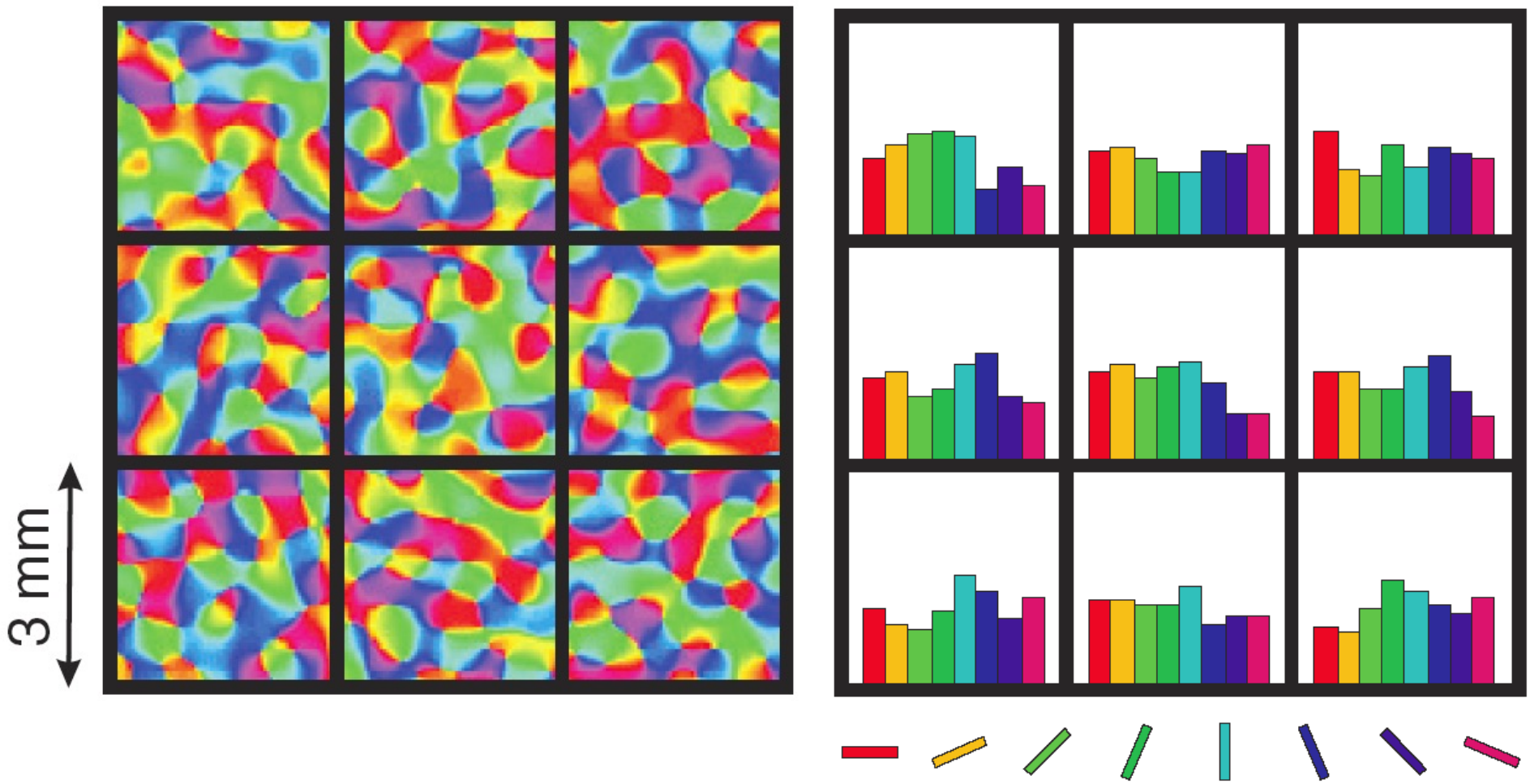




Human Early Visual Cortex

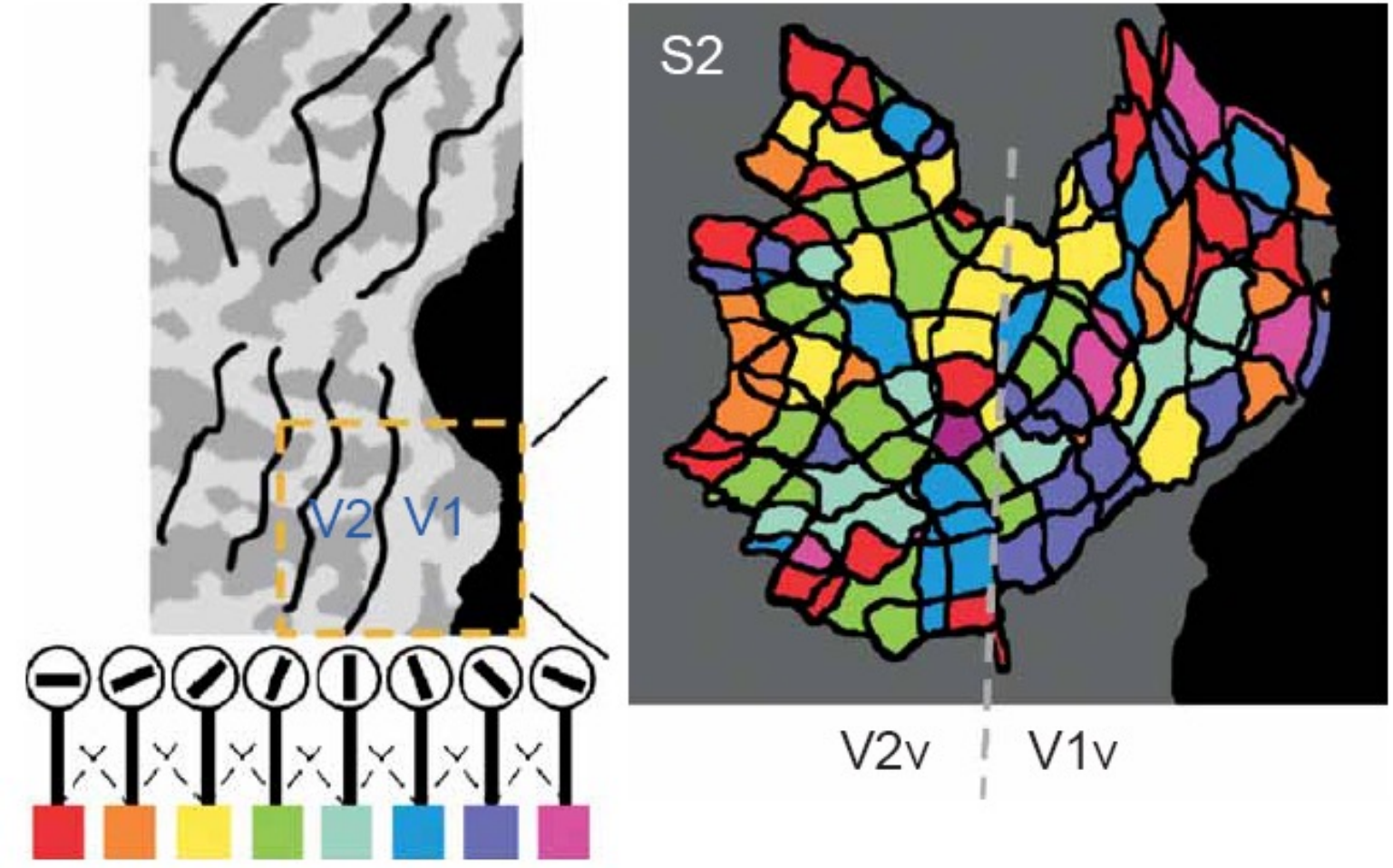
(1057 visually most responsive voxels)





Boynton (2005), News & Views on Kamitani & Tong (2005) and Haynes & Rees (2005)

Lower spatial frequency clumping



Kamitani & Tong (2005)

Contrast
Resolution
Paradigms
Processing