What fMRI Can, Can't, and Might Do

Peter A. Bandettini, Ph.D

bandettini@nih.gov

Unit on Functional Imaging Methods
&
3T Neuroimaging Core Facility

Laboratory of Brain and Cognition
National Institute of Mental Health

- Functional Imaging
  - –Xenon Computerized Tomography (Xe CT)
  - –Positron Emission Tomography (PET)
  - –Single Photon Computed Tomography (SPECT)
  - –Functional MRI (fMRI)
  - –Electroencephalography (EEG)
  - –Magnetoencphalography (MEG)
  - –Transcranial Magnetic Stimulation (TMS)

MRI vs. fMRI

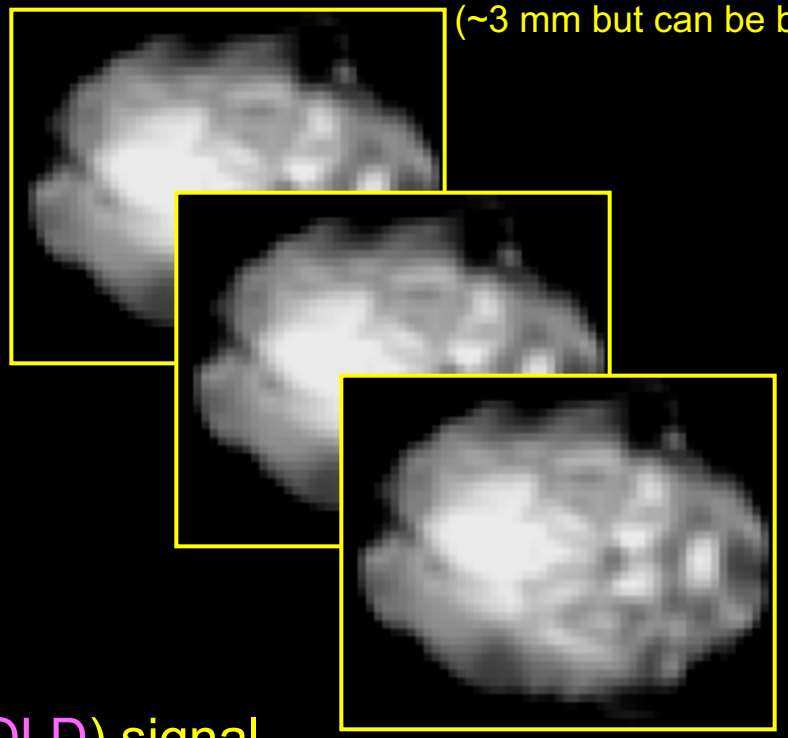
MRI

high resolution
(1 mm)

one image

fMRI

low resolution
(~3 mm but can be better)



...

many images
(e.g., every 2 sec for 5 mins)

fMRI

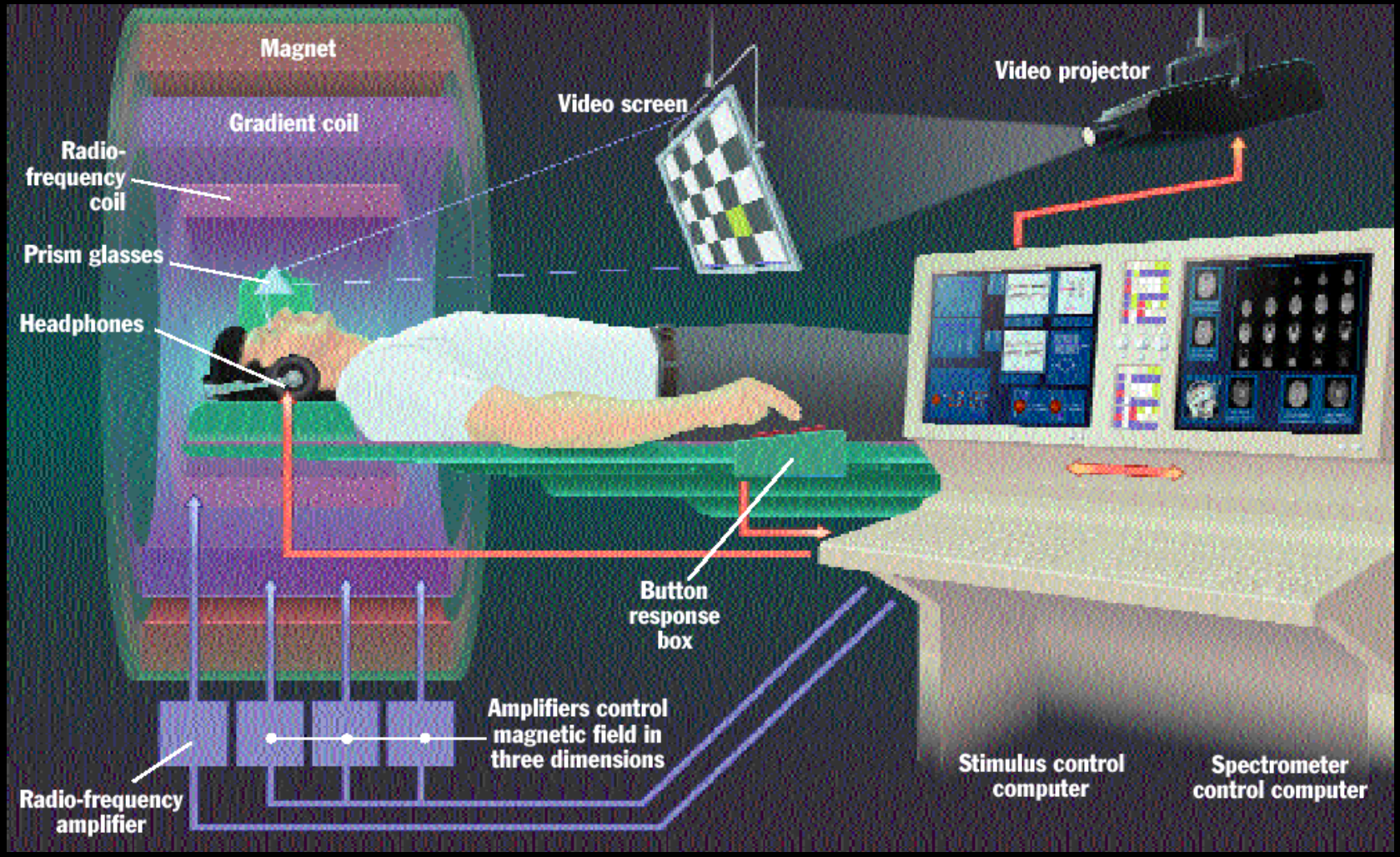
Blood Oxygenation Level Dependent (BOLD) signal

indirect measure of neural activity

↑ neural activity ➔ ↑ blood oxygen ➔ ↑ fMRI signal

Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH

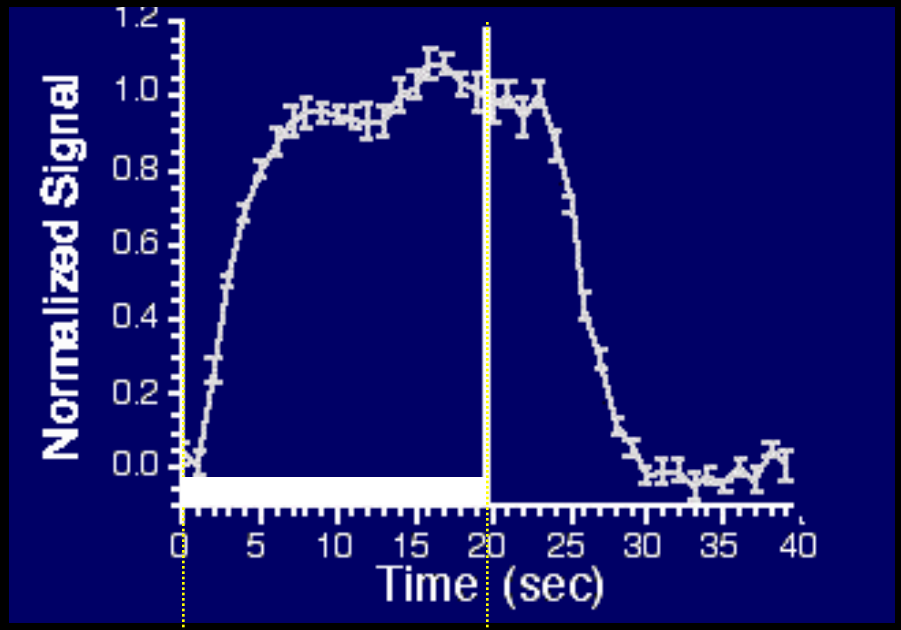
fMRI Setup

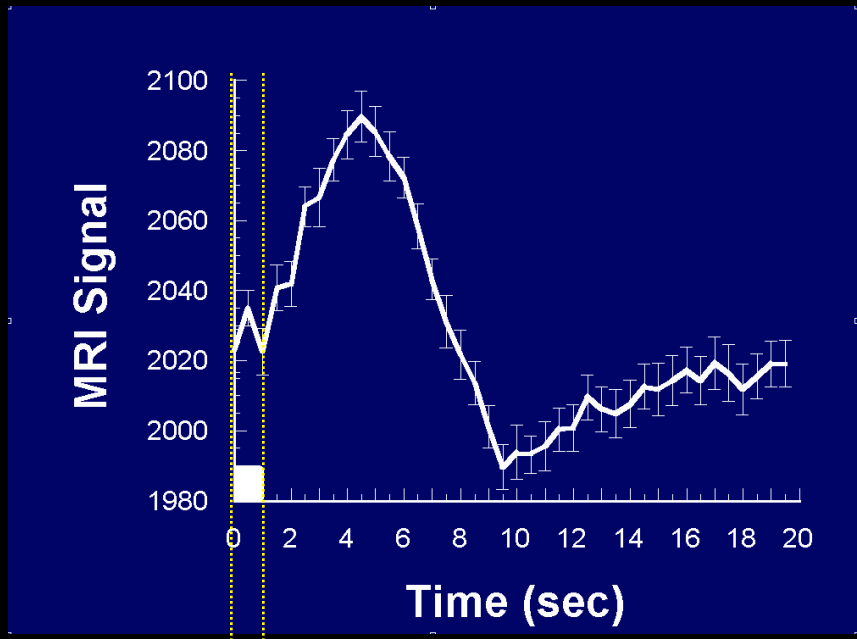


Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH

The FMRI Signal

Based on Local Blood Flow Response in the Brain



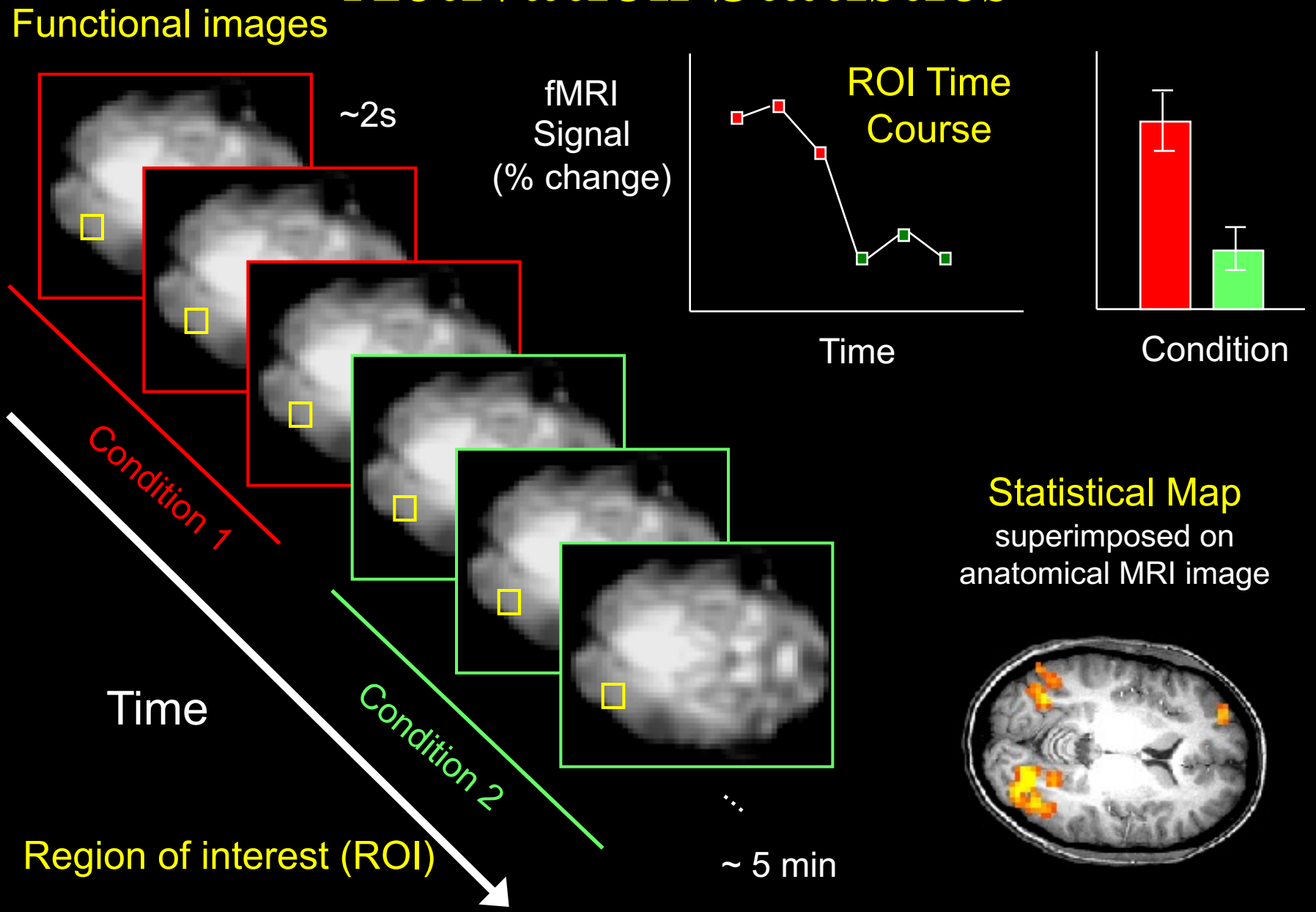


task

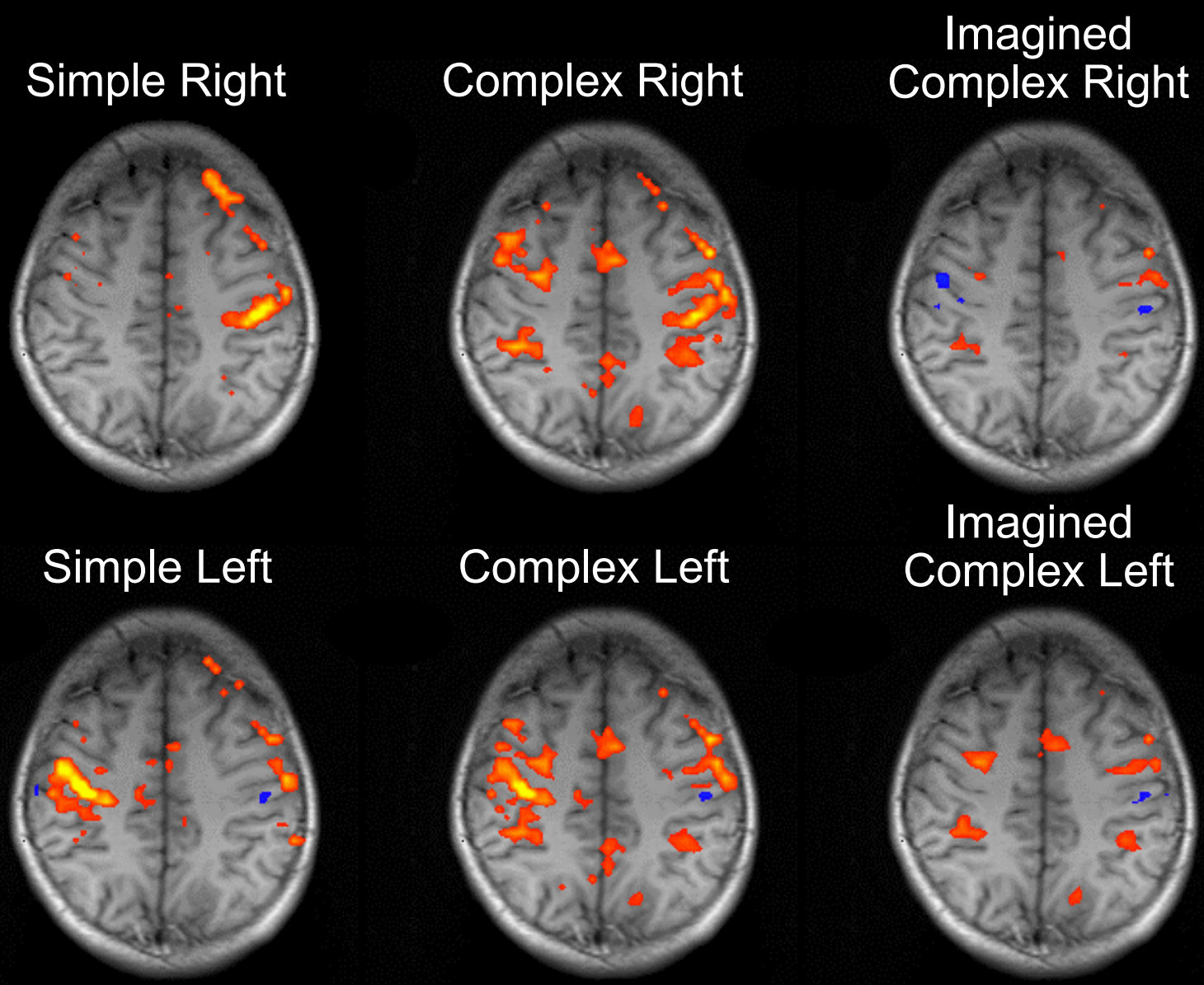
task

Courtesy, Rasmus Birn, Unit on Functional Imaging Methods, NIMH

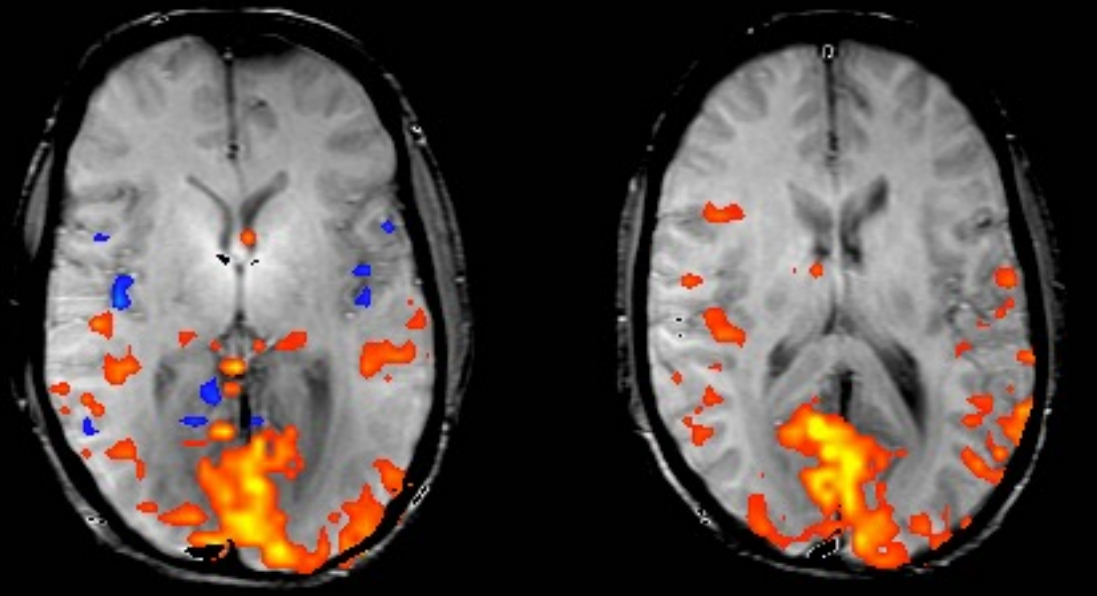
Activation Statistics



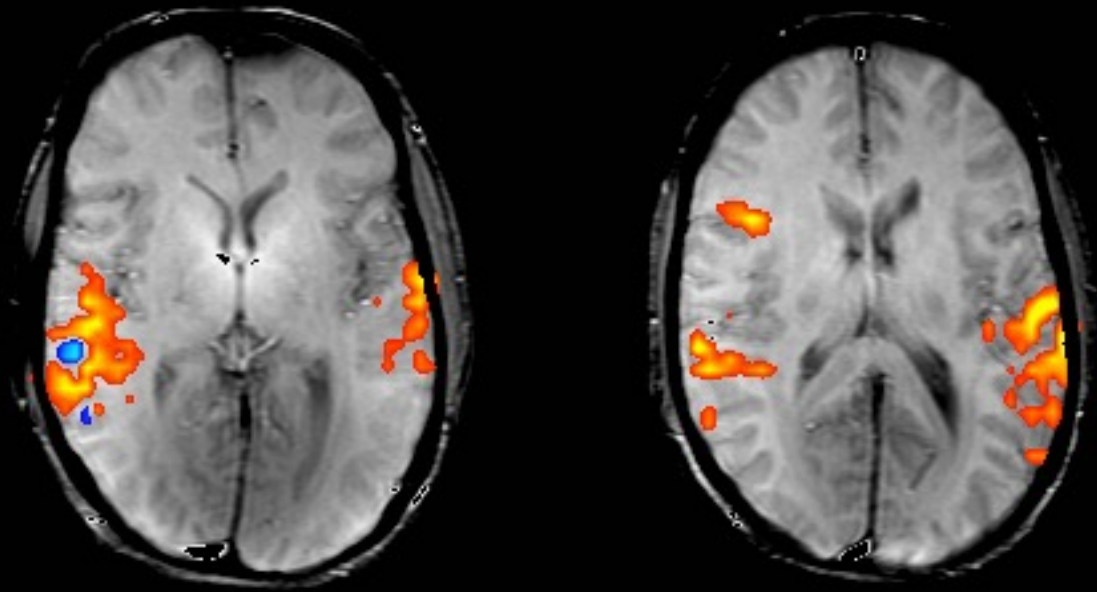
Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH


Simple Right
Complex Right
Imagined Complex Right
Simple Left
Complex Left
Imagined Complex Left

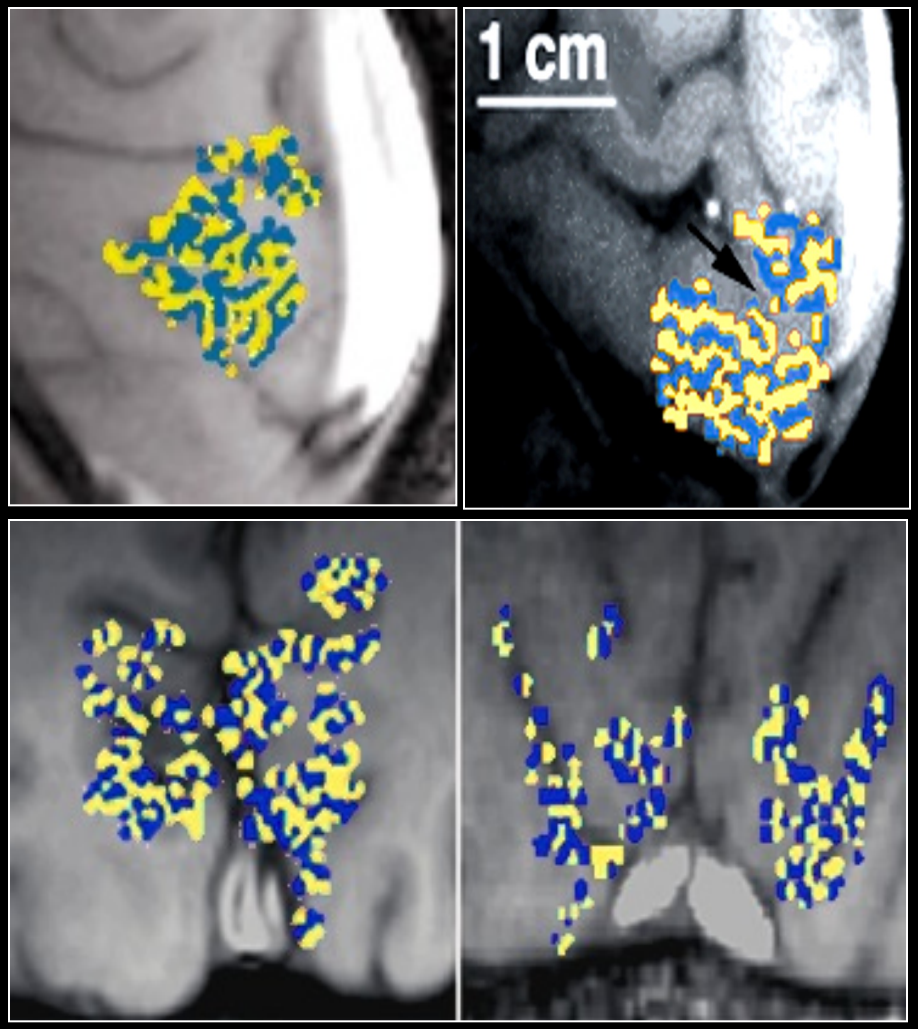
Reading



Listening

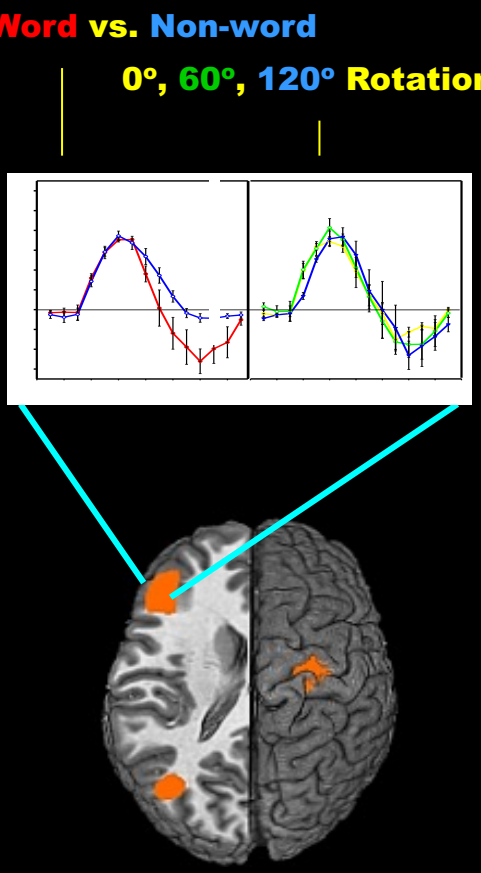


Spatial Resolution: Ocular Dominance Column Mapping



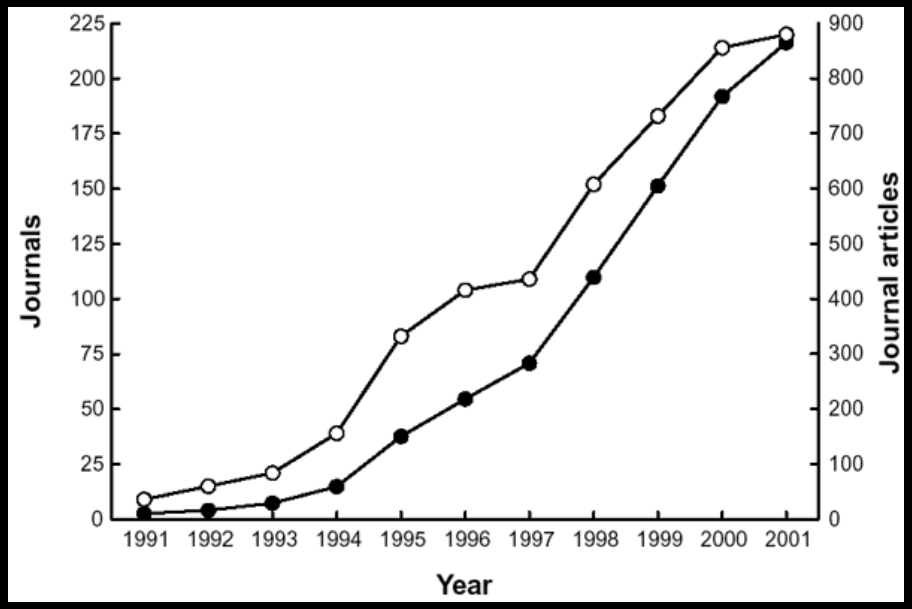
Menon, et al. (1997). J Neurophysiol 77(5): 2780-7.

Temporal Resolution: Word processing

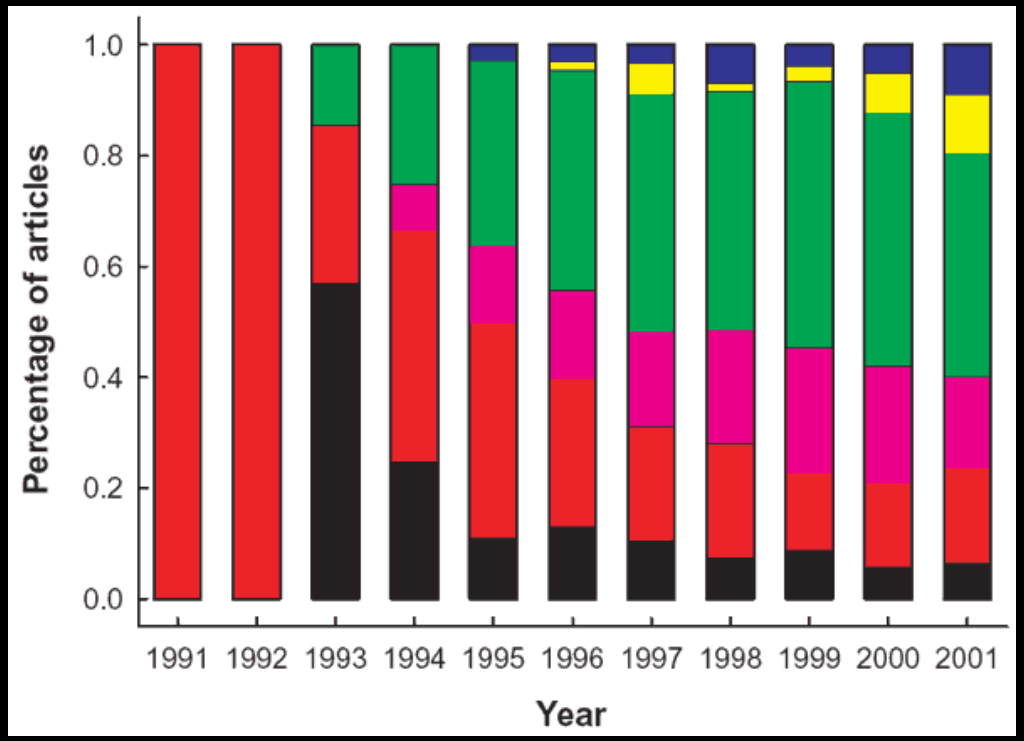


Bellgowan, et al (2003), PNAS 100, 15820–15283

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



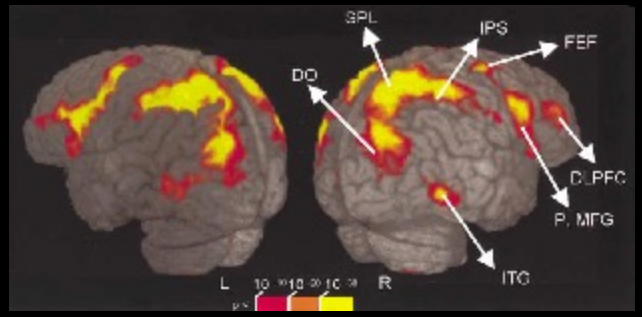
Motor (black)
Primary Sensory (red)
Integrative Sensory (violet)
Basic Cognition (green)
High-Order Cognition (yellow)
Emotion (blue)

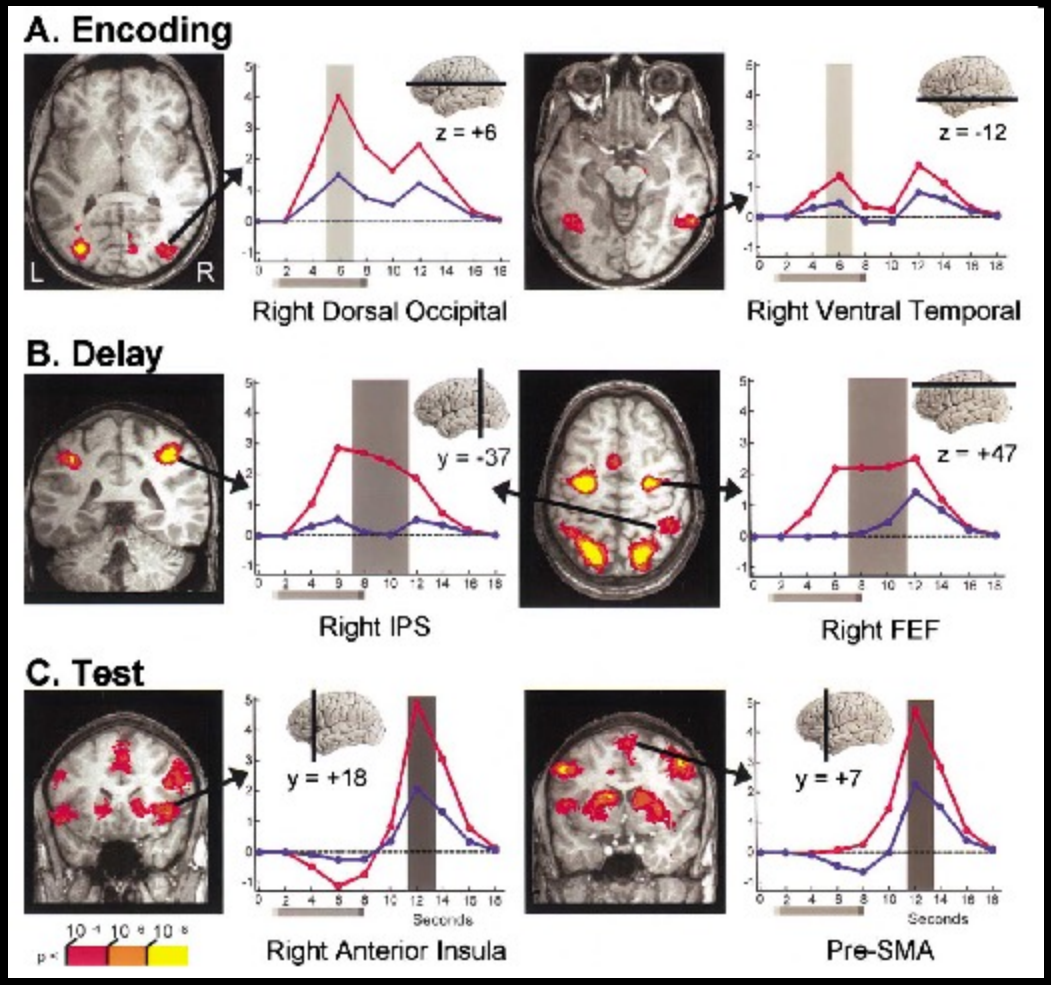


Neuron, Vol. 35, 975–987, August 29, 2002, Copyright ©2002 by Cell Press

Neural Correlates of Visual Working Memory: fMRI Amplitude Predicts Task Performance

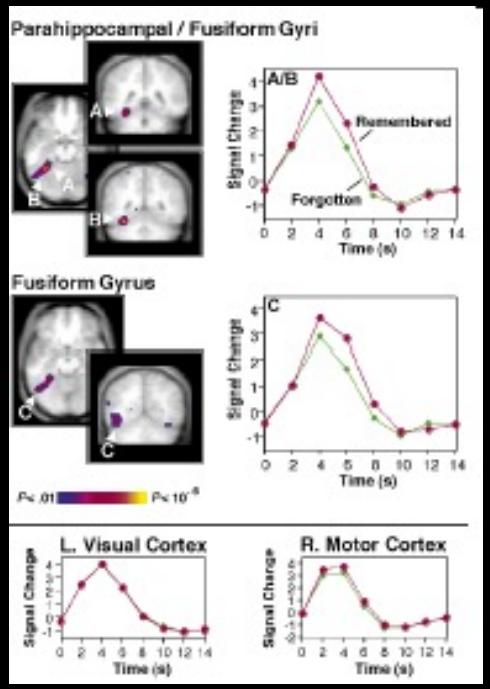
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892

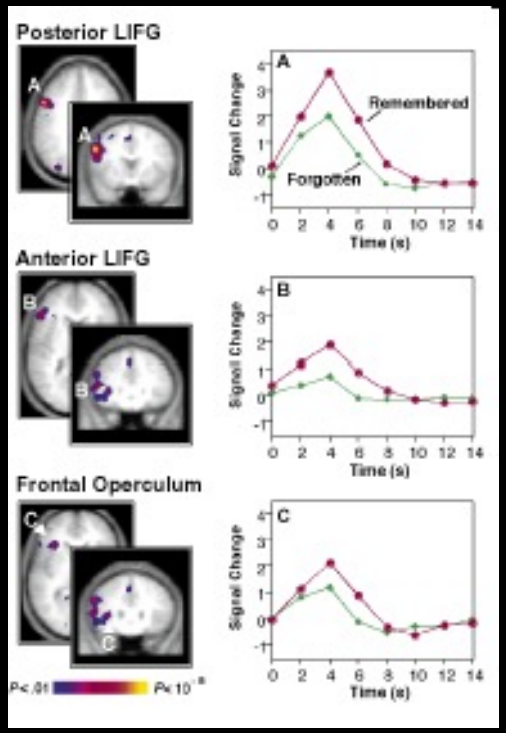




Building Memories: Remembering and Forgetting of Verbal Experiences as Predicted by Brain Activity

Anthony D. Wagner,* Daniel L. Schacter, Michael Rotte,† Wilma Koutstaal, Anat Maril, Anders M. Dale, Bruce R. Rosen, Randy L. Buckner





Science, Vol 281, August 1998

Classification of spatial patterns

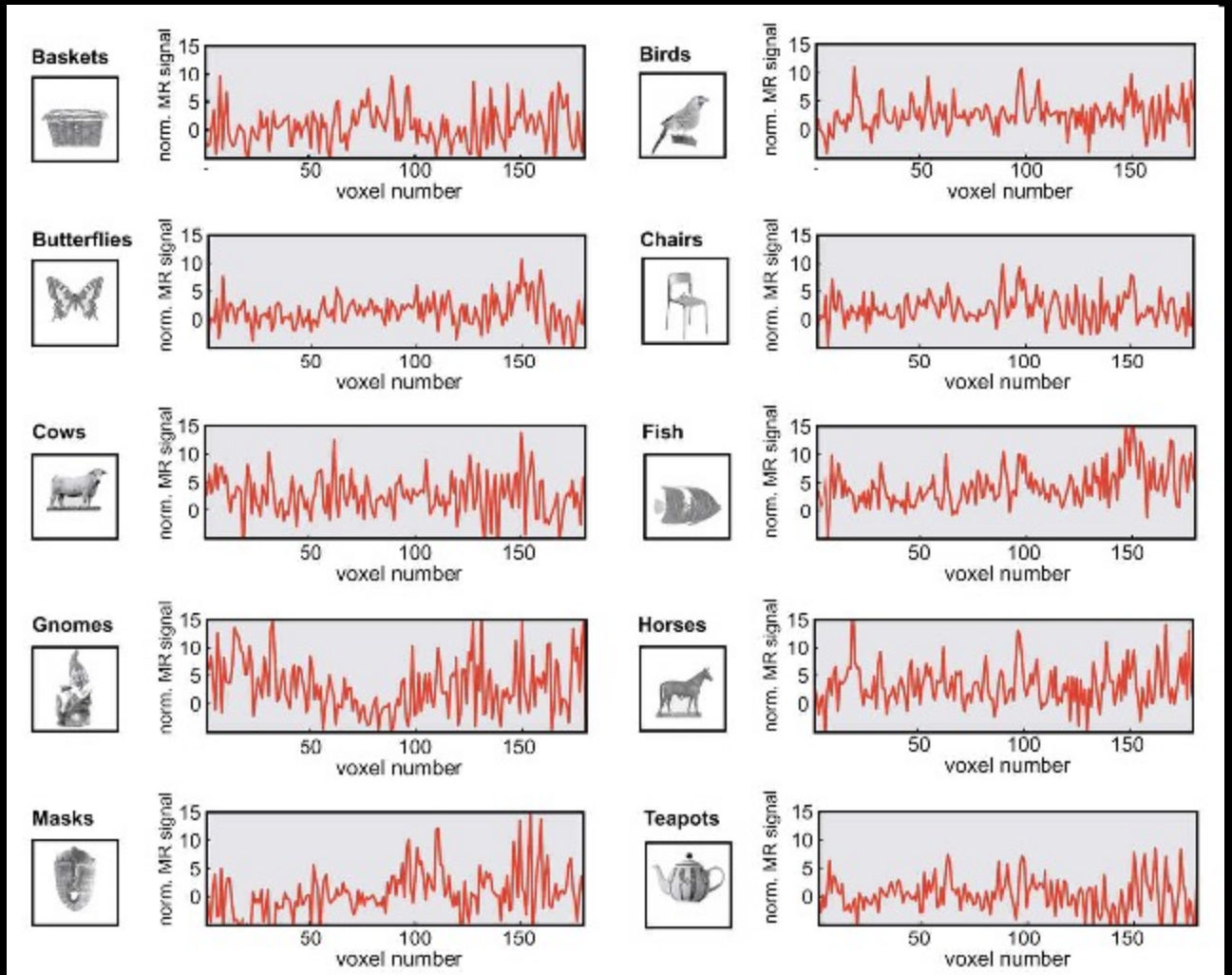
Functional magnetic resonance imaging (fMRI) "brain reading": detecting and classifying distributed patterns of fMRI activity in human visual cortex

David D. Cox[a,b,*] and Robert L. Savoy[a,b,c]

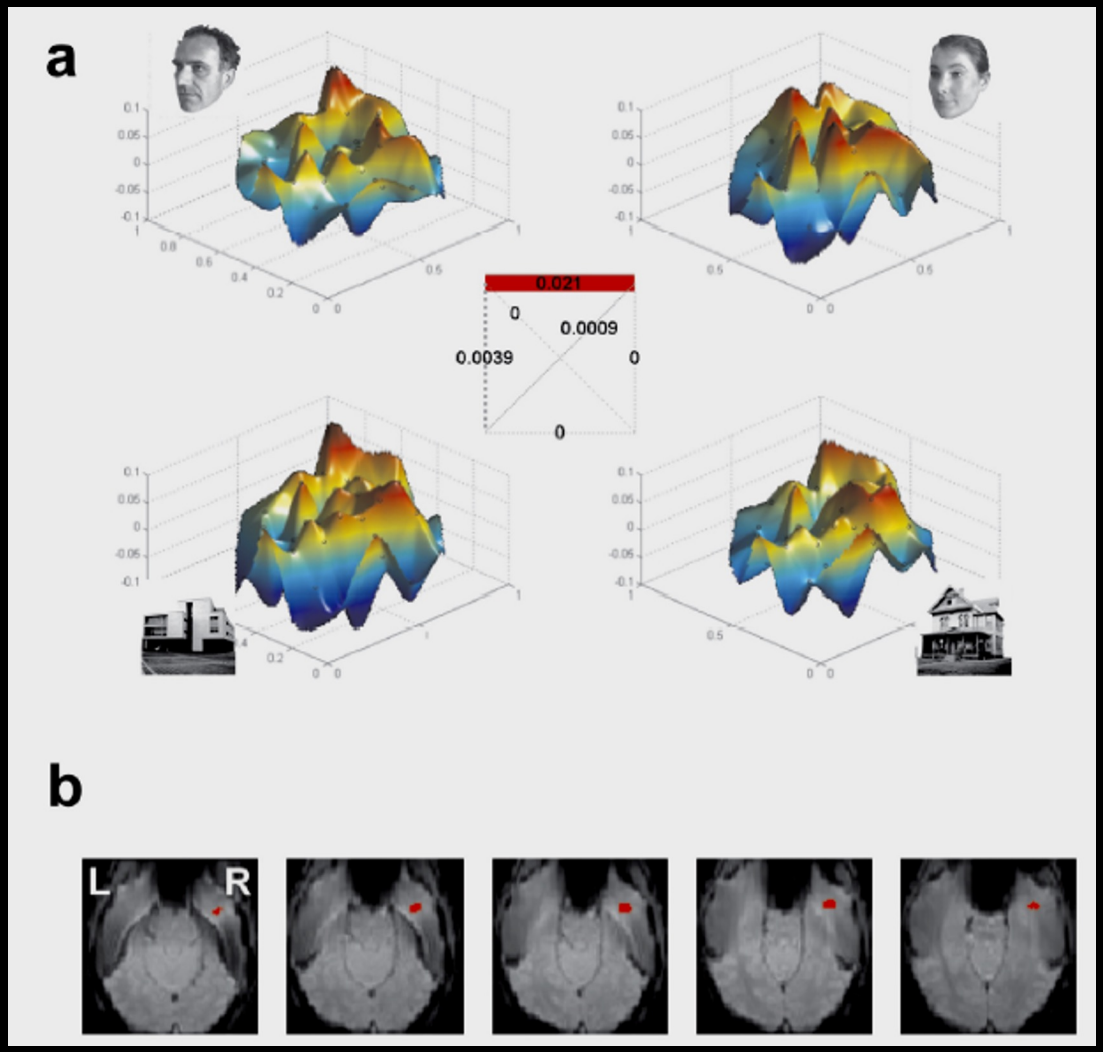
[a] Rowland Institute for Science, Cambridge, MA 02142, USA
[b] Athinoula A. Martinos Center for Structural and Functional Biomedical Imaging, Charlestown, MA 02129, USA
[c] HyperVision, Inc., P.O. Box 158, Lexington, MA 02420, USA

Received 15 July 2002; accepted 10 December 2002

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

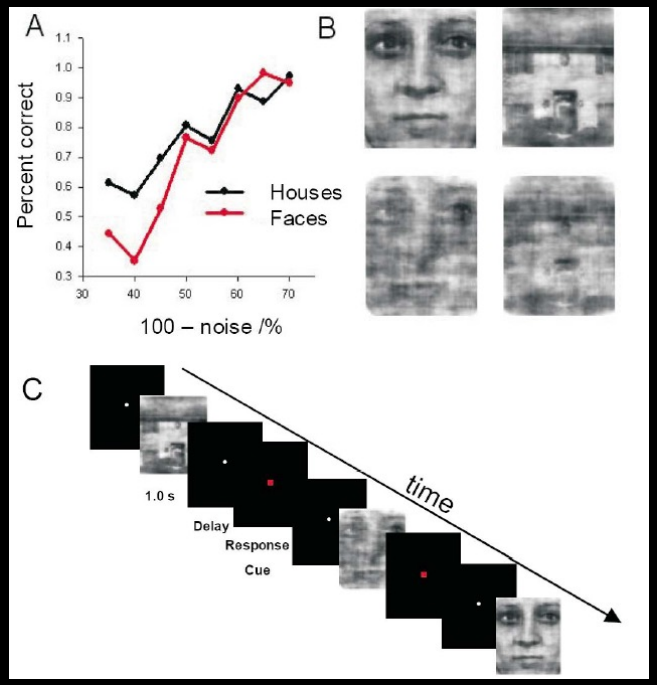


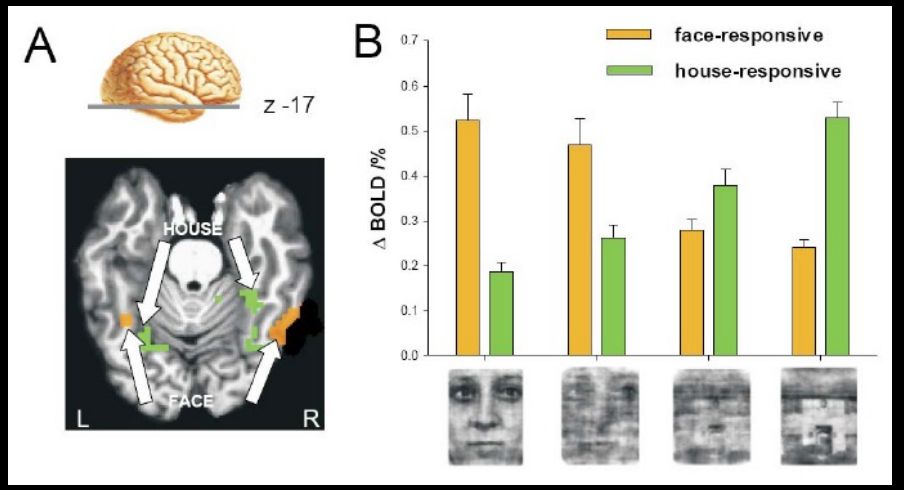
Voxel-Wise Mapping of Pattern Differences

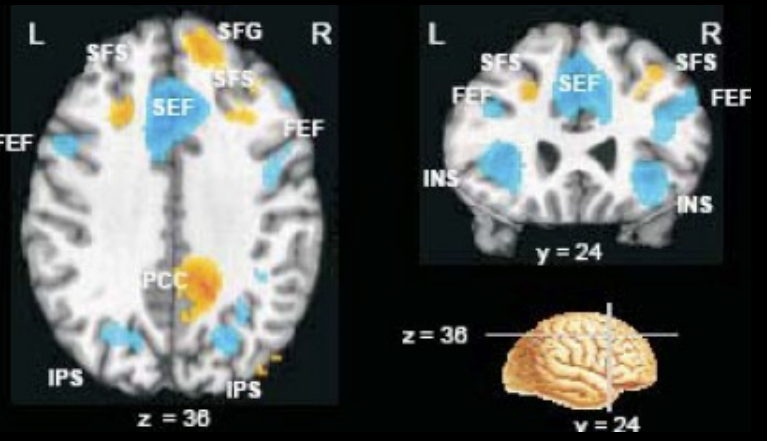


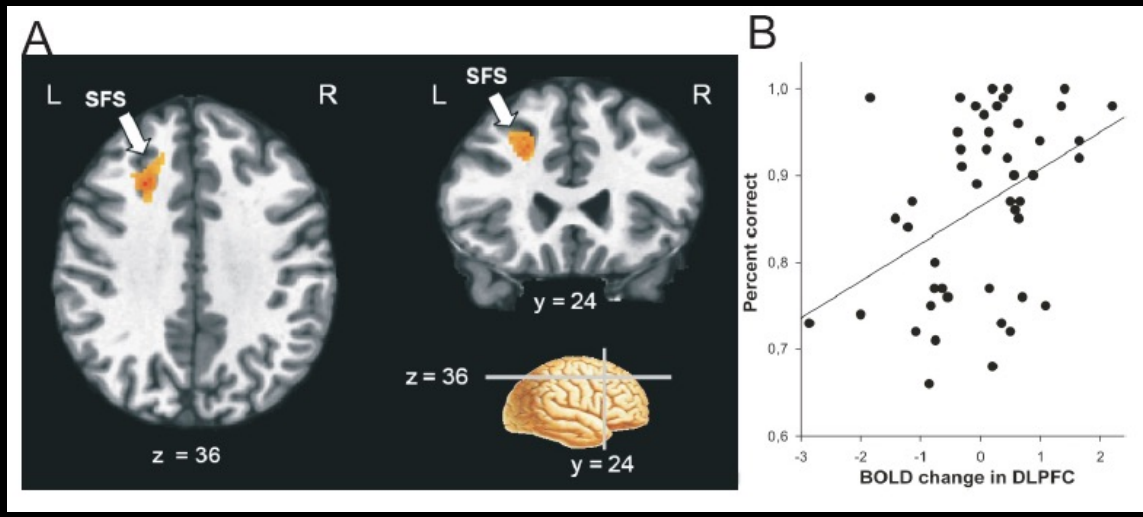
Kriegeskorte et al. HBM 2004

Perceptual decision making







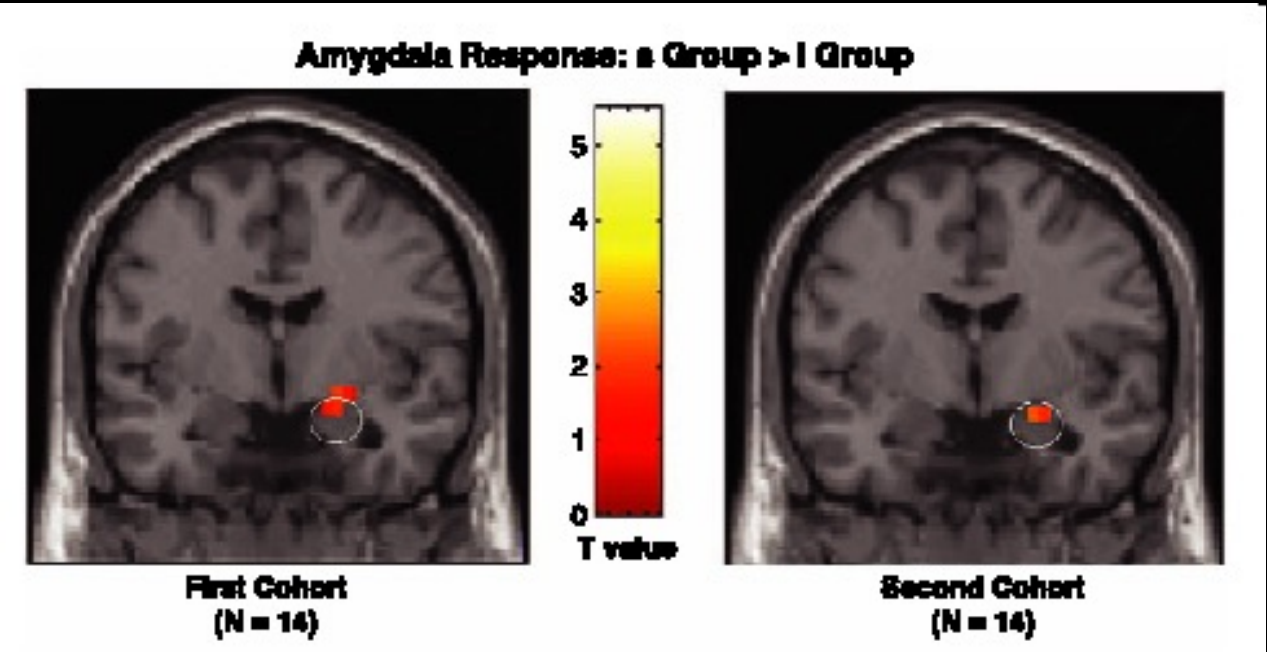


Heekeren, Marrett, Bandettini, Ungerleider, *submitted*

Comparison of two groups of *normal* individuals with differences in the Serotonin Transporter Gene

Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

Ahmad R. Hariri,[1] Venkata S. Mattay,[1] Alessandro Tessitore,[1] Bhaskar Kolachana,[1] Francesco Fera,[1] David Goldman,[2] Michael F. Egan,[1] Daniel R. Weinberger[1]*



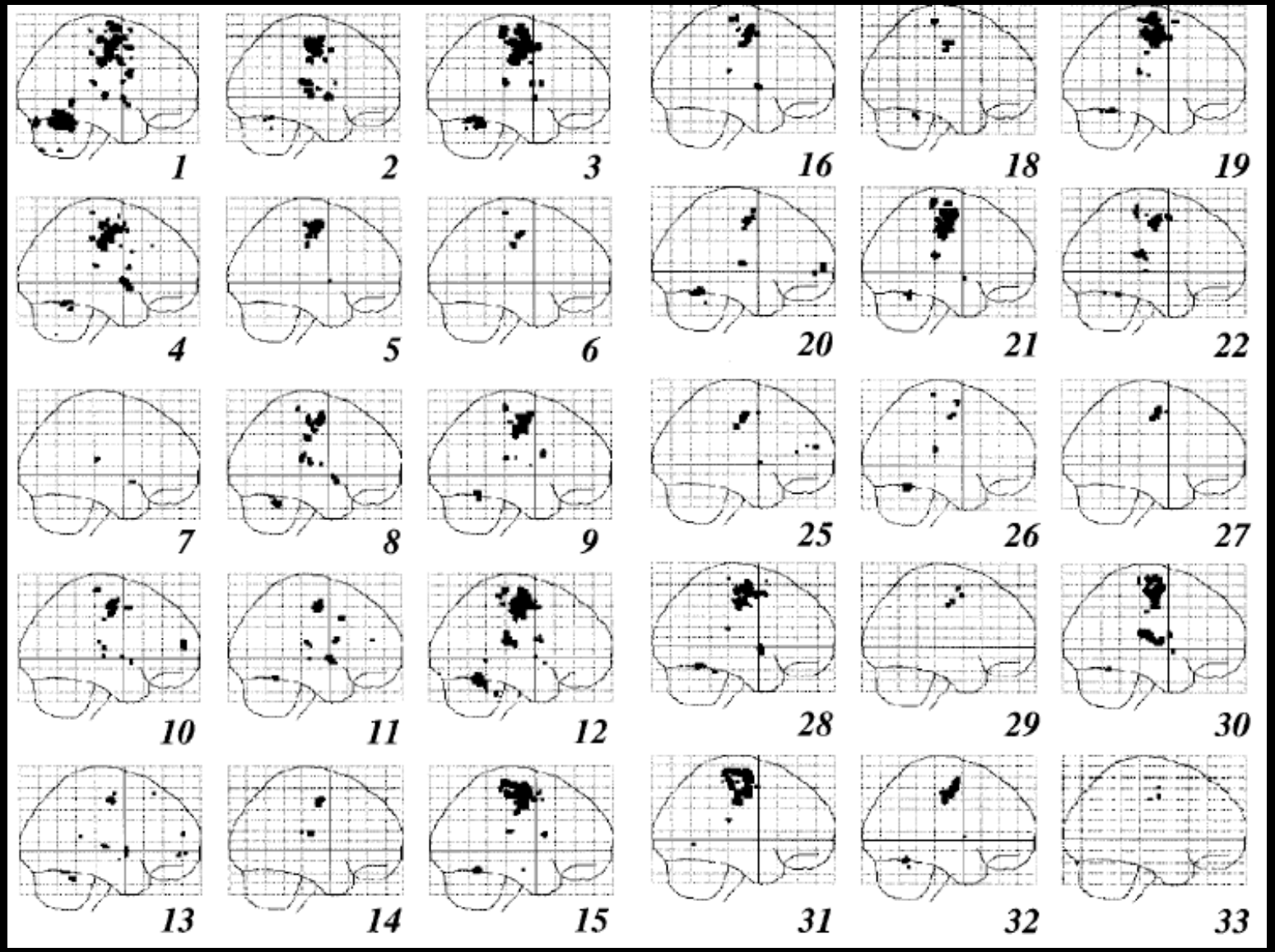
SCIENCE VOL 297 19 JULY 2002

The Biggest Unknowns in Functional MRI

1. Relationship between neuronal activity and BOLD contrast?
2. Source of BOLD dynamic characteristics?
3. Sources of variability?
4. What's really in the noise?
5. What's "resting" state?
6. Other sources of functional contrast?
7. Ultimate temporal resolution?
8. Ultimate spatial resolution?
9. Ultimate clinical utility?
10. Best display methods?
11. Best processing methods?
12. Optimal Field Strength?

Sources of Variability in fMRI

-Signal to noise (about 2/1)
-Scanner variability
-Motion
-Hemodynamic response variability
-Differences in structural anatomy
-Differences in functional anatomy
-Differences in strategy for task
-Learning, performance, habituation, attention, cognitive state

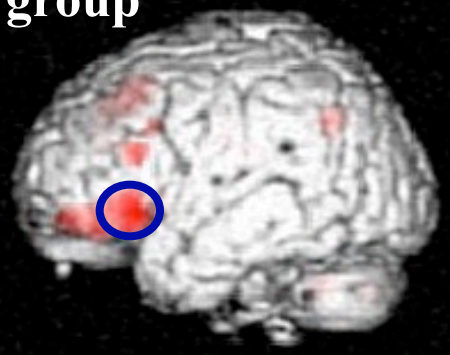


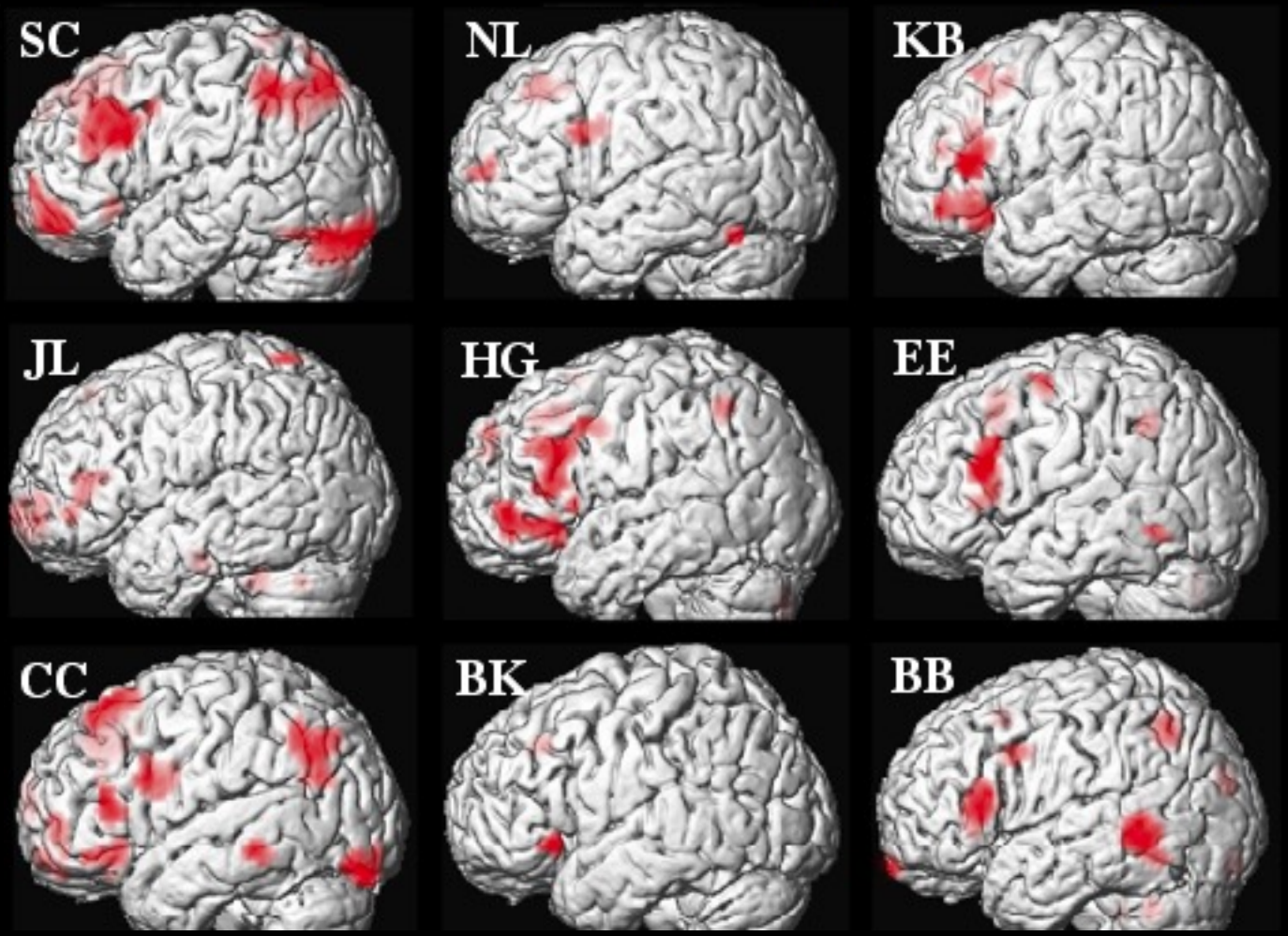
McGonigle, et al (2000), NeuroImage 11, 708-734

Extensive Individual Differences in Brain Activations During Episodic Retrieval

Miller et al., 2002

Individual activations from the left hemisphere of the 9 subjects

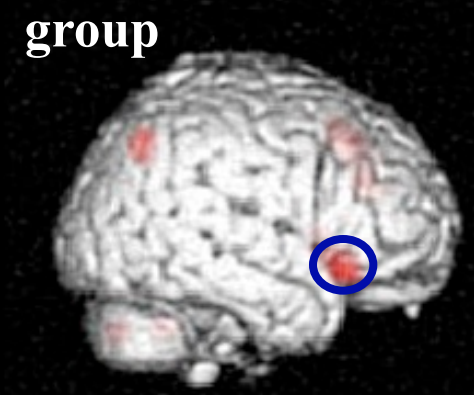




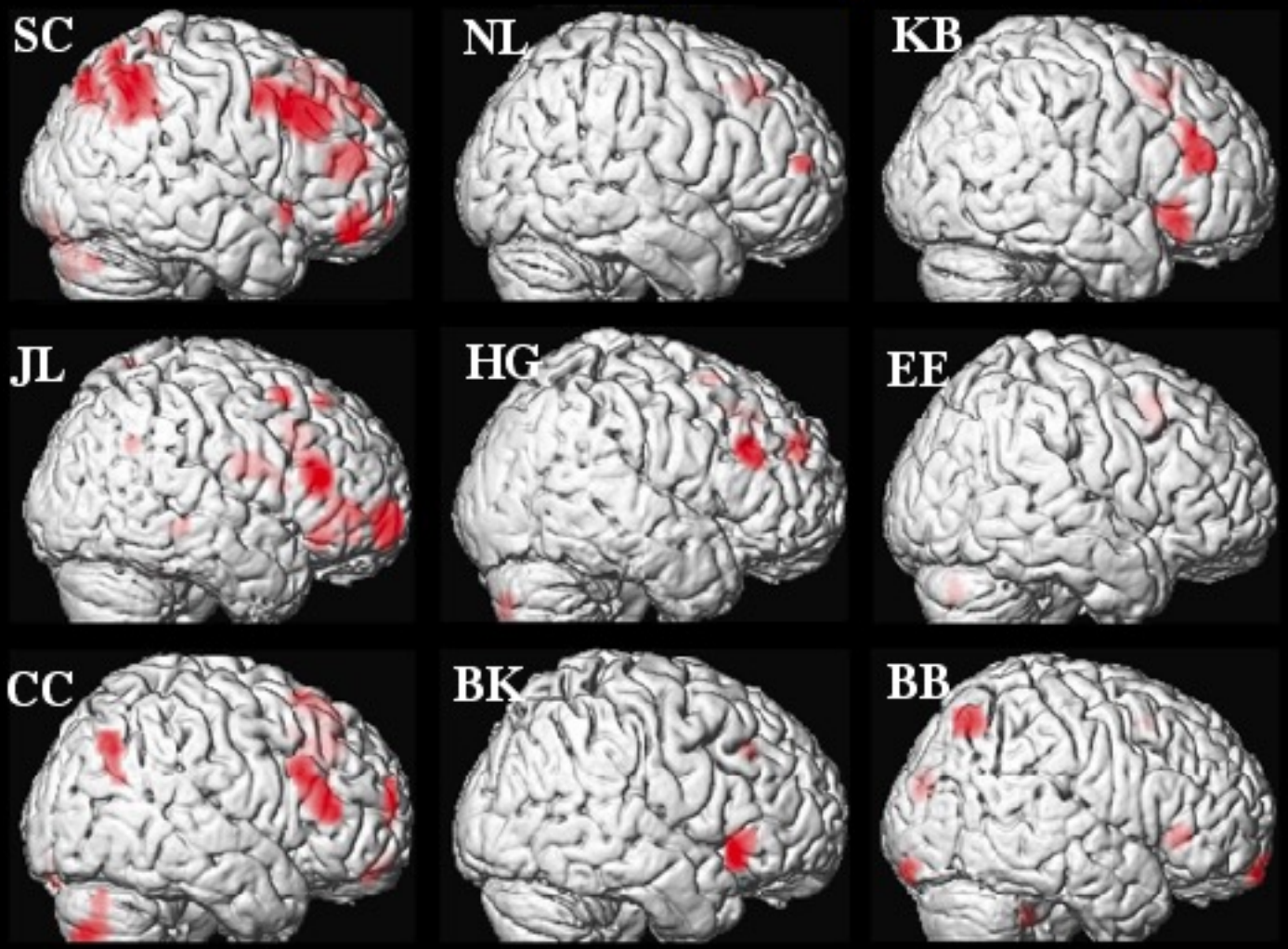
Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

Extensive Individual Differences in Brain Activations During Episodic Retrieval

Miller et al.. 2002

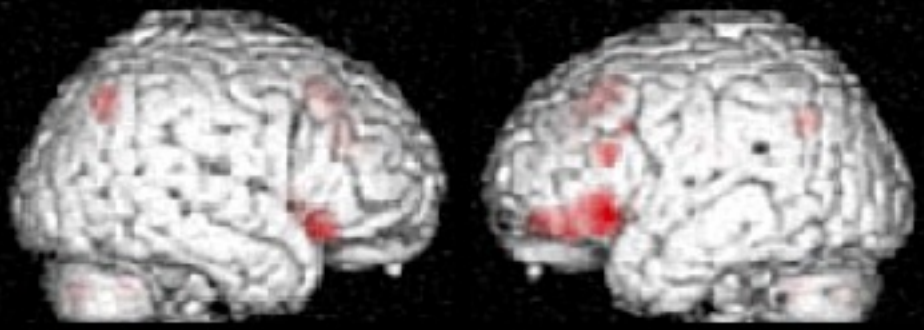


Individual activations from the right hemisphere of the 9 subjects

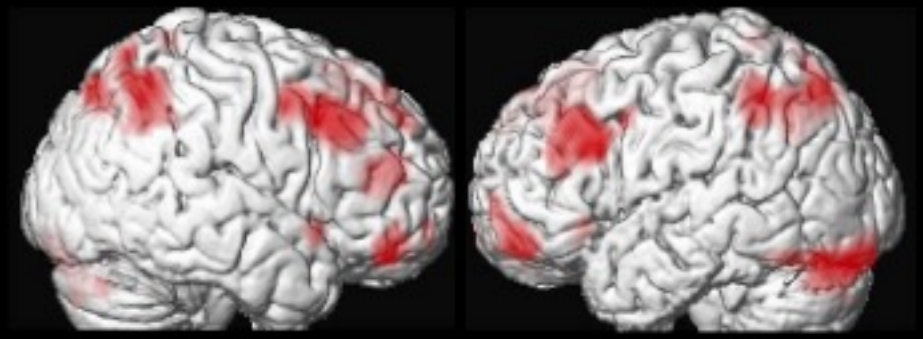


Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

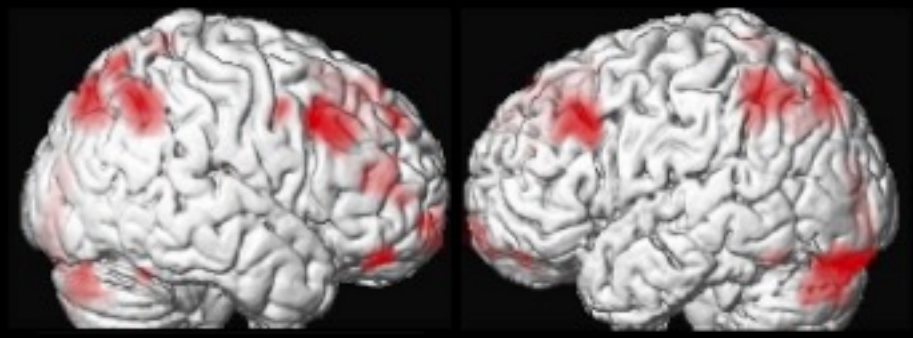
These individual patterns of activations are stable over time



Group Analysis of Episodic Retrieval



Subject SC

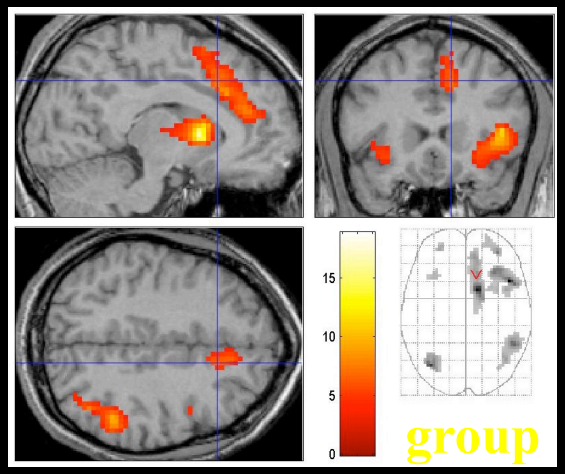


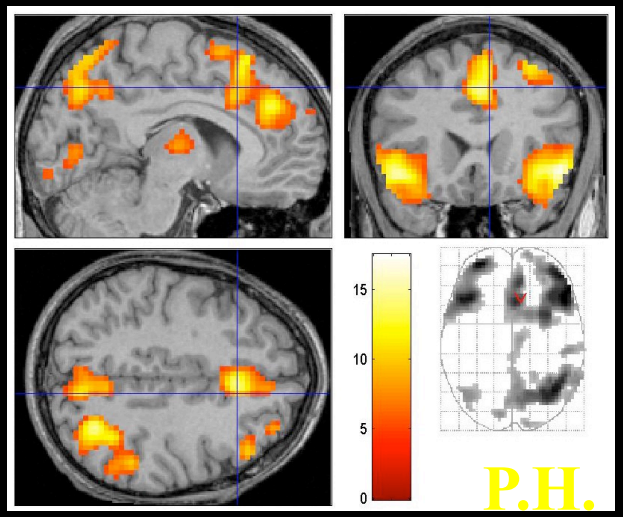
Subject SC 6 months later

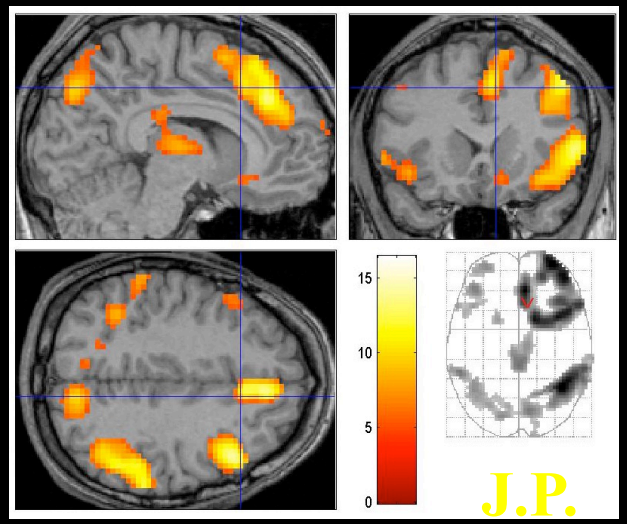
Courtesy, Mike Miller, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

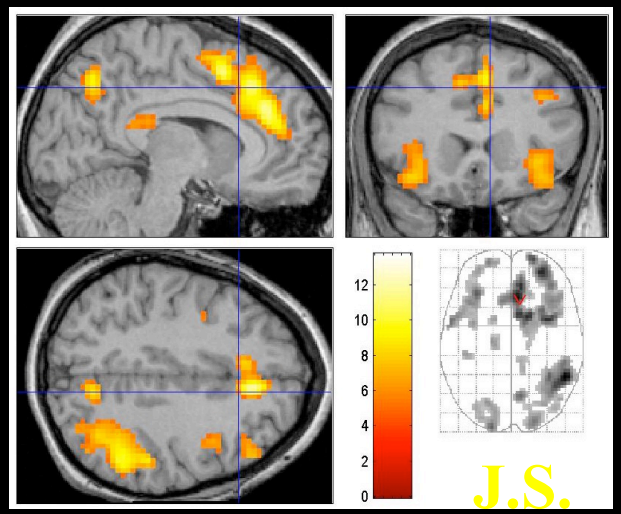
Individual patterns of activity are much more consistent across subjects for other retrieval tasks.

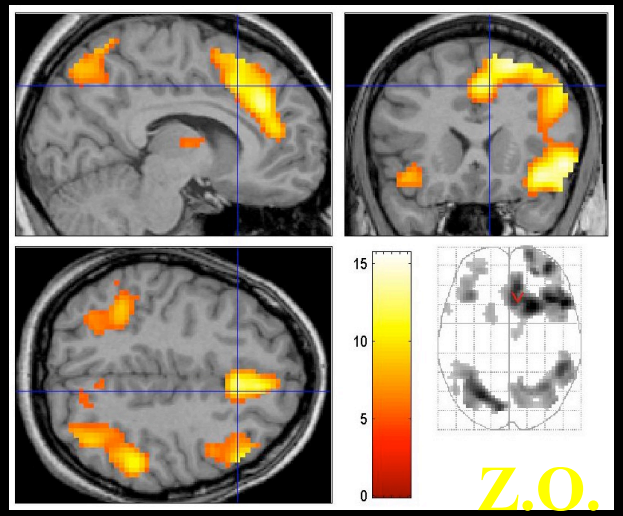
spatial working memory







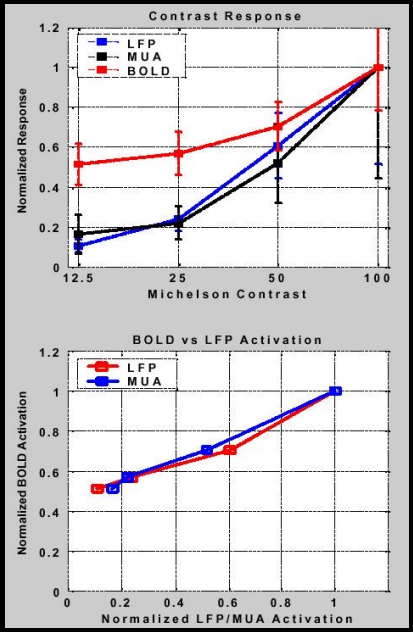




Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

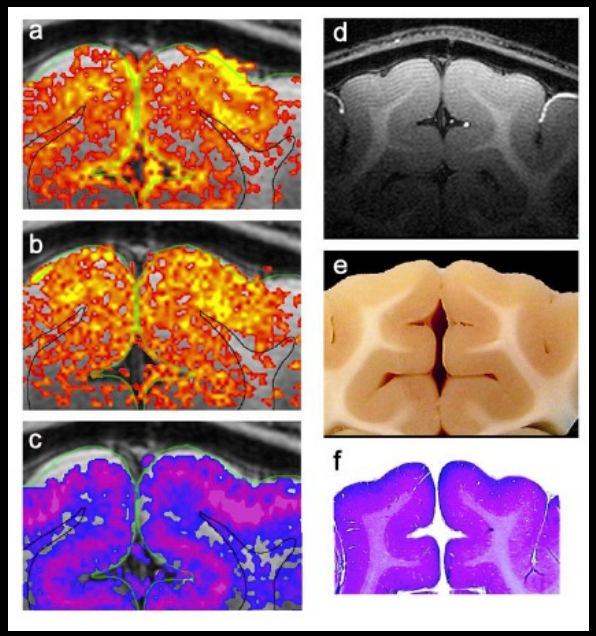
Relationship between neuronal activity and BOLD contrast?

Magnitude

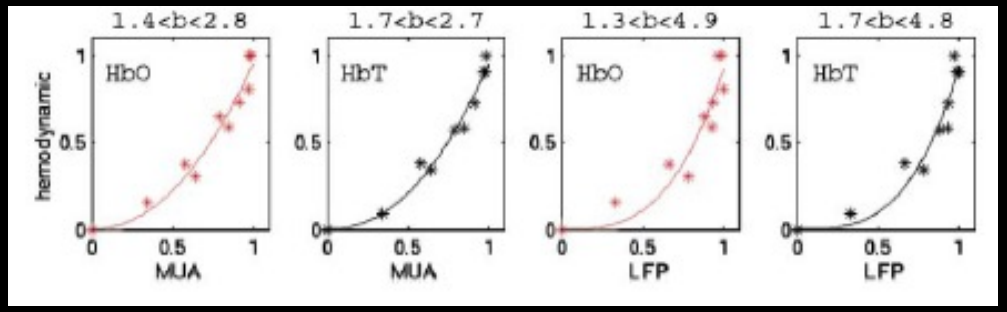


Logothetis et al. (2001) Nature, 412, 150-157

Location

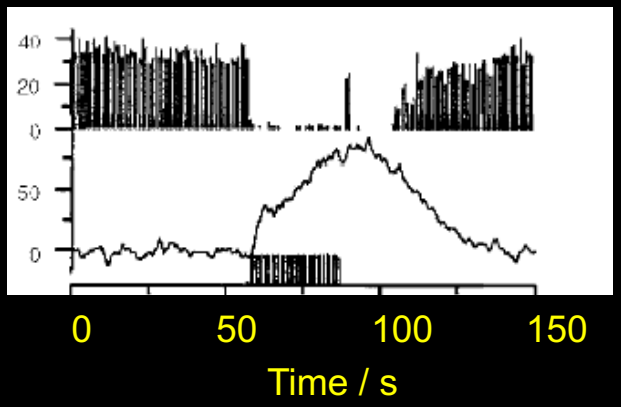


Harel et al. (2004) ISMRM, 200



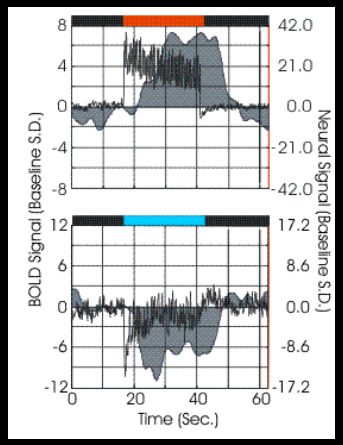
Devor et al. (2001) Neuron, 39, 353-359

Inhibition



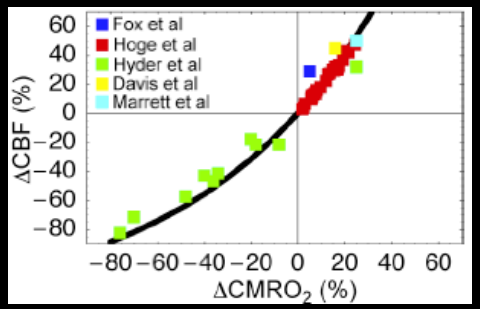
Mathiesen, et al (1998), J Physiol 512.2:555-566

Neg. BOLD



Schmuel et al. (2003) OHBM, 308

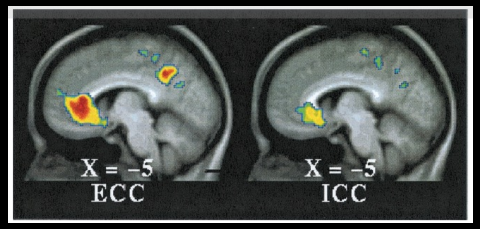
Why?



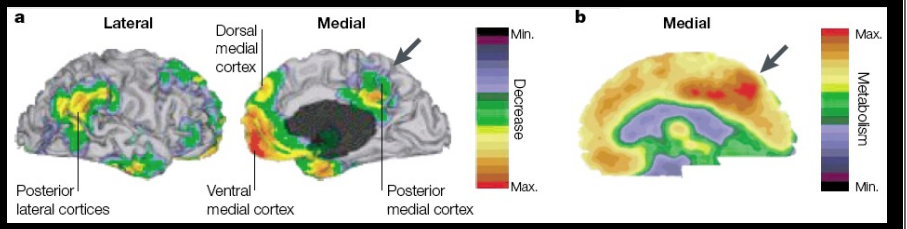
to preserve $[O_2]/[CO_2]$ at mitochondria

Buxton (2004) ISMRM, 273

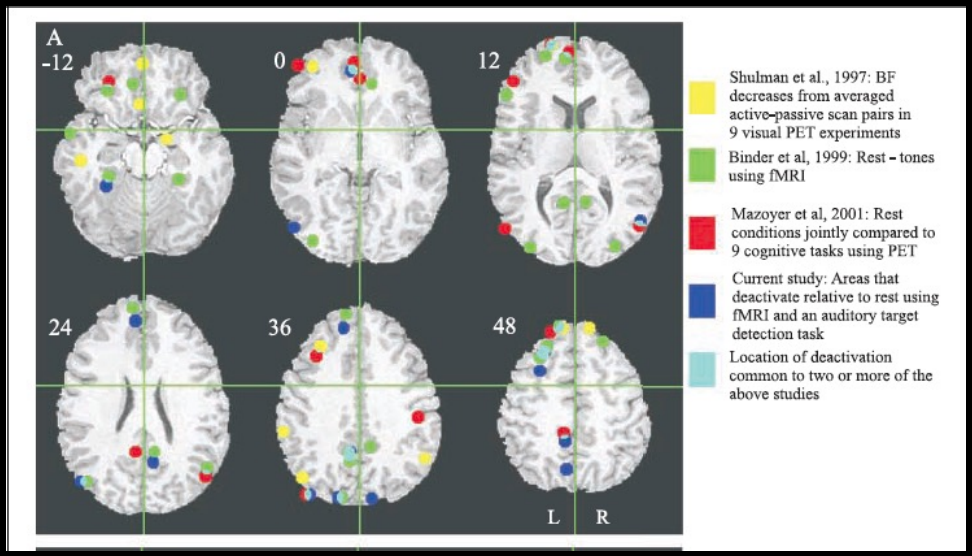
Negaitve Signal Changes..



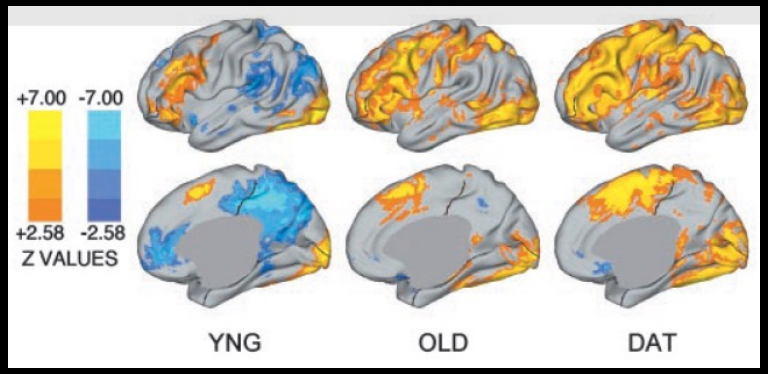
Gusnard, et al (2001), PNAS 98 (7), 4259-4264



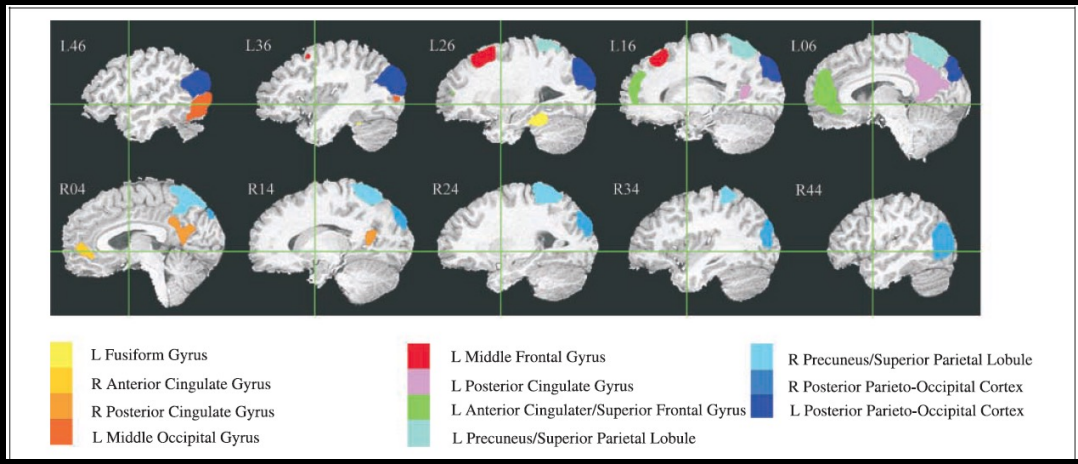
Gusnard, et al (2001), Nature Reviews Neuroscience (2), 685-694



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

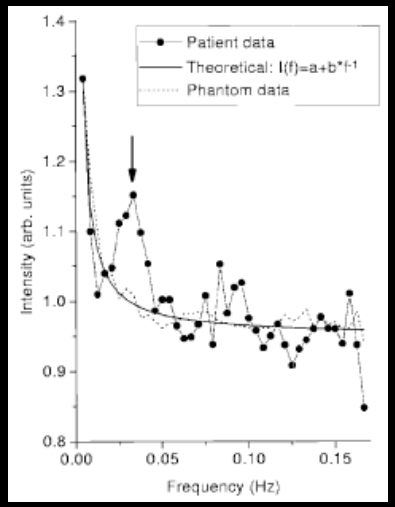


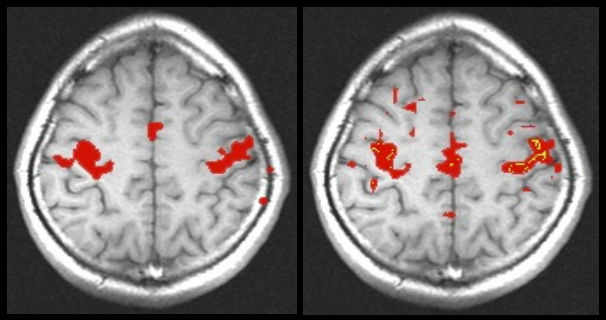
Lustig, et al (2003), PNAS 100 (19), 14504-14509



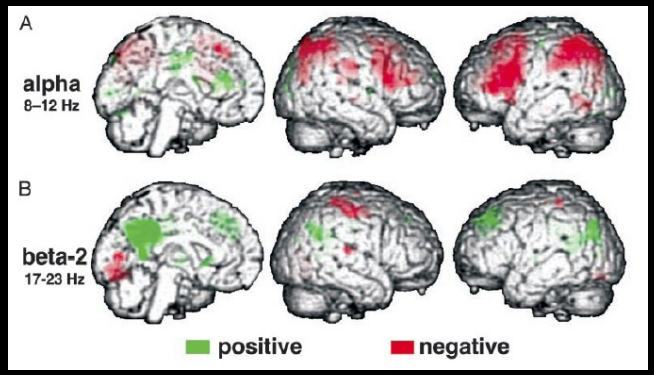
McKiernan, et al (2003), Journ. of Cog. Neurosci. 15 (3), 394-408

Baseline fluctuations…

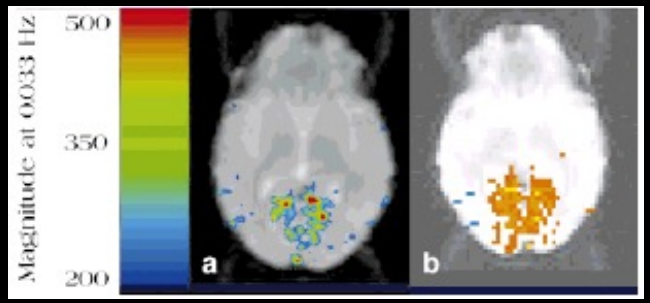




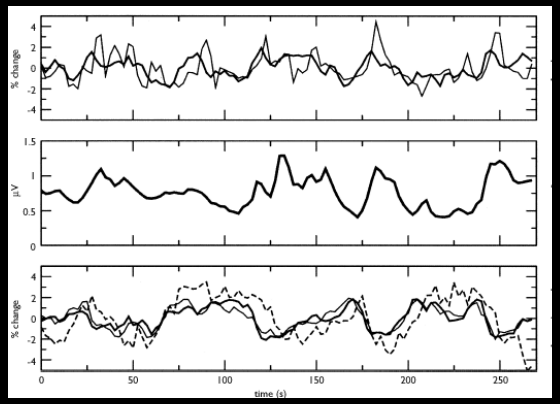
Biswal, et al (1995), MRM 34, 537-541

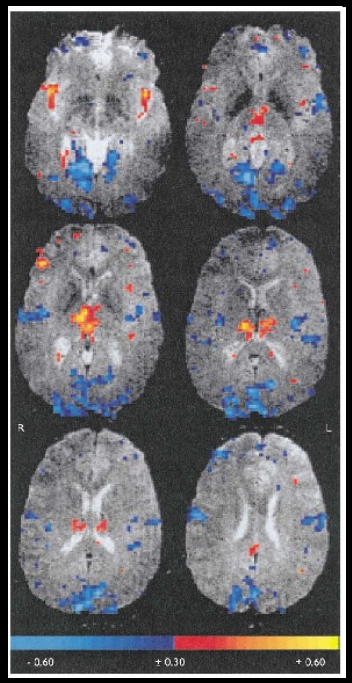


Laufs, et al (1995), PNAS 100 (19), 11053=11058

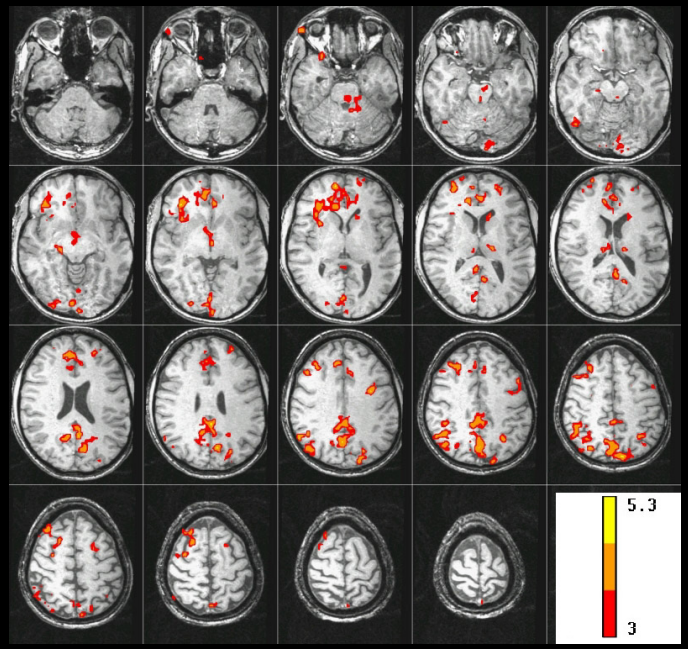


Kiviniemi, et al (2000), MRM 44, 373-378





Goldman, et al (2002), Neuroreport



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

What it can do

-map brain activation in individuals and groups
-spatial resolution: 0.5 mm
-temporal resolution (absolute: 4 sec, relative: 100 ms)
-track changes over time (sec to years)
-predict some behavior

What it can't do

-differentiate excitation vs. inhibition
-demonstrate causality
-classify individuals
-predict long term behavior

What it might do

-predict wider range of behavior
-characterize baseline activity
-classify individuals within a narrow context

Functional Imaging Methods Unit
&
Functional MRI Facility

Computer Specialist:

Adam Thomas

Staff Scientists:

Sean Marrett

Jerzy Bodurka

Frank Ye

Wen-Ming Luh

Rasmus Birn

Post Docs:

Hauke Heekeren

David Knight

Anthony Boemio

Niko Kriegeskorte

Scanning Technologists:

Karen Bove-Bettis

Paula Rowser

Alda Ottley

Ellen Condon

Program Assistant:

Kay Kuhns

Graduate Student:

Natalia Petridou