“Cutting Edge” of fMRI

Extracting transient neuronal activity
Peter Bandettini, NIMH, Bethesda, MD, USA

Magnetic Source MRI
Jin-Hu Xiong, San Antonio, TX, USA

BOLD latency mapping and regional multivariate pattern extraction
Rainer Goebel, Maastricht, Netherlands

Physiologic parameter quantification based on T2’ mapping
Hongyu An, Chapel Hill, NC, USA

Extracting transient neuronal activity

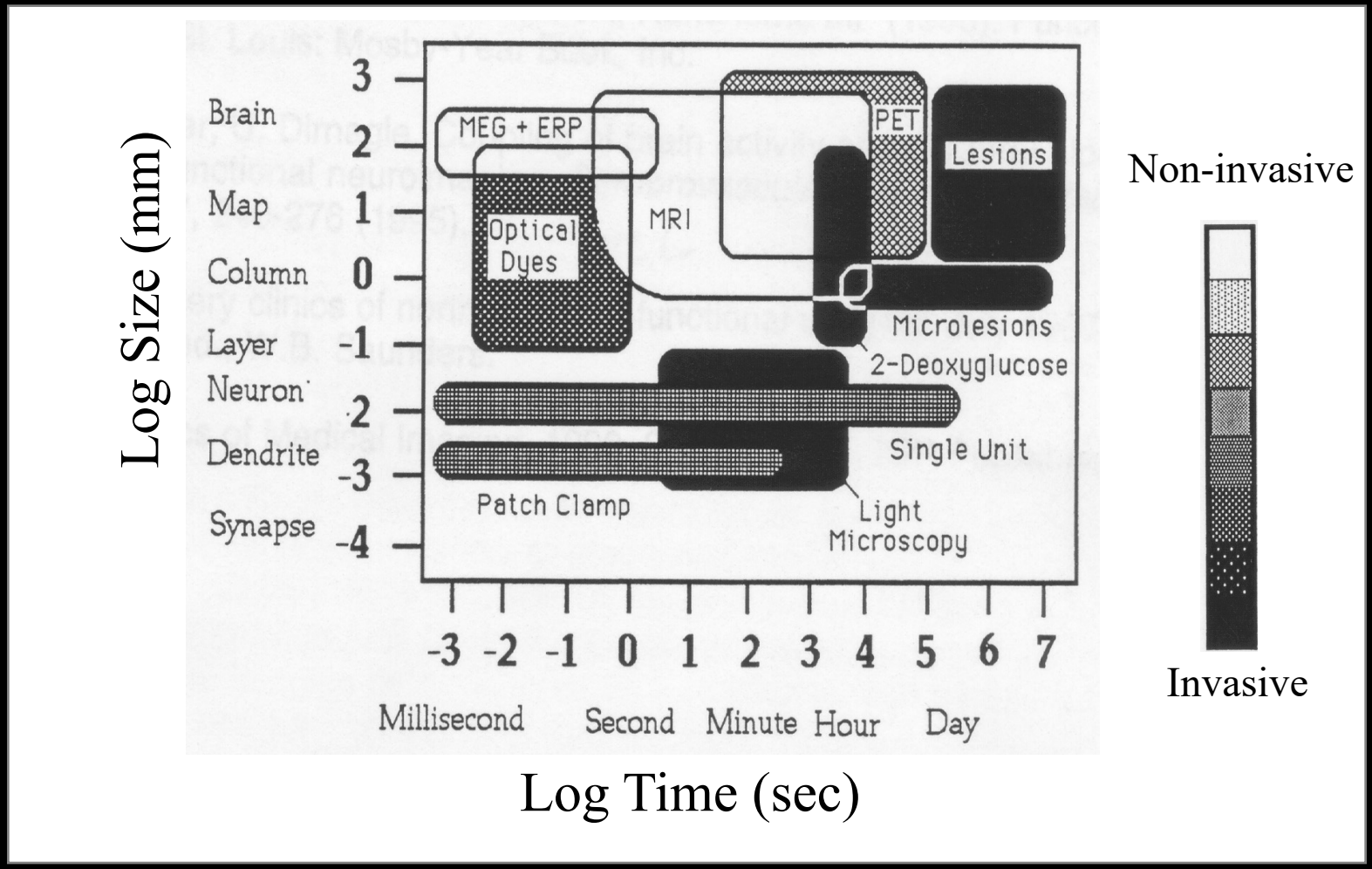
Peter A. Bandettini, Ph.D

Unit on Functional Imaging Methods
&
Functional MRI Facility

Laboratory of Brain and Cognition
National Institute of Mental Health

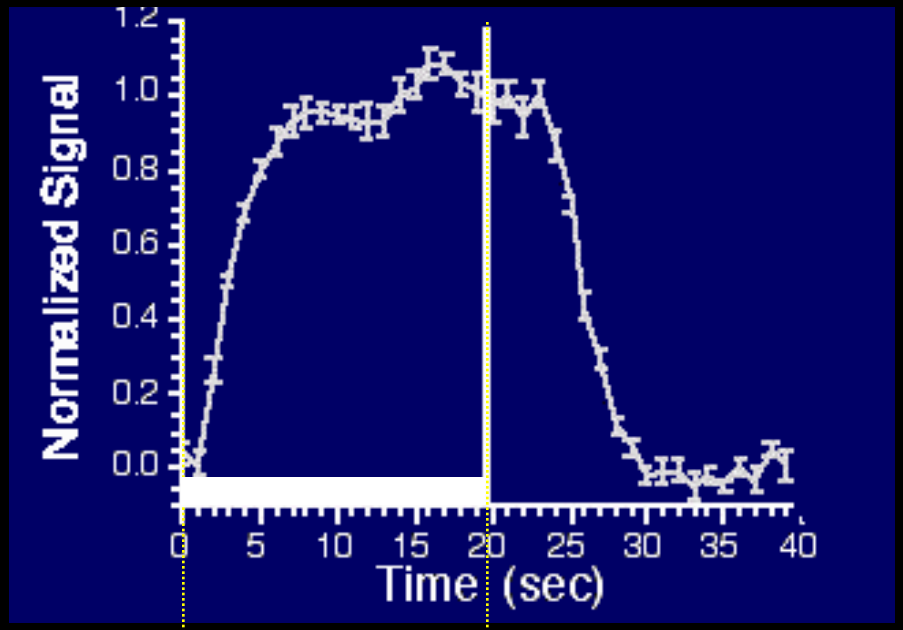
NIMH
National Institute
of Mental Health

Functional Neuroimaging Techniques

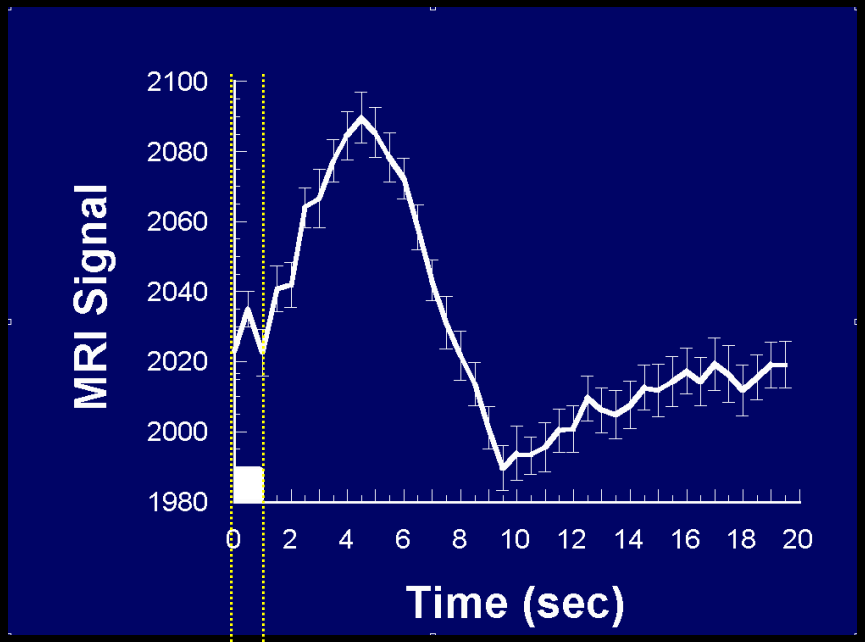


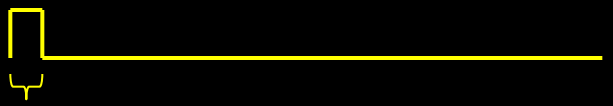
Extracting transient neuronal activity

- Initial transient mapping
- BOLD latency and width modulation/mapping
- Direct neuronal current imaging


Normalized Signal
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
35
40
Time (sec)

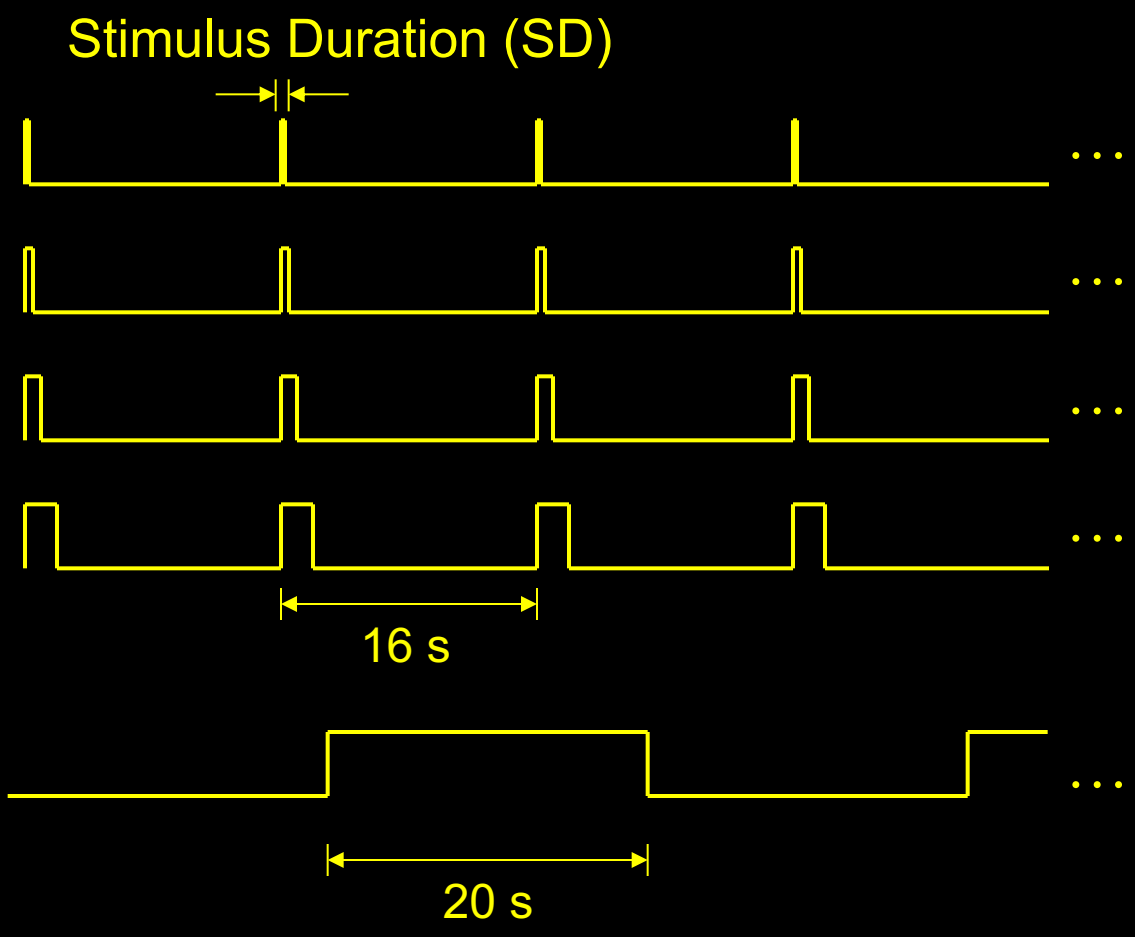
task


MRI Signal
2100
2080
2060
2040
2020
2000
1980
0
2
4
6
8
10
12
14
16
18
20
Time (sec)

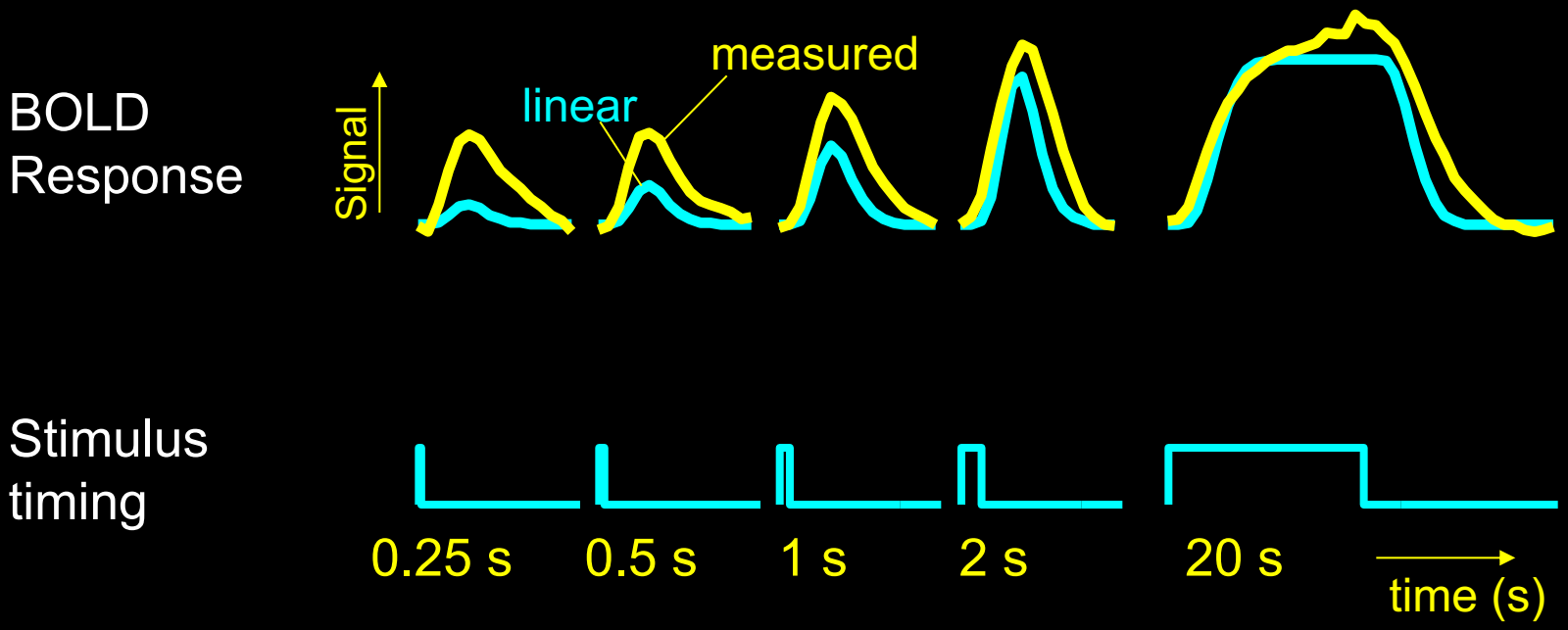


task

Methods



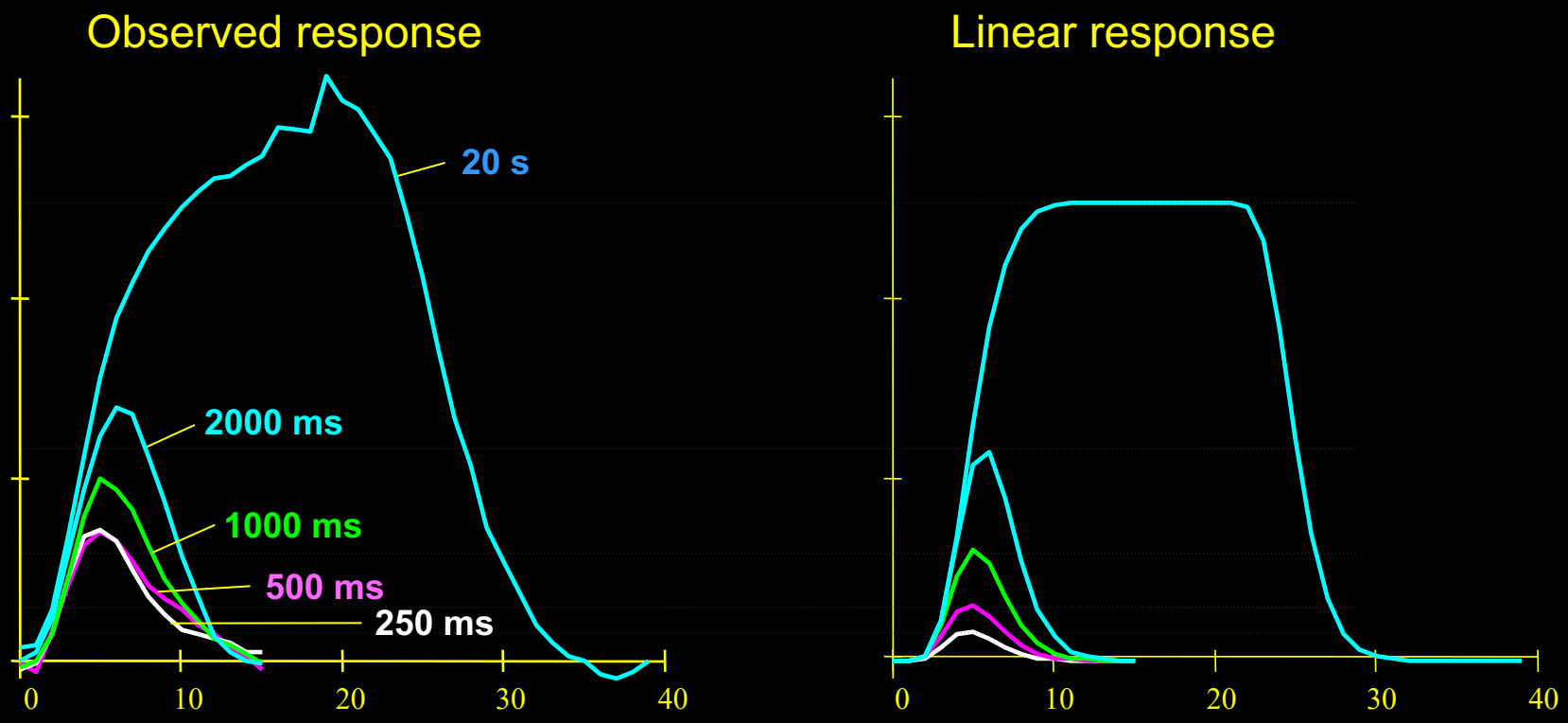
	Visual	*Motor*
···	SD = 250 ms	SD = 500 ms
···	SD = 500 ms	SD = 1000 ms
···	SD = 1000 ms	SD = 2000 ms
···	SD = 2000 ms	SD = 4000 ms
···	Blocked Trial	



Brief stimuli produce larger responses than expected

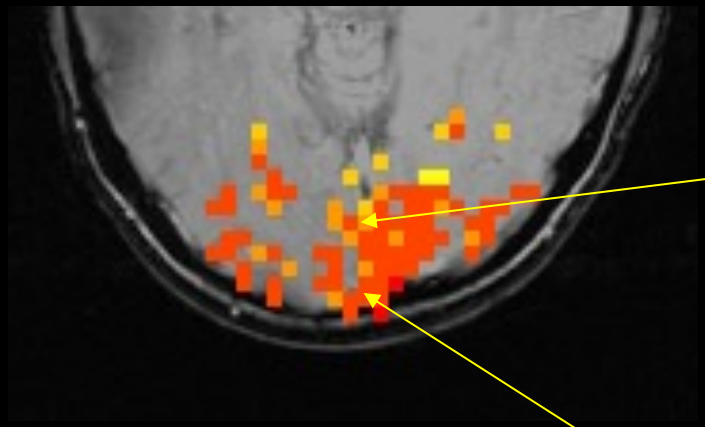
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." *NeuroImage*, 14: 817-826.

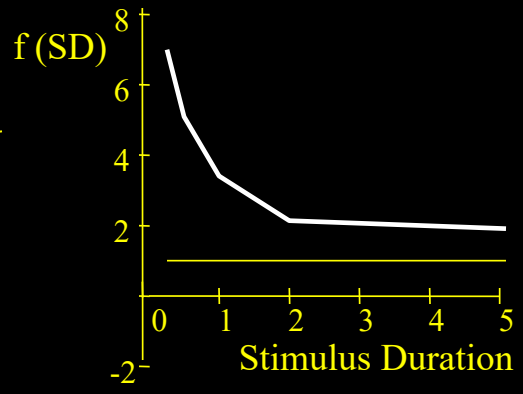
BOLD response is nonlinear

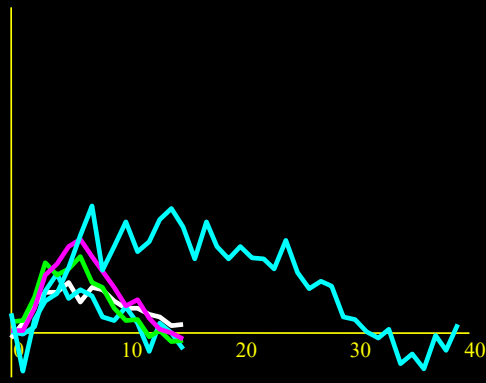


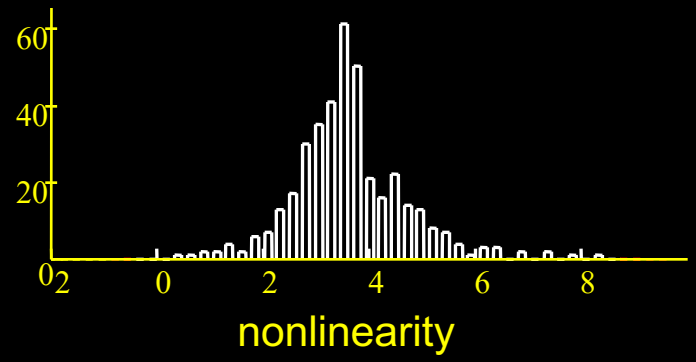
Short duration stimuli produce larger responses than expected

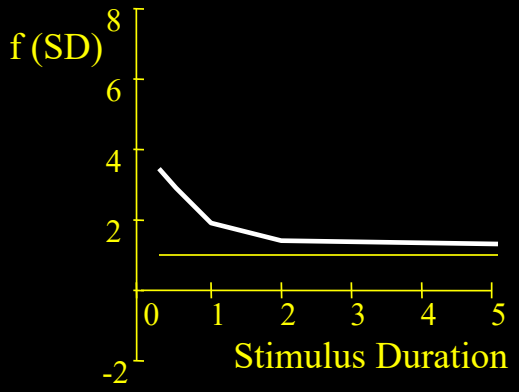
Spatial Heterogeneity of BOLD Nonlinearity

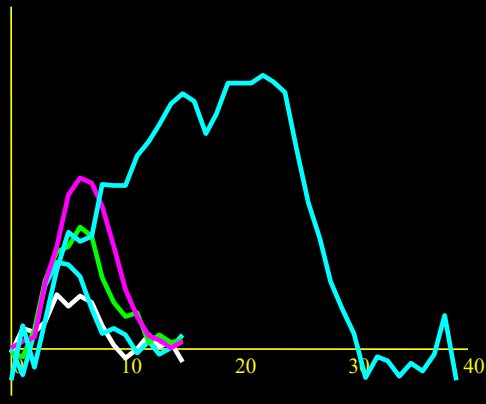












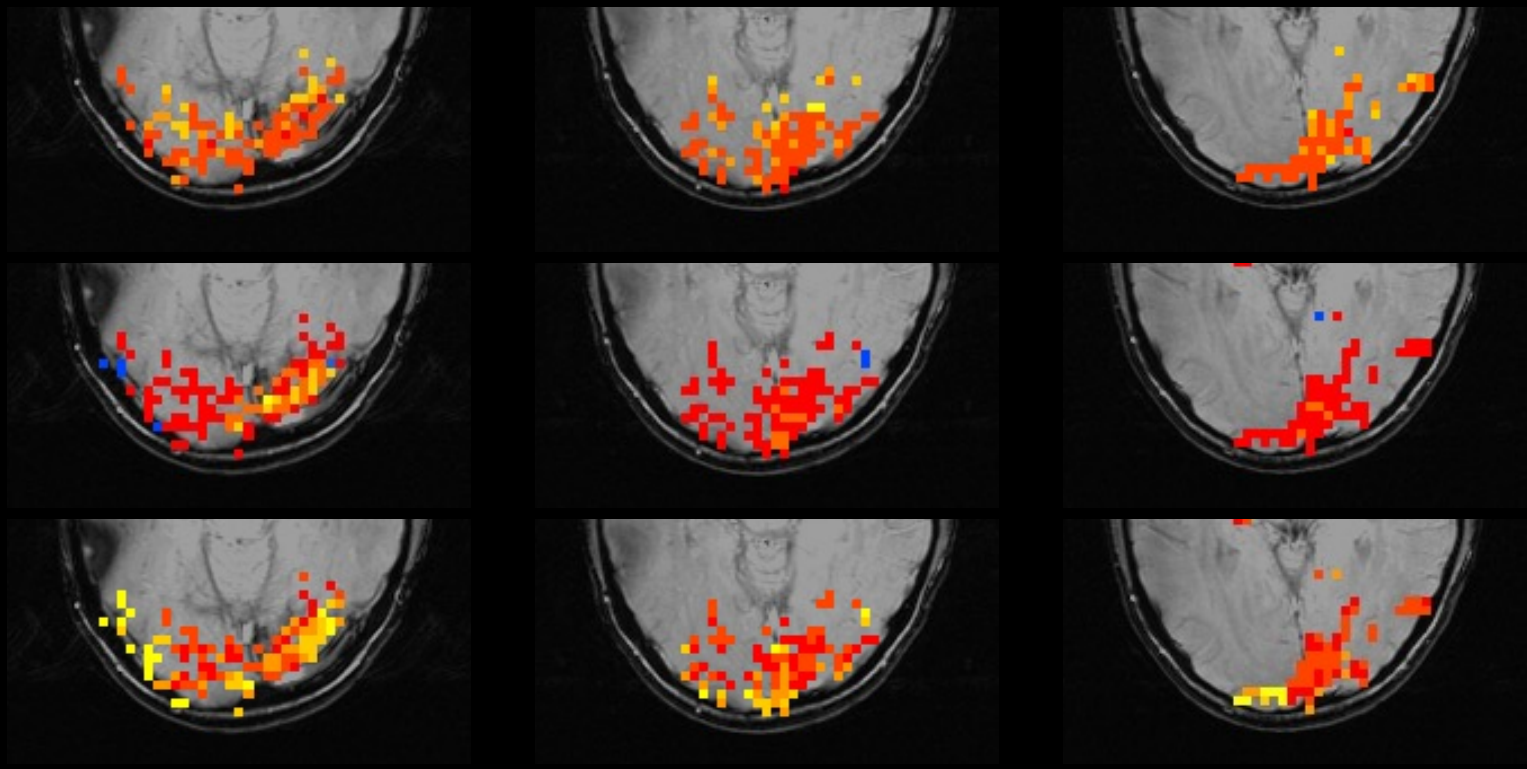
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." *NeuroImage*, 14: 817-826.

Results – visual task

Nonlinearity

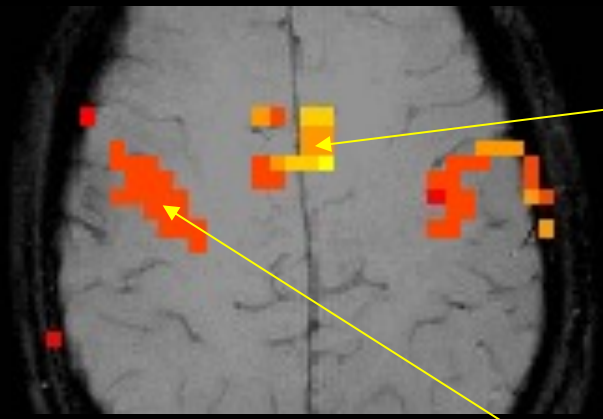
Magnitude

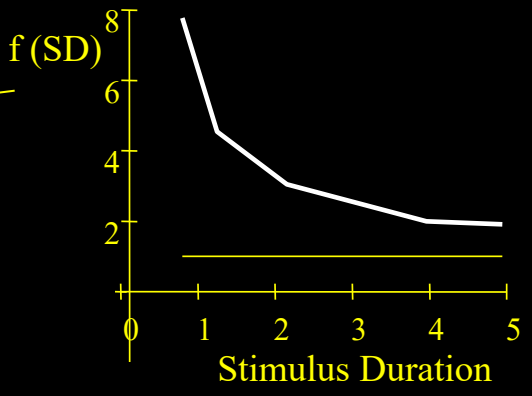
Latency

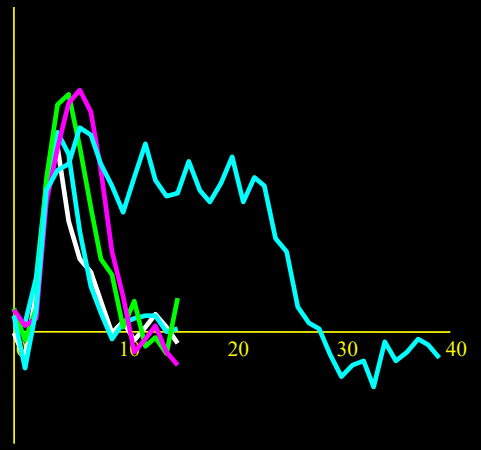


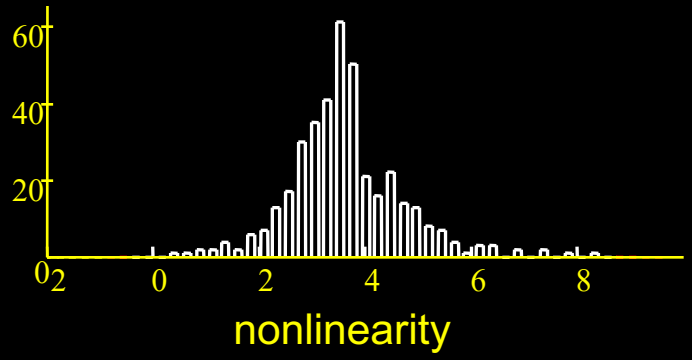
R. M. Birn, Z. Saad, P. A. Bandettini, (2001) "Spatial heterogeneity of the nonlinear dynamics in the fMRI BOLD response." *NeuroImage*, 14: 817-826.

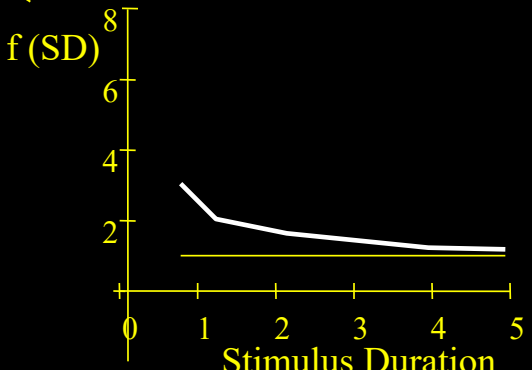
Results – motor task

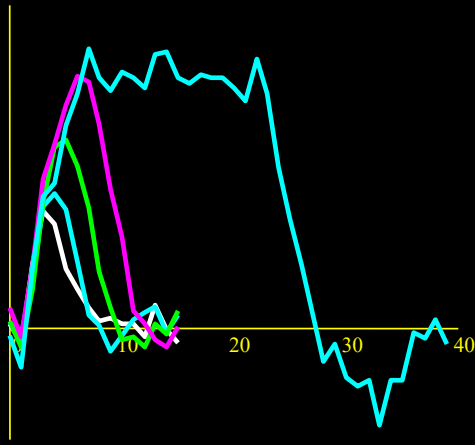










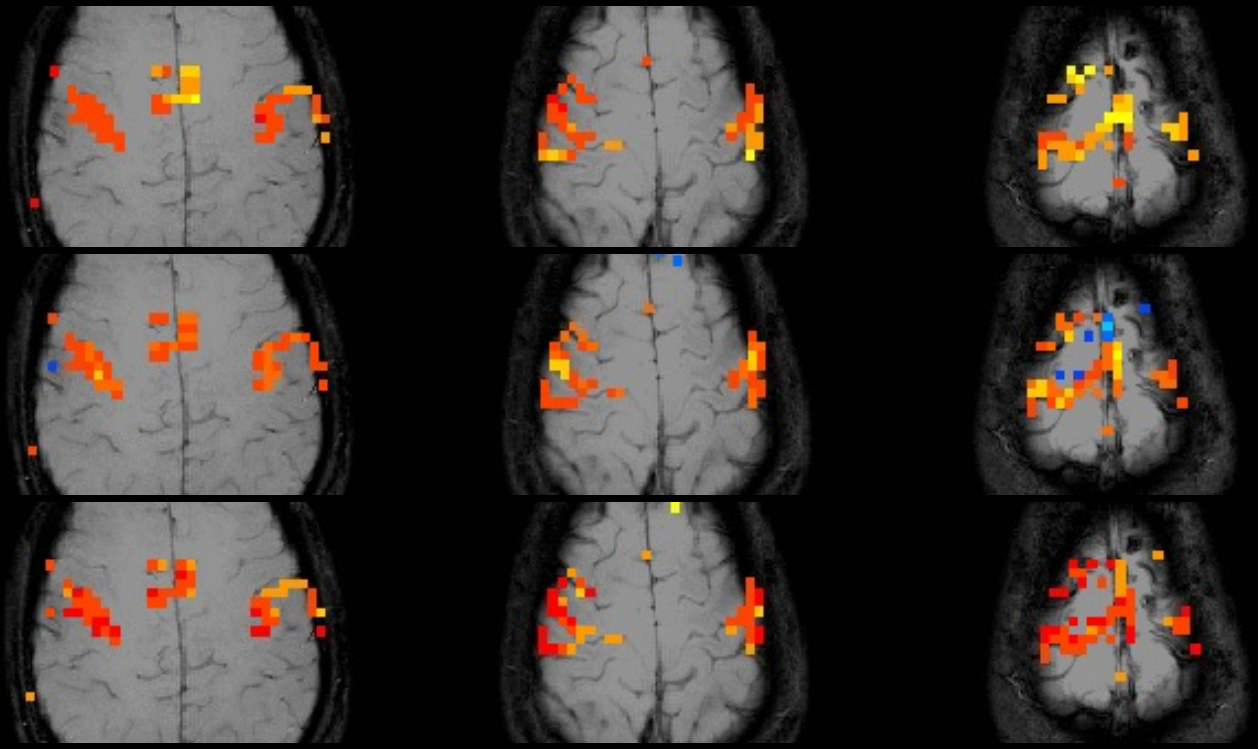


Results – motor task

Nonlinearity

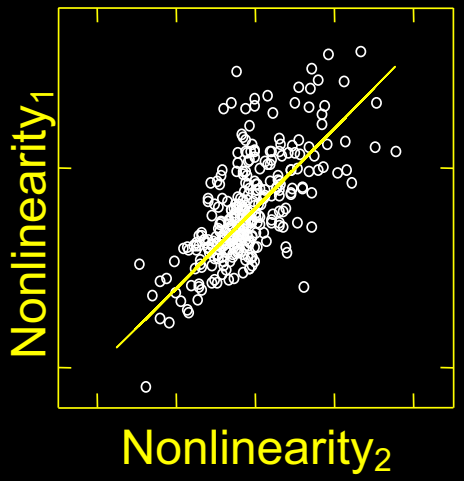
Magnitude

Latency

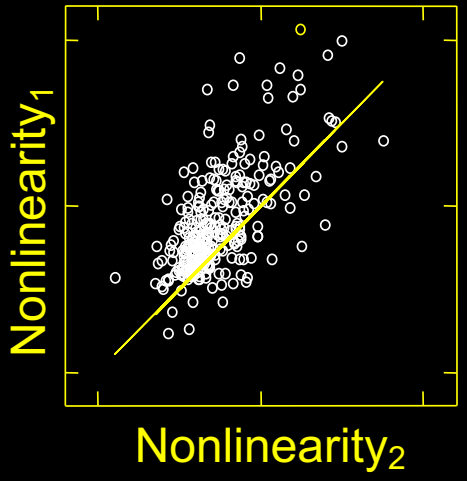


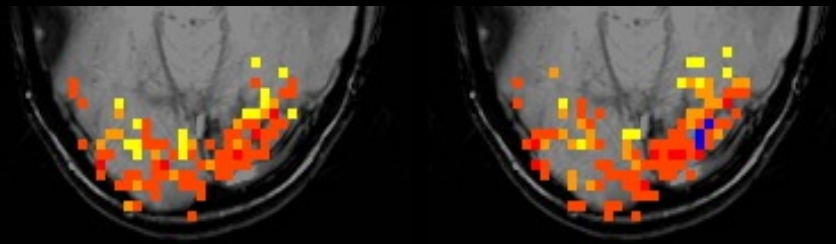
Reproducibility

Visual task

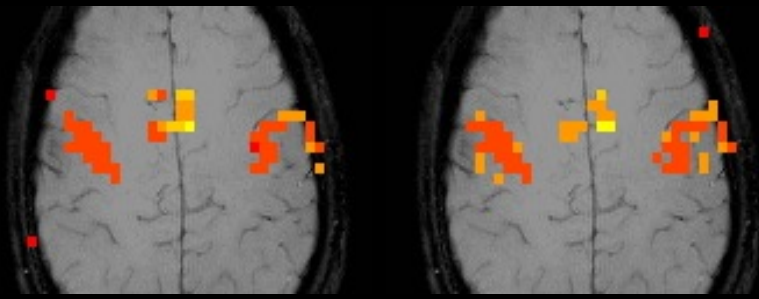


Motor task





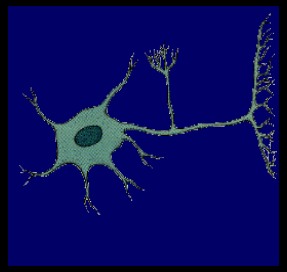
Experiment 1 Experiment 2

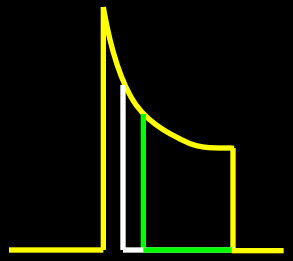


Experiment 1 Experiment 2

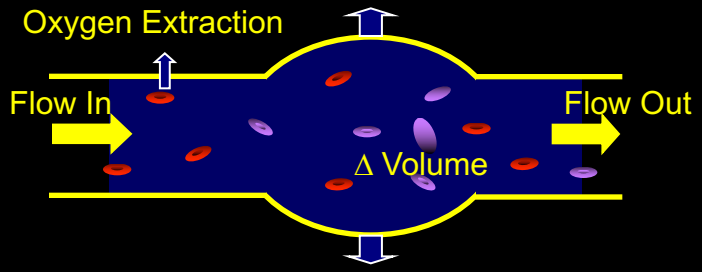
Sources of this Nonlinearity

- Neuronal



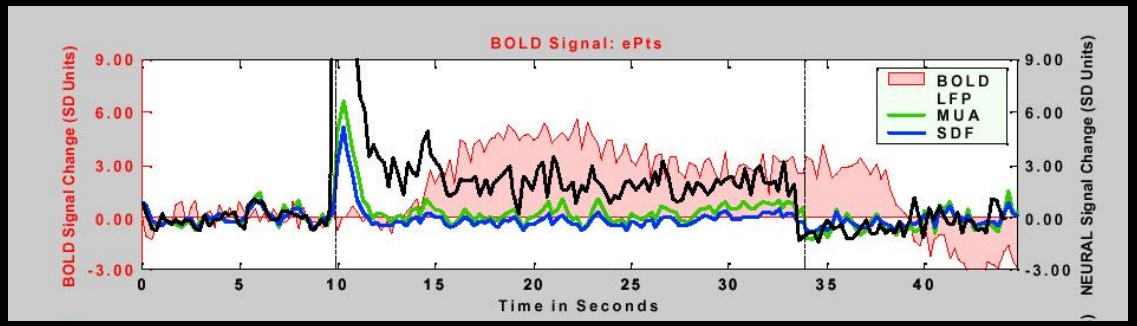


- Hemodynamic
  - Oxygen extraction
  - Blood volume dynamics

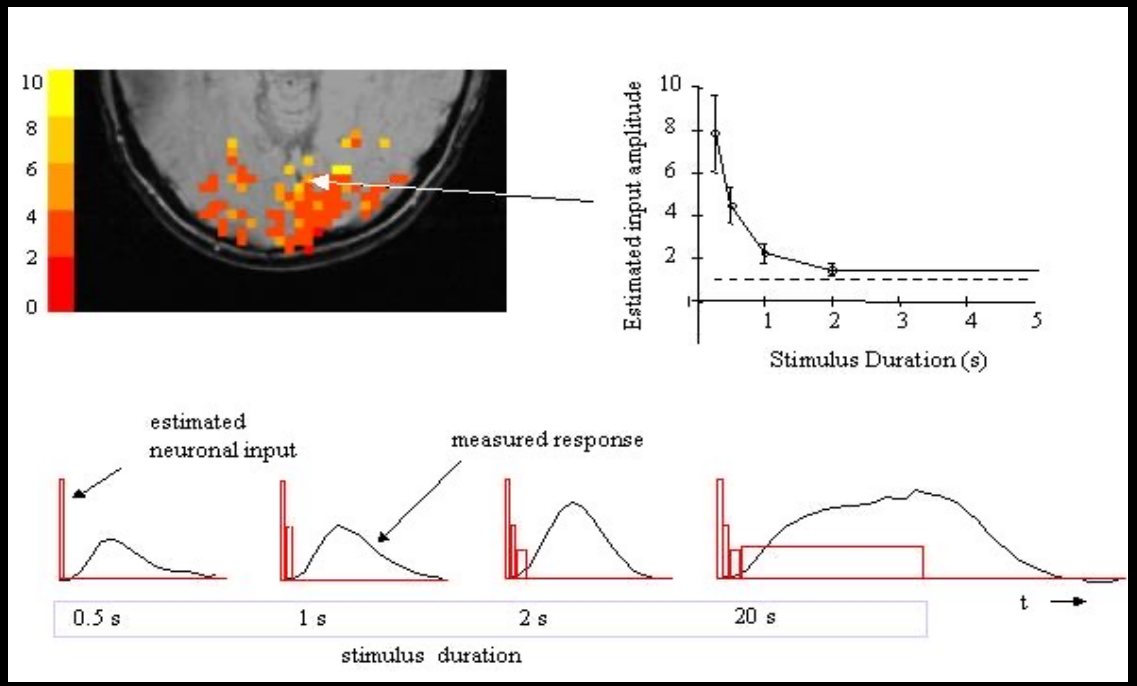


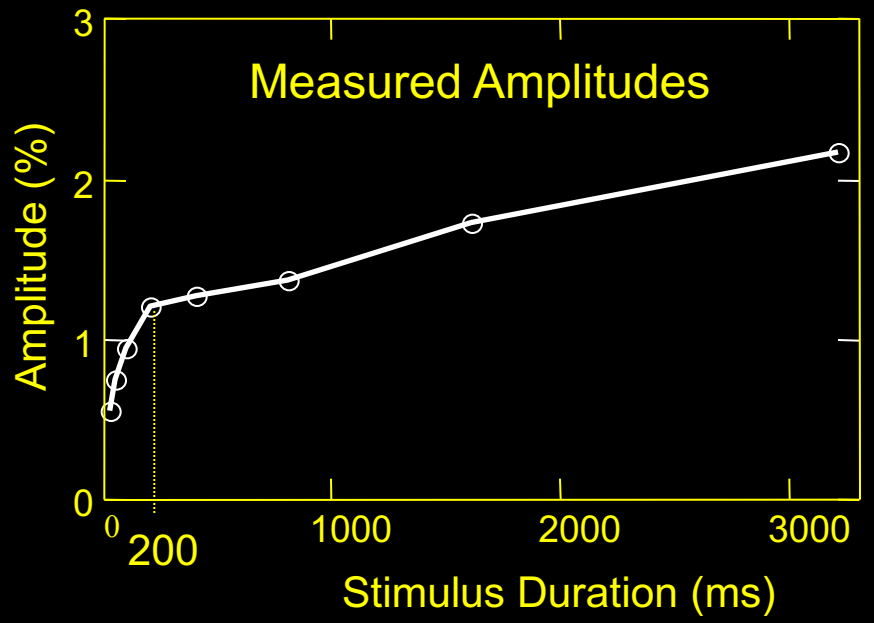
BOLD Correlation with Neuronal Activity

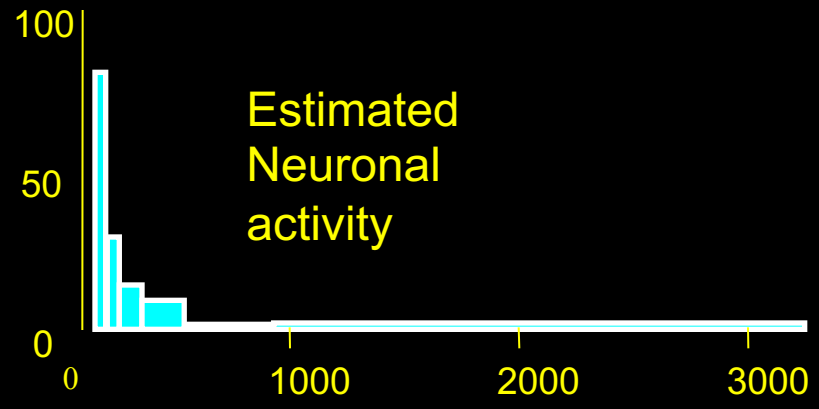
Logothetis et al. (2001) "Neurophysiological investigation of the basis of the fMRI signal" Nature, 412, 150-157.

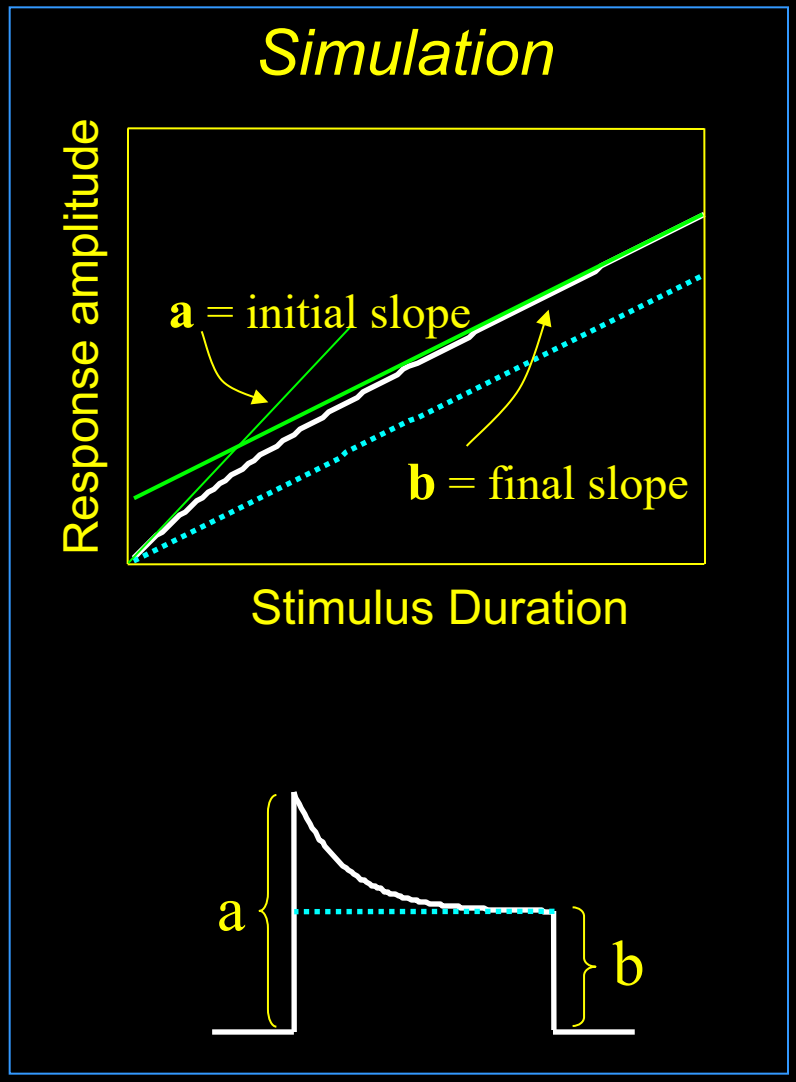


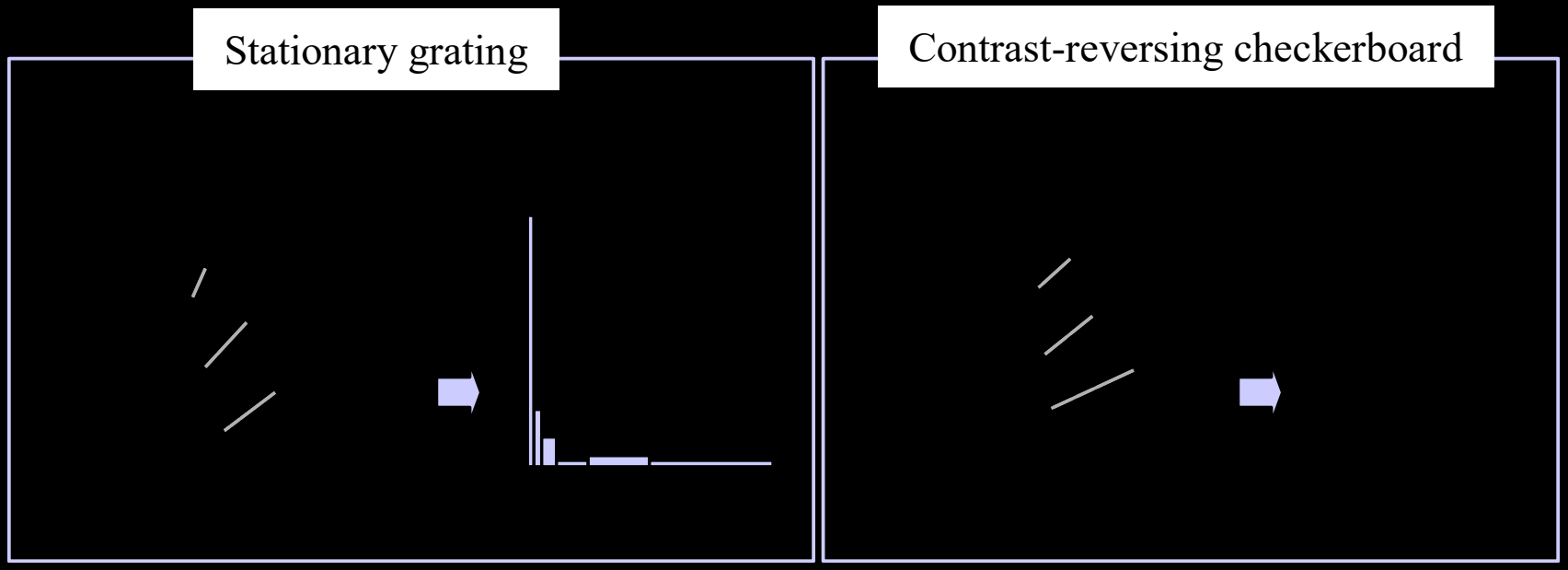
P. A. Bandettini and L. G. Ungerleider, (2001) "From neuron to BOLD: new connections." Nature Neuroscience, 4: 864-866.




Measured Amplitudes
Amplitude (%)
3
2
1
0
0
200
1000
2000
3000
Stimulus Duration (ms)


100
50
0
0
1000
2000
3000
Estimated
Neuronal
activity


Simulation
Response amplitude
a = initial slope
b = final slope
Stimulus Duration
a
b


Stationary grating
Contrast-reversing checkerboard

Extracting transient neuronal activity

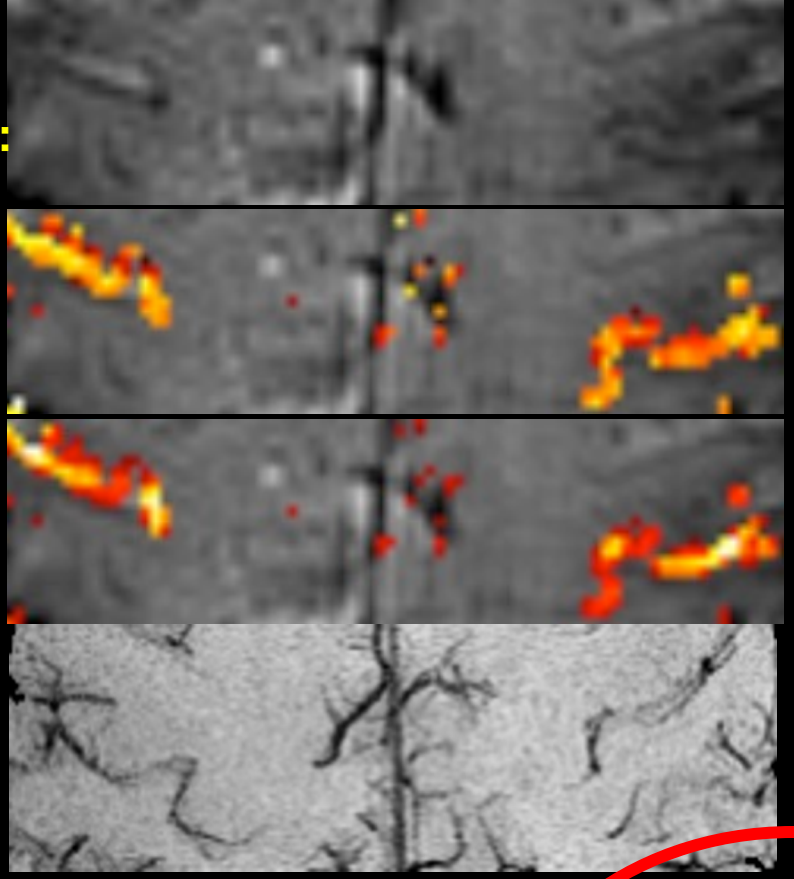
- Initial transient mapping
- BOLD latency and width modulation/mapping
- Direct neuronal current imaging

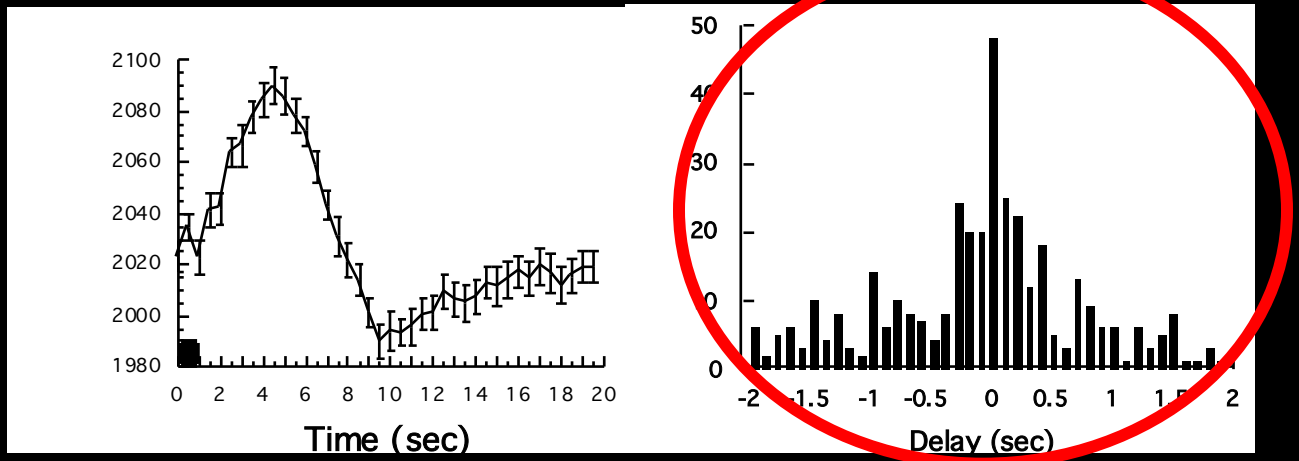
The major obstacle in BOLD contrast temporal resolution:

Latency

Magnitude

Venogram

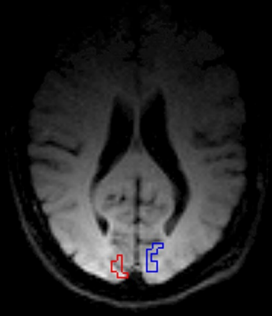




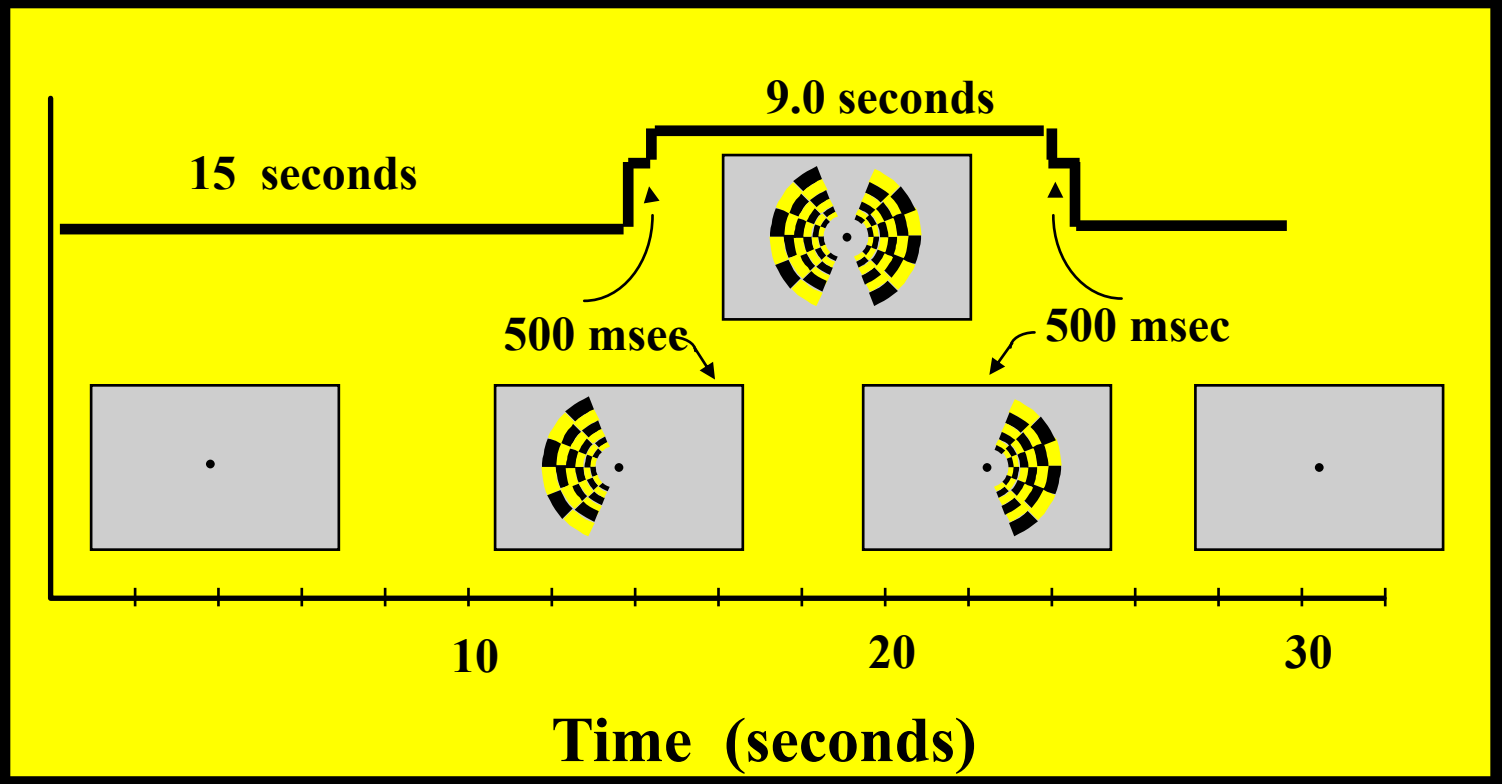
P. A. Bandettini, The temporal resolution of Functional MRI *in* "Functional MRI" (C. Moonen, and P. Bandettini., Eds.), p. 205-220, Springer - Verlag,. 1999.

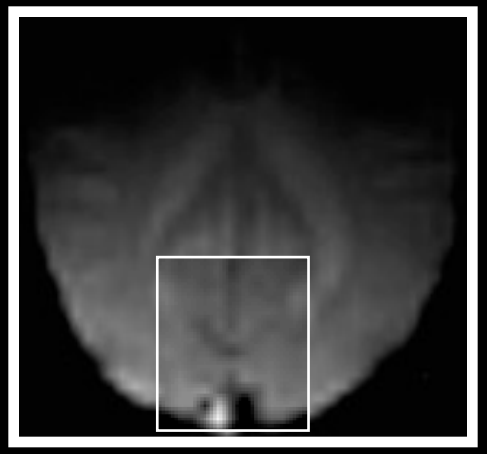
Hemi-Field Experiment

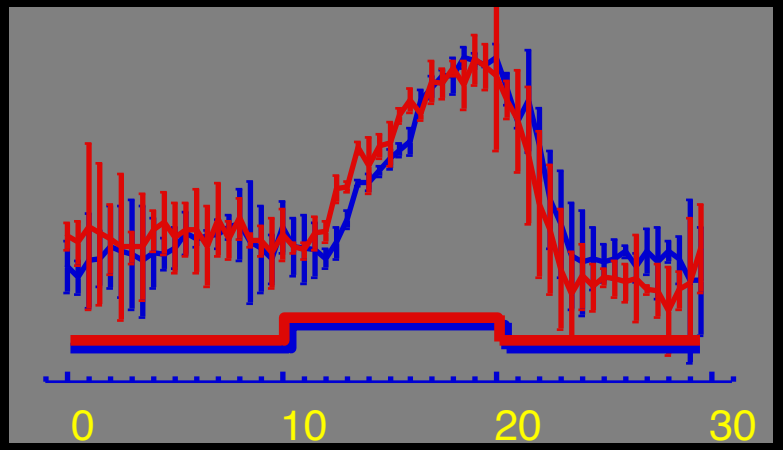
Right Hemisphere



Left Hemisphere







500 ms

500 ms

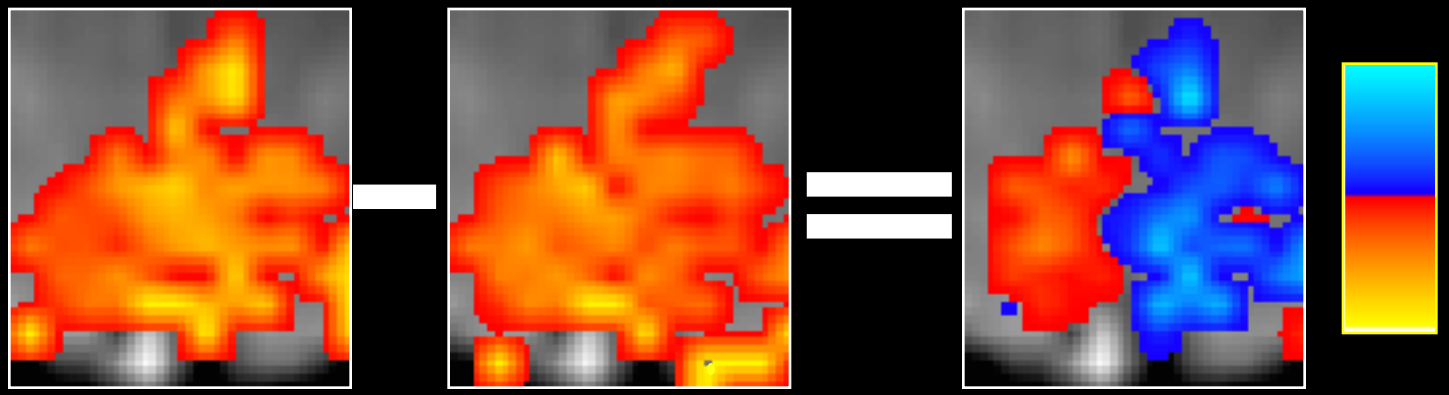
Right Hemifield

Left Hemifield

+ 2.5 s

0 s

- 2.5 s



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

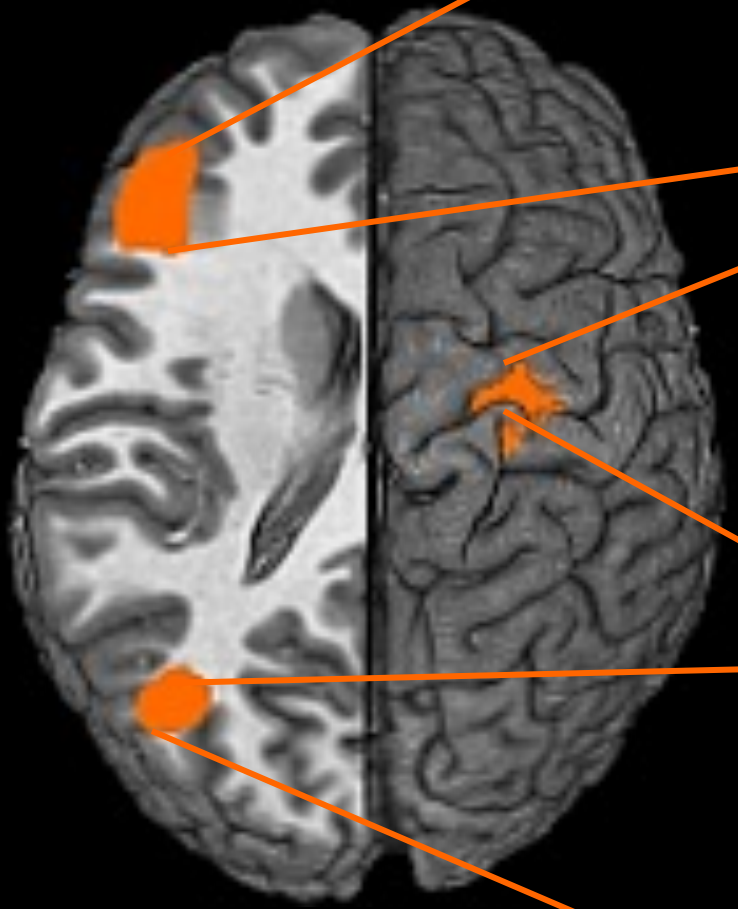
Communicated by Leslie G. Ungerleider, National Institutes of Health, Bethesda, MD, December 19, 2002 (received for review October 31, 2002)

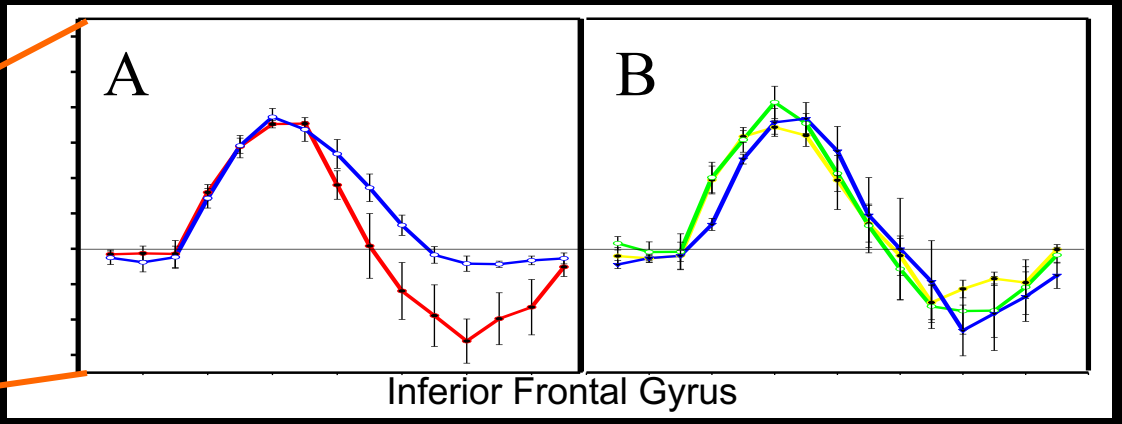
Proc. Nat'l. Acad. Sci. USA 100, 1415-1419 (2003).

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

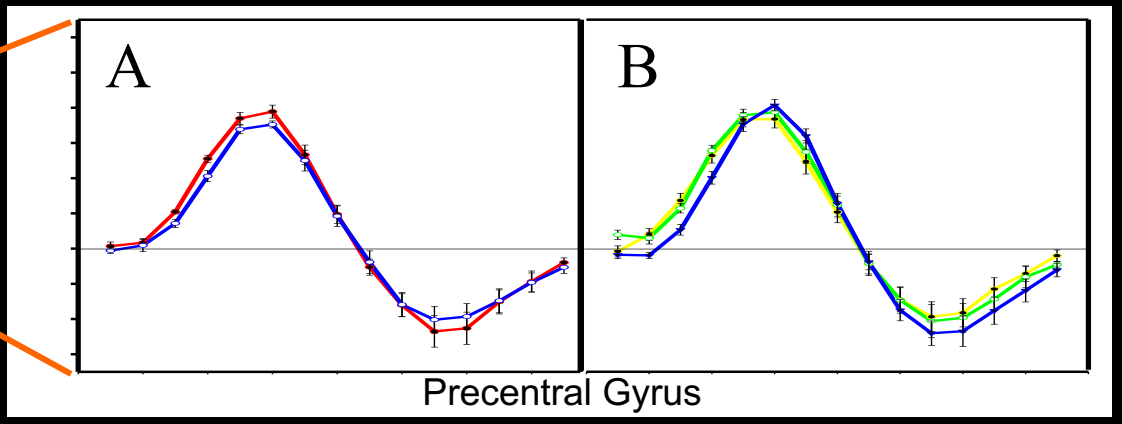
Word vs. Non-word 0°, 60°, 120° Rotation

Regions of Interest

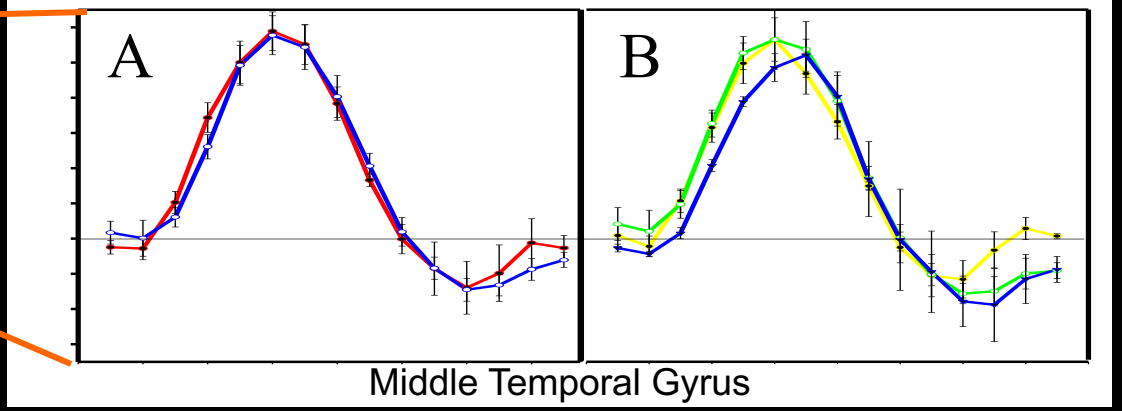




Inferior Frontal Gyrus

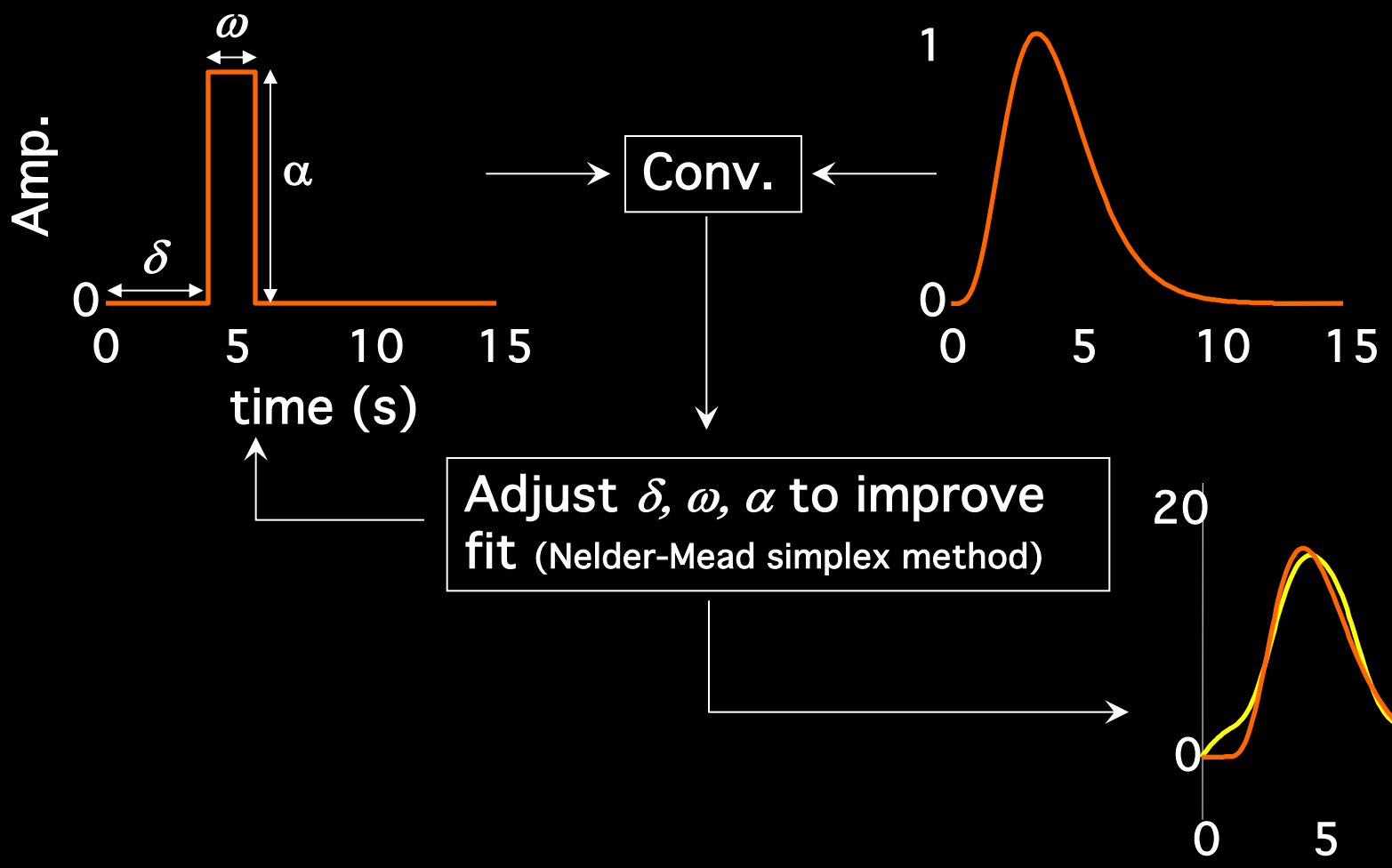


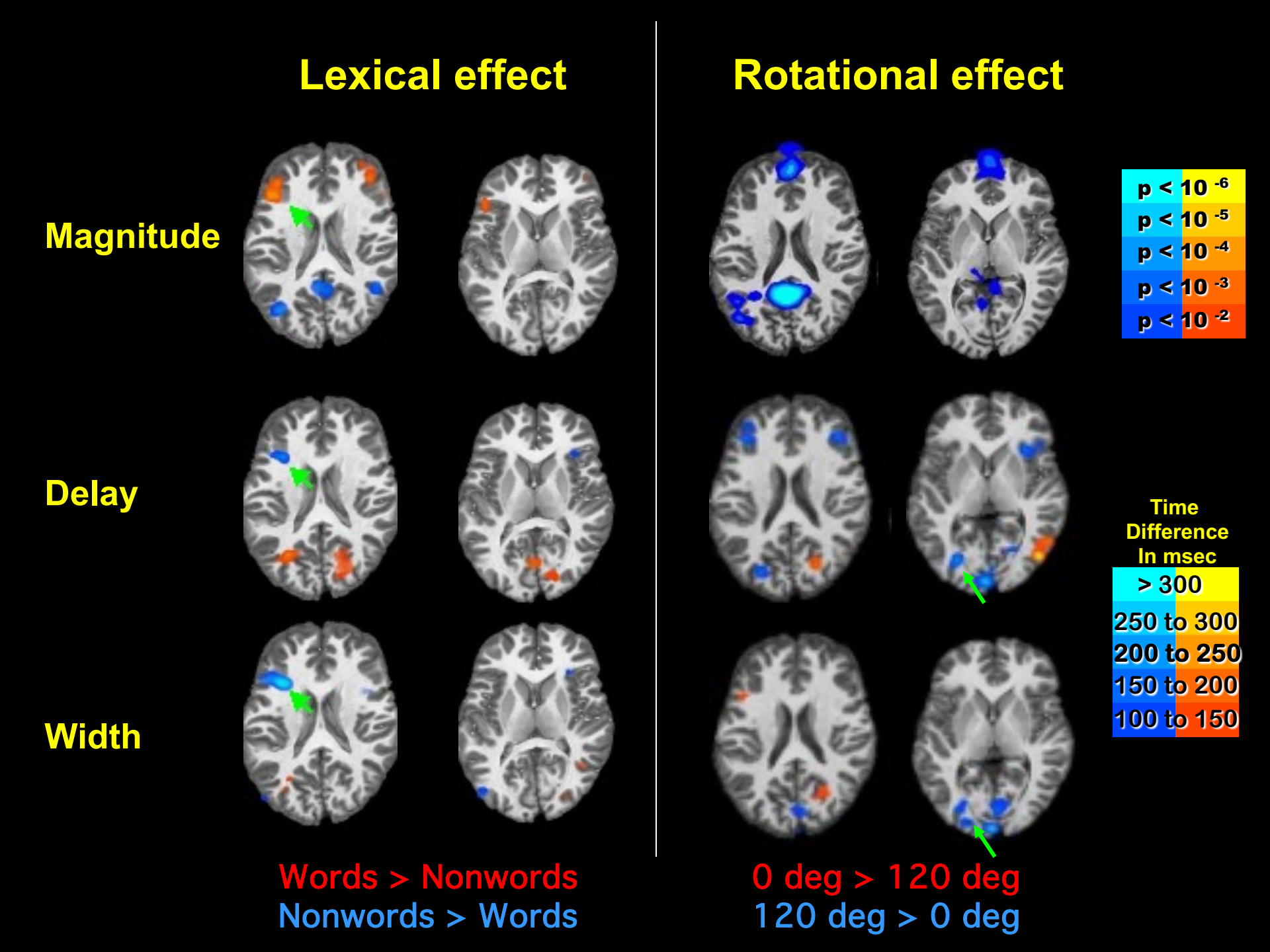
Precentral Gyrus



Middle Temporal Gyrus

Estimation of Delay, Width & Amplitude




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

Extracting transient neuronal activity

- Initial transient mapping
- BOLD latency and width modulation/mapping
- Direct neuronal current imaging

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

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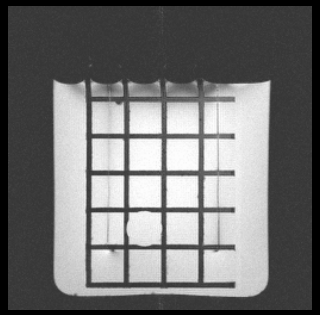
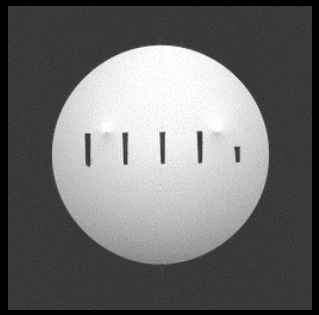
Magn. Reson. Med 47: 1052-1058, (2002)

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

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

- Question: Is this detectable?





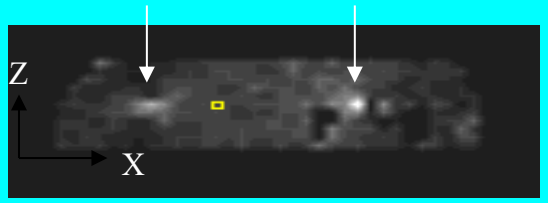
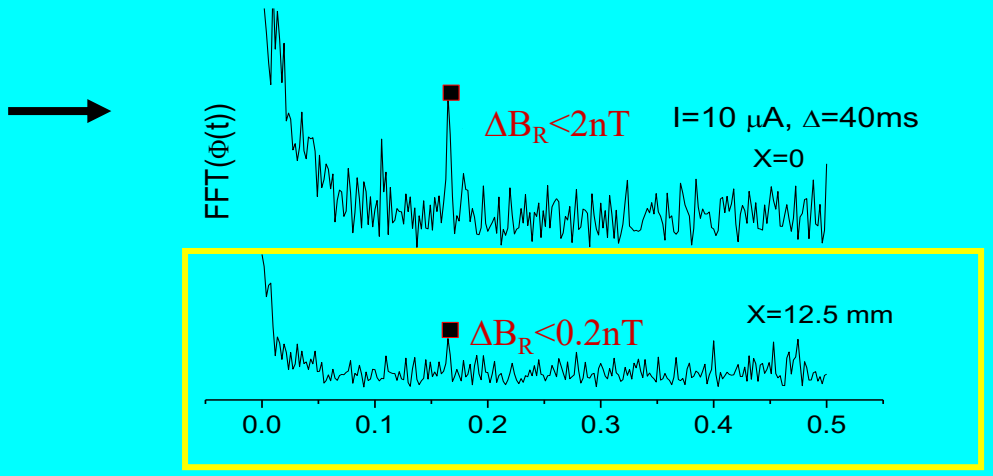
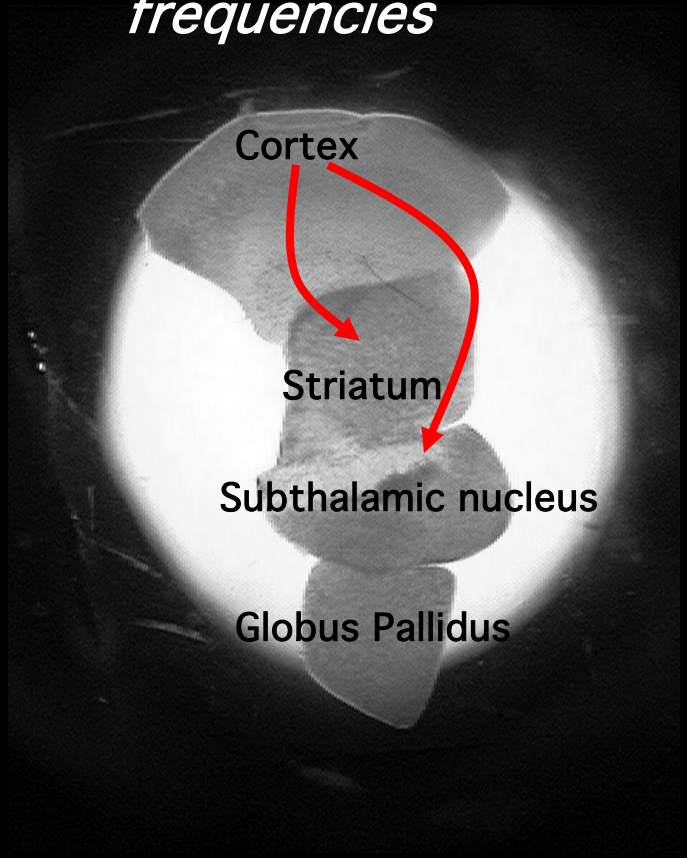

Z
X

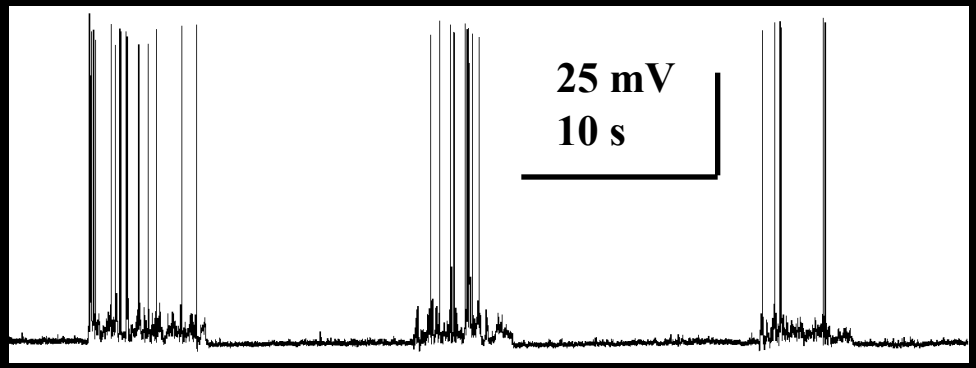
Figure 1


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

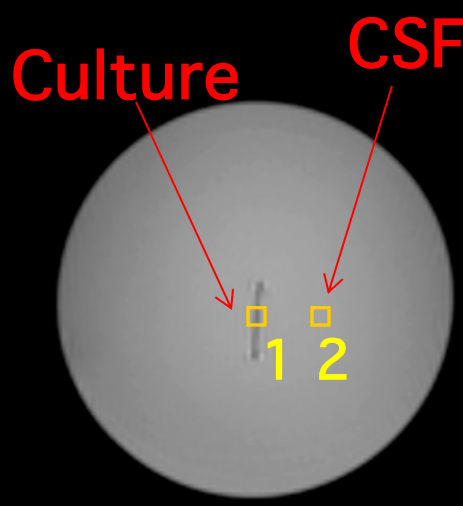
In Vitro Results

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

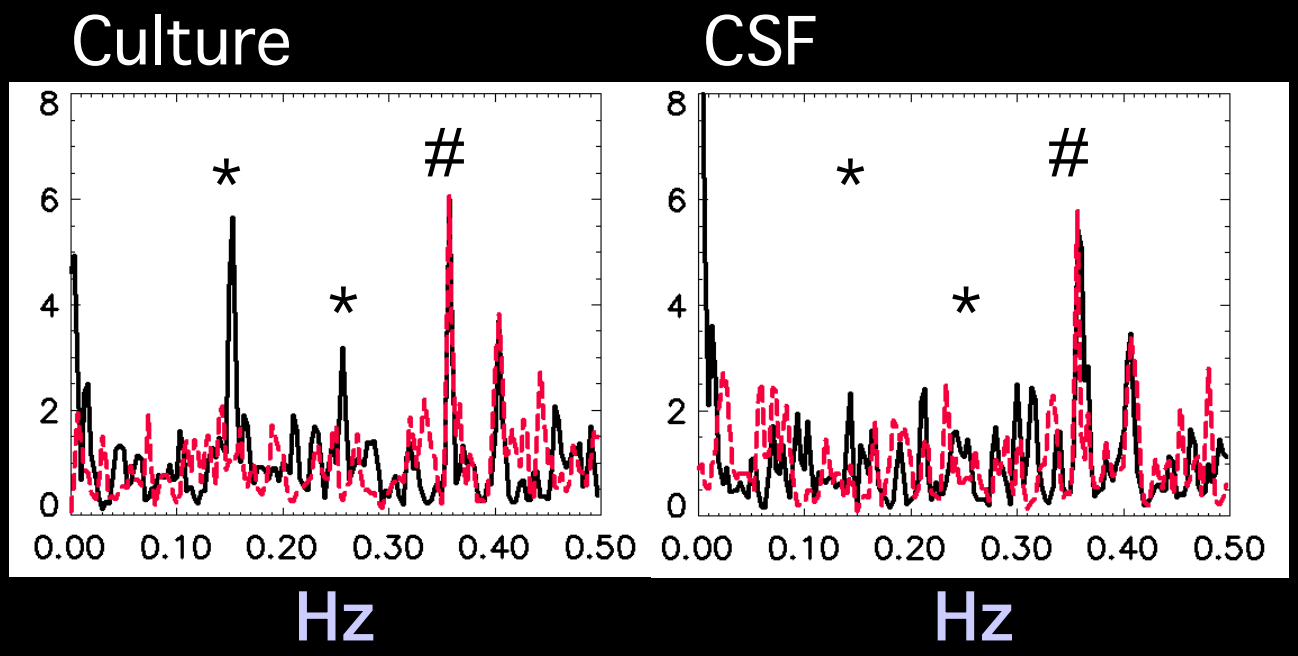




Plenz, D. and S.T. Kital. Nature, 1999. **400**: p. 677-682.



FSE image



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

*: activity

#: scanner pump frequency

Petridou et al. Poster #694
Poster discussion: Saturday, 9:42-9:54 AM