Picturing the Brain:

Powerful Predictions or False Prophecy?

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

NIMH
National Institute
of Mental Health

What is the current state of technology of brain imaging?

How have these technologies been used to date?

How will the advent of more reliable brain imaging technologies benefit society?

Are current neuro-imaging technologies powerful enough to predict social behavior?

a. If not, how far are we from being able to use neuro-imaging as a predictor of social/ethical behavior?
b. If so, is it socially acceptable to use it for determining social and/or ethical behavior.

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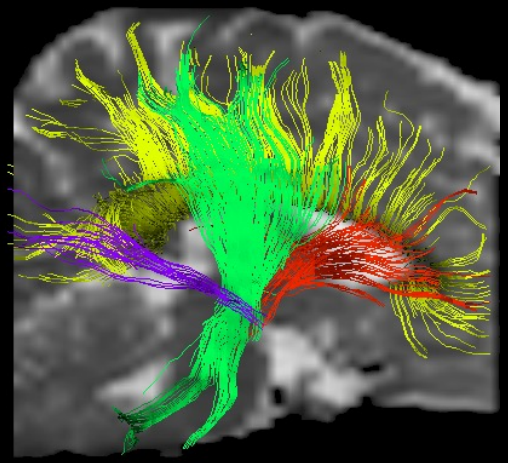
Two Types of Neuroimaging

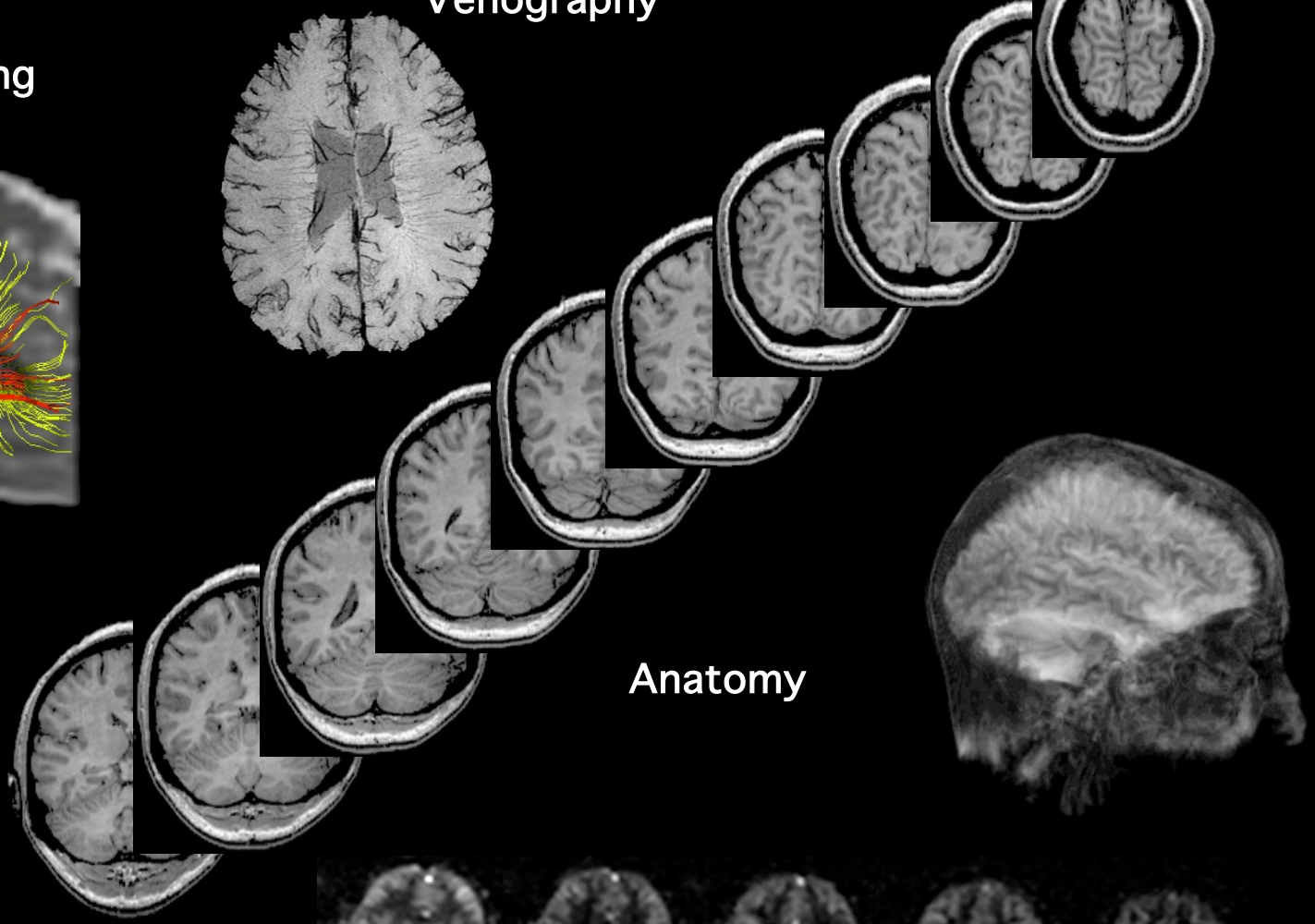
- Structural/Anatomical Imaging
- Functional Imaging

- Structural/Anatomical Imaging
  - X-ray
  - Computerized Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
    - Angiography
    - Venography
    - Perfusion
    - Diffusion Tensor Imaging

Fiber Track Imaging



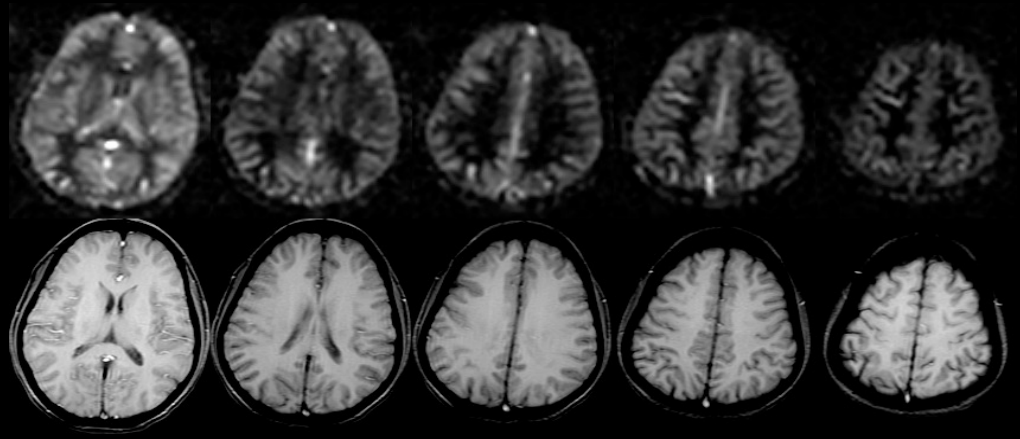
Venography



Anatomy

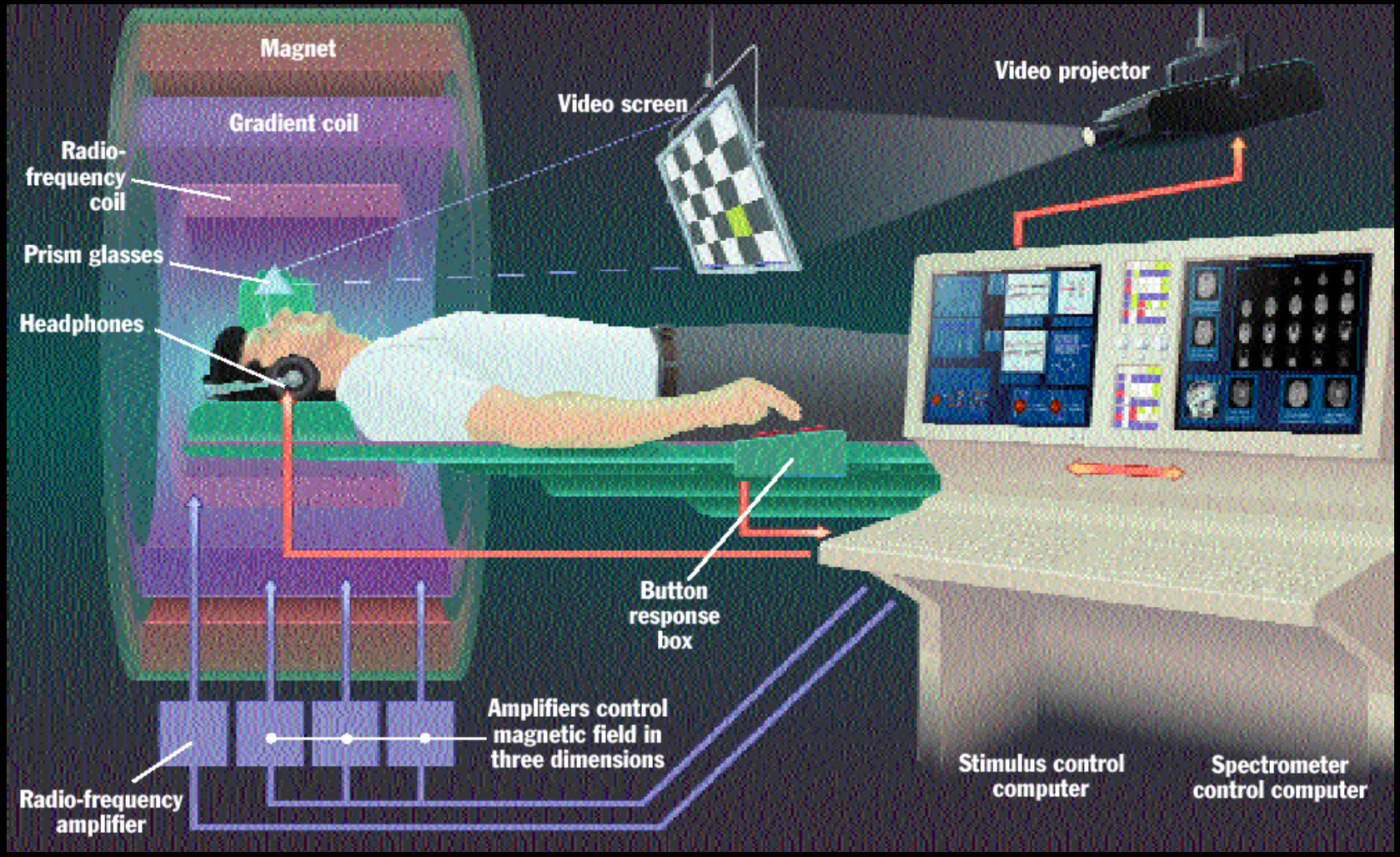
Angiography

Perfusion



- 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)

fMRI Setup



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

MRI vs. fMRI

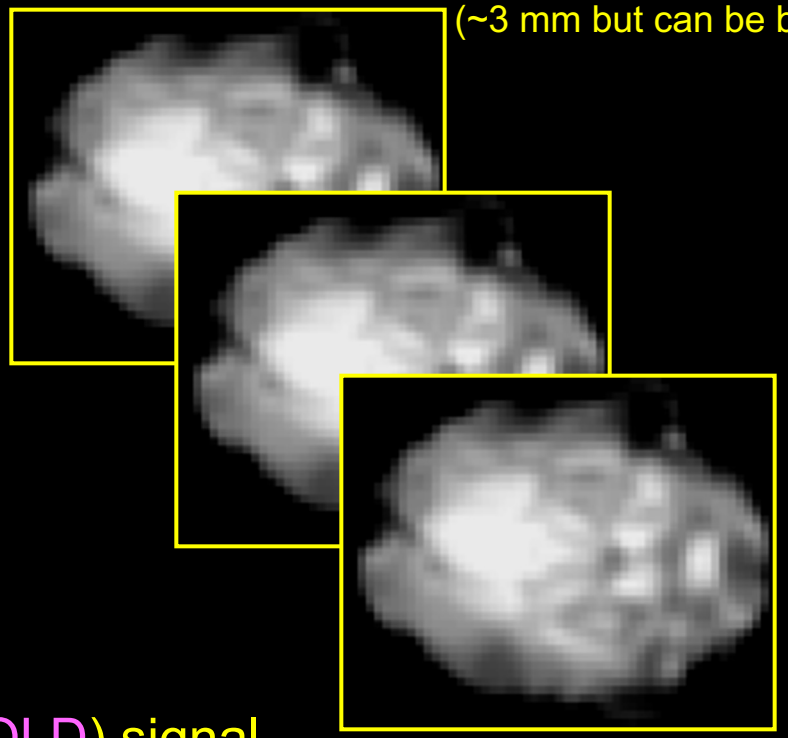
high resolution
(1 mm)

MRI

one image

fMRI

low resolution
(~3 mm but can be better)



...

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

fMRI

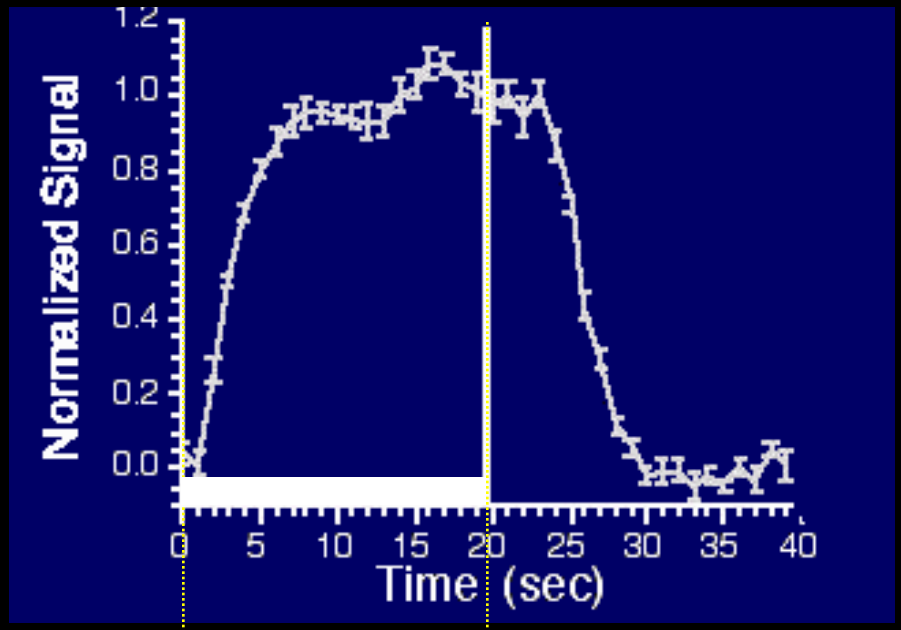
Blood Oxygenation Level Dependent (BOLD) signal
indirect measure of neural activity

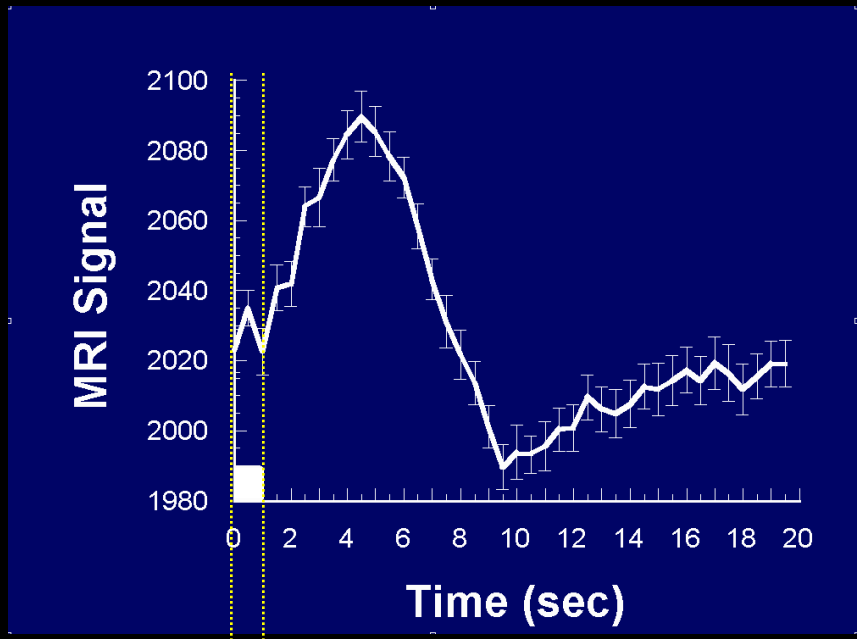
↑ neural activity ➔ ↑ blood oxygen ➔ ↑ fMRI signal

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

The FMRI Signal

Based on Local Blood Flow Response in the Brain



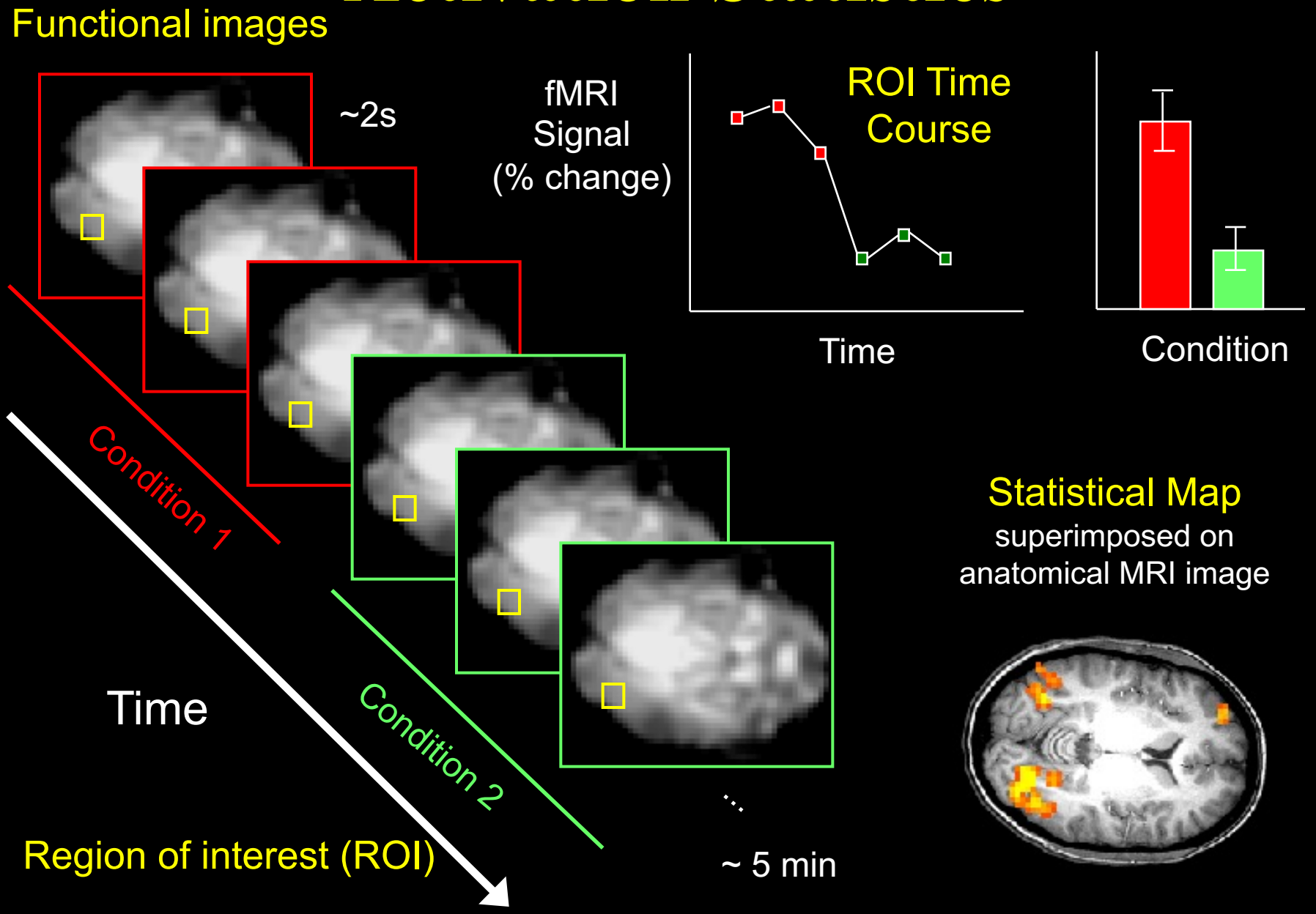


task

task

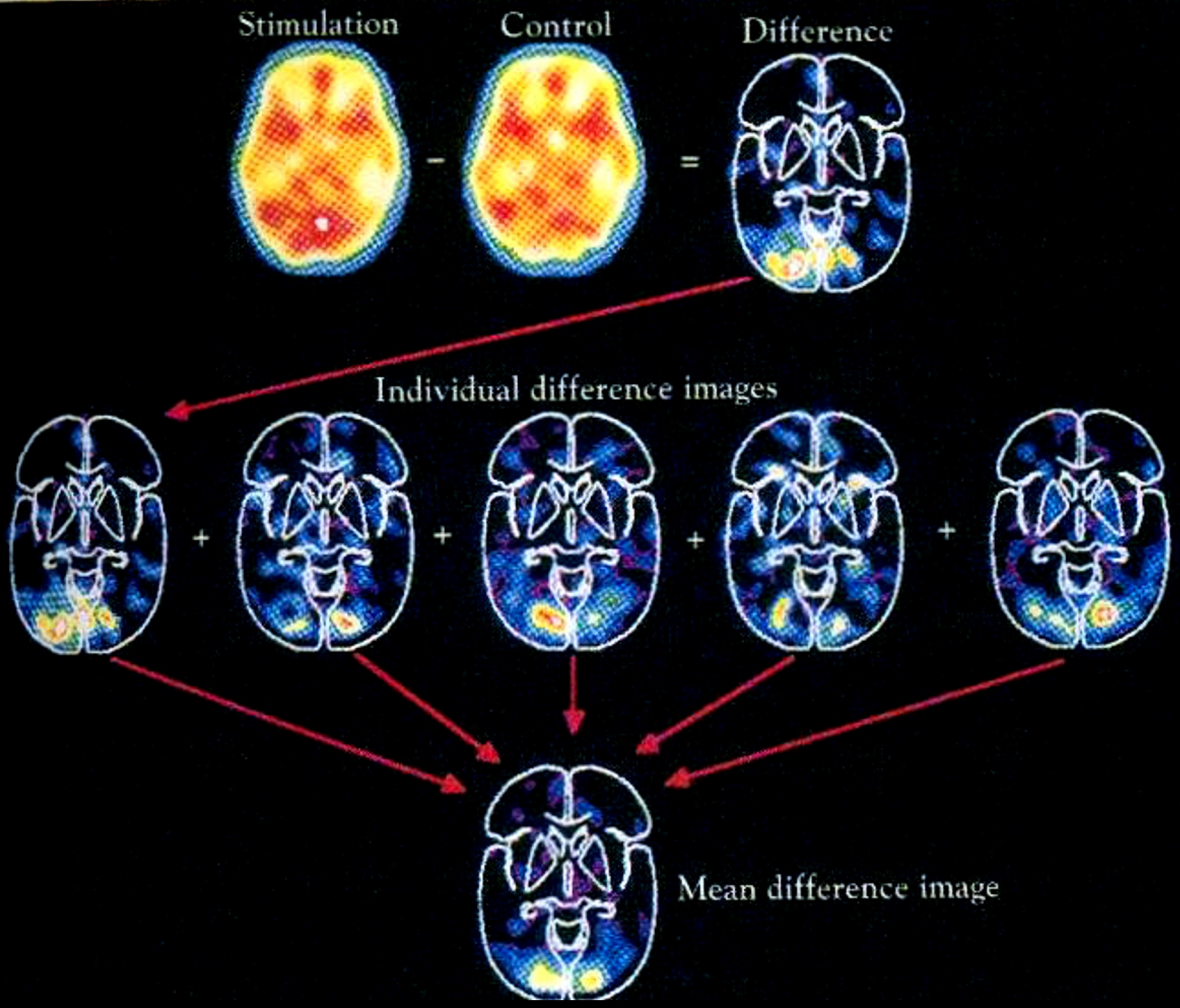
Courtesy, Rasmus Birn, Unit on Functional Imaging Methods,

Activation Statistics



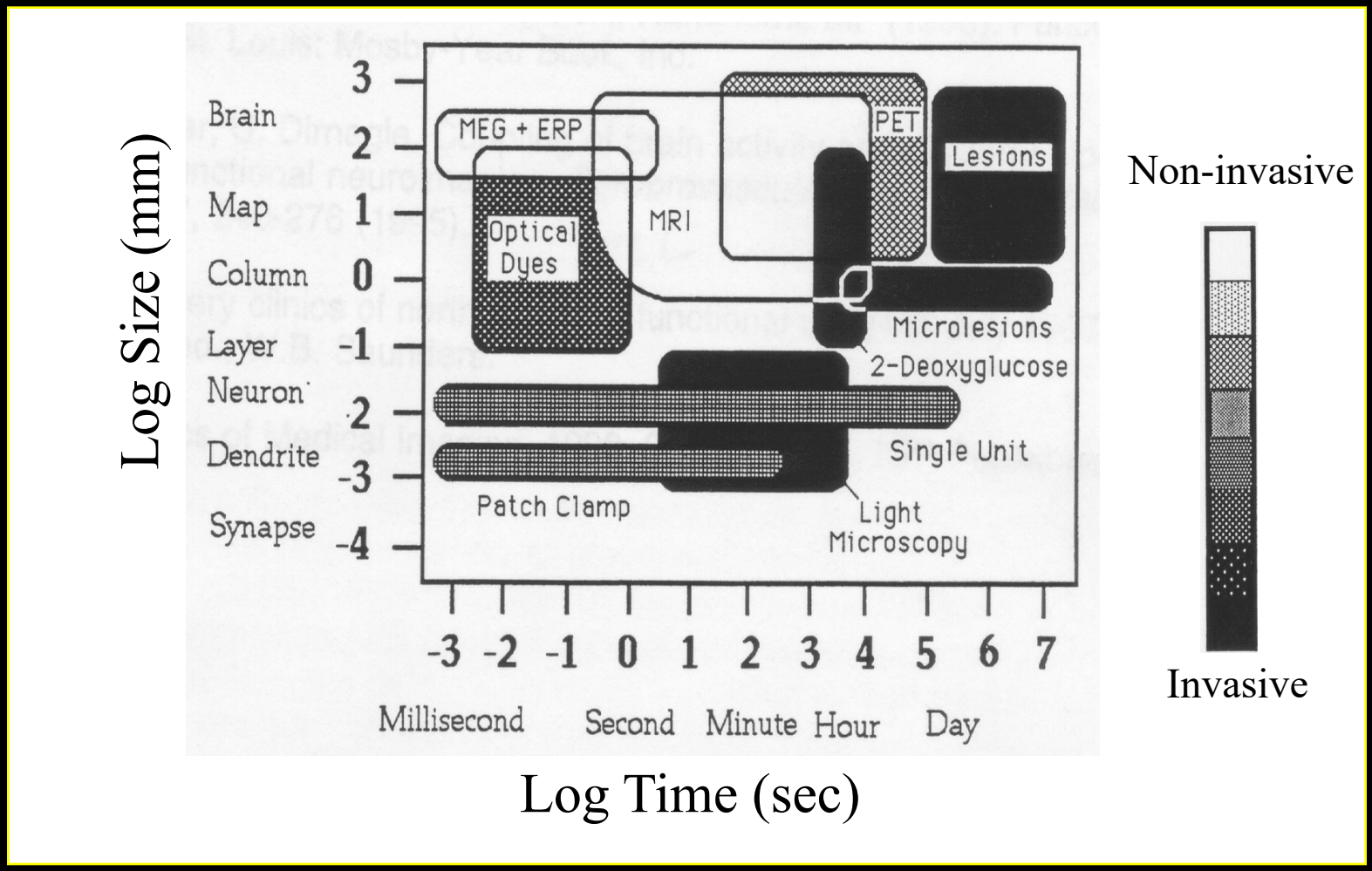
Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH

PET and fMRI Activation



Source: Posner & Raichle, Images of Mind

Functional Neuroimaging Techniques



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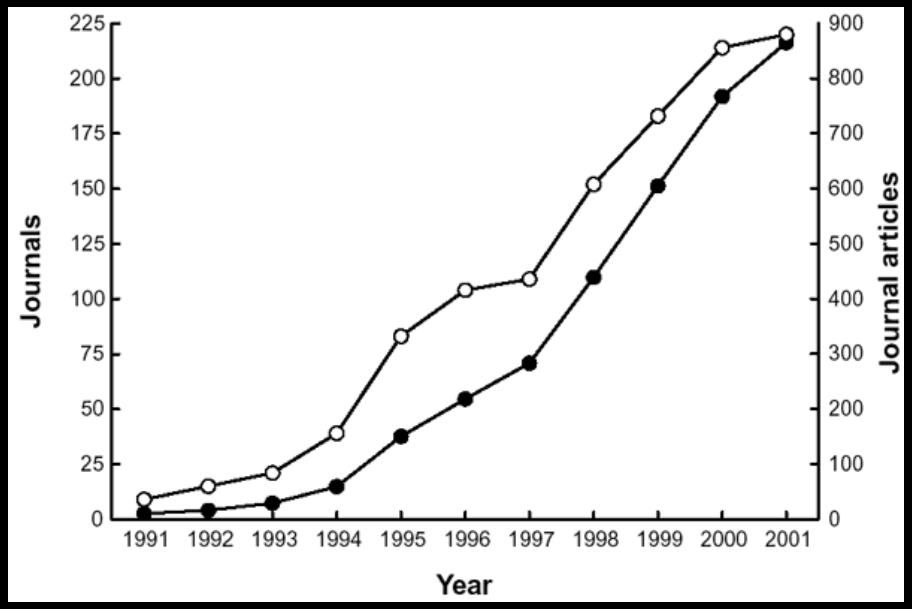
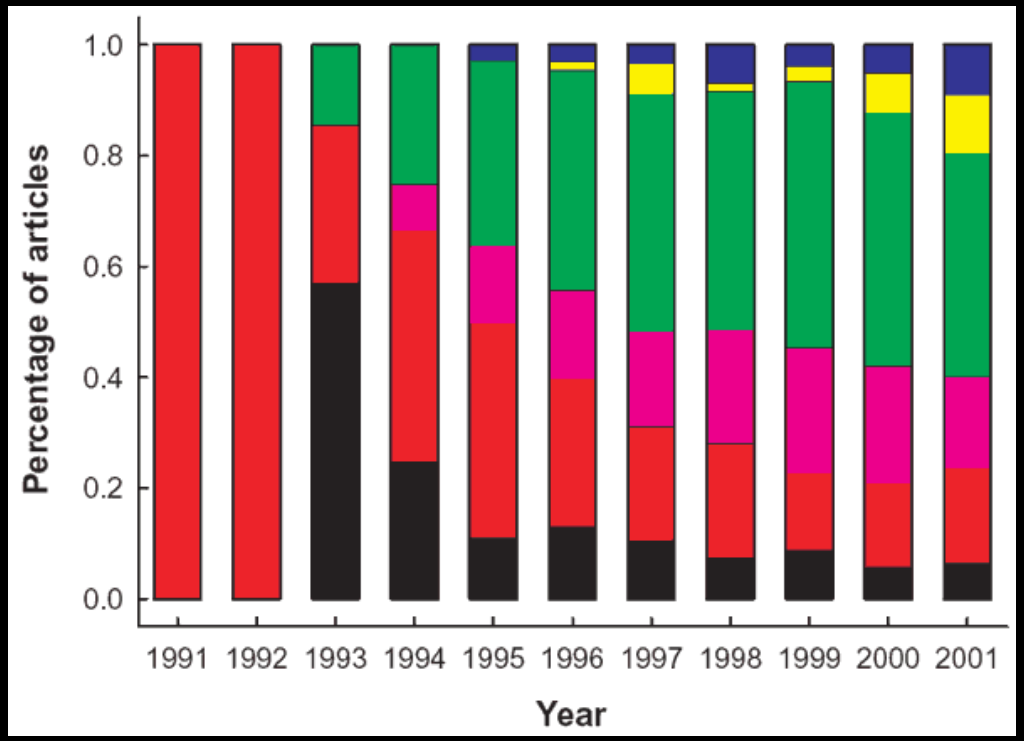
J. Illes, M. P. Kirschen,
J. D. E. Gabrielli,
Nature Neuroscience,
6 (3)m p.205



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



Current Uses of fMRI

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
- -epileptic foci mapping
- -drug effects

Potential uses of fMRI

Complementary use for clinical diagnosis

- -utilization of clinical research results

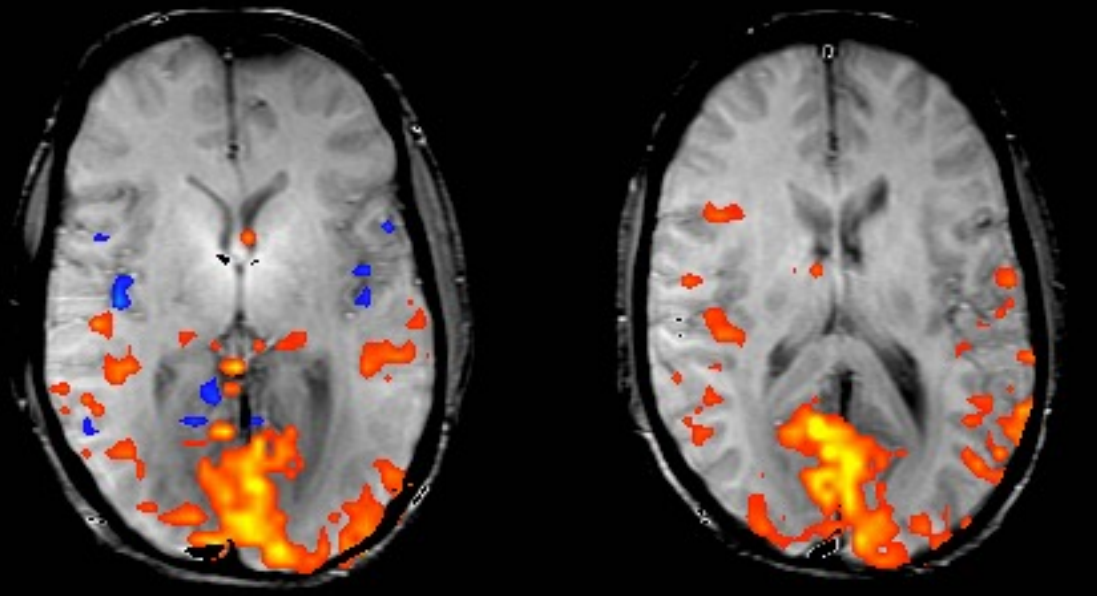
Clinical treatment and assessment

- -drug, therapy, rehabilitation, biofeedback

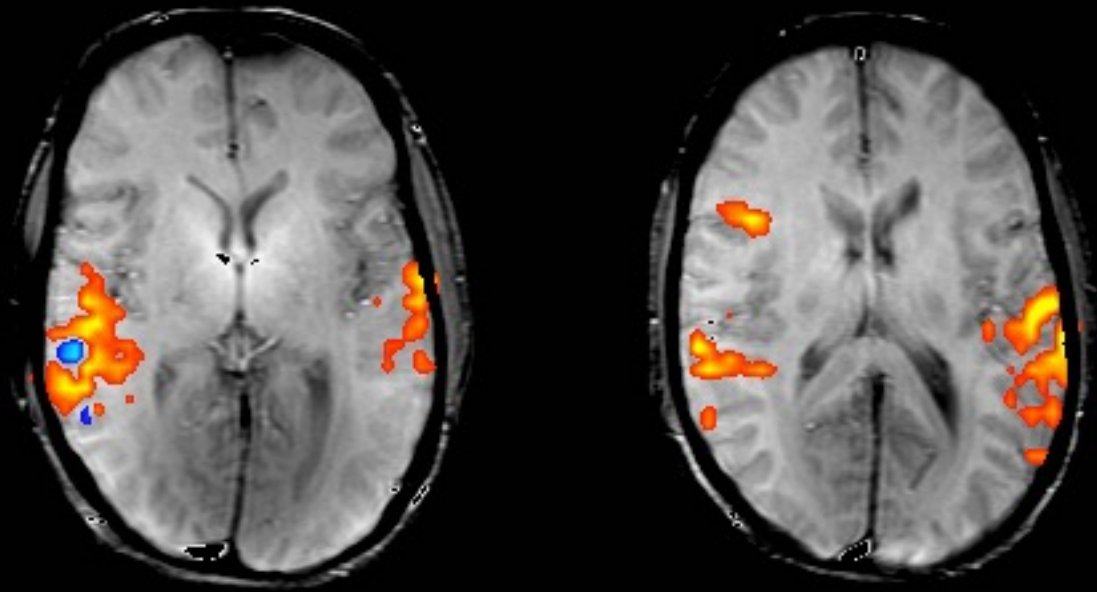
Non clinical uses

- -complementary use with behavioral results
- -lie detection
- -prediction of behavior tendencies (many contexts)
- -brain/computer interface

Reading



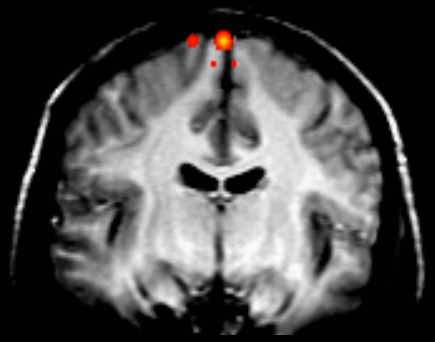
Listening

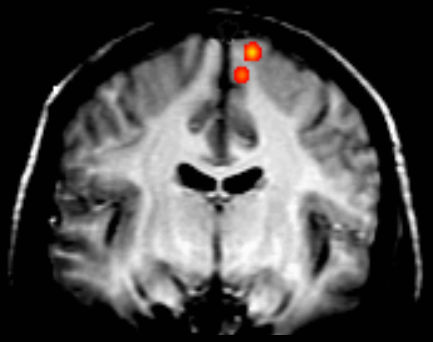


Left

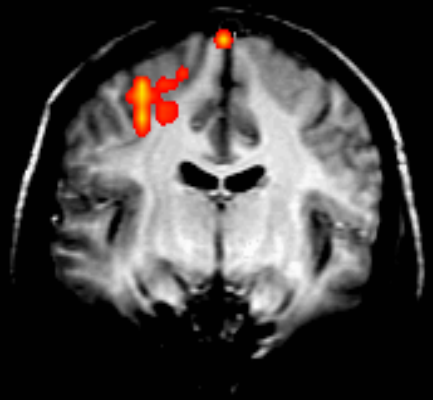
Right

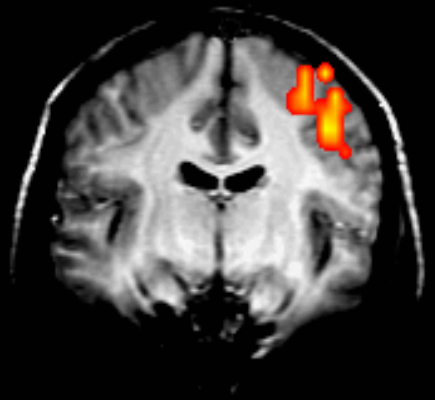
Toe movement

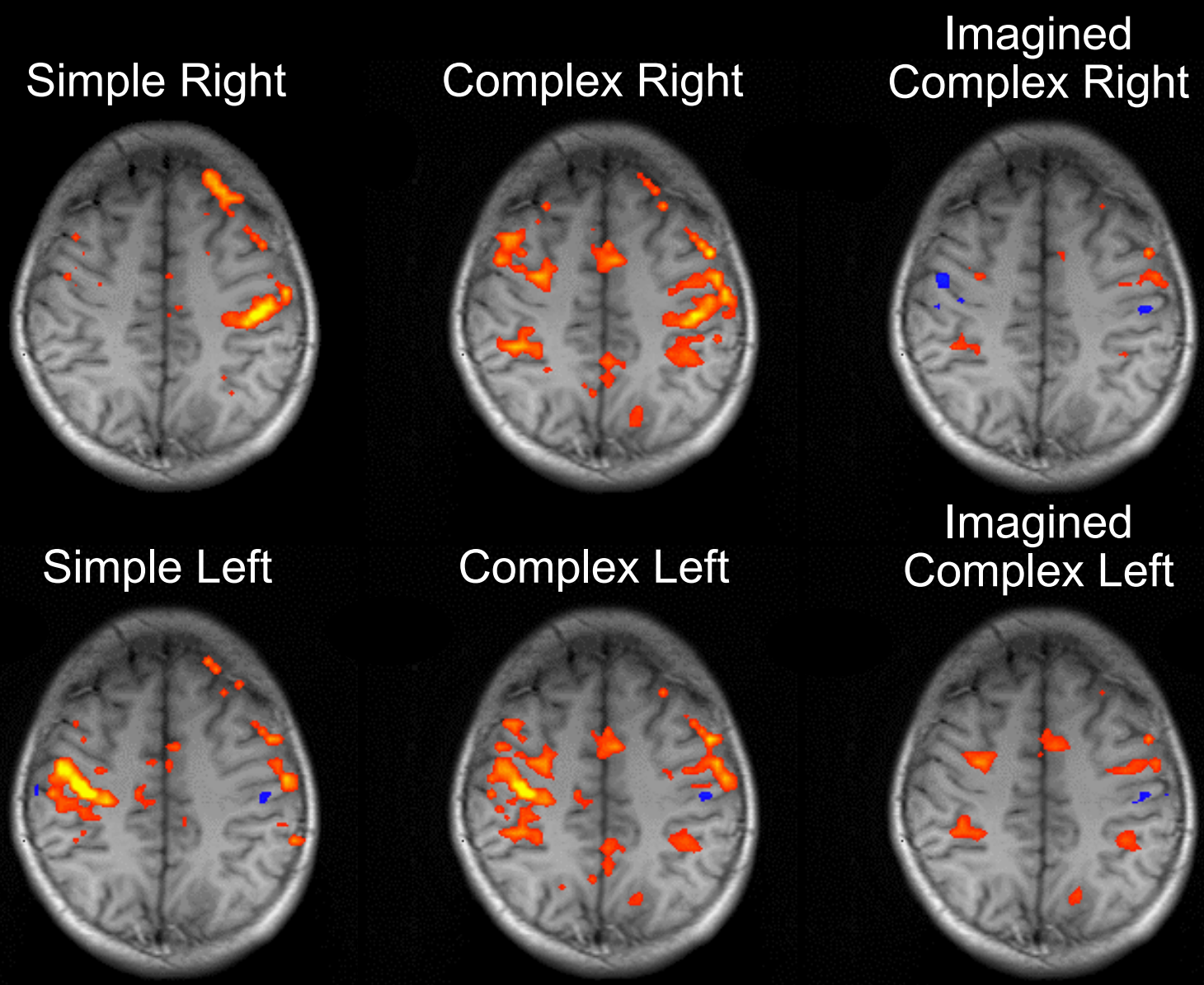




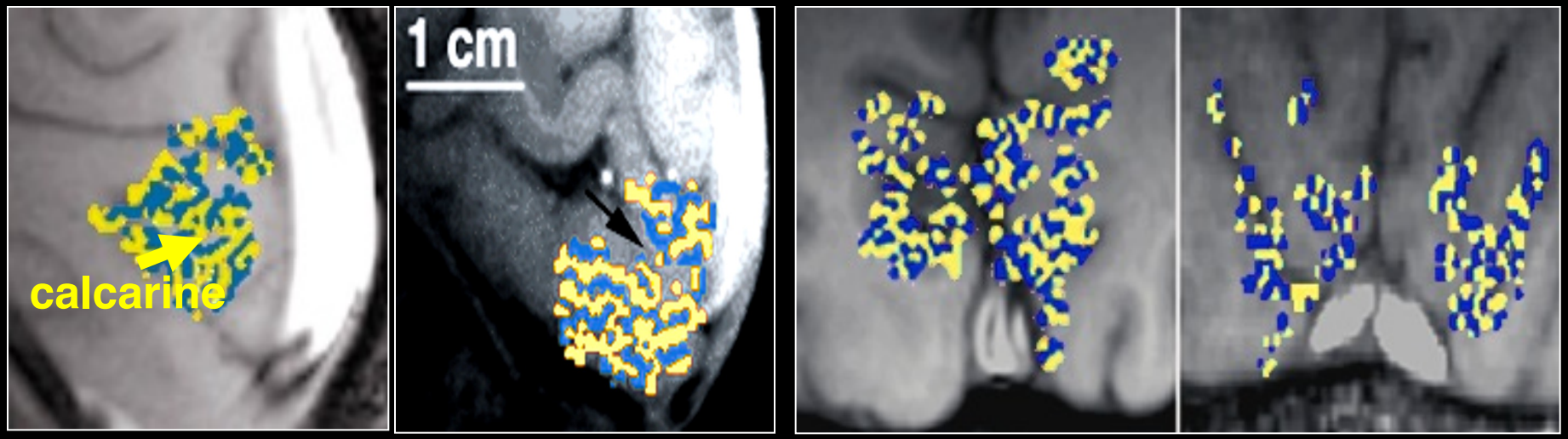
Finger movement






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

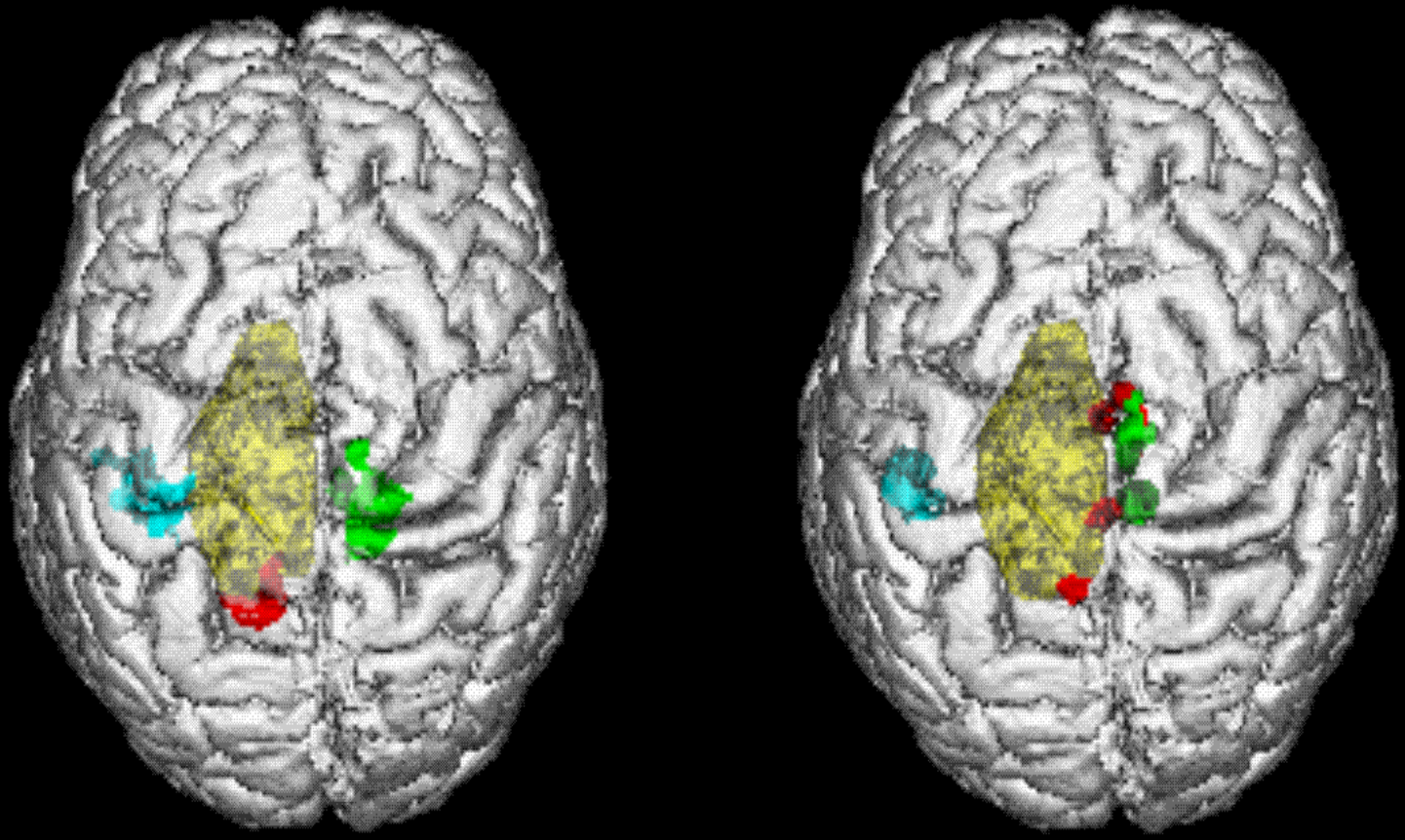
Ocular Dominance Column Mapping using fMRI



Menon, R. S., S. Ogawa, et al. (1997). "Ocular dominance in human V1 demonstrated by functional magnetic resonance imaging." J Neurophysiol 77(5): 2780-7.

Presurgical Mapping

Left Foot Tumor Right Foot Right Hand

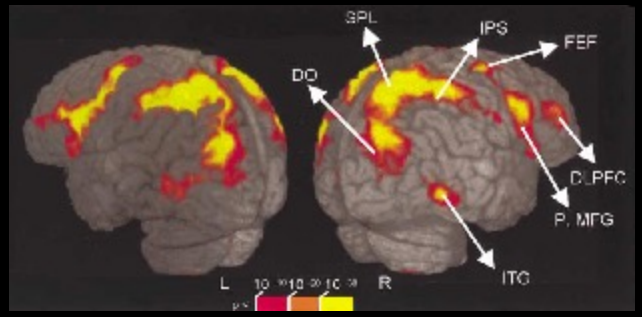


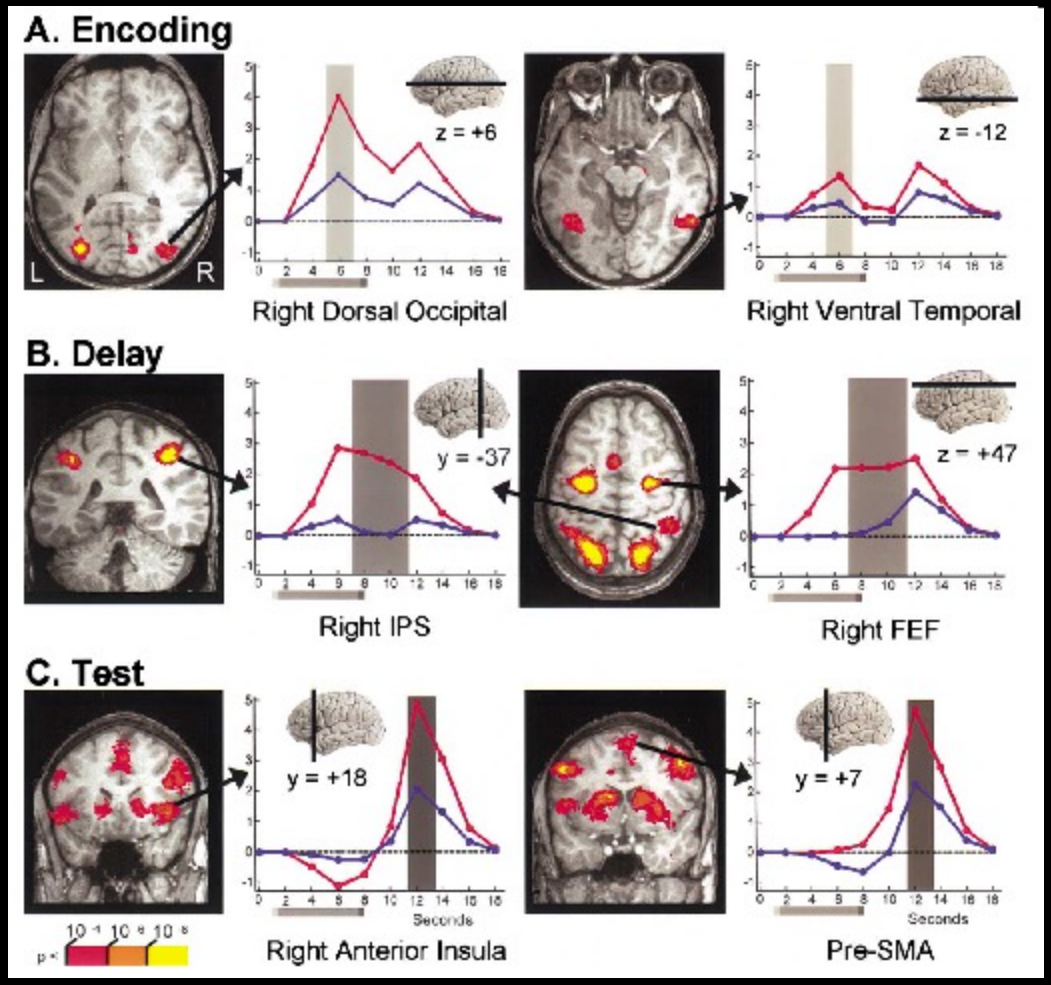
fMRI O-15 PET

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

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

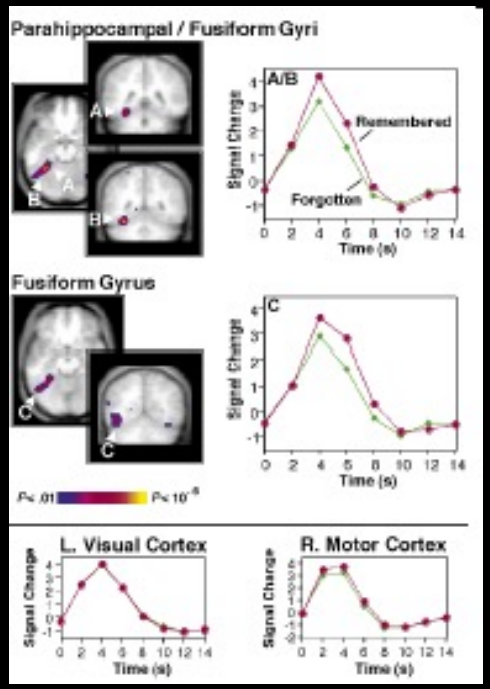
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892

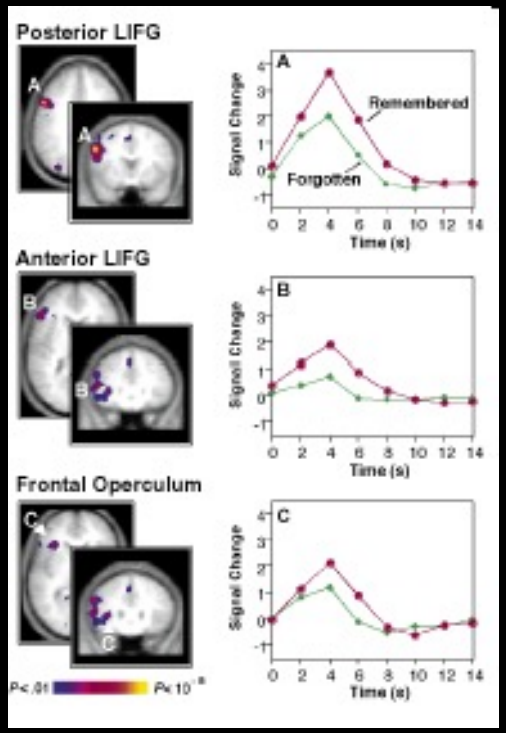




Building Memories: Remembering and Forgetting of Verbal Experiences as Predicted by Brain Activity

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

Sources of Variability in fMRI

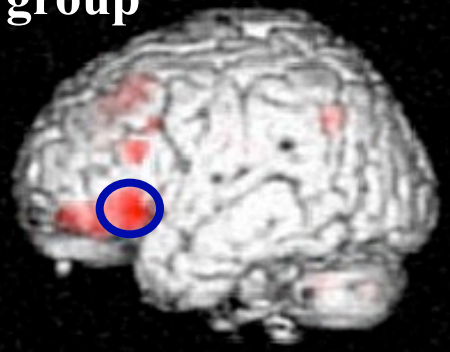
-Signal to noise (about 2/1)
-Hemodynamic response variability
(many influences on this)
-Motion
-Differences in structural anatomy
-Differences in strategy for task
(tasks are complicated)

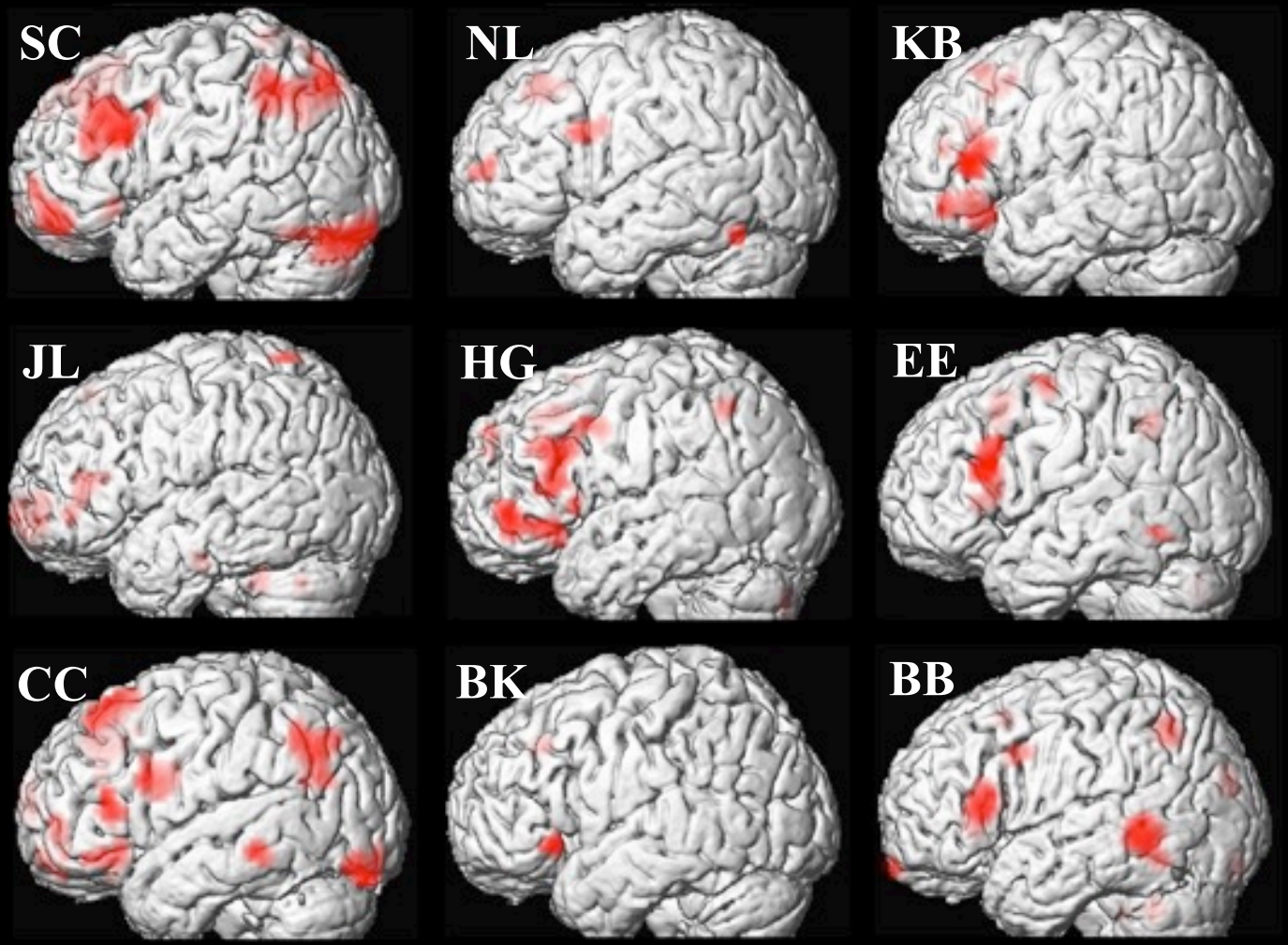
...all of these make fMRI studies to predict or categorize individuals highly problemati

Extensive Individual Differences in Brain Activations During Episodic Retrieval

Miller et al., 2002

Individual activations from the left hemisphere of the 9 subjects



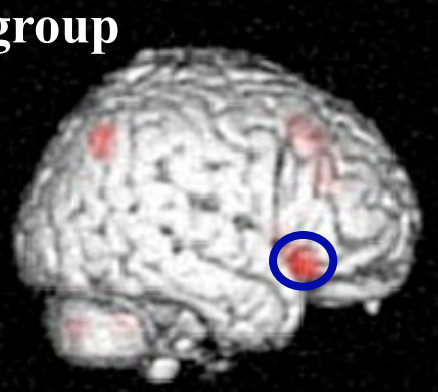


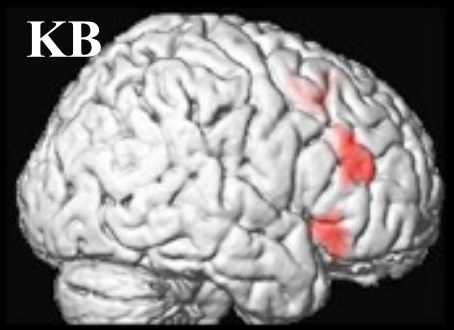
Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

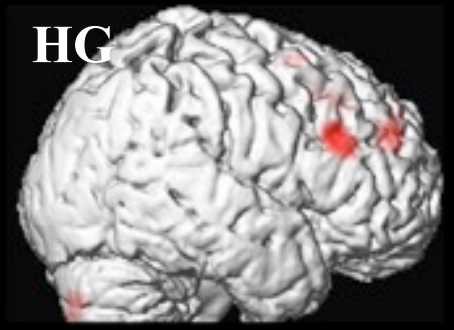
Extensive Individual Differences in Brain Activations During Episodic Retrieval

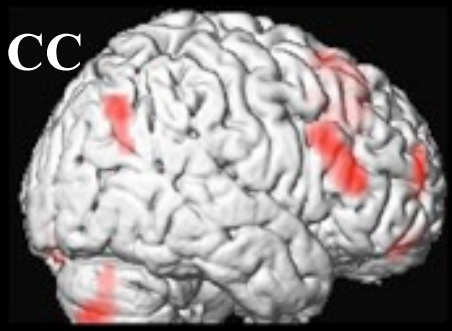
Miller et al., 2002

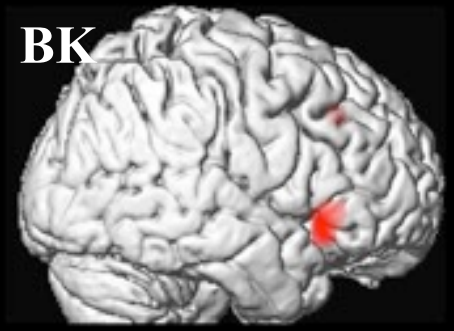
Individual activations from the right hemisphere of the 9 subjects





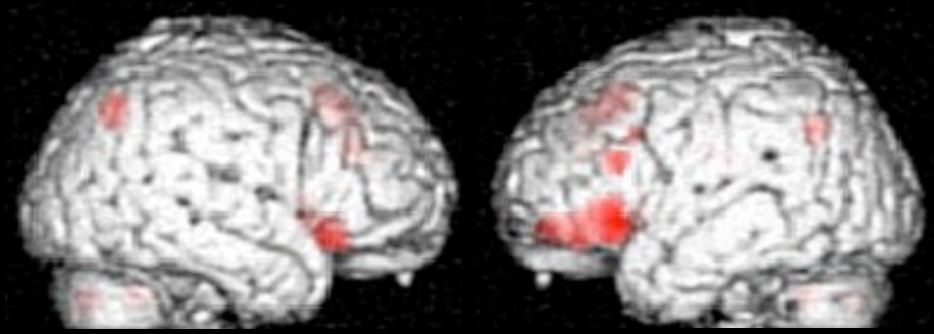




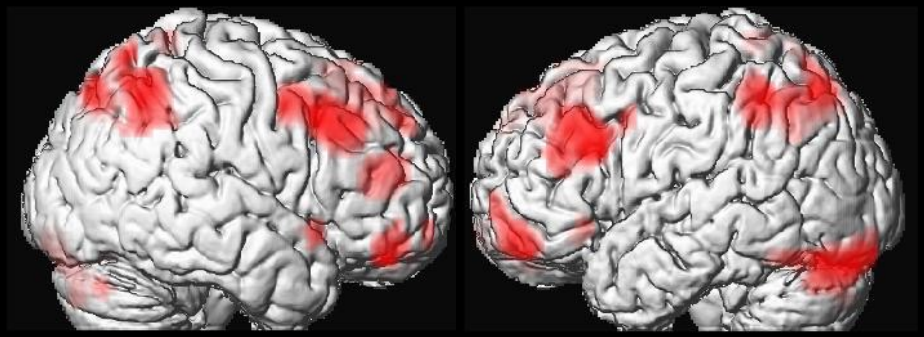


Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

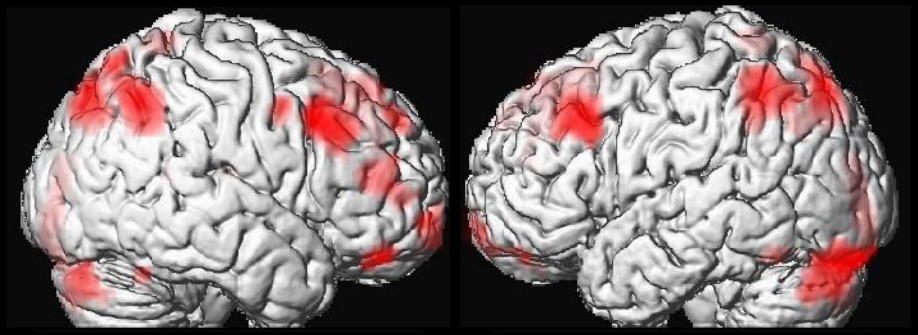
These individual patterns of activations are stable over time



Group Analysis of Episodic Retrieval



Subject SC

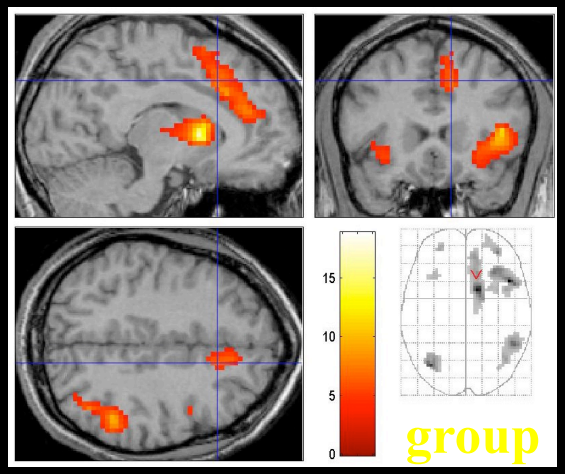


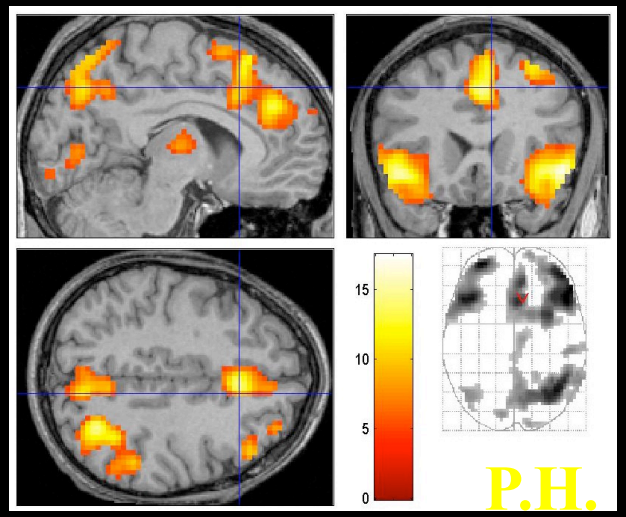
Subject SC 6 months later

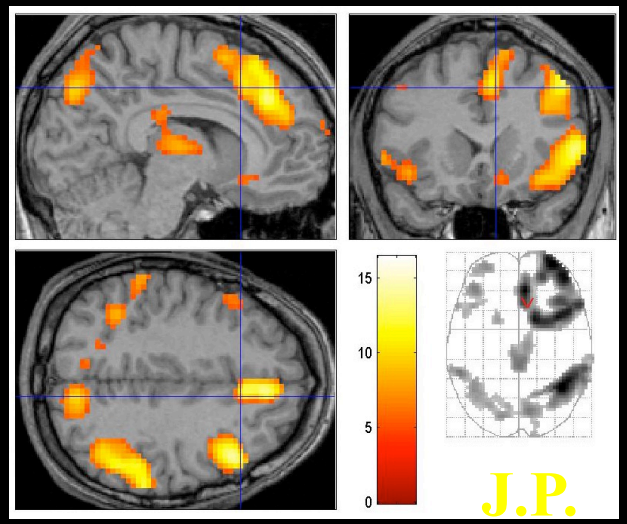
Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

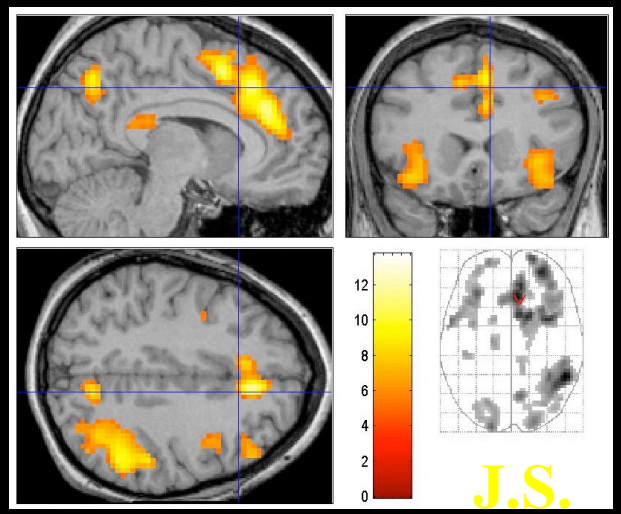
Individual patterns of activity are much more consistent across subjects for other retrieval tasks.

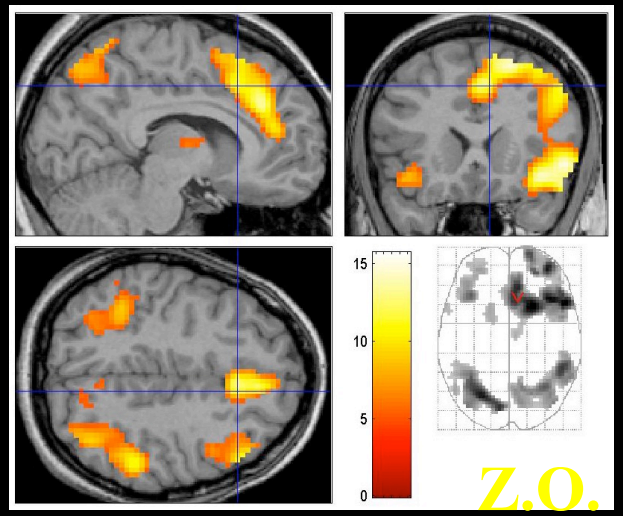
spatial working memory







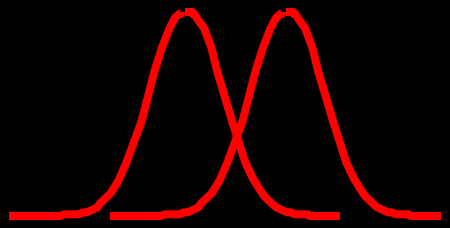




Courtesy, Mike Miler, UC Santa Barbara and Jack Van Horn, fMRI Data Center, Dartmouth University

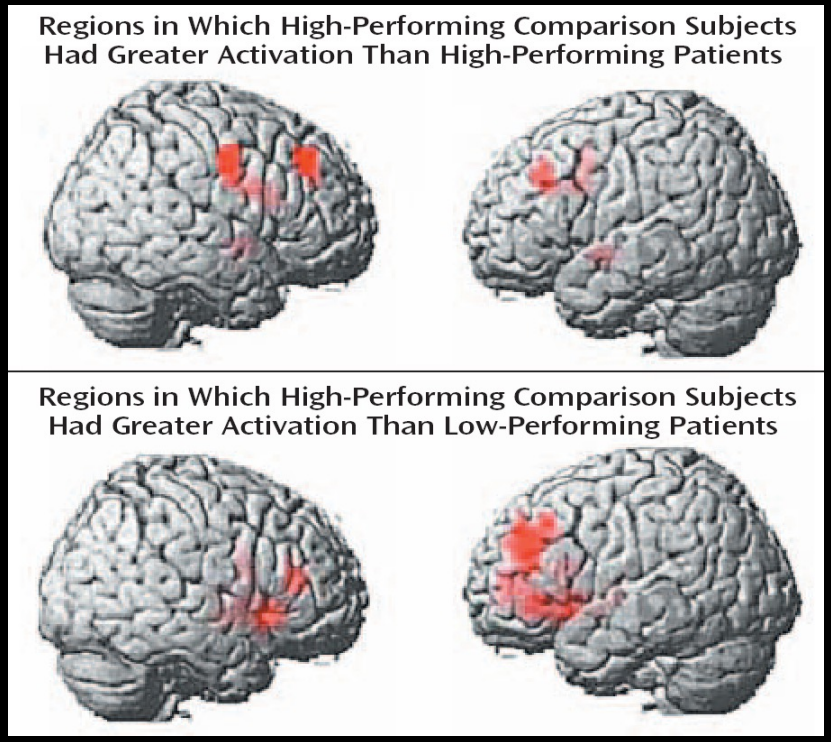
The problem of drawing individual inferences from fMRI data

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.

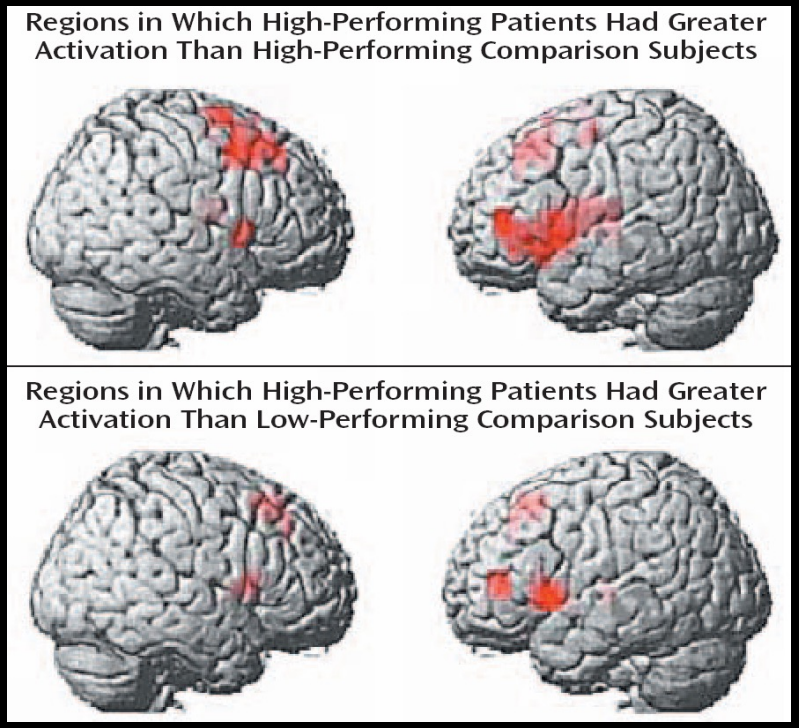


Patients with Schizophrenia

Hypofrontality



..and Hyperfrontality

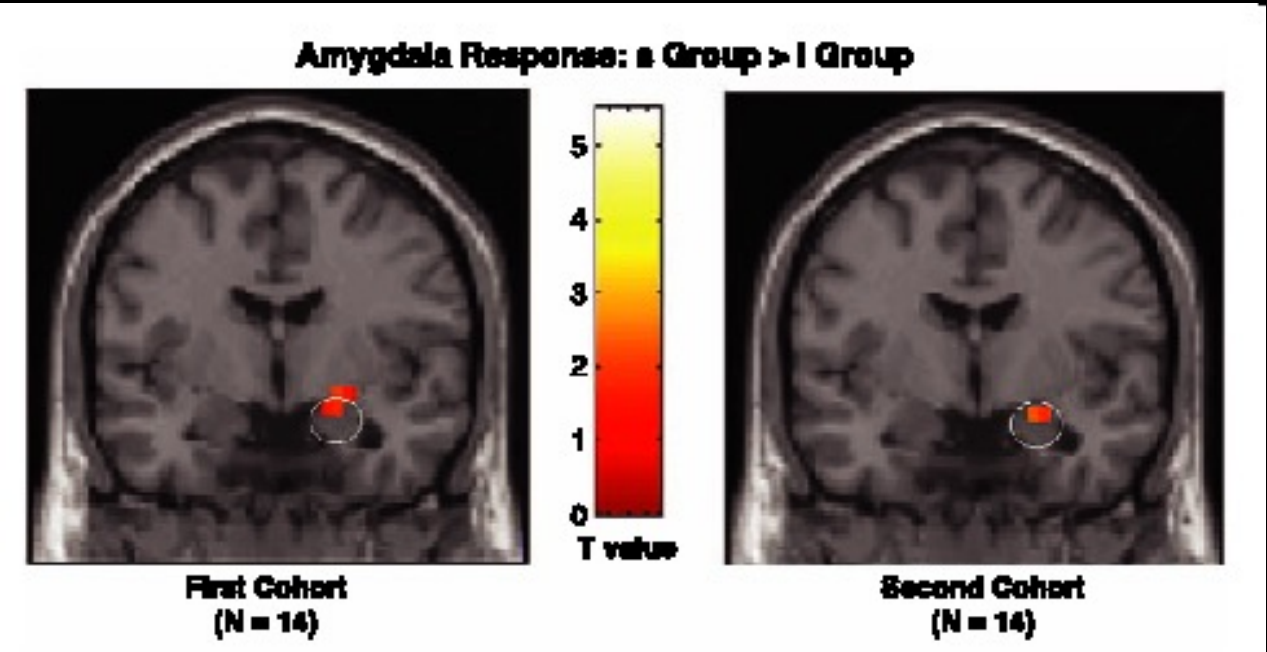


(Callicott et al. Am J Psych 2003)

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

◆ Human Brain Mapping 15:157–164(2002) ◆
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Lie Detection by Functional Magnetic Resonance Imaging

Tatia M.C. Lee,[1*] Ho-Ling Liu,[2] Li-Hai Tan,[3] Chetwyn C.H. Chan,[4]
Srikanth Mahankali,[5] Ching-Mei Feng,[5] Jinwen Hou,[5]
Peter T. Fox,[5] and Jia-Hong Gao[5]

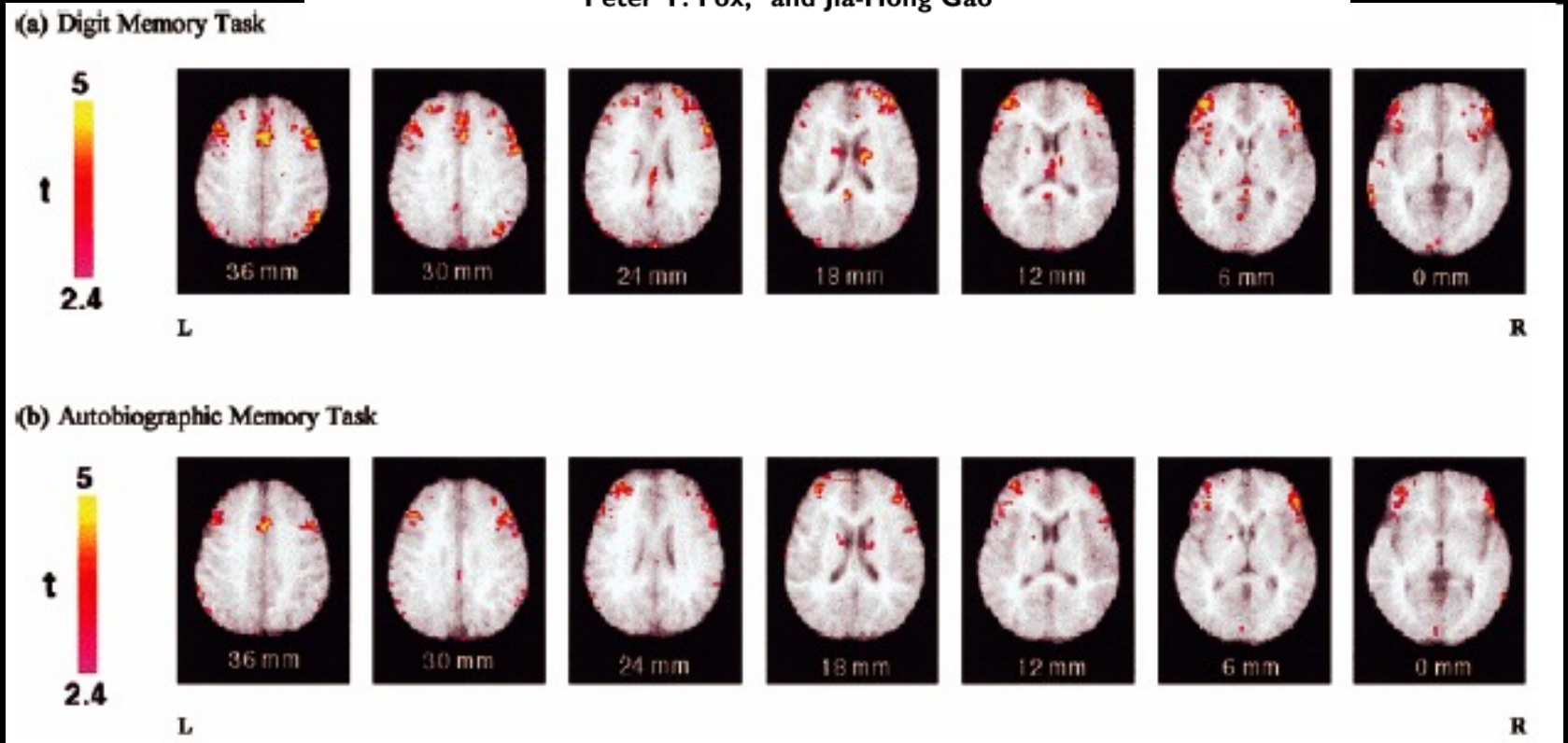

Figure 1.

Functional maps. Normalized activation brain maps averaged across five subjects demonstrating the statistically significant activations ($P < 0.01$) in the faking memory impairment condition with the activation for making accurate recall removed when performing on forced choice testing using (**a**) Digit Memory and (**b**) Autobiographic Memory tasks. Planes are axial sections, labeled with the height (mm) relative to the bicommissural line. L, left hemisphere; R, right hemisphere.

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

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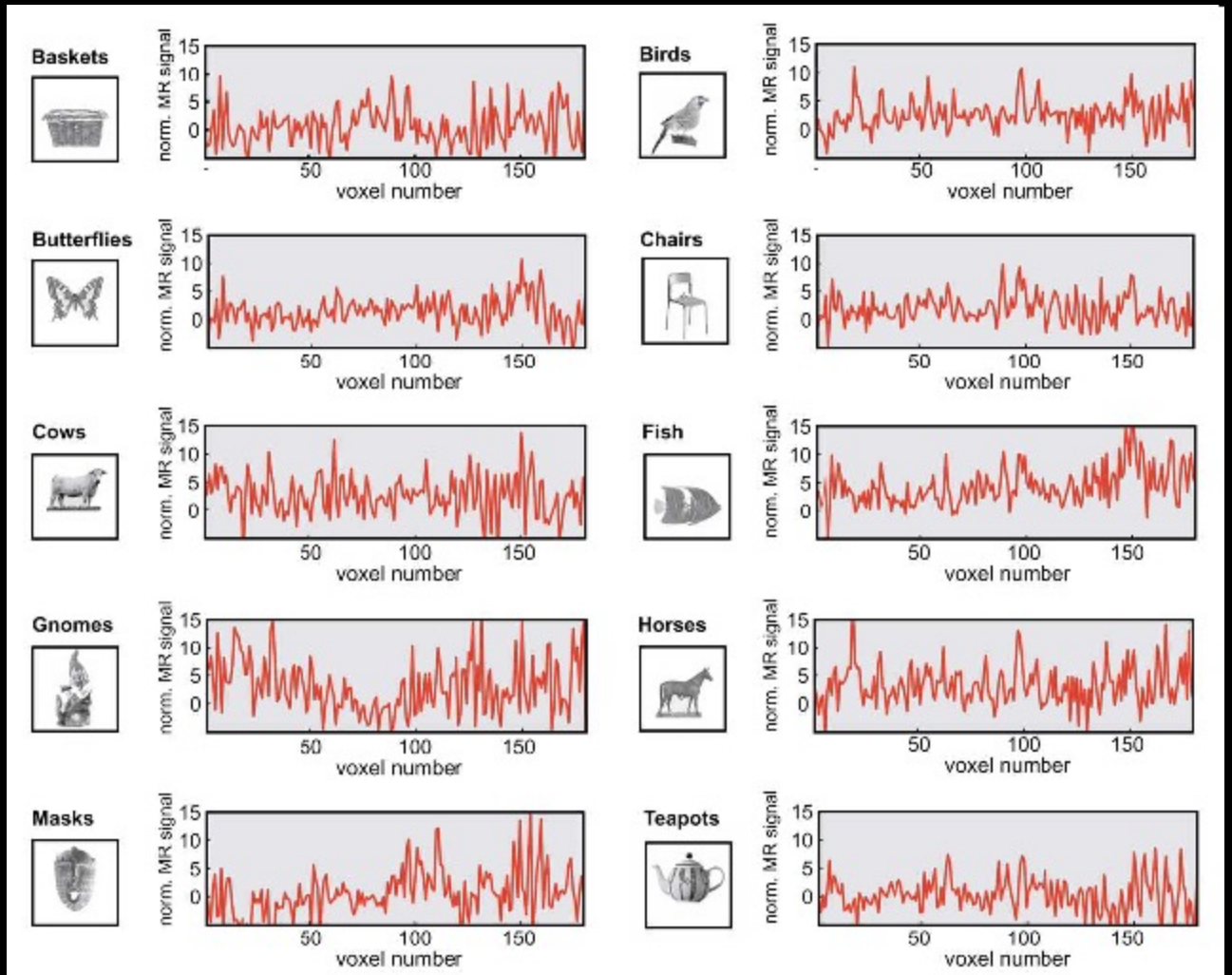

What is the current state of technology of brain imaging?

How have these technologies been used to date?

How will the advent of more reliable brain imaging technologies benefit society?

Are current neuro-imaging technologies powerful enough to predict social behavior?

a. If not, how far are we from being able to use neuro-imaging as a predictor of social/ethical behavior?
b. If so, is it socially acceptable to use if for determining social and/or ethical behavior.

Benefits to Society

-better understand biological basis of behavior and performance
-better understand basis of changes with development, aging, learning
-aid in clinical diagnosis and guide treatment
-aid in behavioral/performance assessment and prediction

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Are current neuro-imaging technologies powerful enough to predict social behavior?

-not enough data yet... as of now, no.

a. If not, how far are we from being able to use neuro-imaging as a predictor of social/ethical behavior?

-hard to say.. Data are highly multi-dimensional. Social behavior is complicated. To draw inferences about individuals, one must do an exhaustive characterization of sources of variability and develop an algorithm for robustly classifying this multidimensional data.

b. If so, is it socially acceptable to use it for determining social and/or ethical behavior.

-the data are easily over-interpreted...this is the primary problem with this avenue. If prediction is above a threshold of reliability (extensively tested), then it would fall in the same category as reliable behavioral or physical tests and the same rules for usage would apply.

-A stringent policy establishing quality of data and interpretation is absolutely necessary if such applications ever become feasible.