Functional MRI

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Section on Functional Imaging Methods

http://fim.nimh.nih.gov

Laboratory of Brain and Cognition

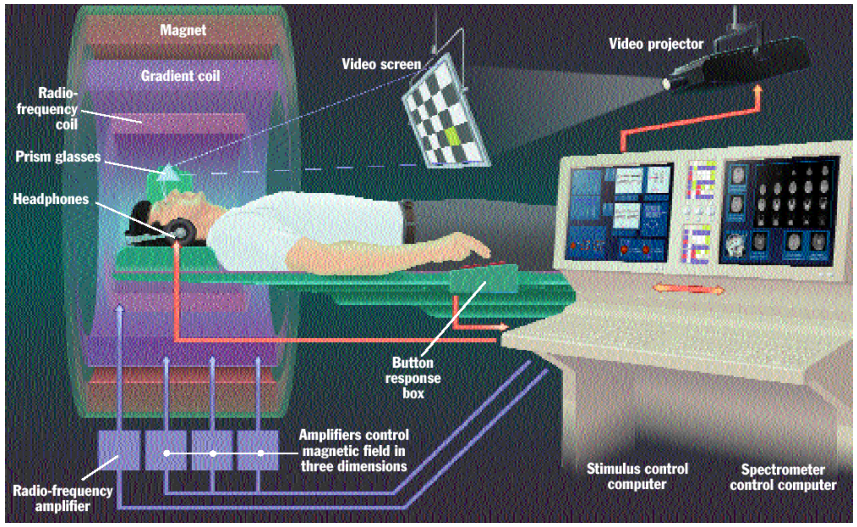
&

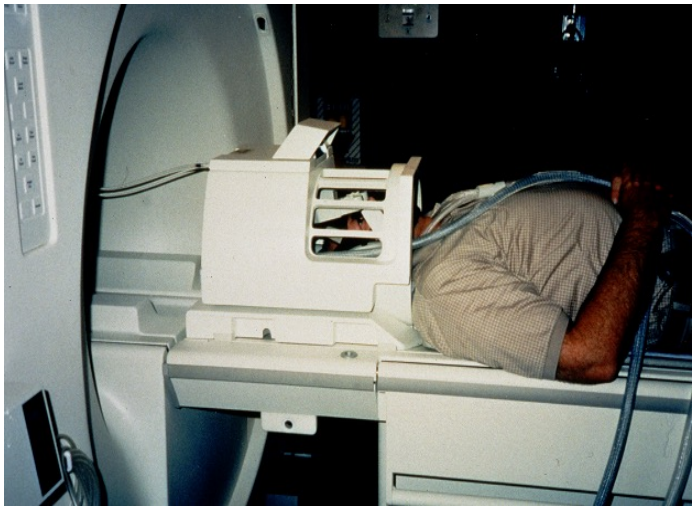
Functional MRI Facility

http://fmrif.nimh.nih.gov

- How does fMRI Work?
- Temporal, spatial, interpretive, practical limitations.
- Costs/Benefits in Security Evaluation?
- Necessary improvements - what needs to be known?

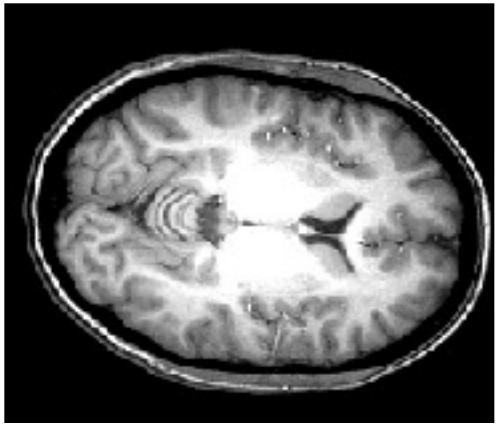
fMRI Setup


Magnet
Gradient coil
Radio-frequency coil
Prism glasses
Headphones
Video screen
Video projector
Button response box
Amplifiers control magnetic field in three dimensions
Radio-frequency amplifier
Stimulus control computer
Spectrometer control computer



MRI vs. fMRI

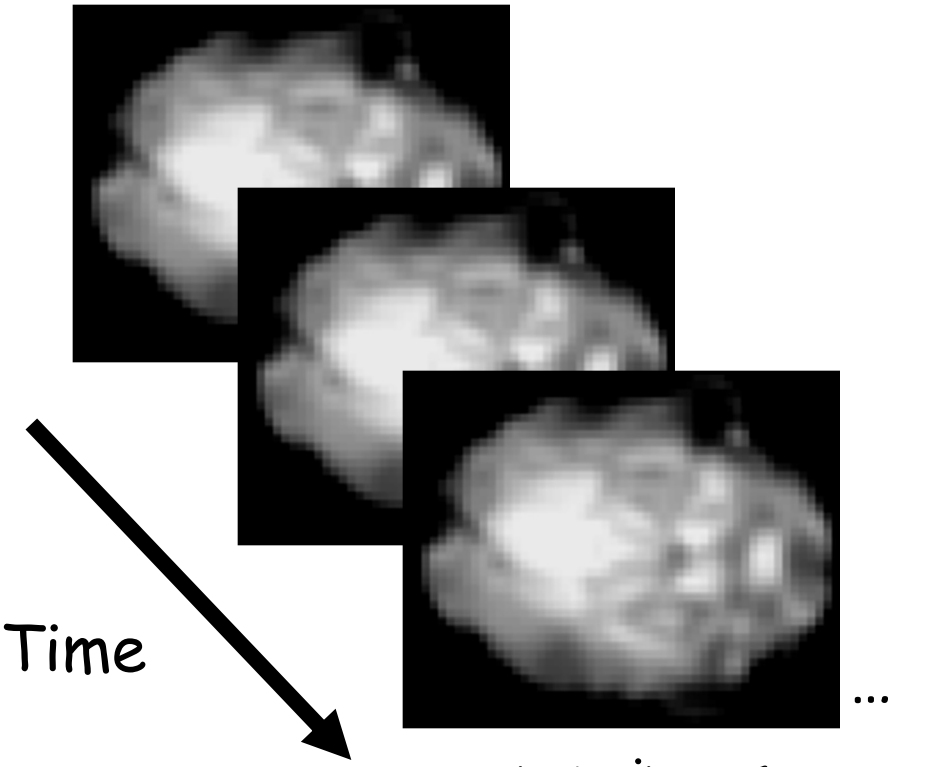
MRI



one image

high resolution
(1 mm or less)

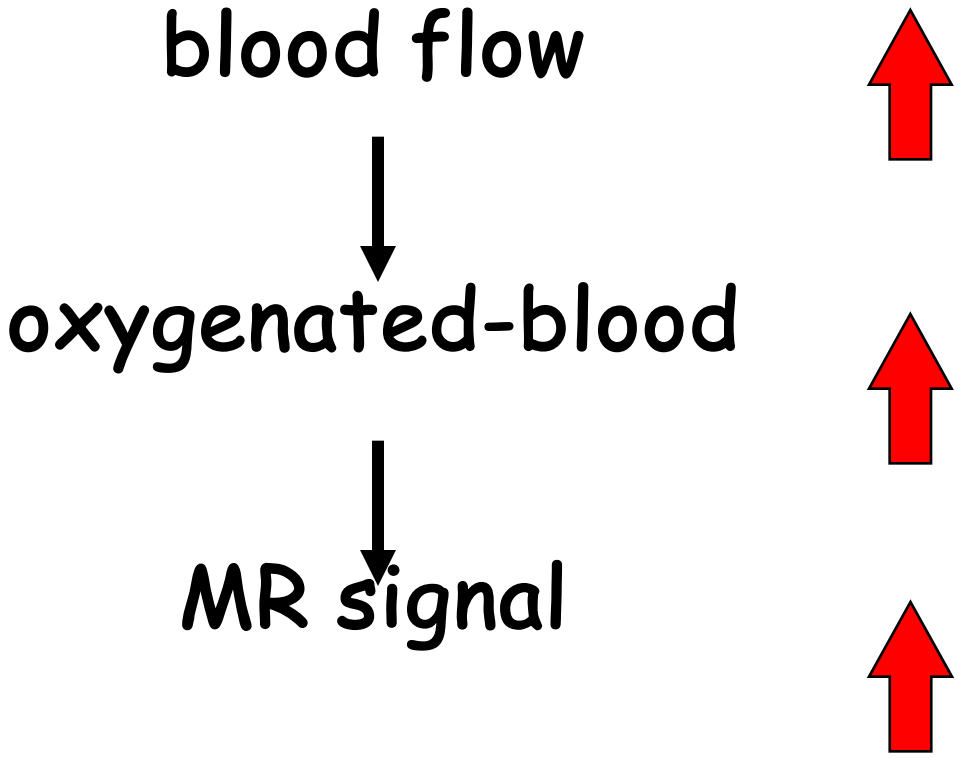
fMRI



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

low resolution
(1.5 to 4 mm)

BOLD (Blood Oxygen Level Dependent) Contrast

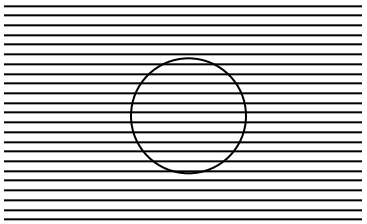


Basis of BOLD Contrast

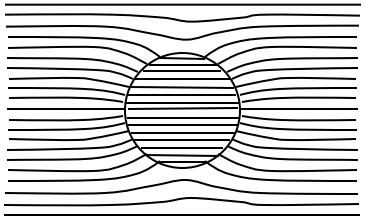
Oxygenated and deoxygenated red blood cells have different magnetic properties

red blood cells

oxygenated



deoxygenated



L. Pauling, C. D. Coryell, *Proc.Natl. Acad. Sci. USA 22, 210-216*, **1936**.

K.R. Thulborn, J. C. Waterton, et al., *Biochim. Biophys. Acta. 714: 265-270*, **1982**.

S. Ogawa, T. M. Lee, A. R. Kay, D. W. Tank, *Proc. Natl. Acad. Sci. USA 87, 9868-9872*, **1990**.

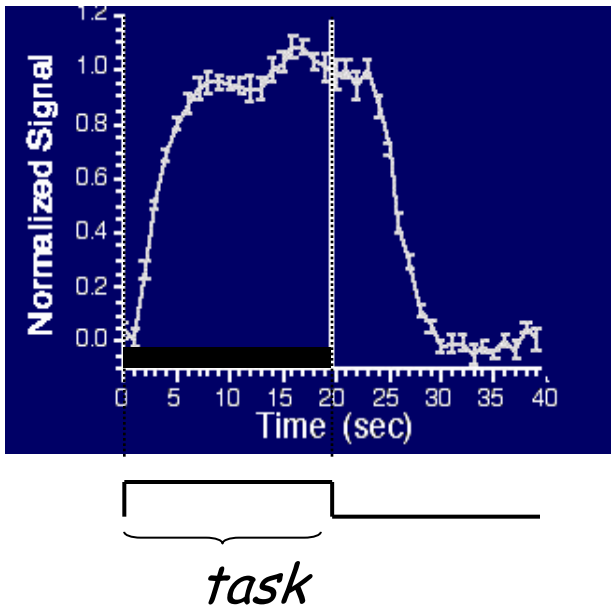
BOLD Contrast Imaging

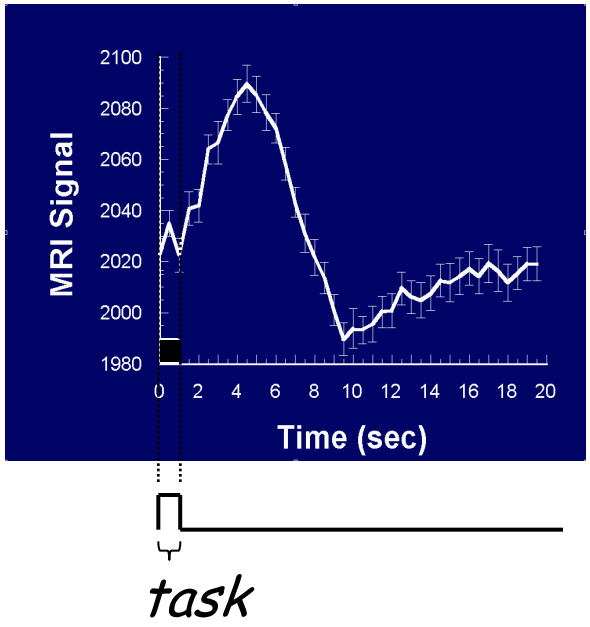
·K. K. Kwong, et al, (1992) "Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation." Proc. Natl. Acad. Sci. USA. 89, 5675-5679.

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

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

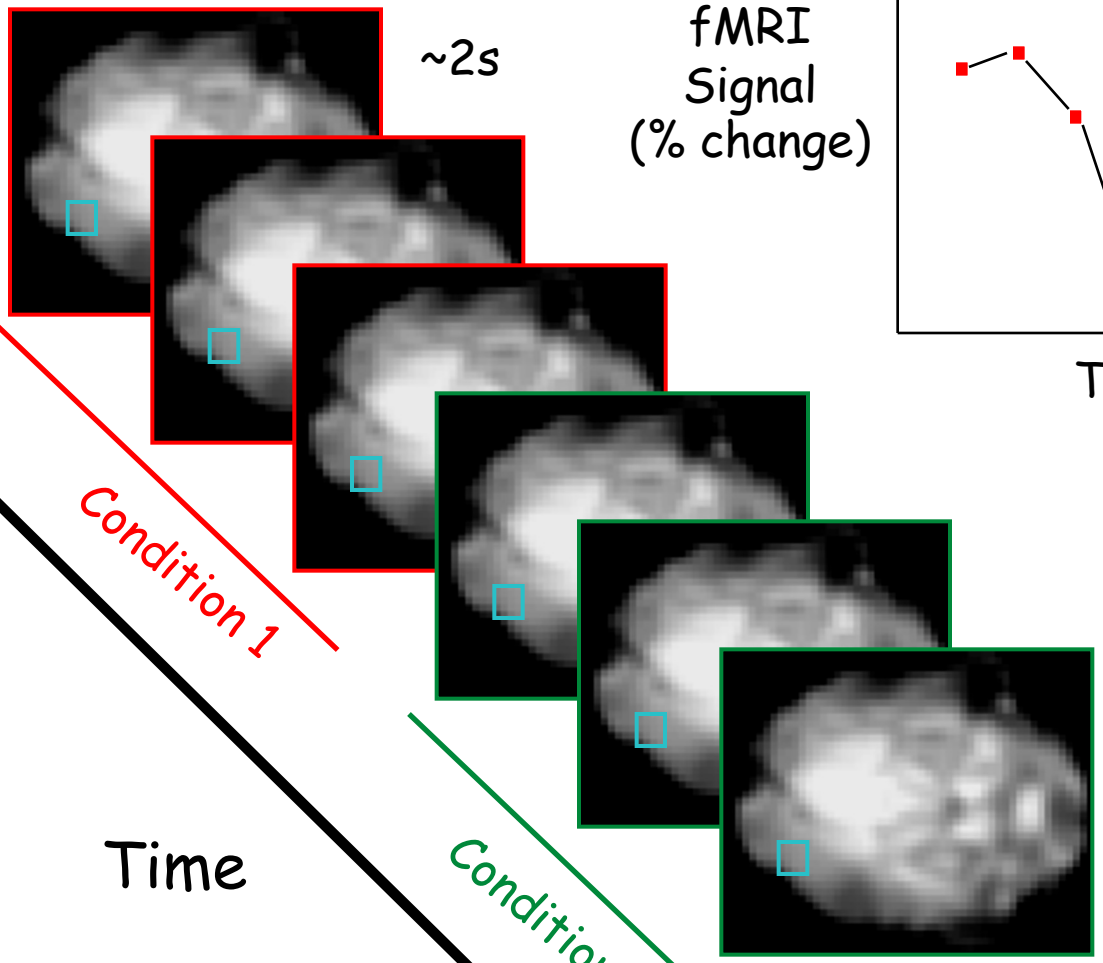
·Blamire, A. M., et al. (1992). "Dynamic mapping of the human visual cortex by high-speed magnetic resonance imaging." Proc. Natl. Acad. Sci. USA 89: 11069-11073.



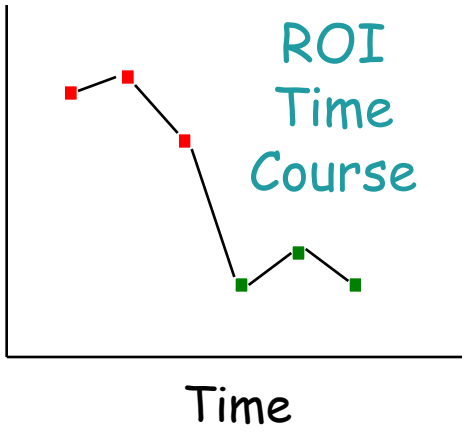


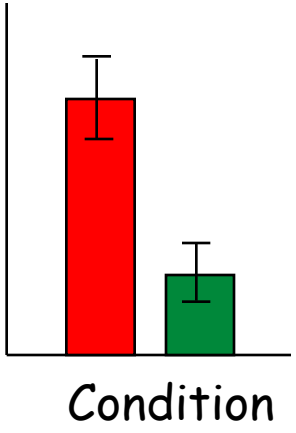
Activation Statistics

Functional images

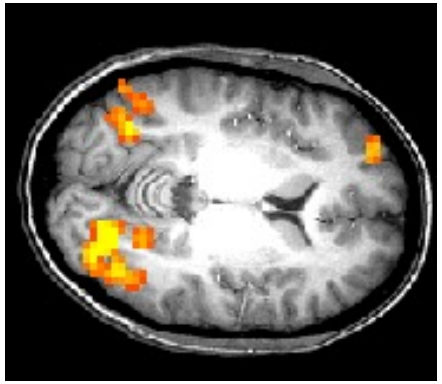


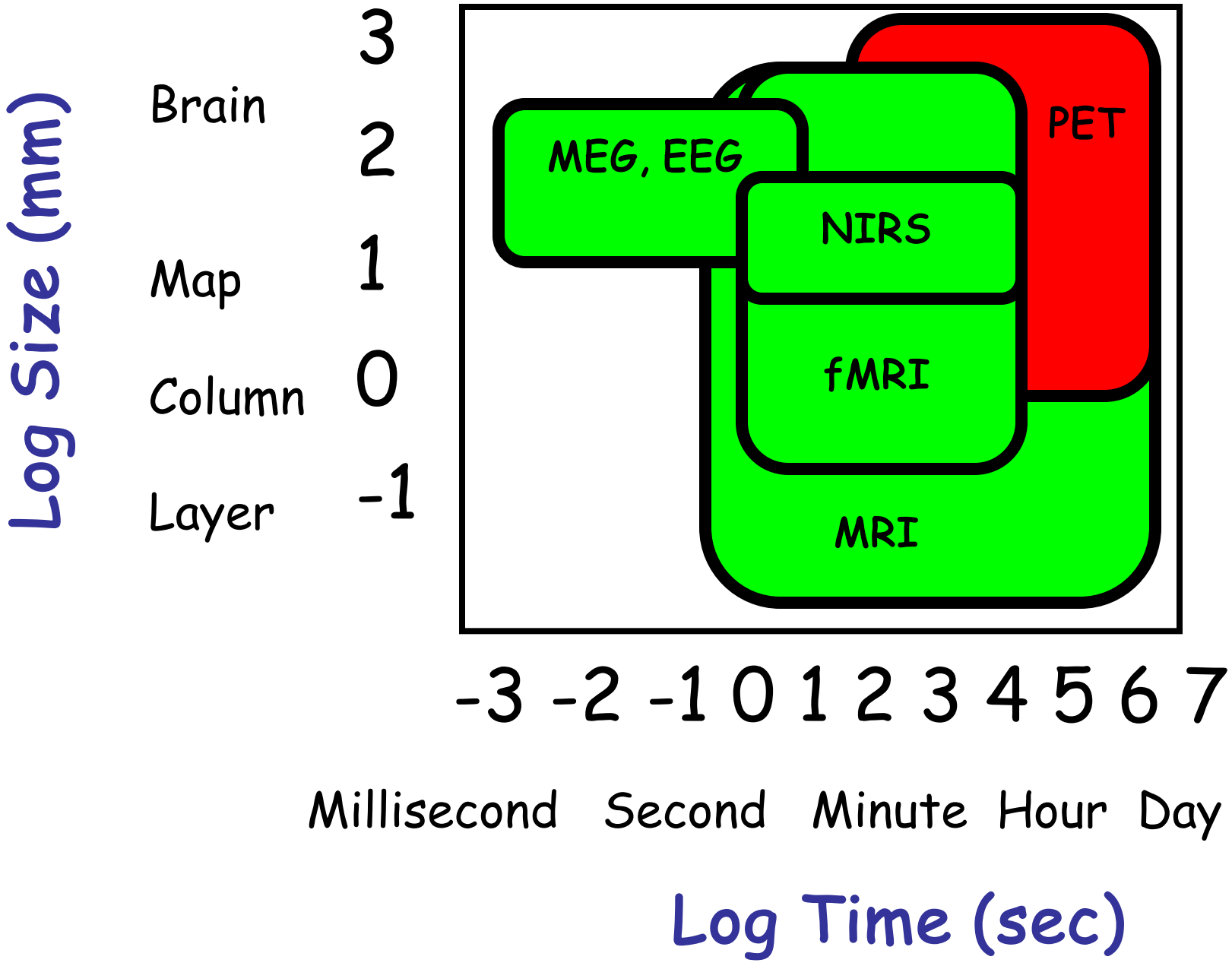
fMRI Signal (% change)



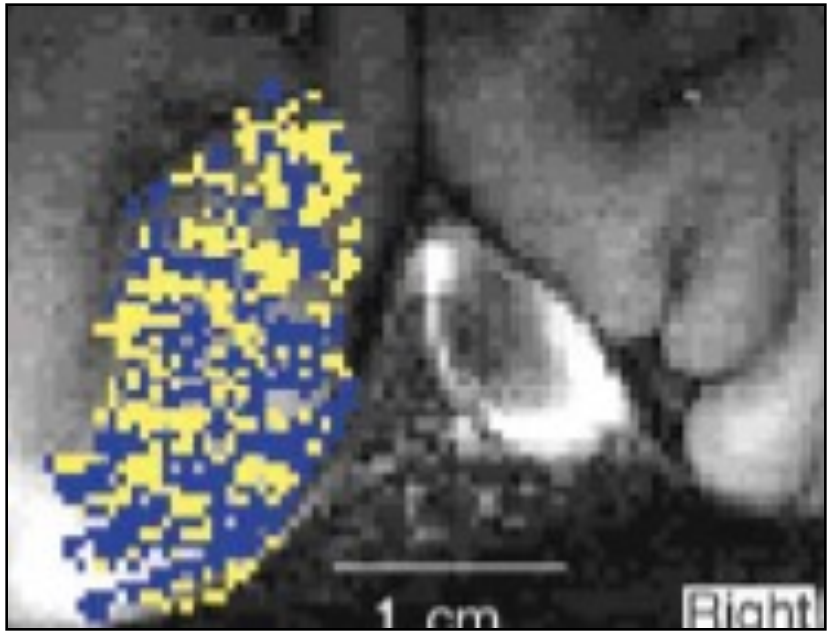


Statistical Map
superimposed on anatomical MRI image



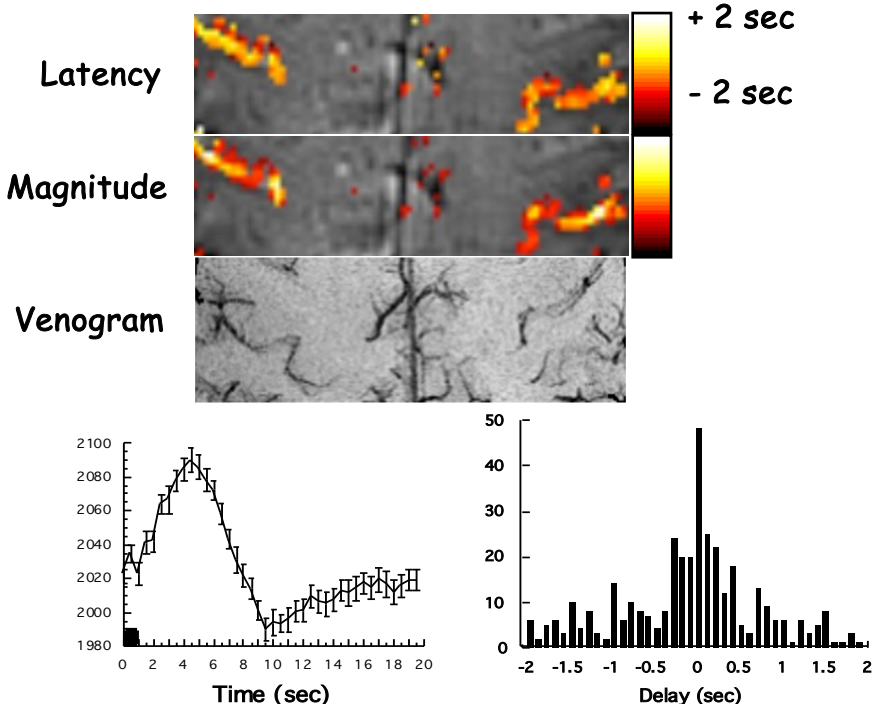

Log Size (mm)
Brain
Map
Column
Layer
3
2
1
0
-1
MEG, EEG
PET
NIRS
fMRI
MRI
-3 -2 -1 0 1 2 3 4 5 6 7
Millisecond
Second
Minute
Hour
Day
Log Time (sec)

Spatial and Temporal Resolution



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

Latency Variation…



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

Spatial

Temporal

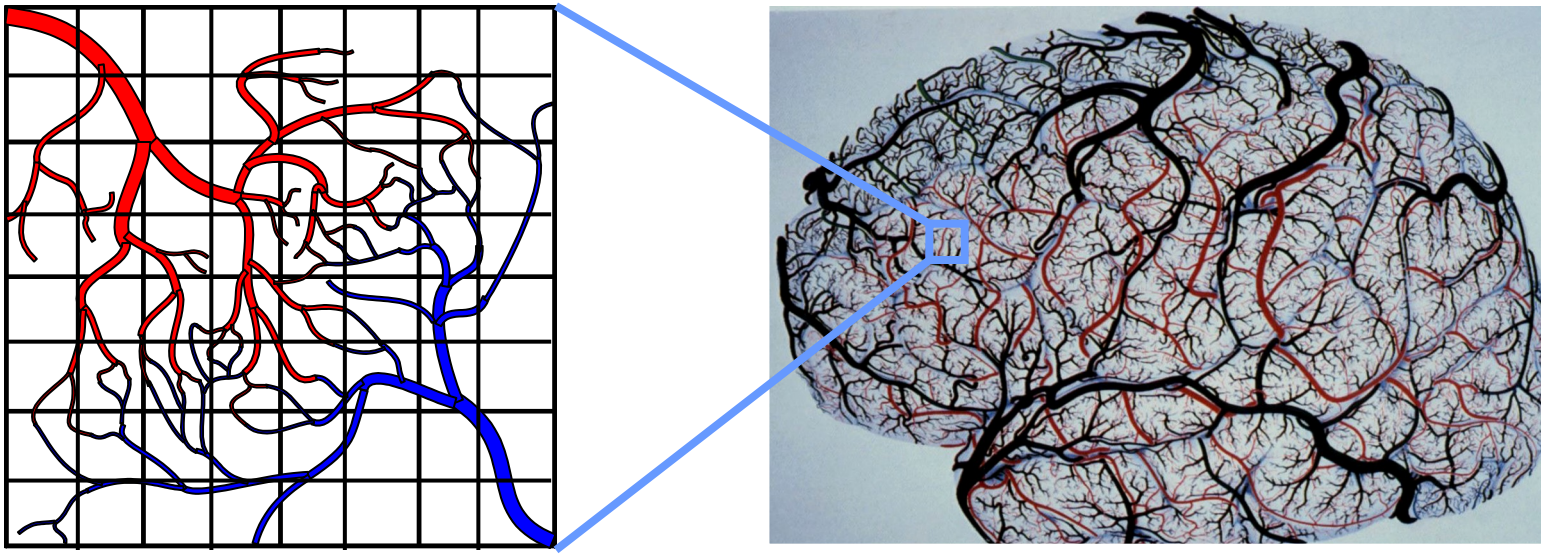
Interpretation

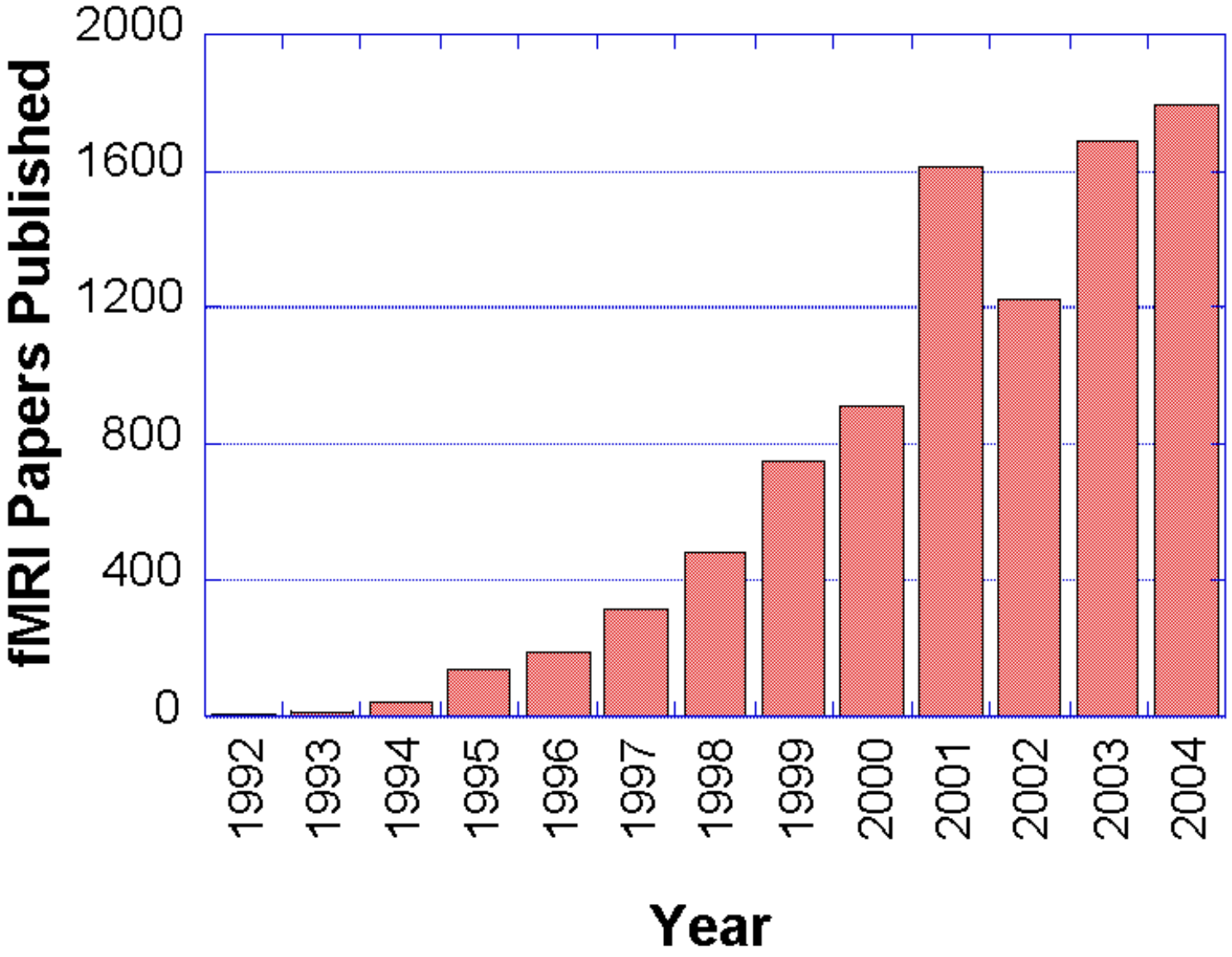
Neuronal Activation ? Measured Signal

? ? ? ?

Hemodynamics

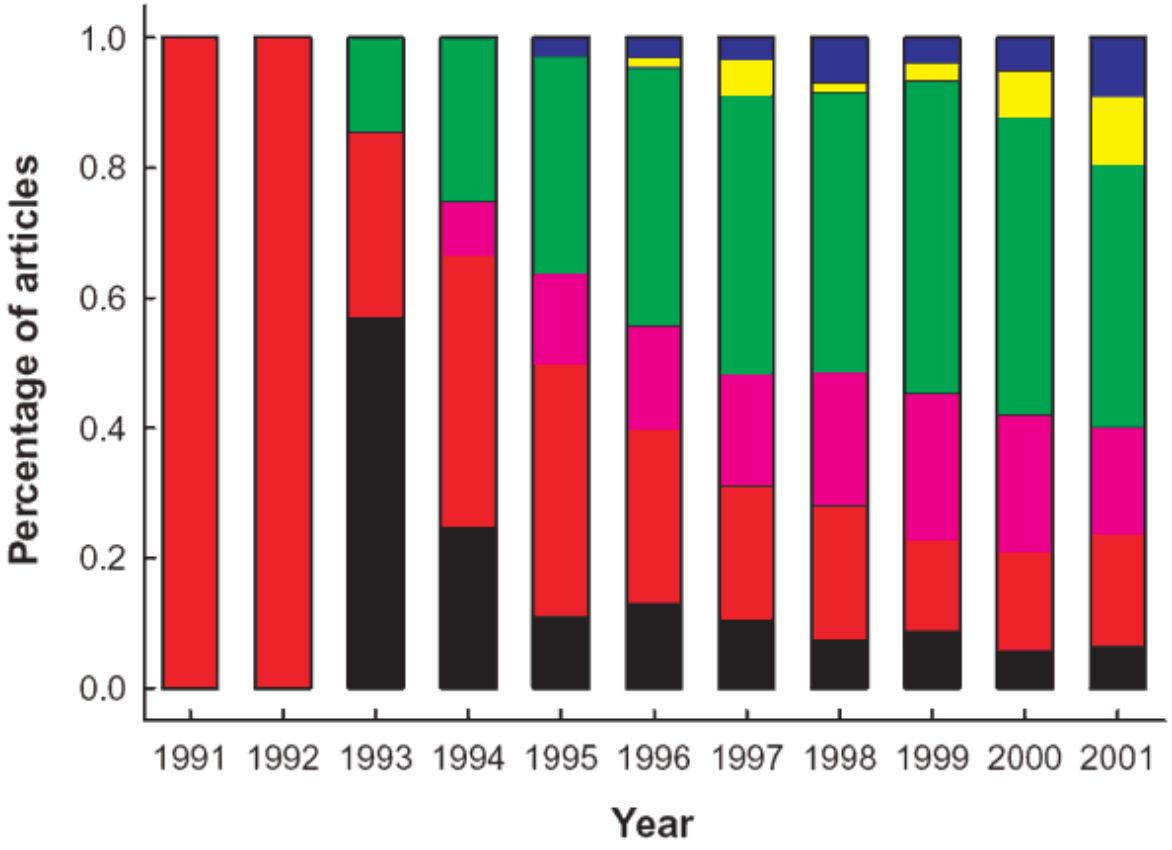
Noise




fMRI Papers Published
2000
1600
1200
800
400
0
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year

Type of fMRI research performed

Motor
Primary Sensory
Integrative Sensory
Basic Cognition
High-Order Cognition
Emotion



J. Illes, M. P. Kirschen, J. D. E. Gabrielli,
Nature Neuroscience, 6 (3) p.205, 2001

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

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

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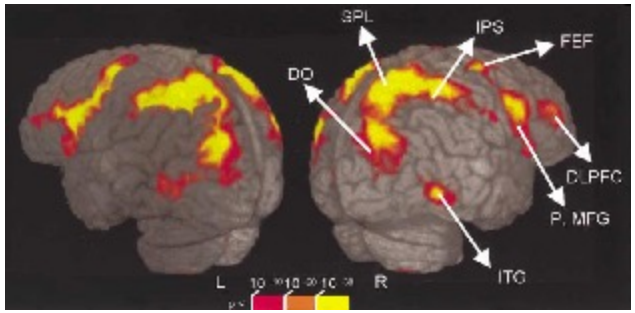
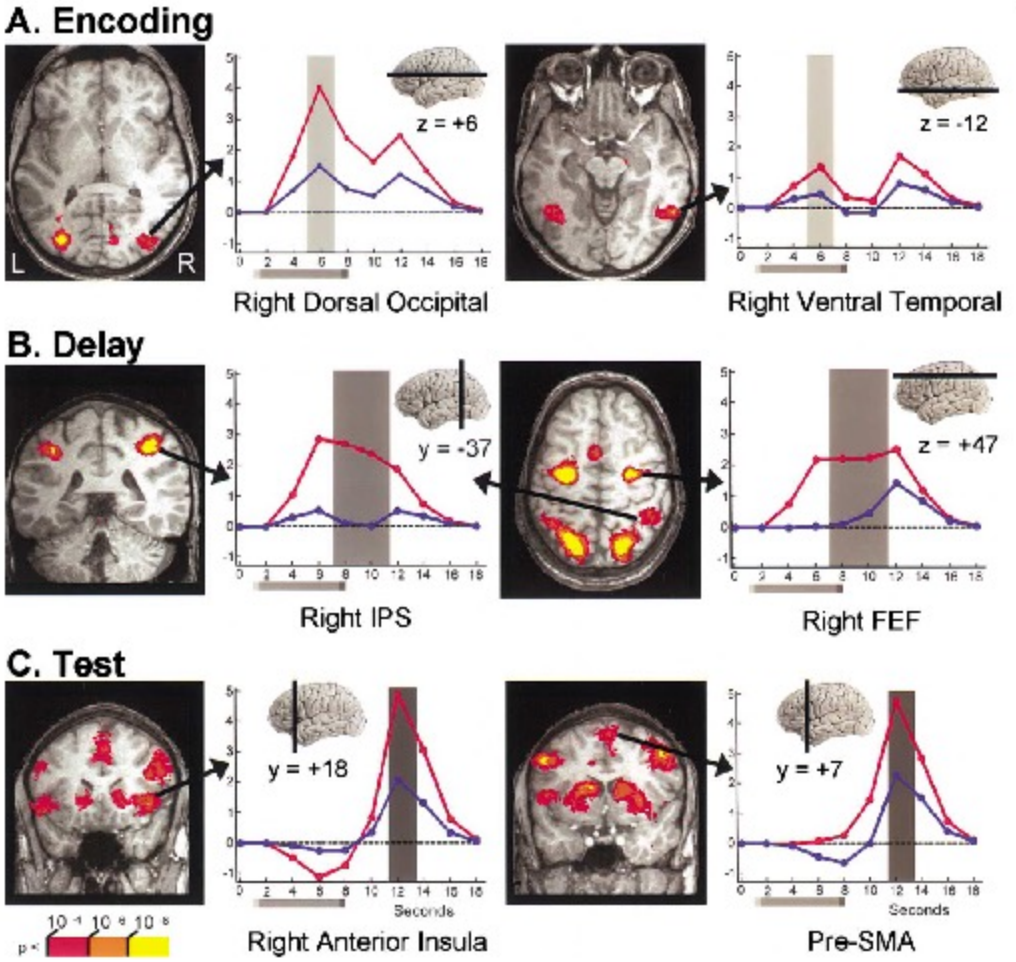


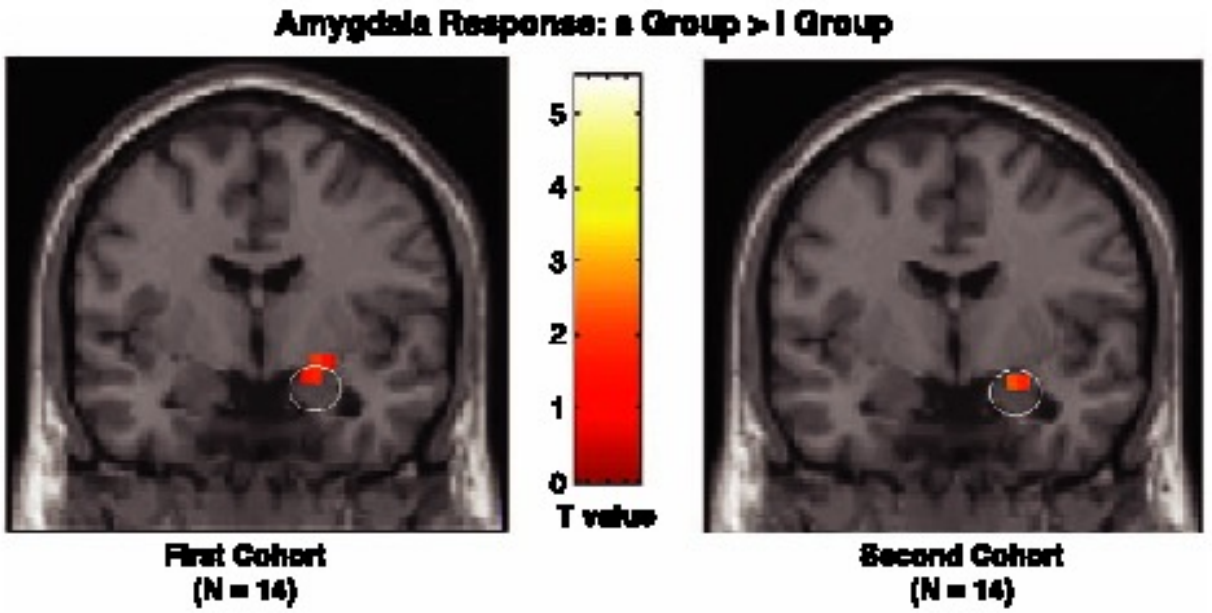


Clinical Applications

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

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

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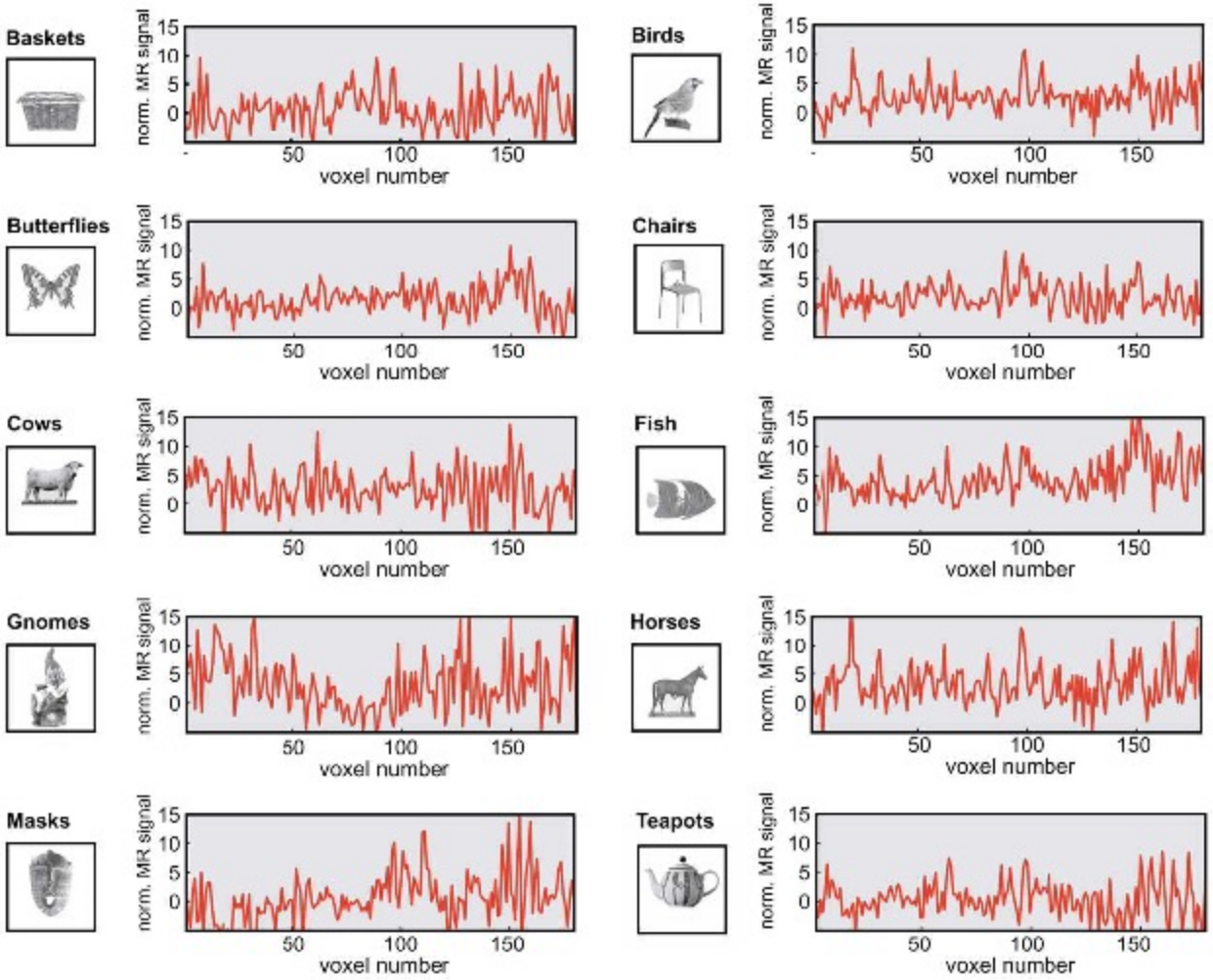
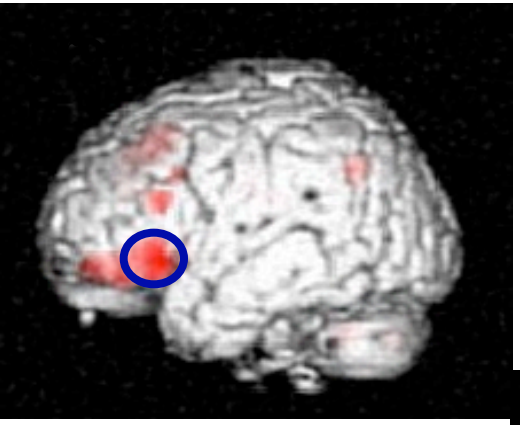
[c] HyperVision, Inc., P.O. Box 158, Lexington, MA 02420, USA

Received 15 July 2002; accepted 10 December 2002

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

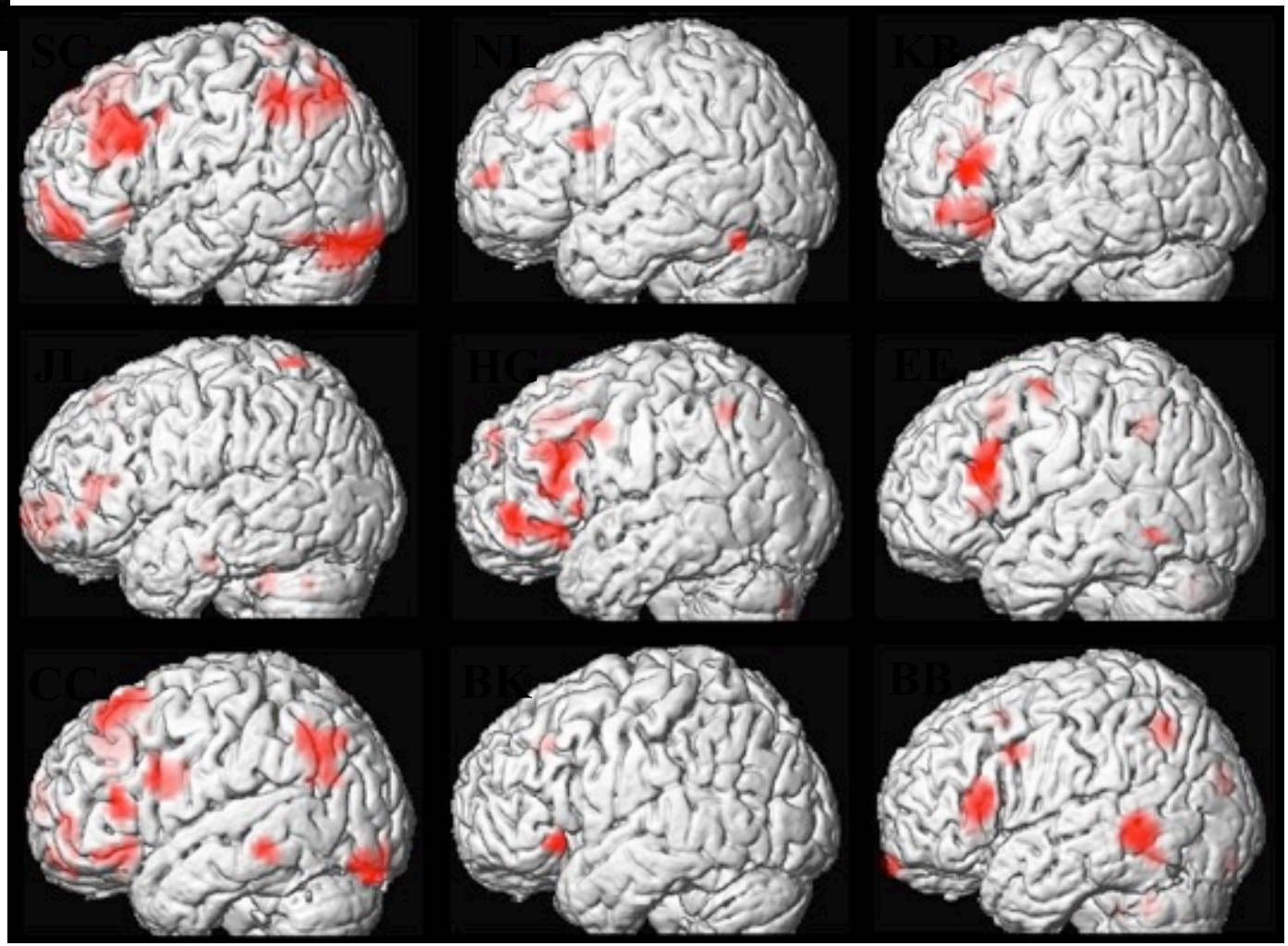




Extensive Individual Differences in Brain Activations During Episodic Retrieval

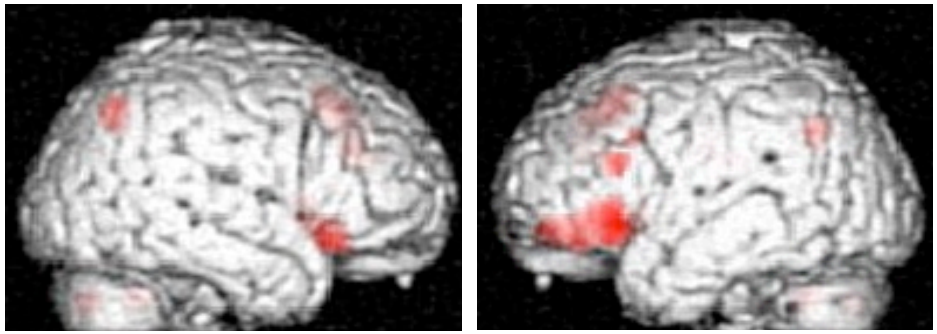
Miller et al., 2002

Individual activations from the left hemisphere of the 9 subjects

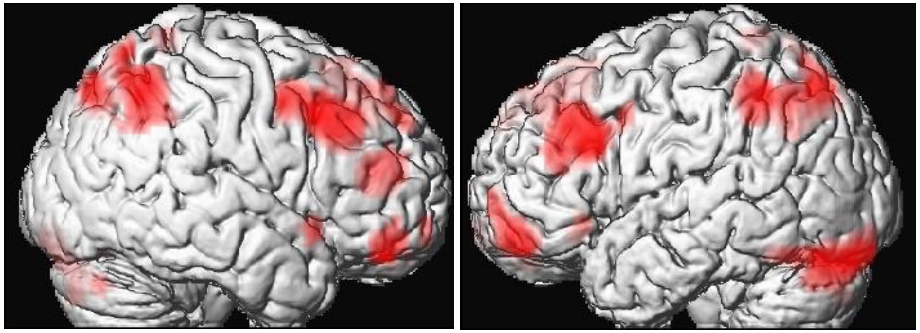


Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

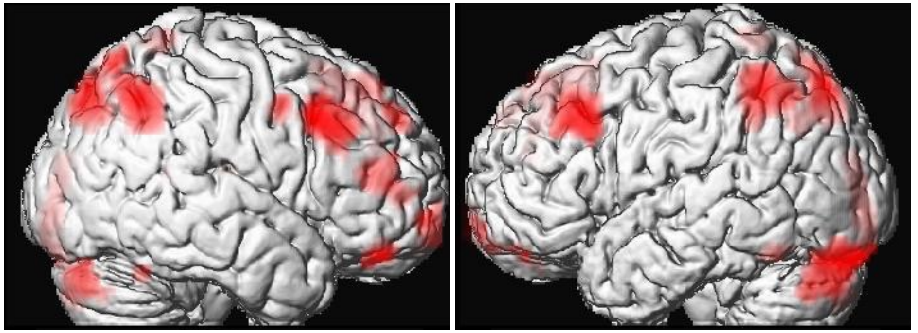
These individual patterns of activations are stable over time



Group Analysis of Episodic Retrieval



Subject SC

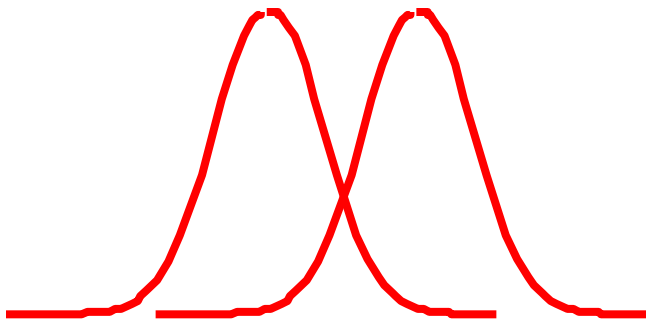


Subject SC 6 months later

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

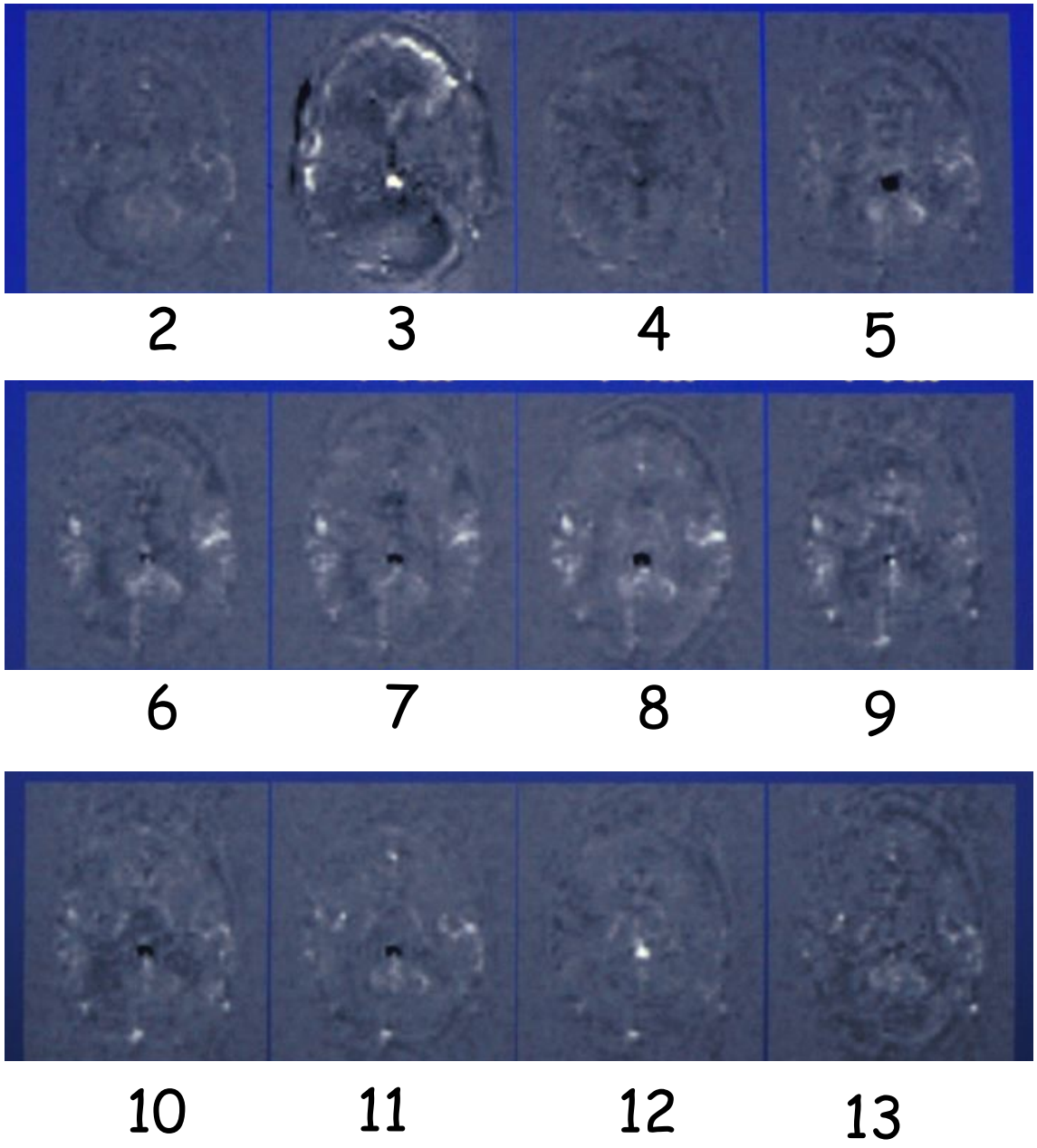
The problem of drawing individual inferences from fMRI data:

When comparing two groups, if one group shows a difference in activation, it does not imply that an individual that shows a similar difference is in that group.



Motion sensitivity

Overt Word Production



Concluding thoughts..

Very difficult to draw individual inferences.

Needs individual calibration.
(example: face recognition..)

Practically, very difficult to implement.
(requires considerable subject cooperation)

Uses

Understanding normal brain organization and changes

- -networks involved with specific tasks (low to high level processing)
- -changes over time (seconds to years)
- -correlates of behavior (response accuracy, performance changes…)

Clinical research

- -correlates of specifically activated networks to clinical populations
- -presurgical mapping

Future Uses

Complementary use for clinical diagnosis

- -utilization of clinical research results
- -prediction of pathology

Clinical treatment and assessment

- -drug, therapy, rehabilitation, biofeedback
- -epileptic foci mapping
- -drug effects

Non clinical uses

- -complementary use with behavioral, anatomical, other modality results
- -lie detection
- -prediction of behavior tendencies
- -brain/computer interface