NEUROIMAGING

at the NIH

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Functional MRI Facility

&

Unit on Functional Imaging Methods

Laboratory of Brain and Cognition, NIMH

NIMH
National Institute of Mental Health

Who we are

Unit on Functional Imaging Methods

Peter Bandettini (Physics/Physiology/Neuroscience...)

Rasmus Birn (Physics)
David Knight (Neuroscience)
Anthony Boemio (Physics/Neuroscience)

Niko Kriegeskorte (Psychology/Statistics)

Natalia Petridou (Biomedical Engineering)
Ilana Levy (Psychology)
Hanh Nguyen (Neuroscience)

FMRI Core Facility

Jerzy Bodurka (Physics)
Sean Marrett (Neuroscience)
Frank Ye (Physics)
Wen-Ming Luh (Physics)

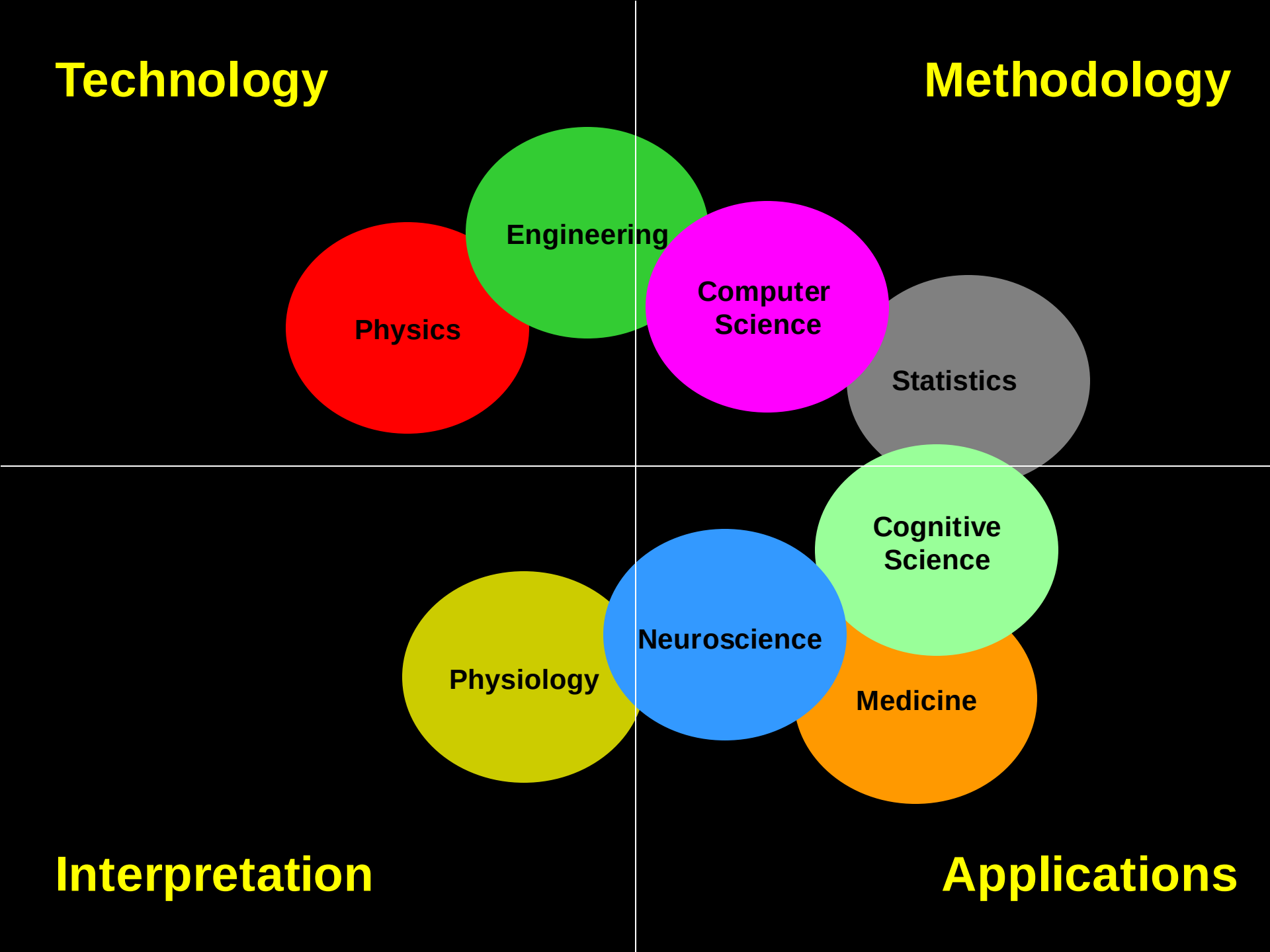
Adam Thomas (Computers/Neurosci)
Karen Bove-Bettis (MR Tech)
Paula Rowser (MR Tech)
Alda Ottley (MR Tech)

What we care about…

Understanding, Developing, and Implementing

Functional MRI

1. Methodology
2. Interpretation
3. Technology
4. Applications

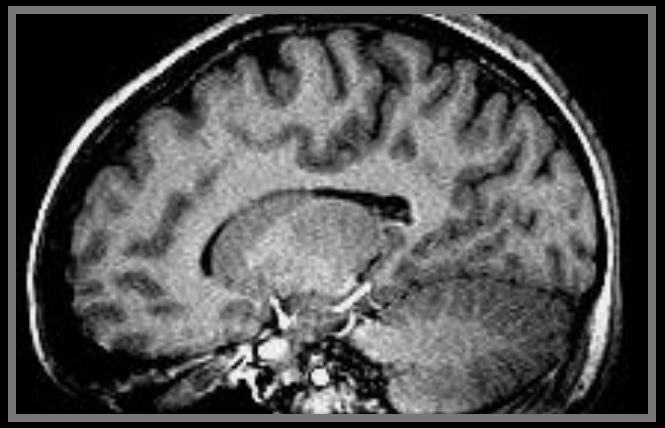

Technology
Methodology
Engineering
Physics
Computer Science
Statistics
Cognitive Science
Neuroscience
Physiology
Medicine
Interpretation
Applications

Two Types of Neuroimaging

- Structural/Anatomical Imaging
- Functional Imaging

Structural Brain Imaging

Reveals the anatomy of the brain and the physical structure of brain pathology.

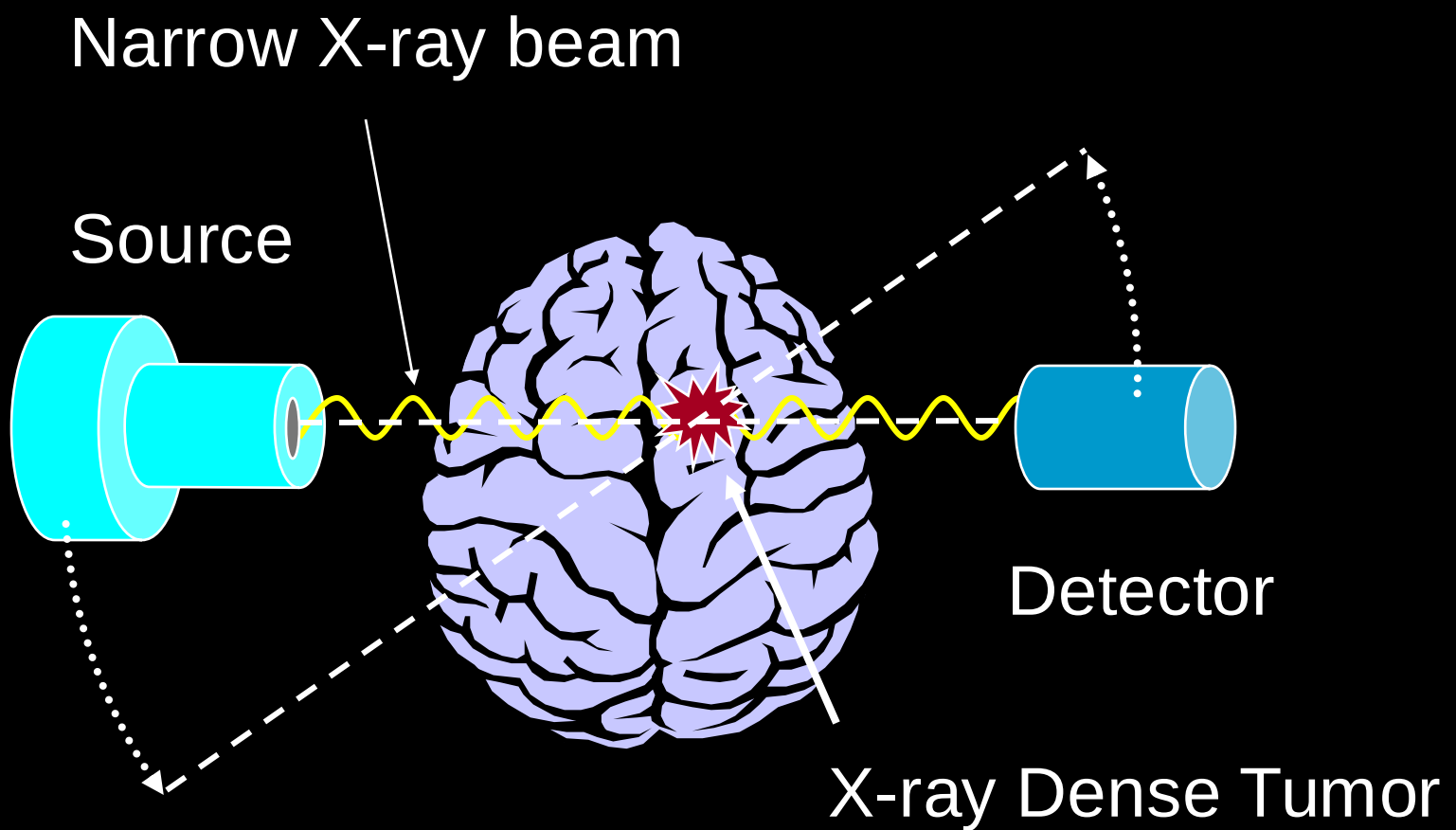


- Structural/Anatomical Imaging
  - X-ray
  - Computerized Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
    - Angiography
    - Venography
    - Perfusion
    - Diffusion Tensor Imaging

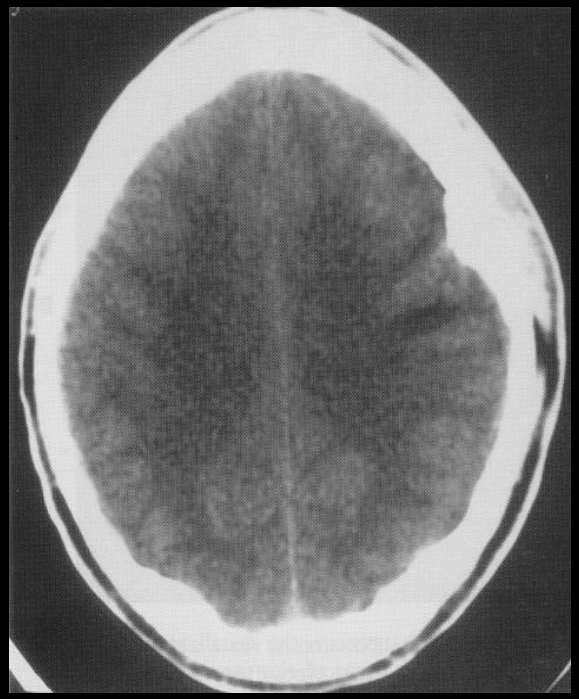
- Functional Imaging
  - –Xenon Computerized Tomography (Xe CT)
  - –Positron Emission Tomography (PET)
  - –Single Photon Computed Tomography (SPECT)
  - –Functional MRI (fMRI)
  - –Electroencephalography (EEG)
  - –Magnetoencphalography (MEG)
  - –Transcranial Magnetic Stimulation (TMS)

Computerized Tomography (CT)

Creation of images in slices or sections.

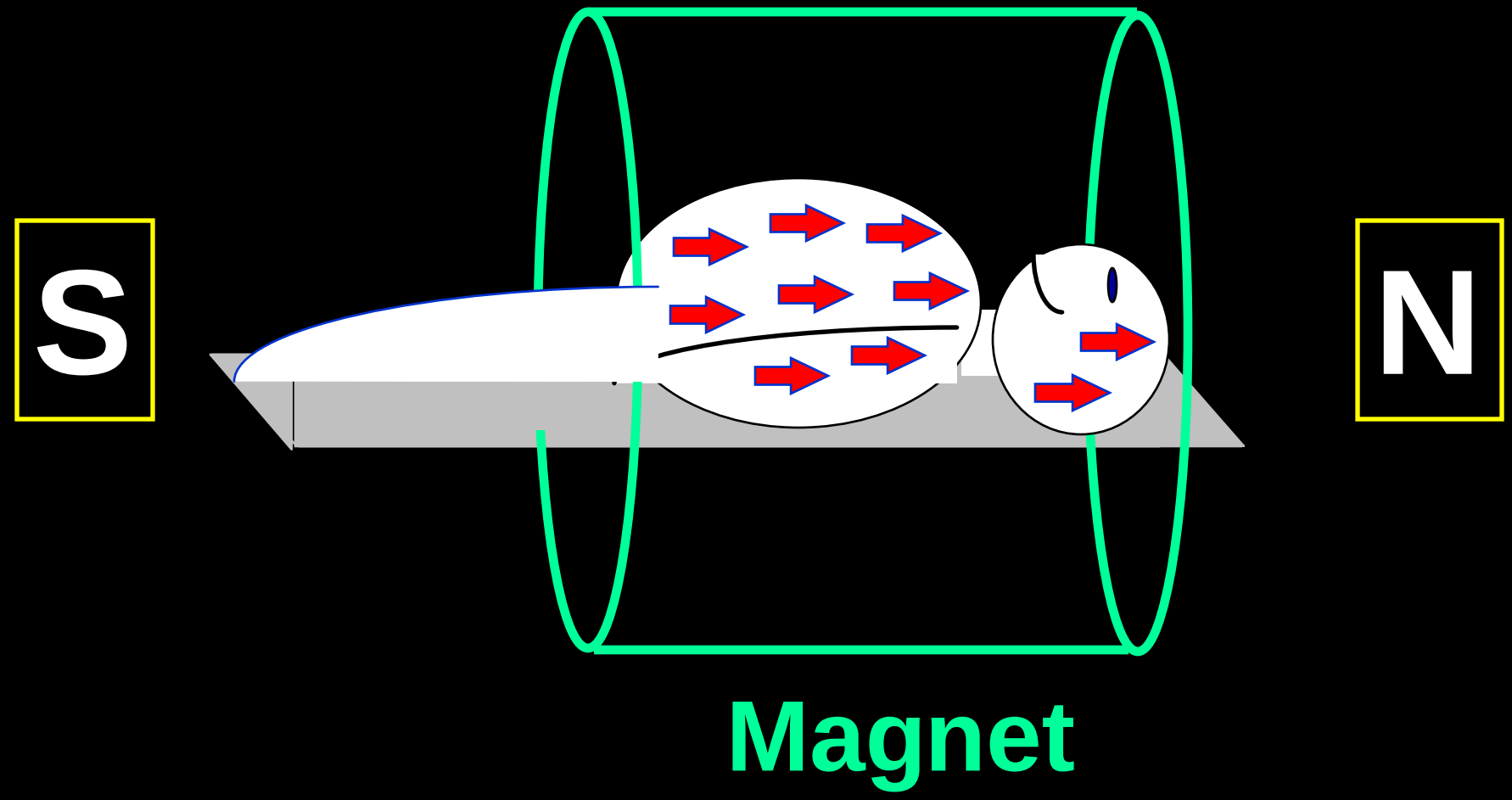


CT Images

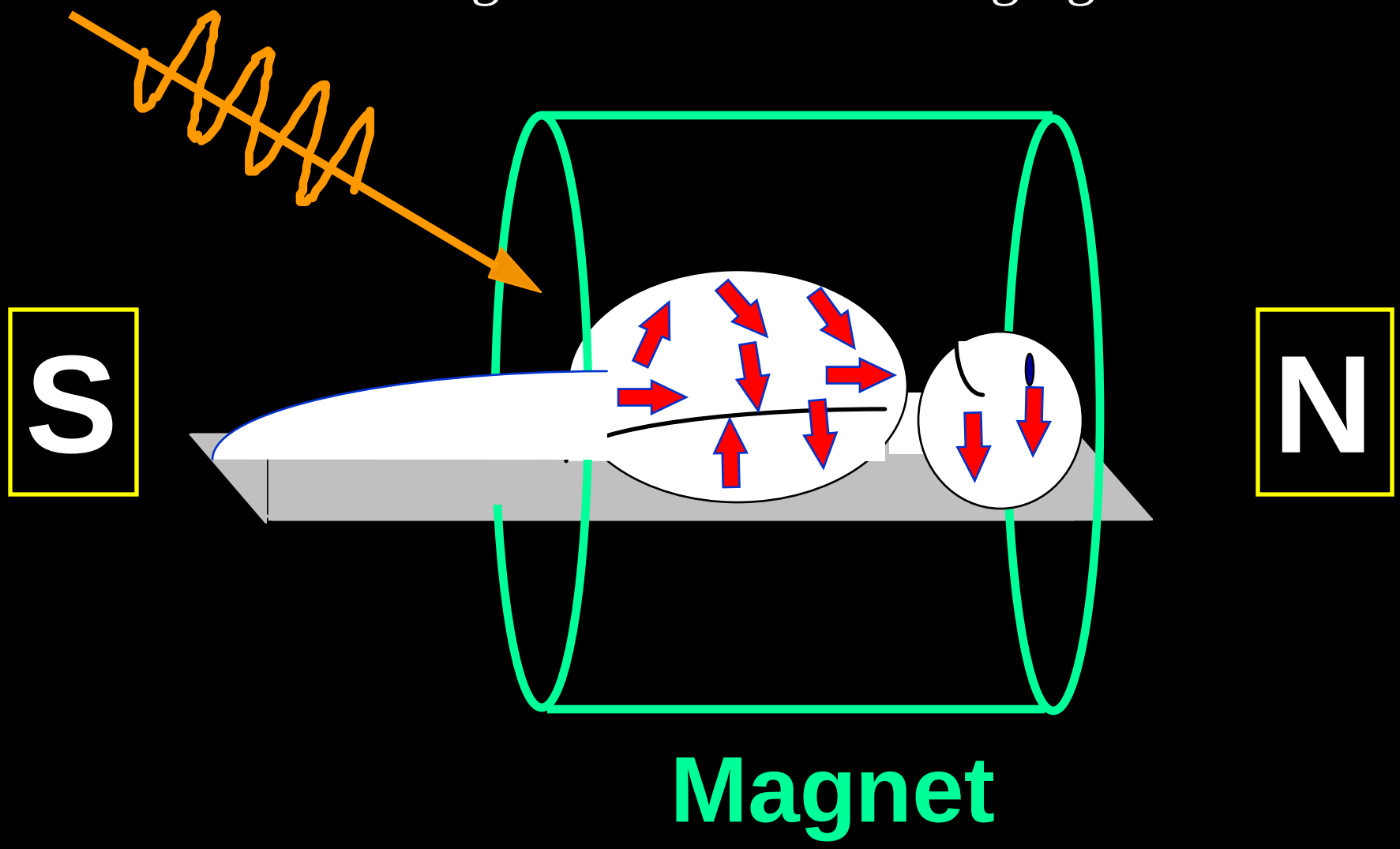


Magnetic Resonance Imaging

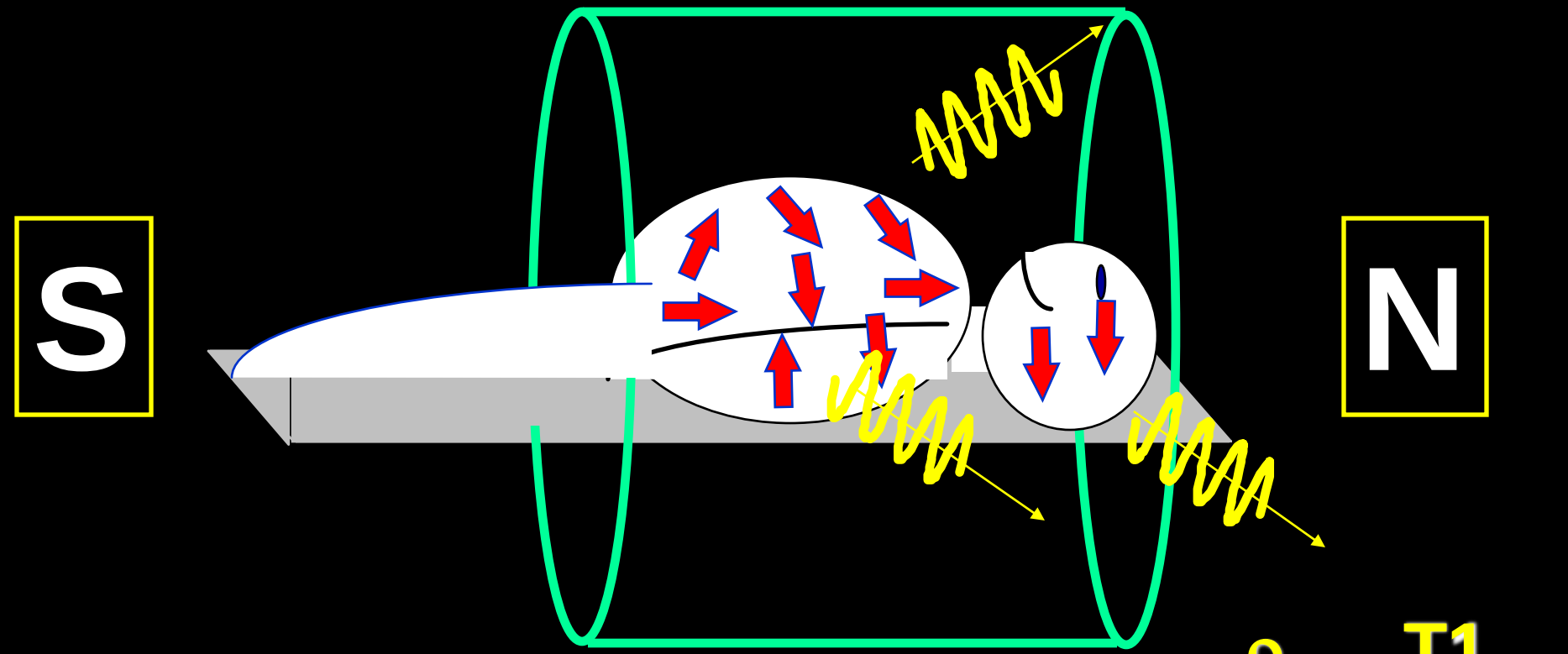
Magnetic Resonance Imaging



Magnetic Resonance Imaging

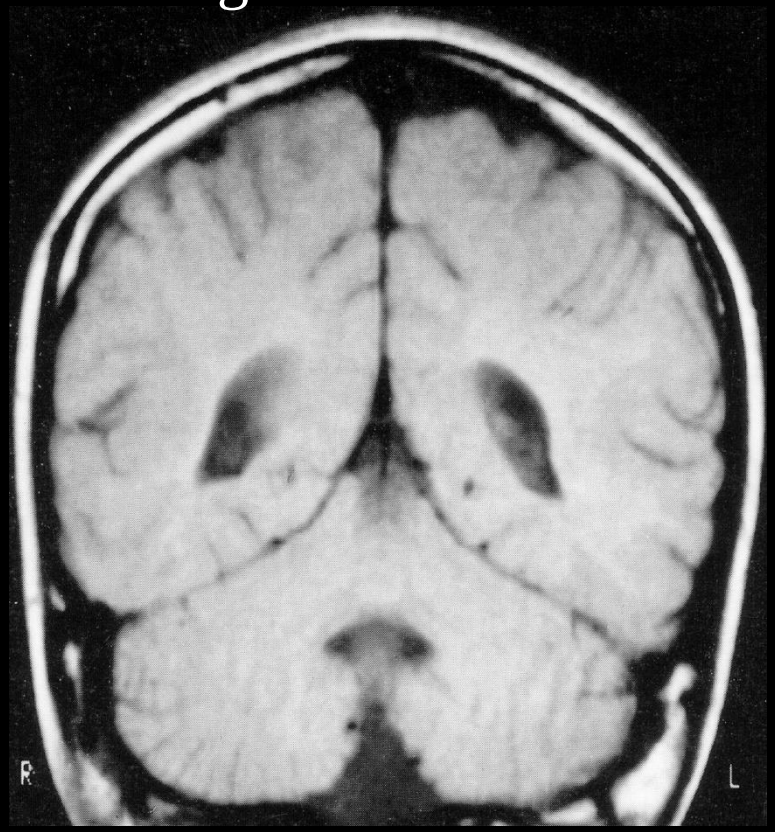


Magnetic Resonance Imaging

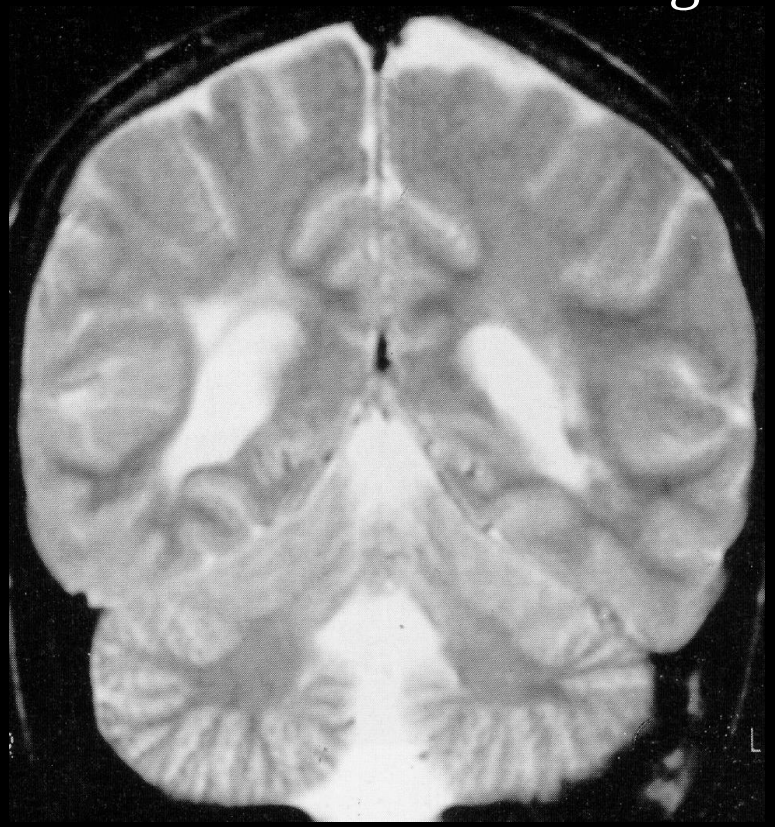


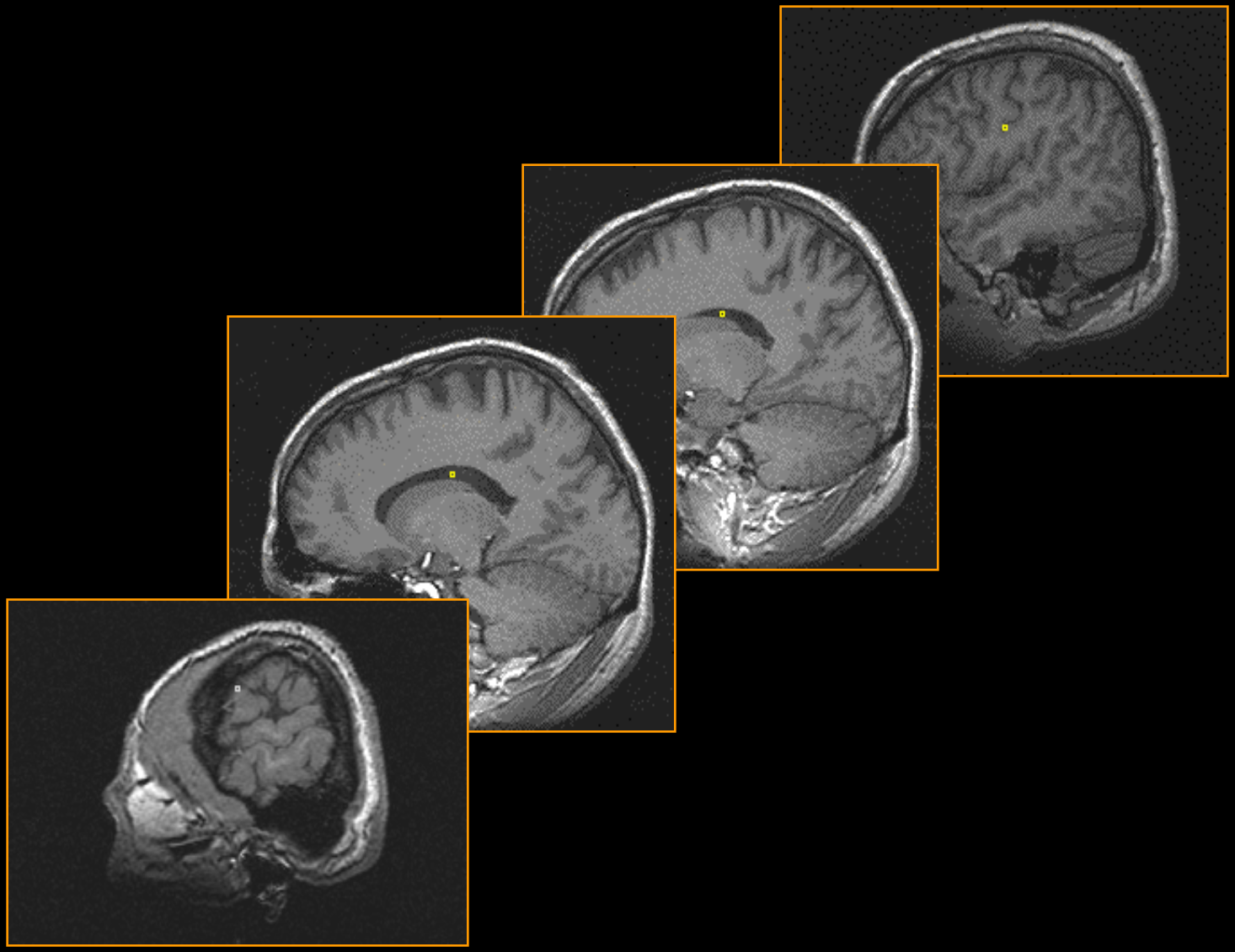
MRI Images with Different Contrast Weighting

T1 Weighted

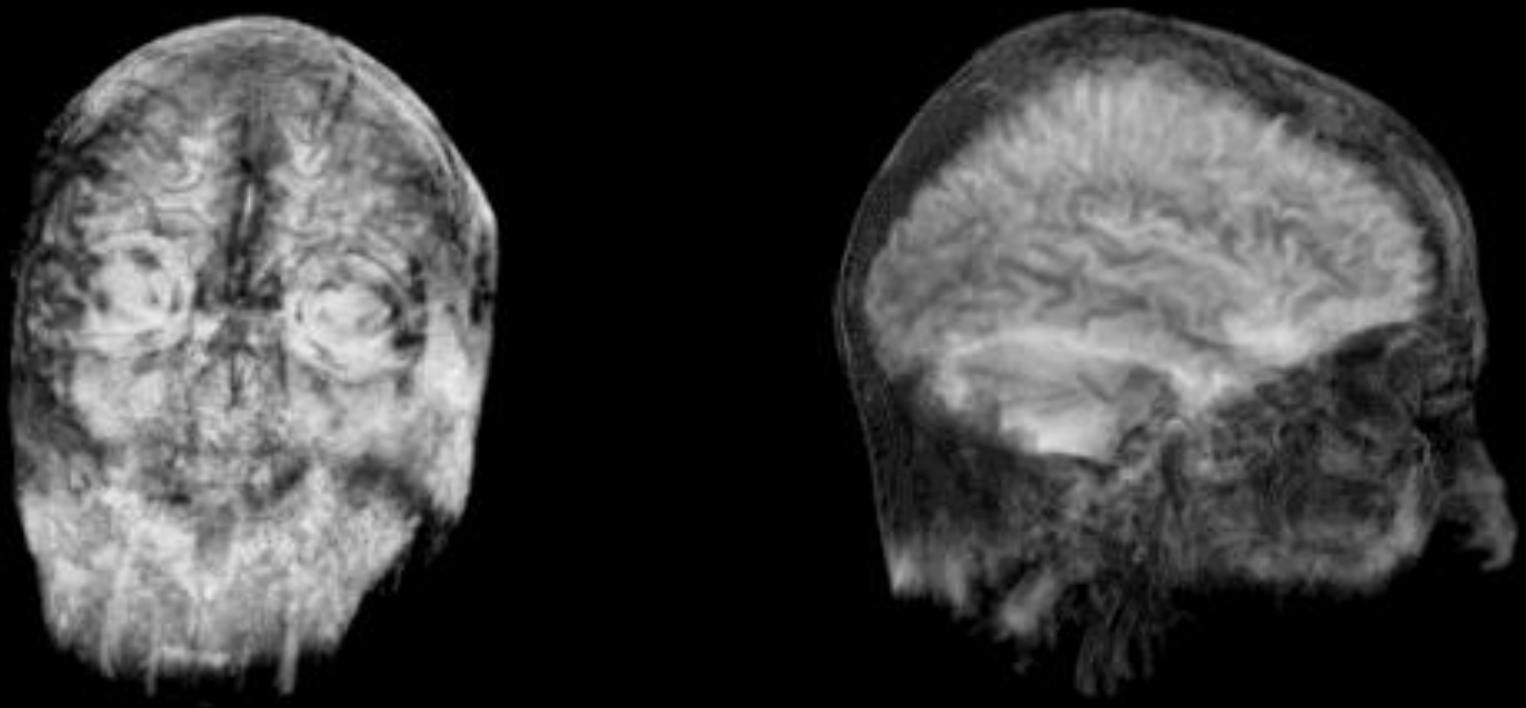


T2 Weighted



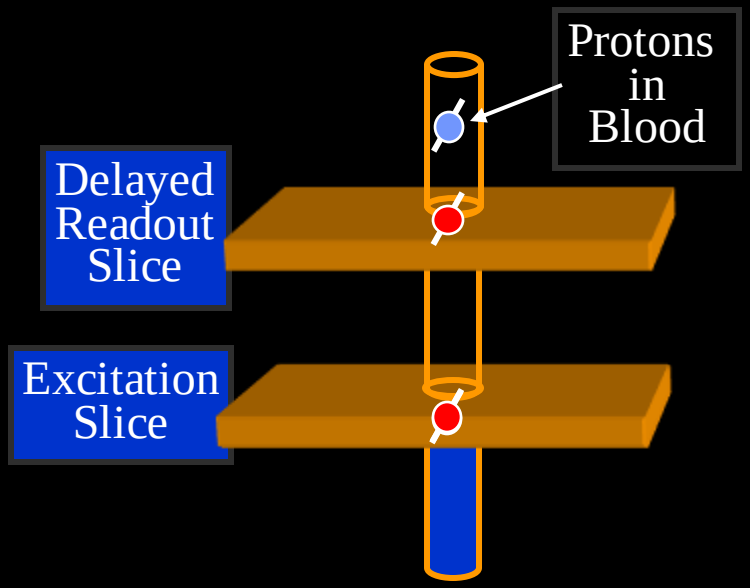


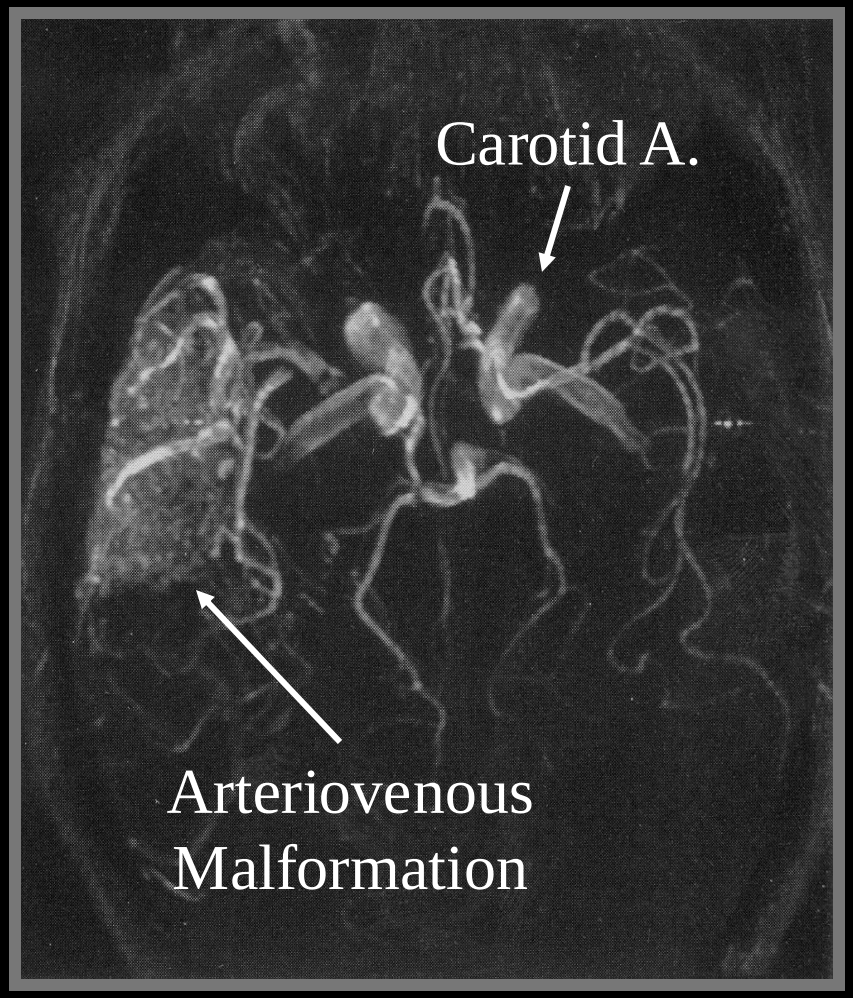
3D Rendered MRI



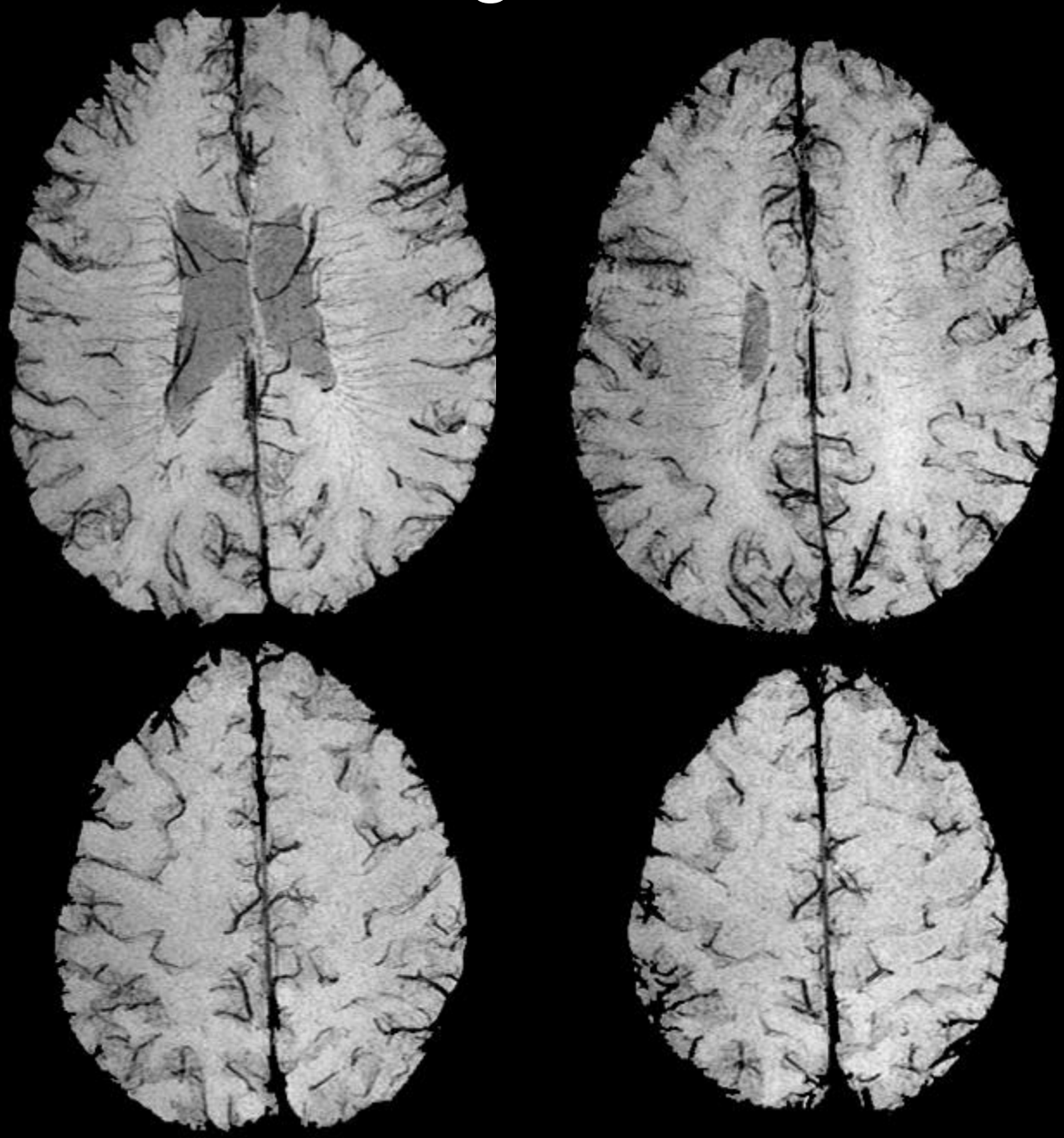
MR Angiography Shows Blood Vessel Structure

- Blood vessel structure can be visualized by injection of MR tracers or by “spin tagging” techniques.

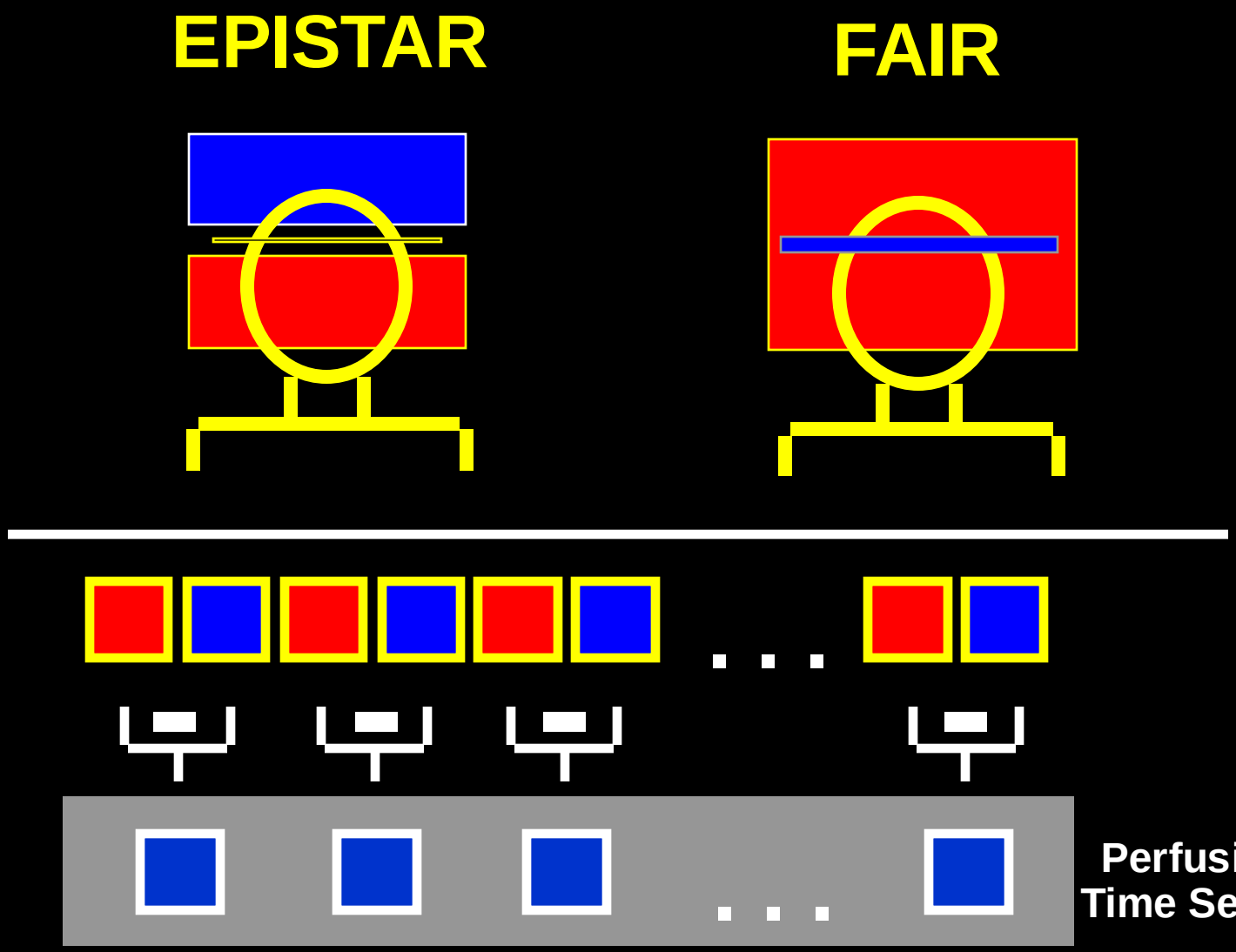




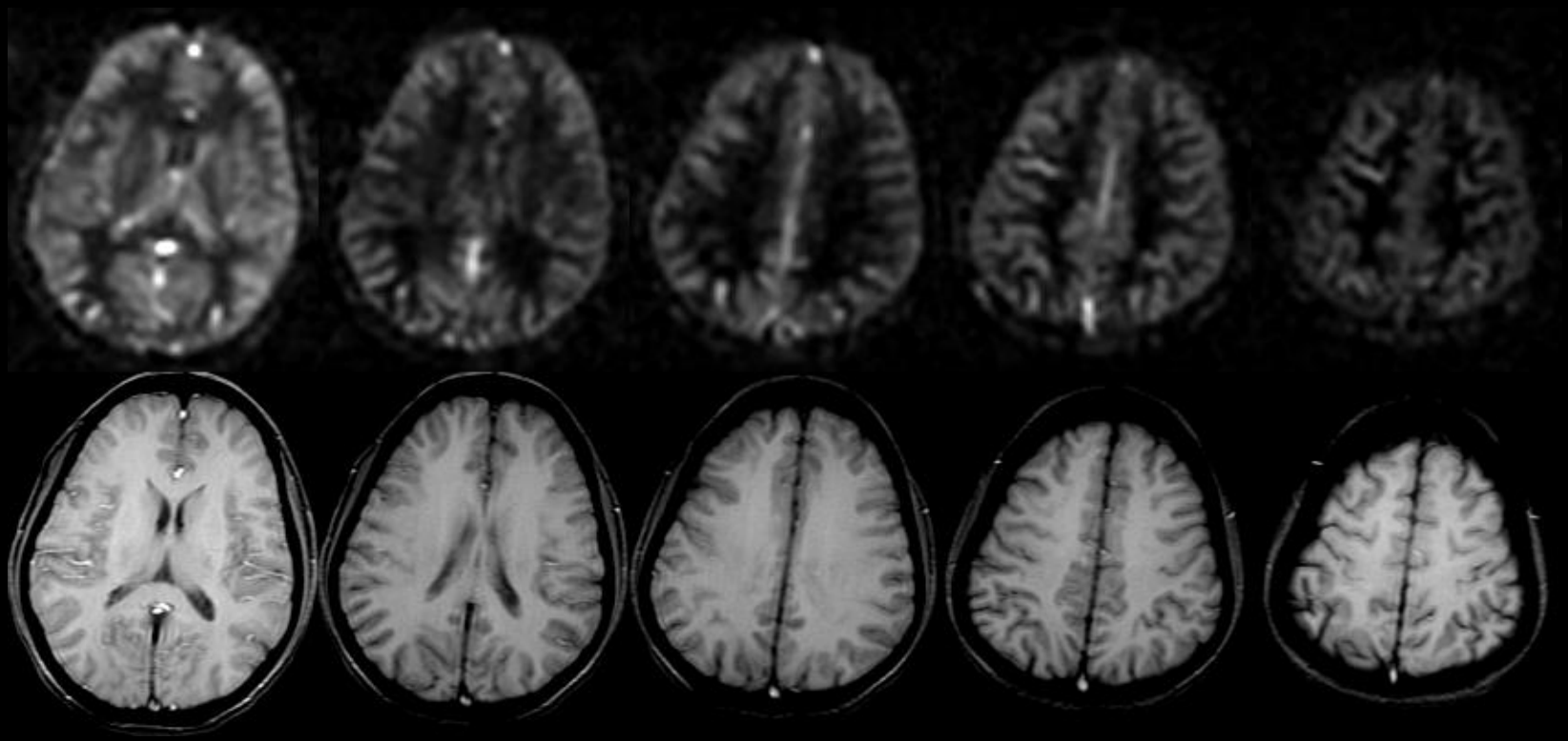
Venograms



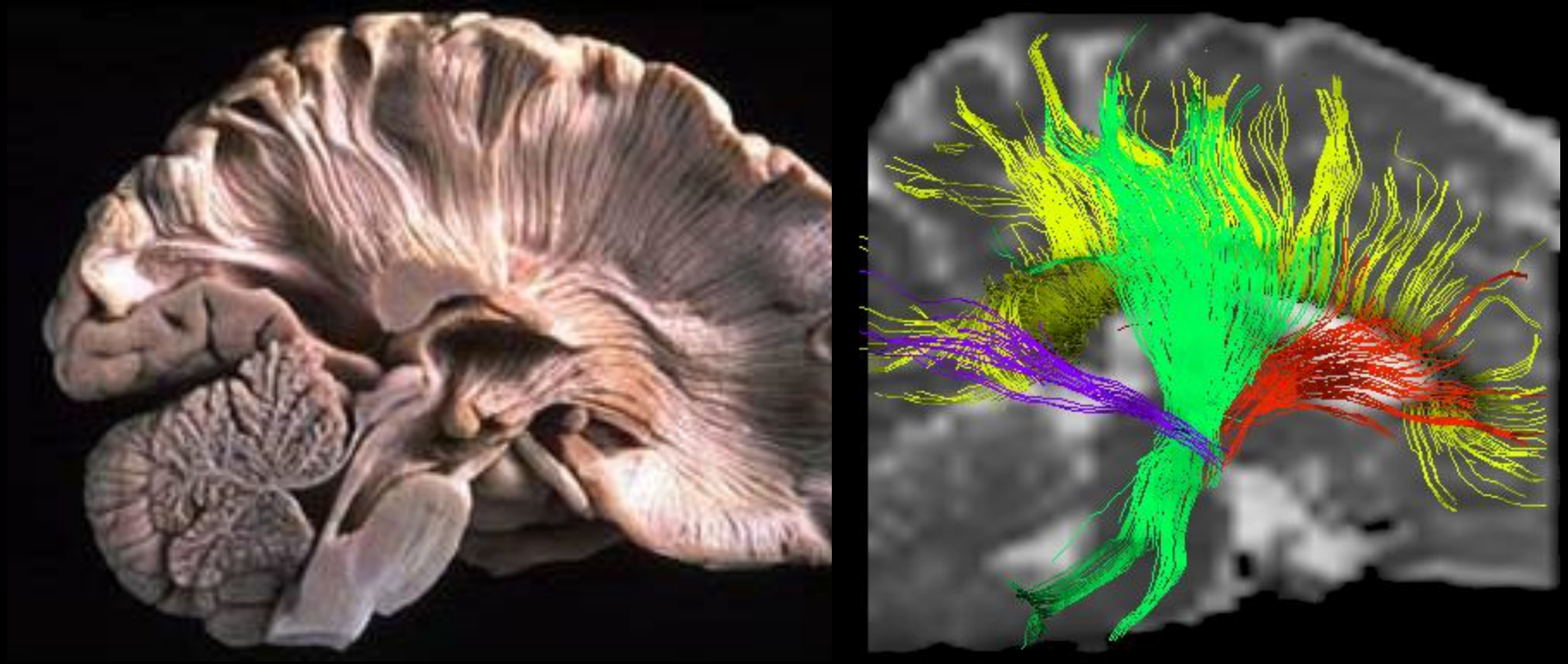
Perfusion / Flow Imaging



Perfusion Imaging with MRI

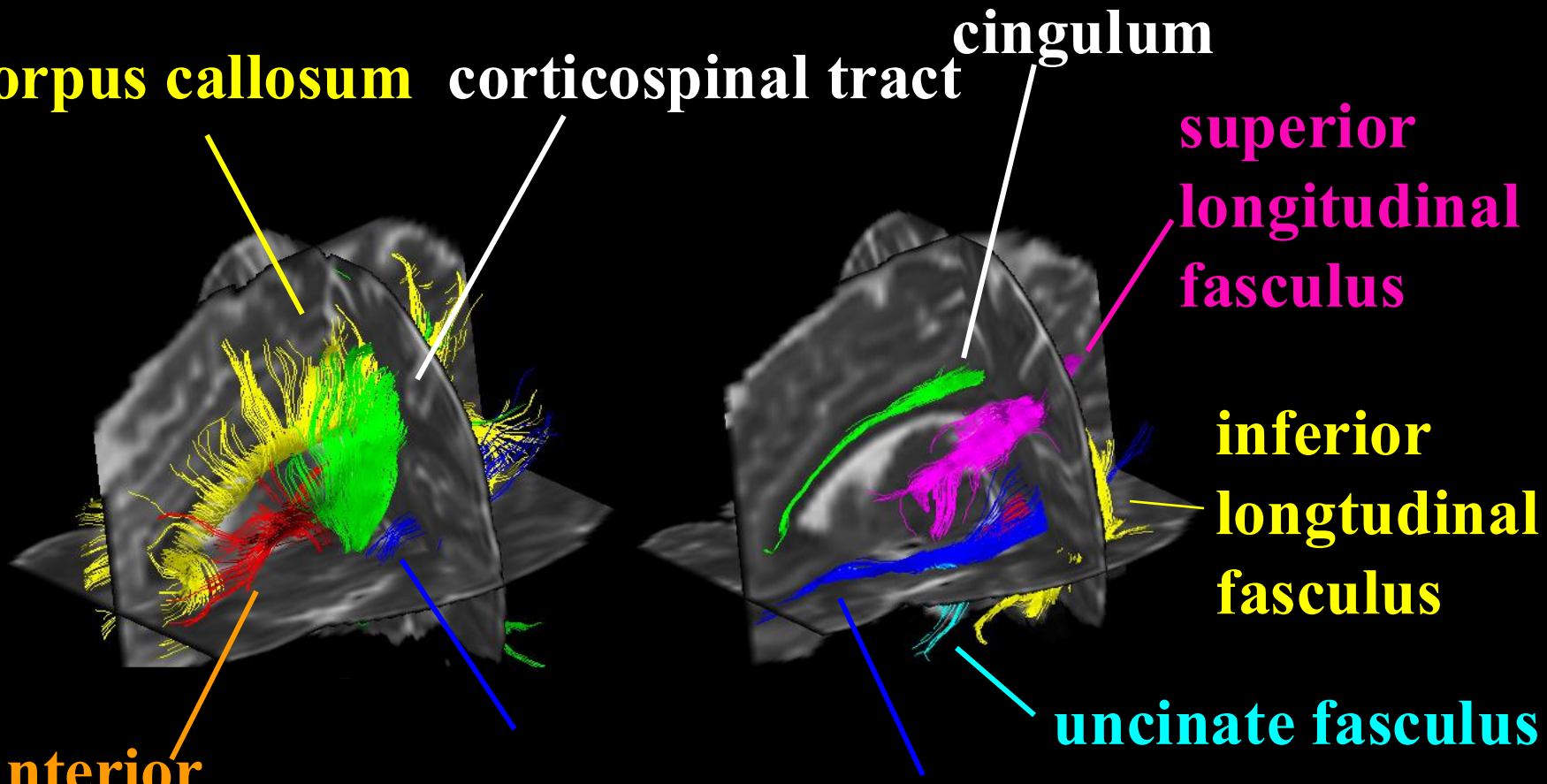


Diffusion Tensor Imaging



S. Mori – Johns Hopkins

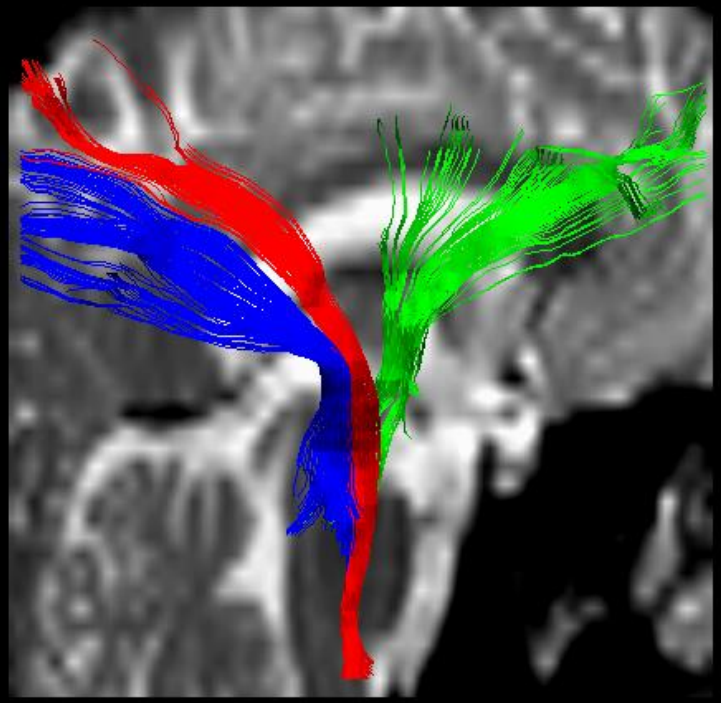
Diffusion Tensor Imaging

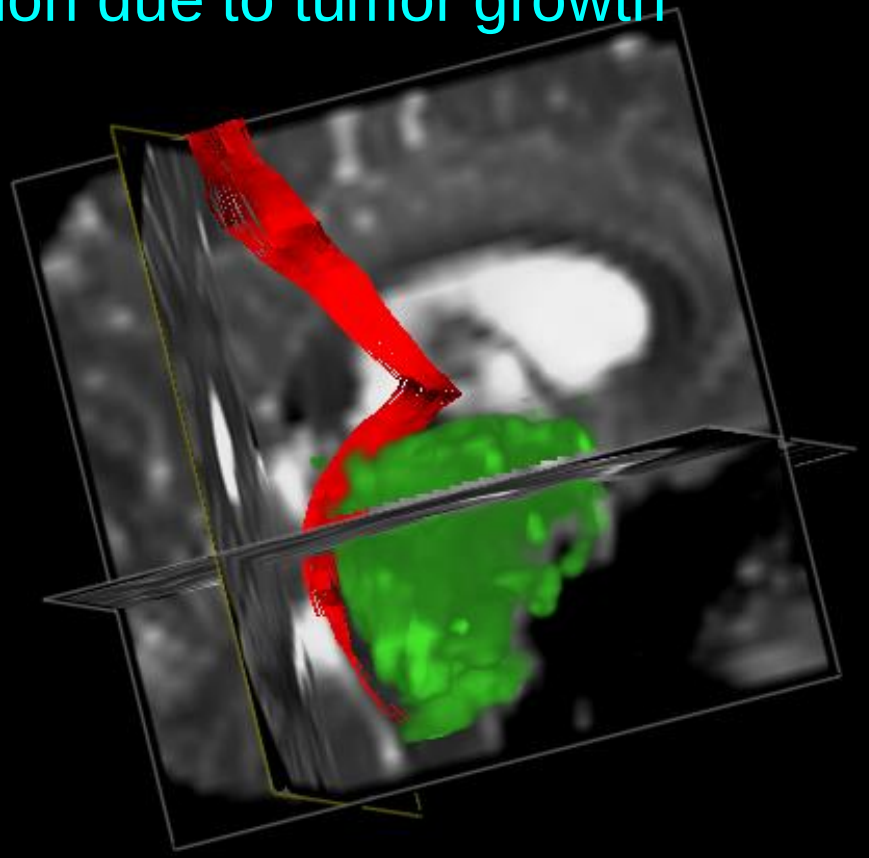


S. Mori - JHU

Anatomical guidance with DTI:

Example: Anatomical deformation due to tumor growth



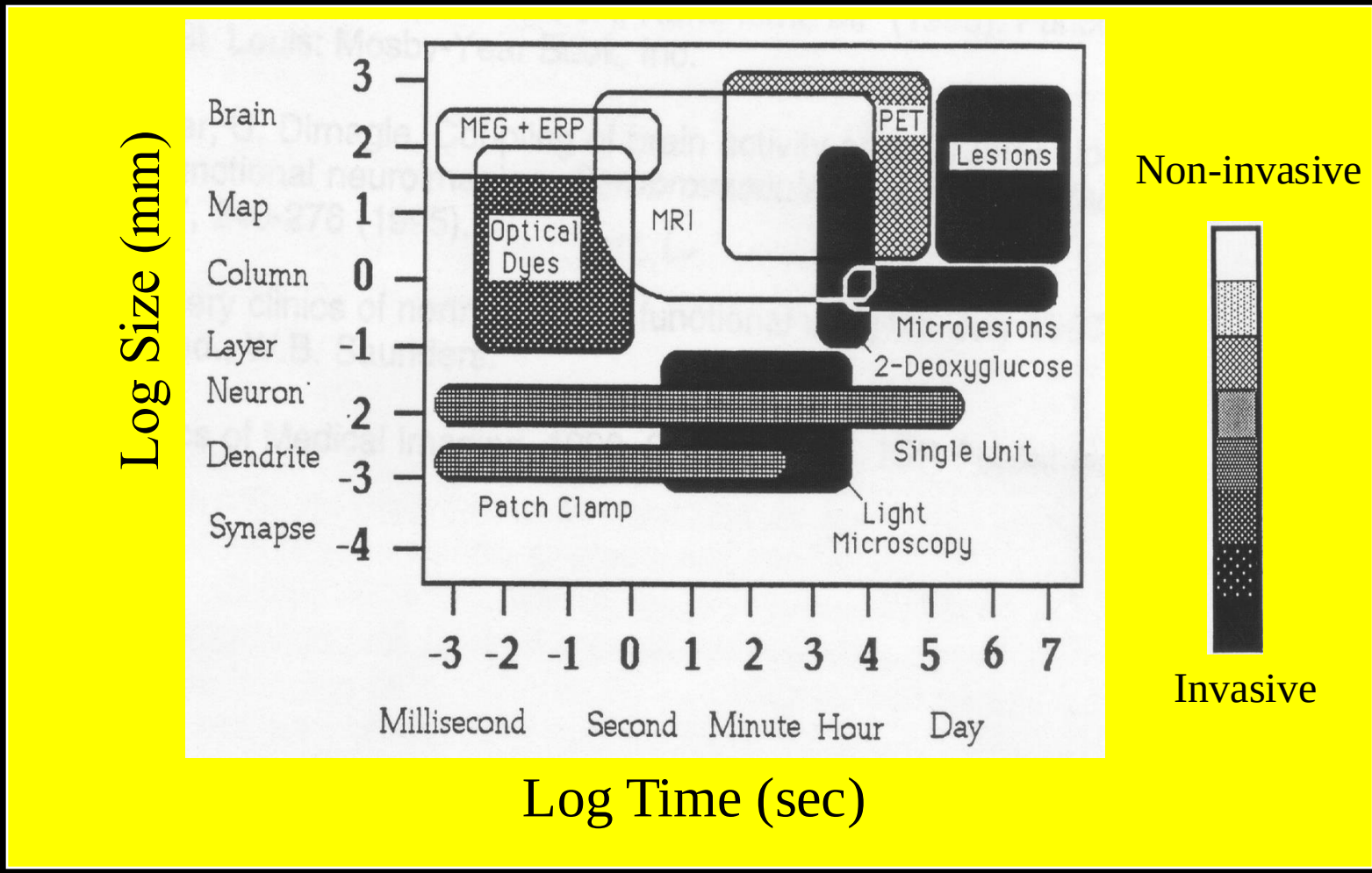


S. Mori - JHU

Functional Imaging

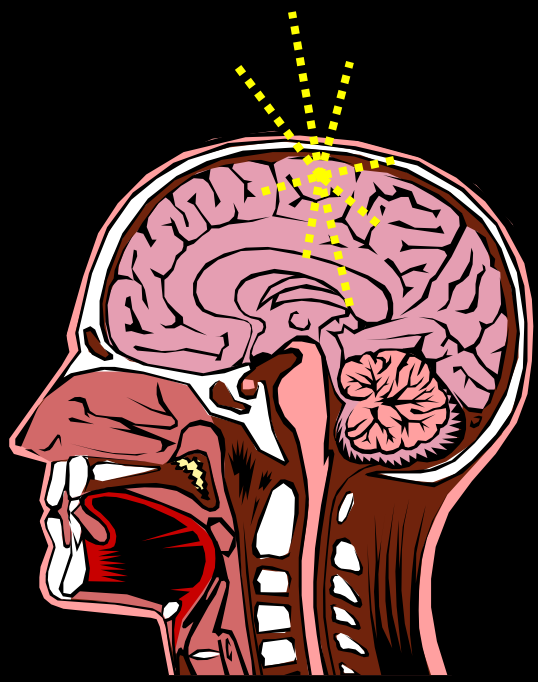
- Unlike structural imaging, functional imaging provides pictures of brain physiology or chemistry.
- By targeting factors that are related to brain activity (eg. blood flow and oxygenation), images of brain activation can be obtained.
- Functional imaging has been used for pre-surgical mapping of function and, eventually, may replace or augment more traditional tests.
- Functional imaging is now a major new research paradigm in neuroscience.

Functional Neuroimaging Techniques

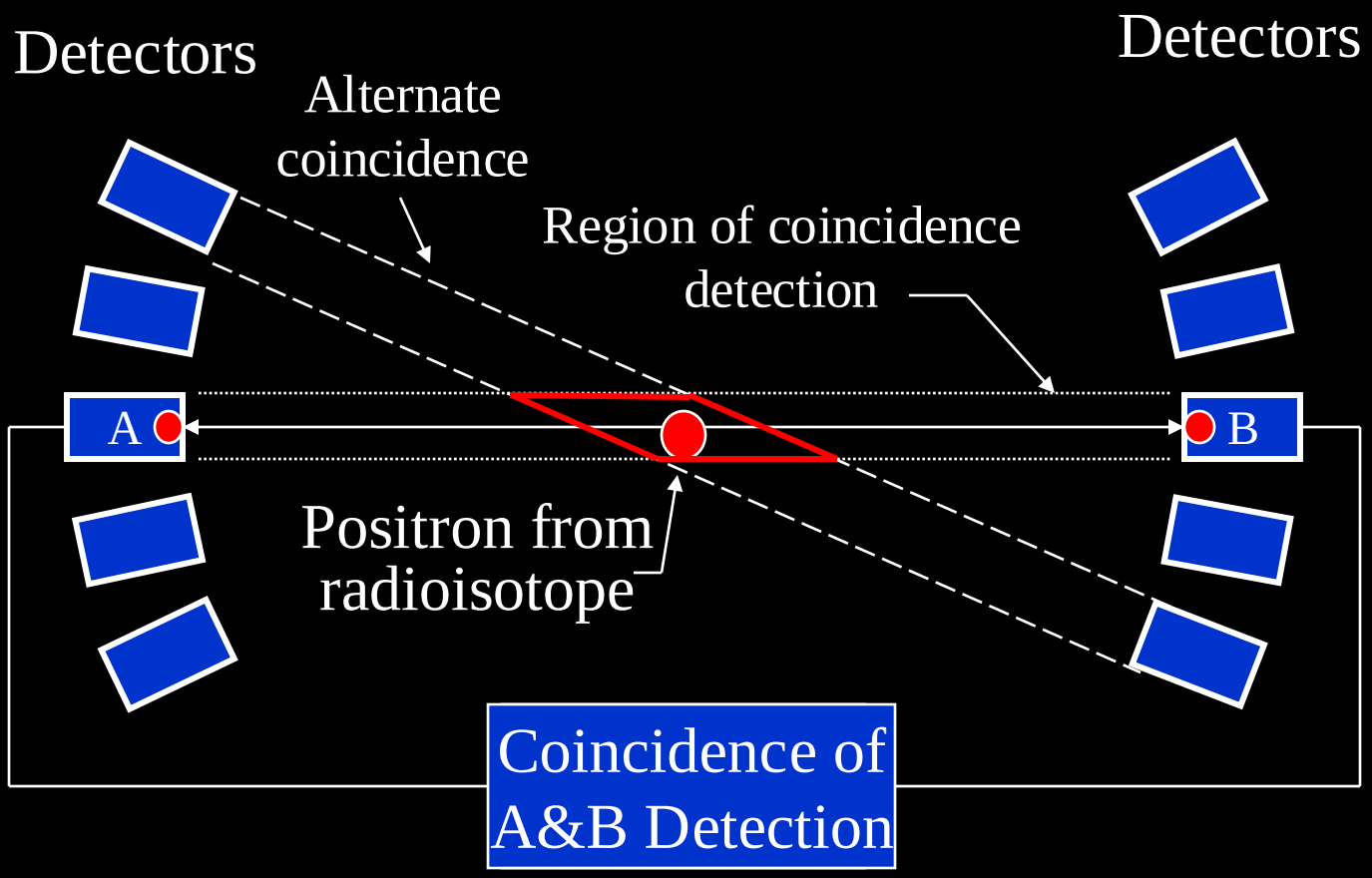


Positron Emission Tomography (PET)

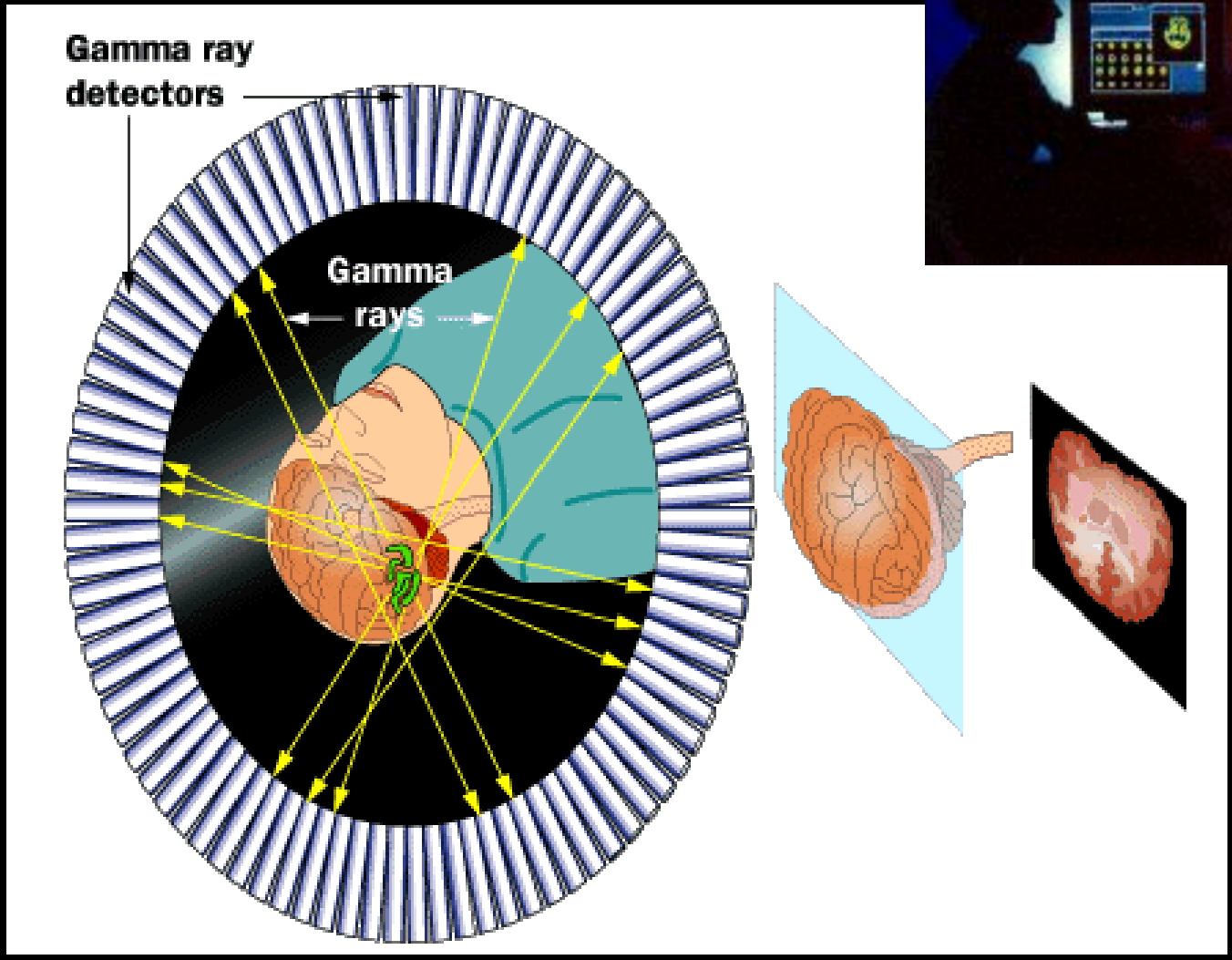
- Positron emission tomography (PET) is a technique for studying functional processes *in vivo* by measuring the concentrations of positron-emitting radioisotopes within the subject.
- PET is primarily used to study biochemical and physiological processes within living organs with 3-dimensional spatial resolution.



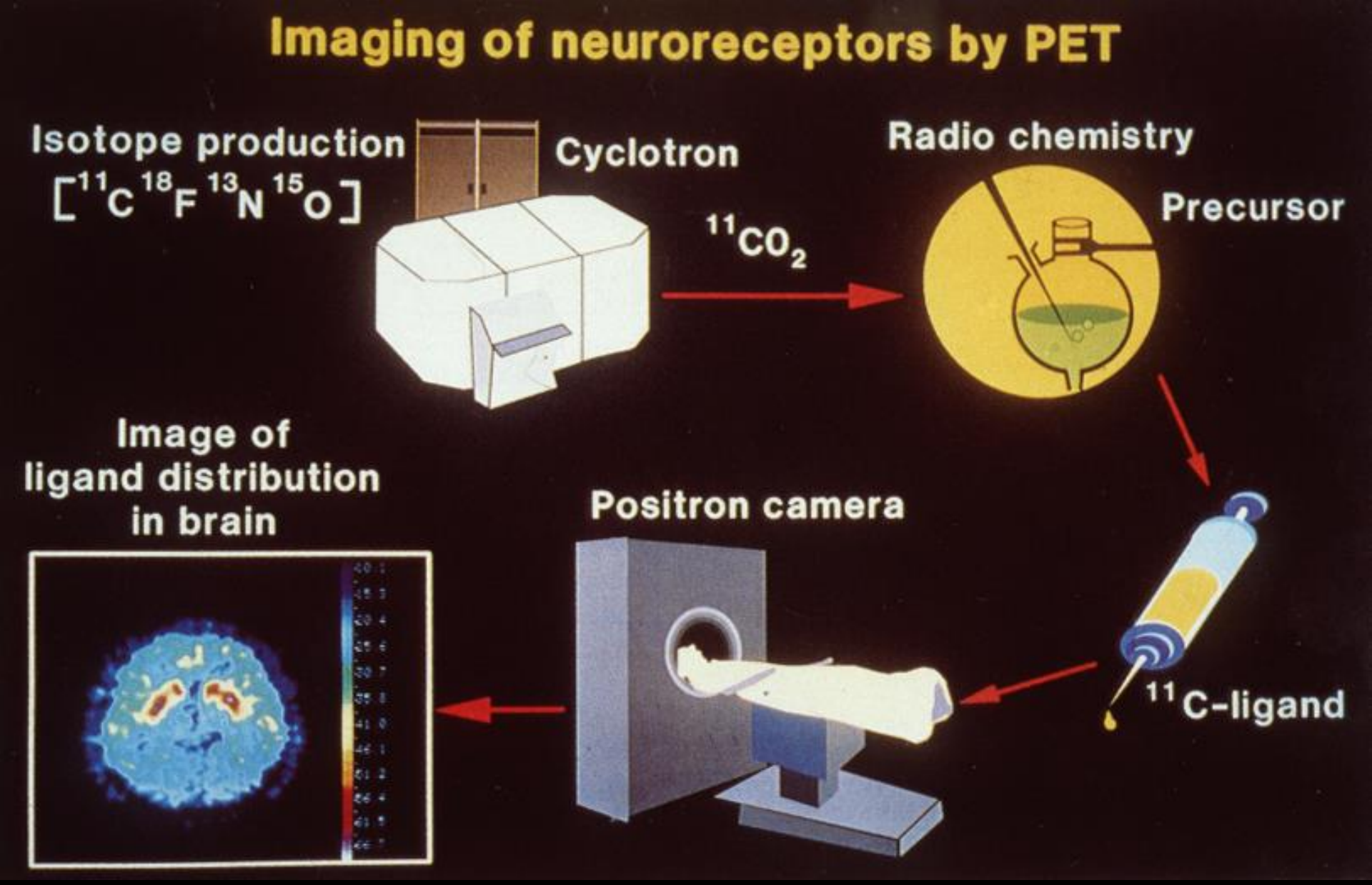
PET mechanism

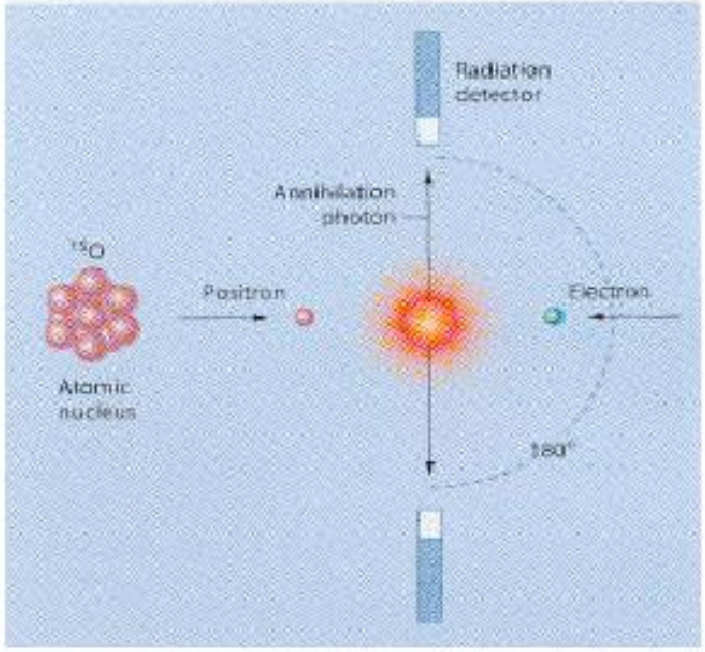


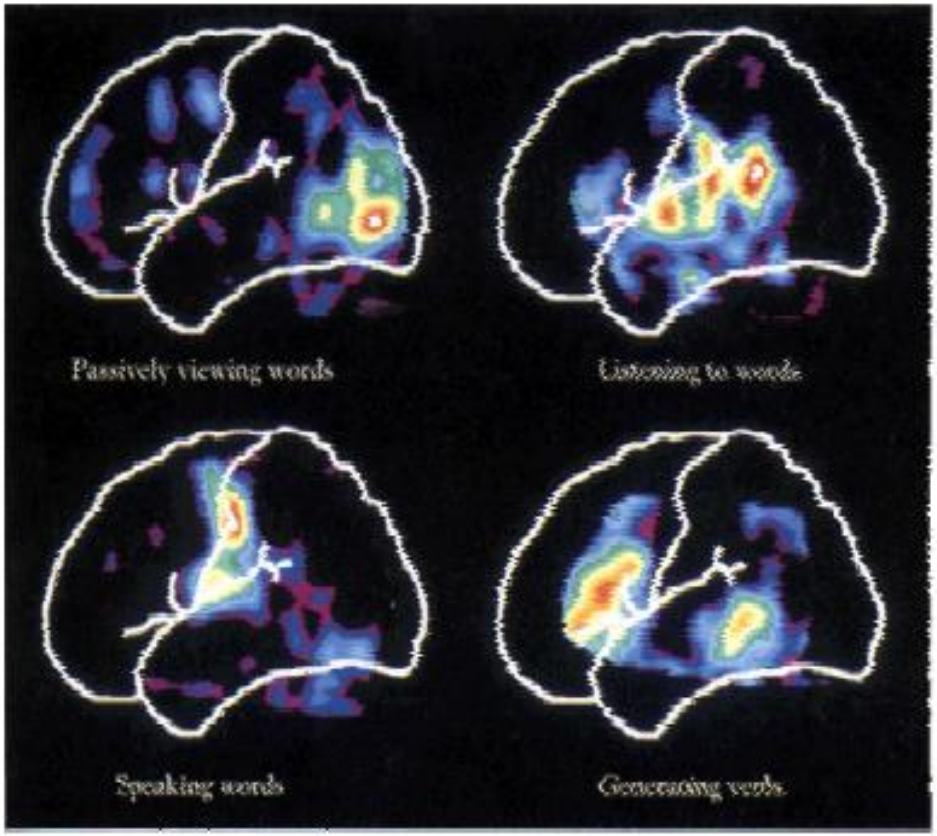
Positron Emission Tomography



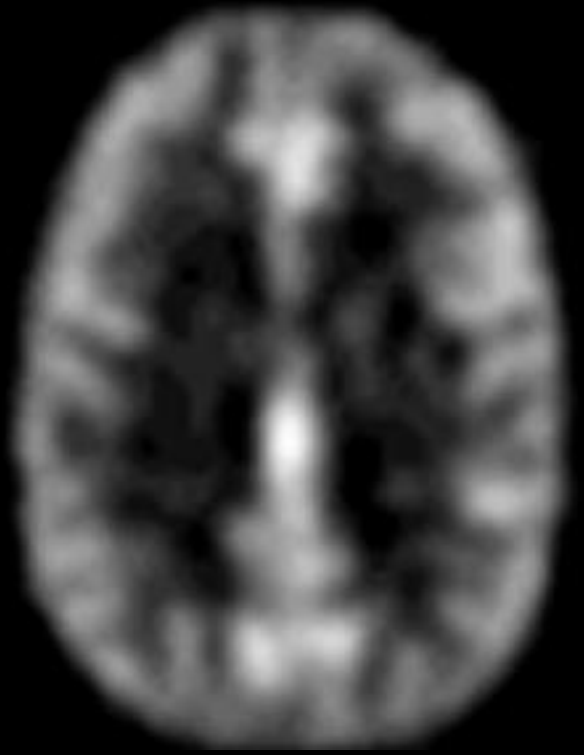
Imaging of neuroreceptors by PET



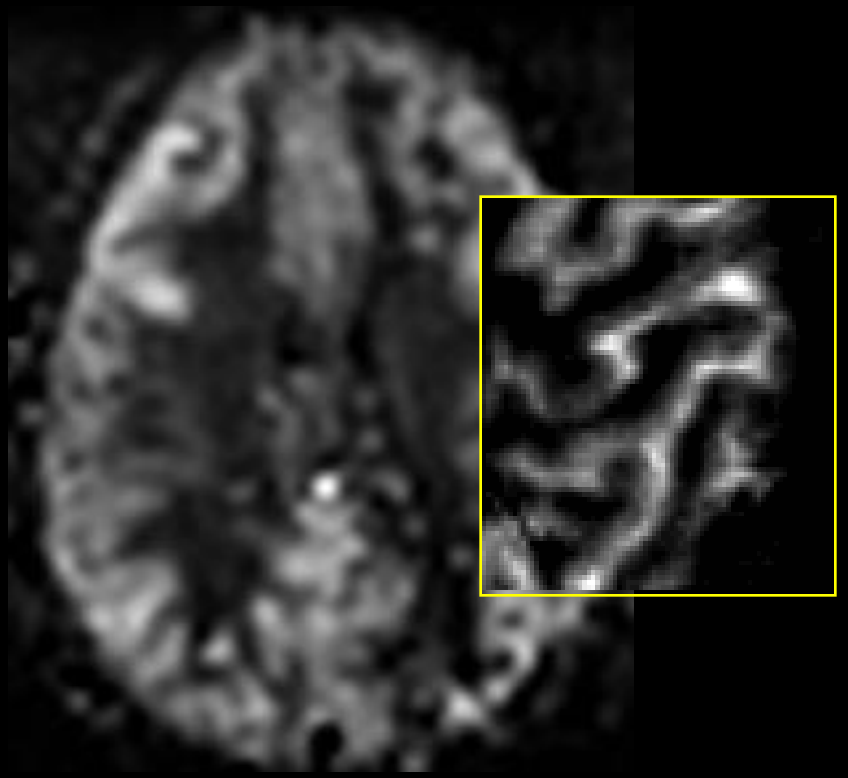

Radiation detector
Annihilation photon
^{15}O
Positron
Electron
Atomic nucleus
180°


Passively viewing words
Listening to words
Speaking words
Generating verbs

Comparison with Positron Emission Tomography

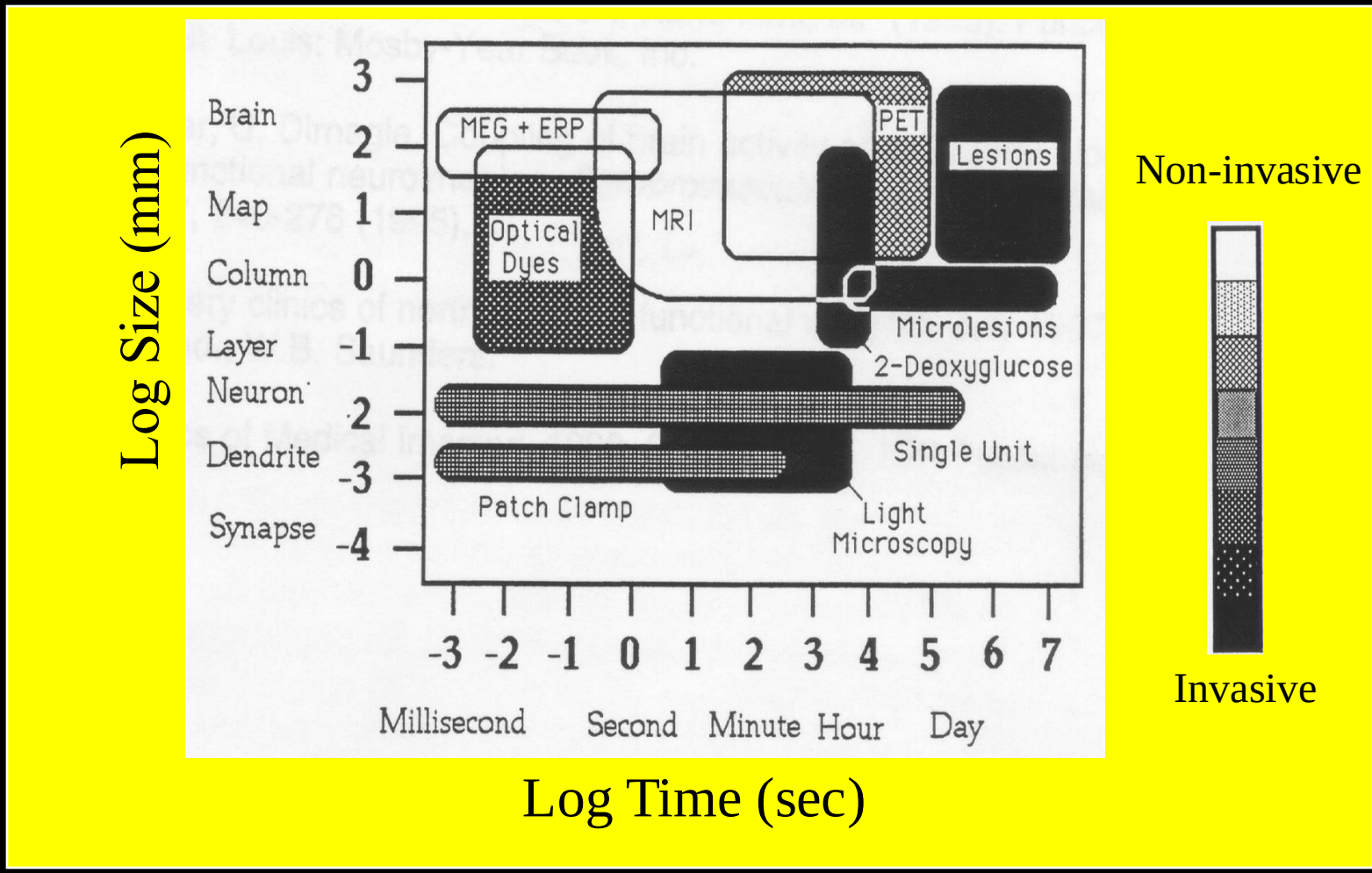


PET: $H_2{}^{15}O$



MRI: ASL

Functional Neuroimaging Techniques



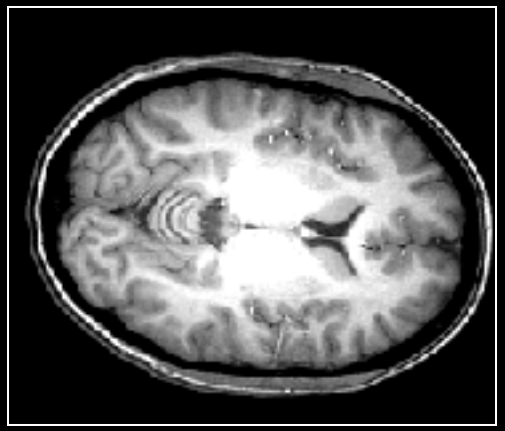
Contrast in Functional MRI

- **Blood Volume**
- **BOLD**
  - **(Blood Oxygenation Level Dependent Contrast)**
- **Perfusion**

MRI vs. fMRI

high resolution
(1 mm)

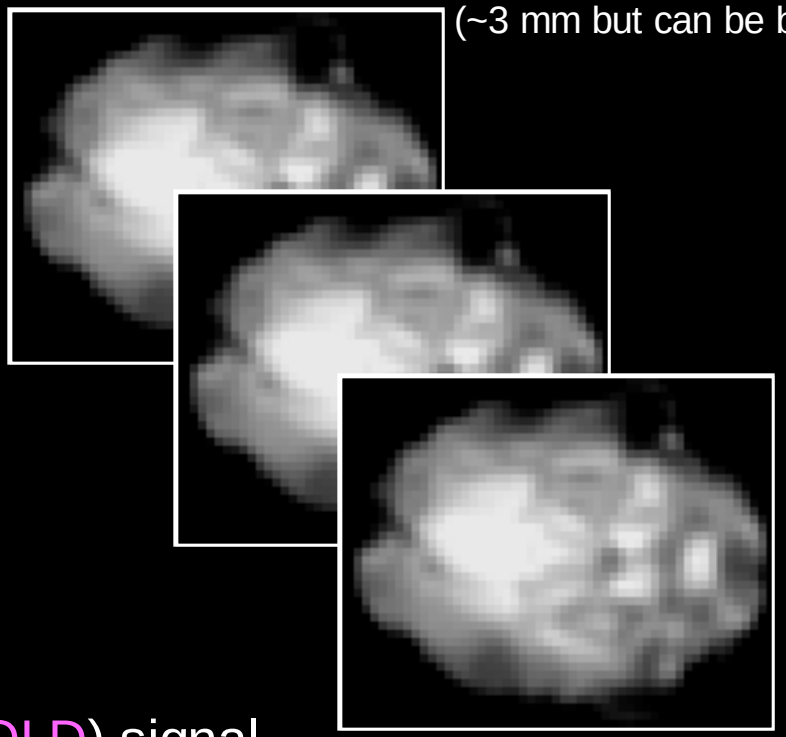
MRI



one image

fMRI

low resolution
(~3 mm but can be better)



...

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

fMRI

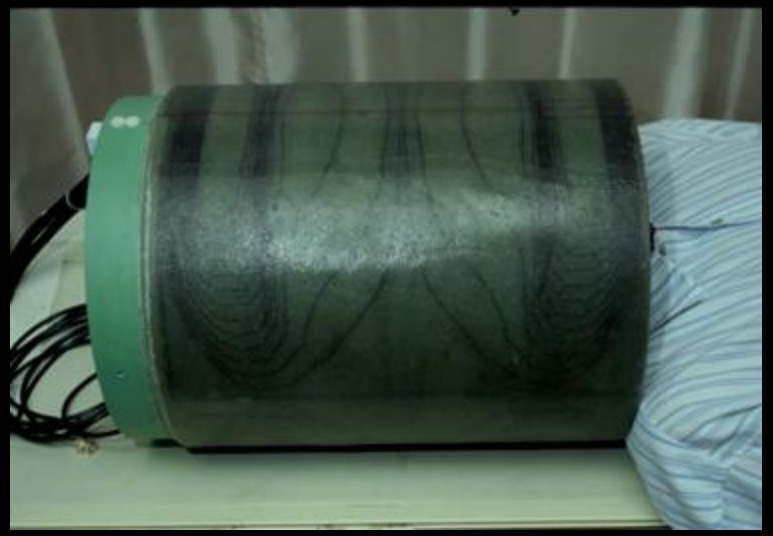
Blood Oxygenation Level Dependent (BOLD) signal
indirect measure of neural activity

↑ neural activity ➔ ↑ blood oxygen ➔ ↑ fMRI signal

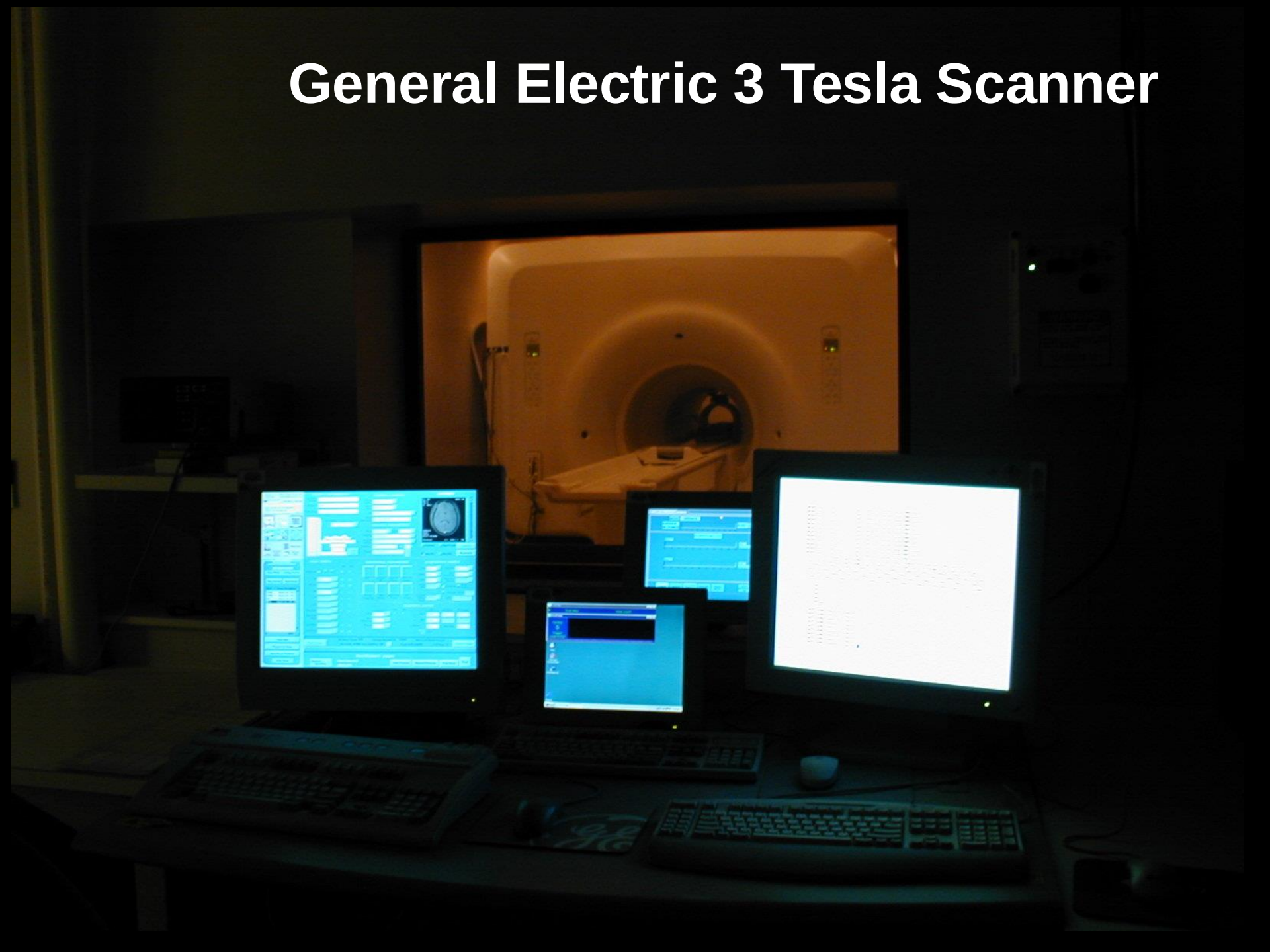
Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH

1991-1992

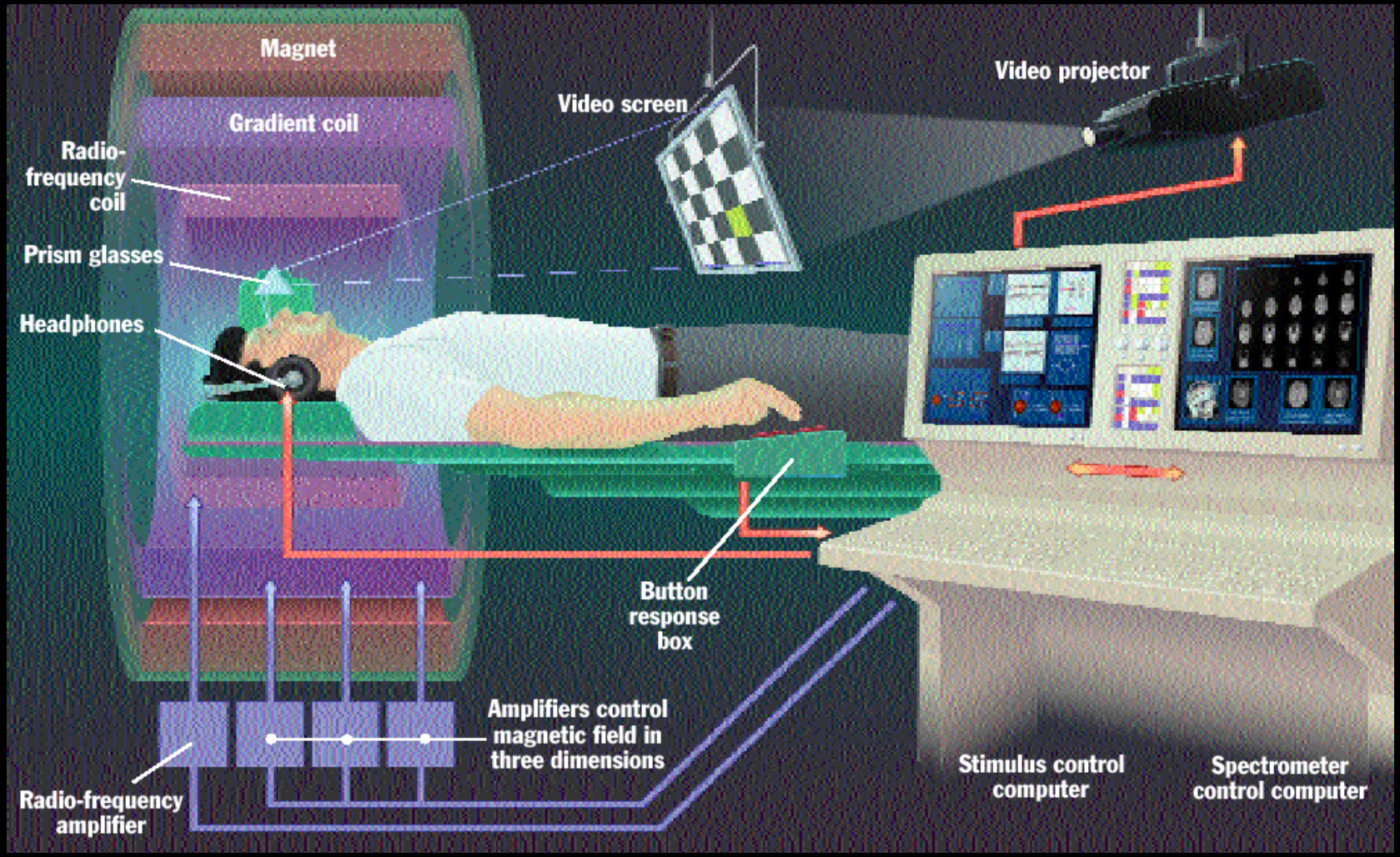
1992-1999



General Electric 3 Tesla Scanner



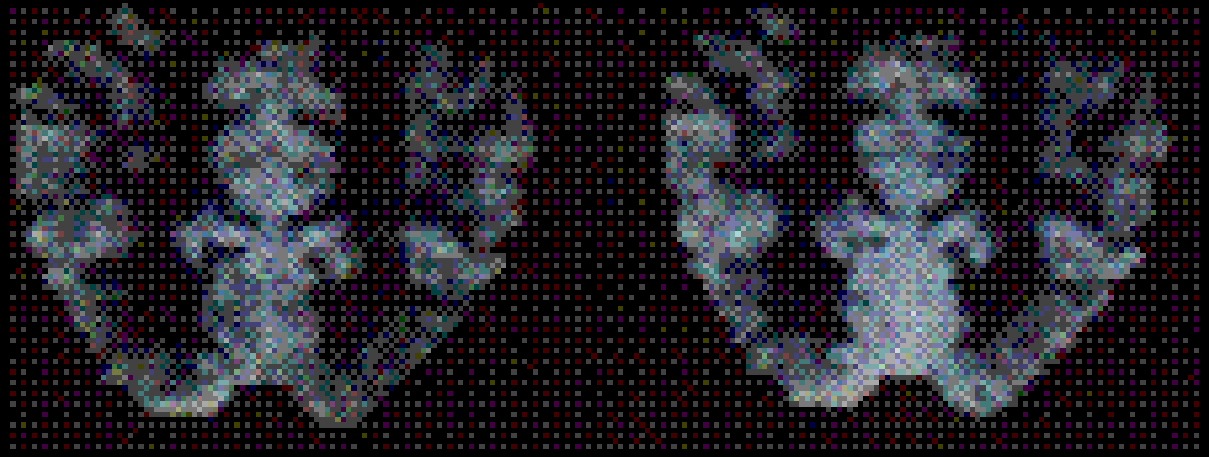
fMRI Setup

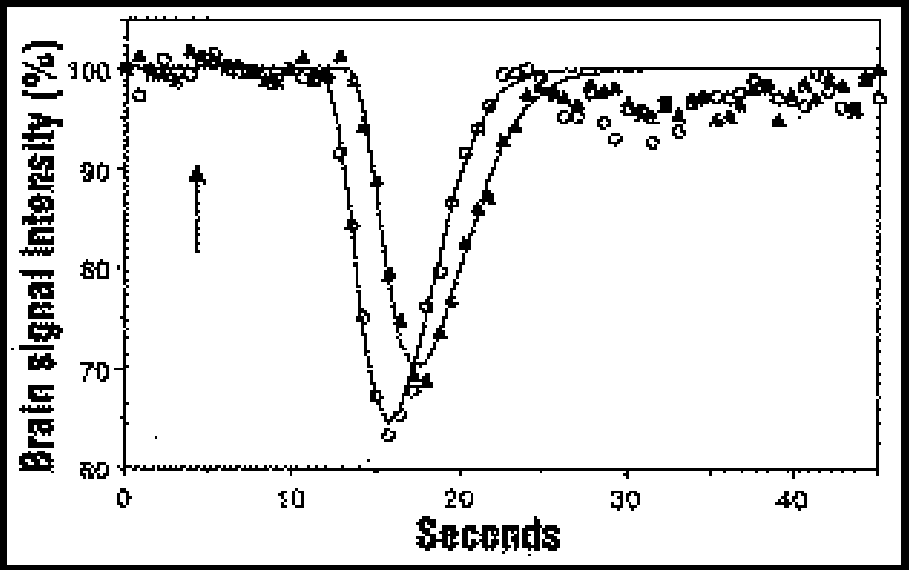


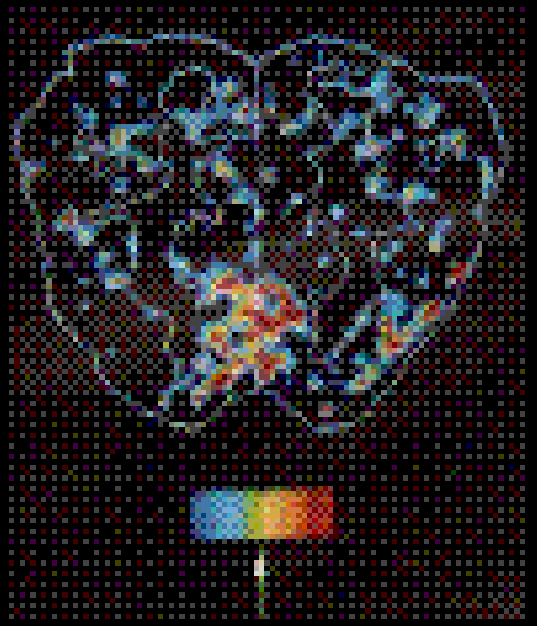
Courtesy, Robert Cox, Scientific and Statistical Computing Core Facility, NIMH

Blood Volume Changes with Brain Activation

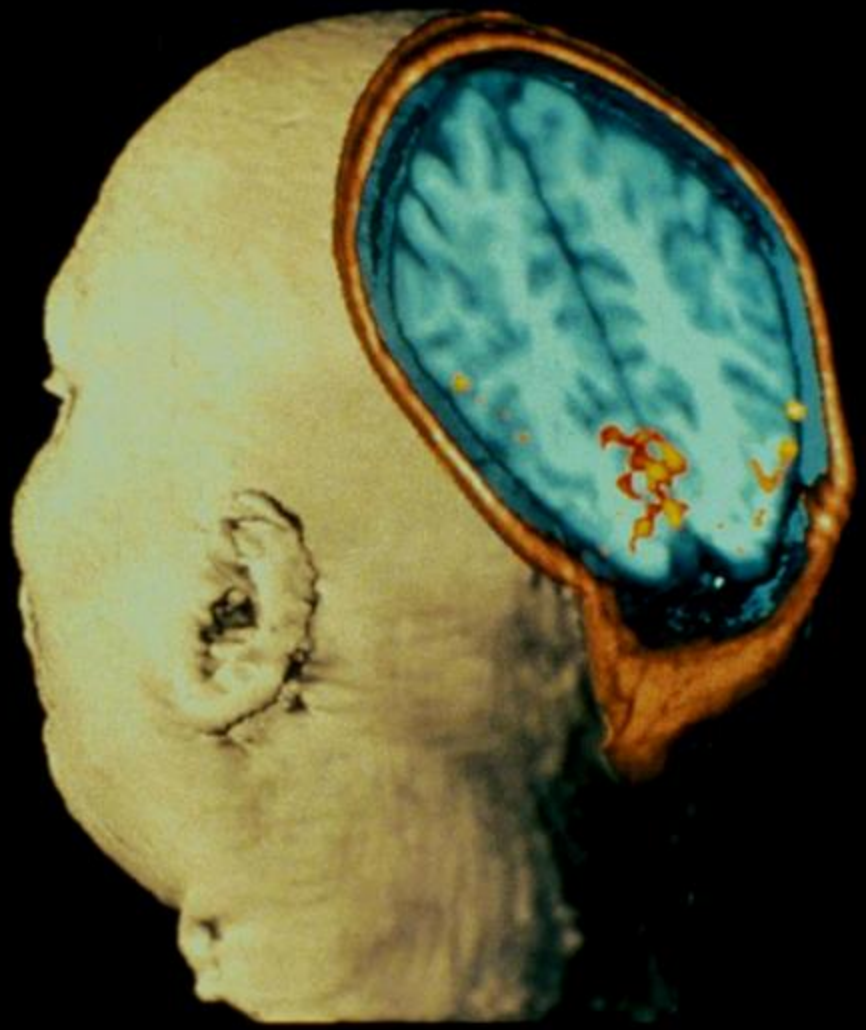
Resting **Active**







Photic Stimulation



MRI Image showing activation of the Visual Cortex

From Belliveau, et al. Science Nov 1991

BOLD

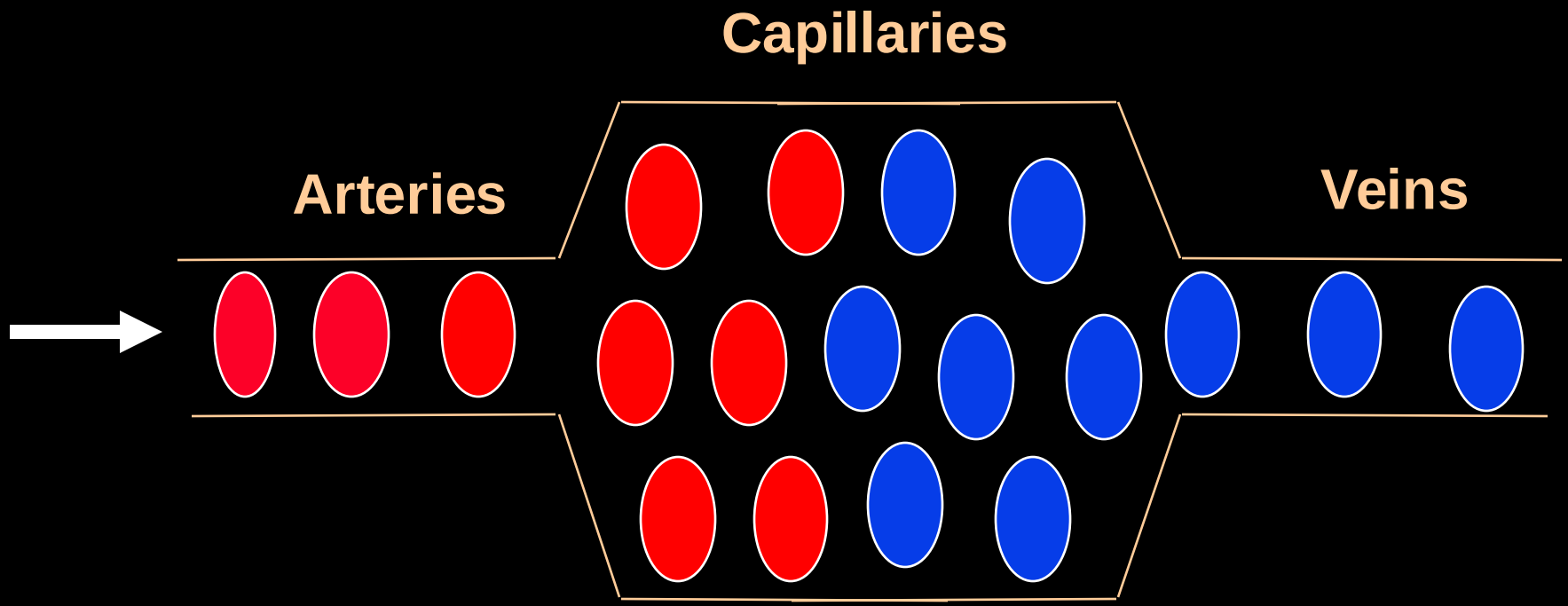
(blood oxygenation level dependence)

blood flow ↑

oxygenated-blood ↑

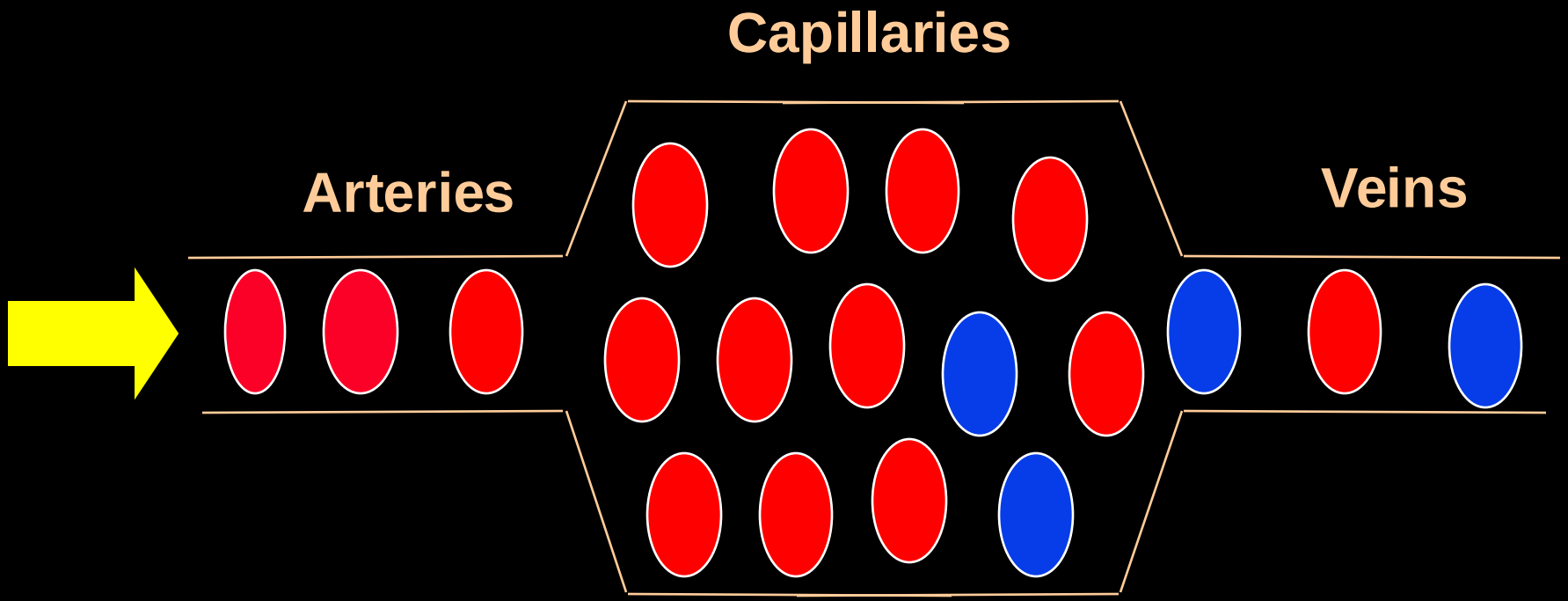
MR signal ↑

BOLD: Resting Perfusion



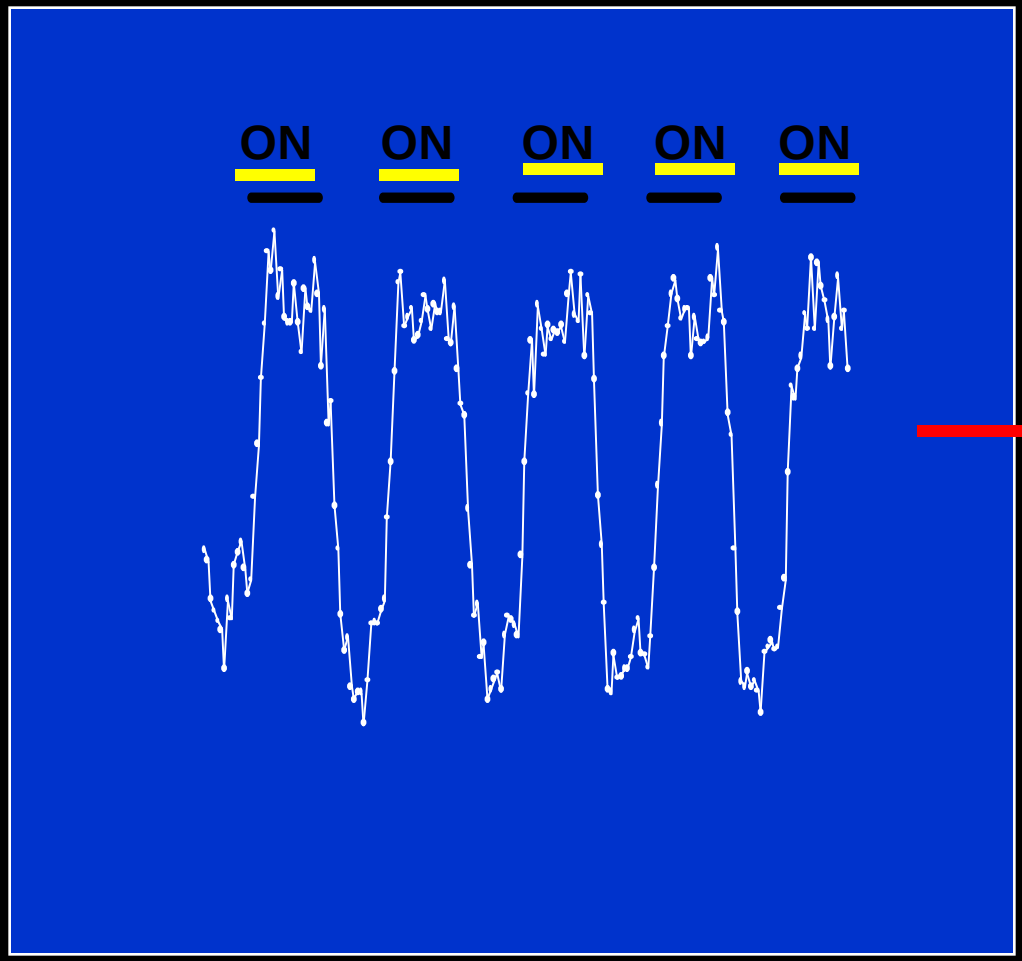
SIGNAL

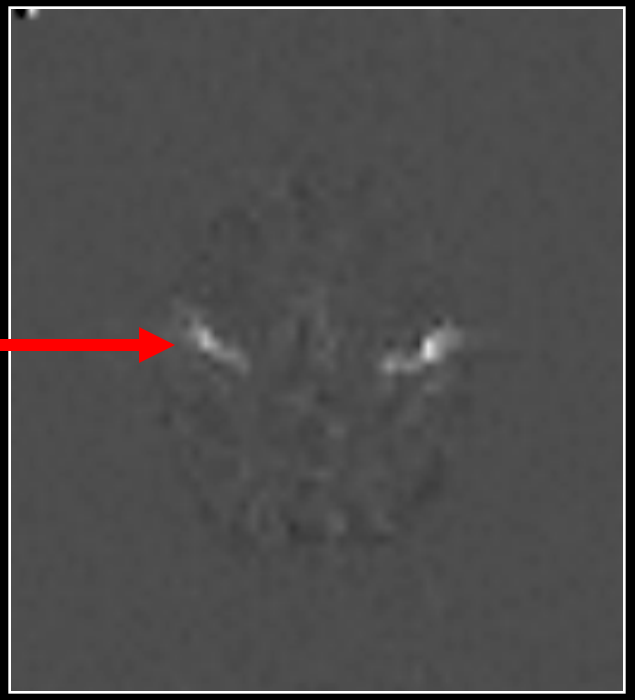
BOLD: Activated Perfusion



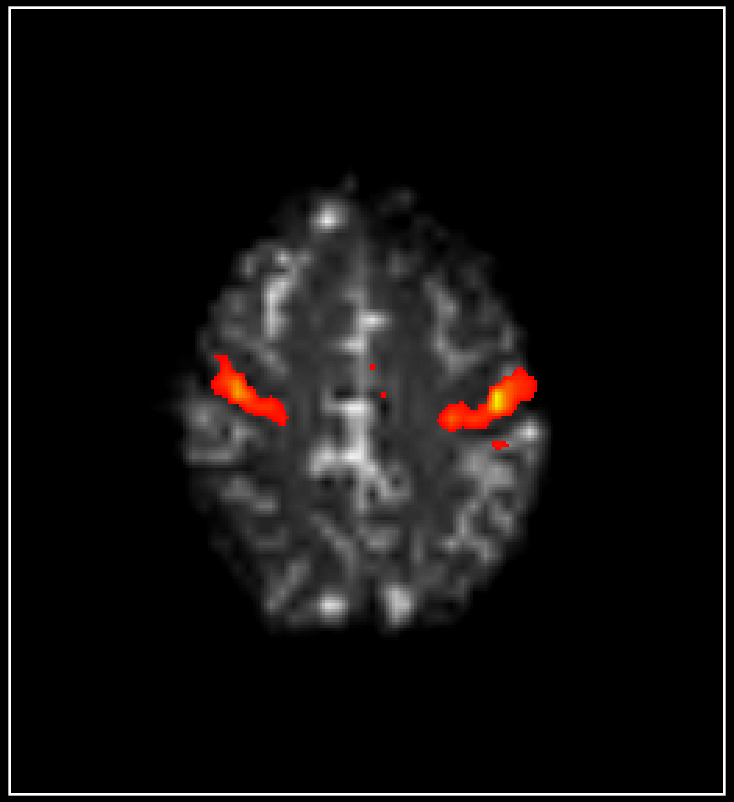
SIGNAL

BOLD: Motor Cortex Activation





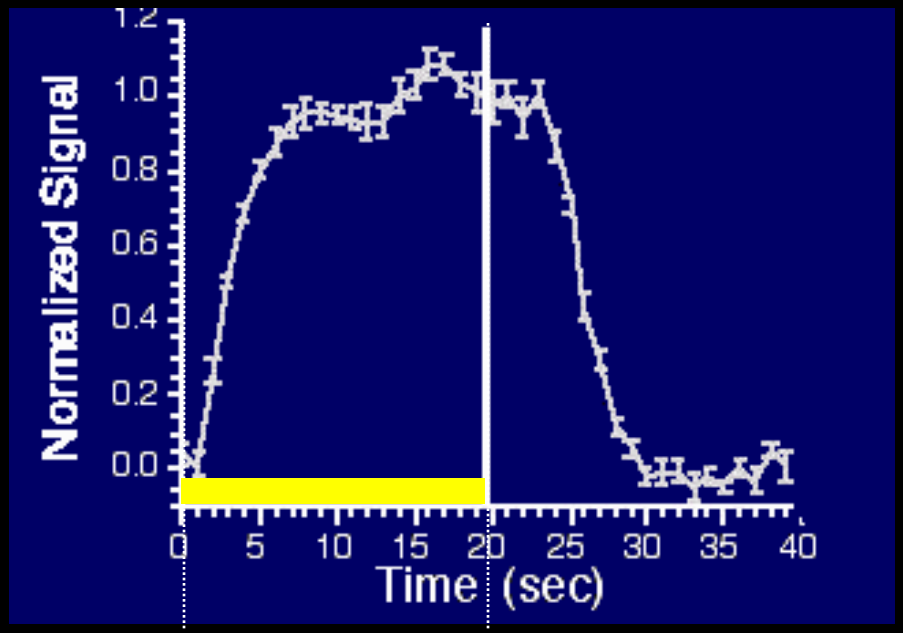
Cross Correlation Image



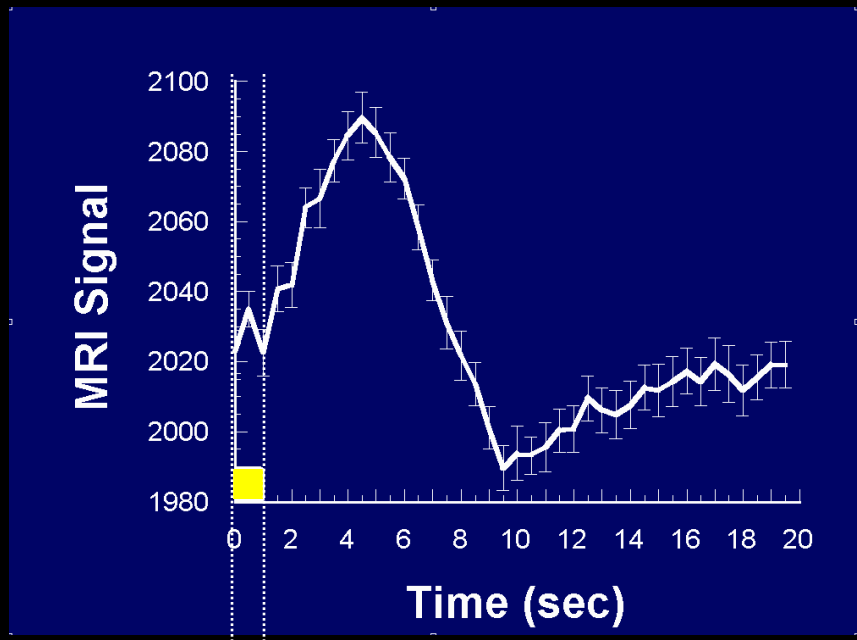
Cross Correlation Image
Anatomical Image

The BOLD Signal

Blood Oxygenation Level Dependent (BOLD) signal changes



task

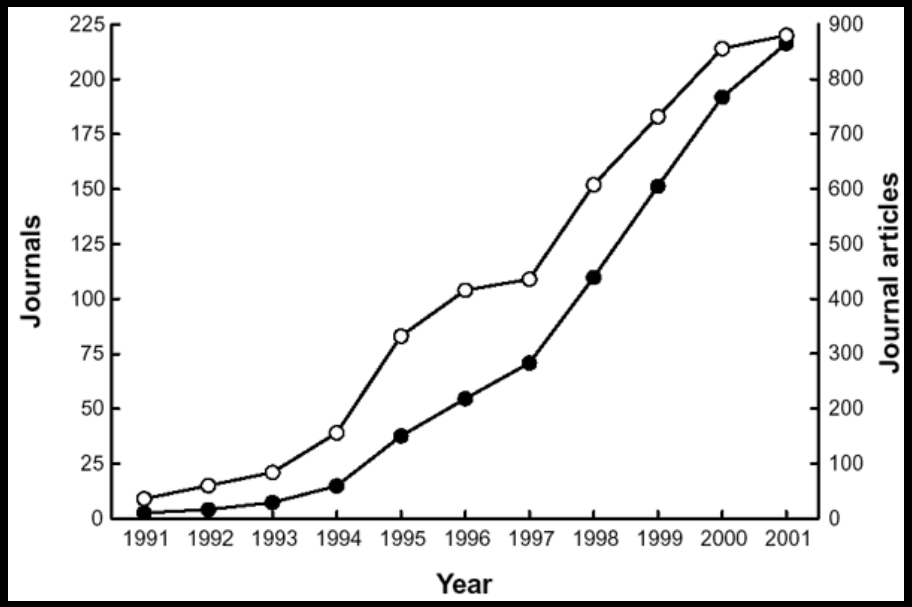


task

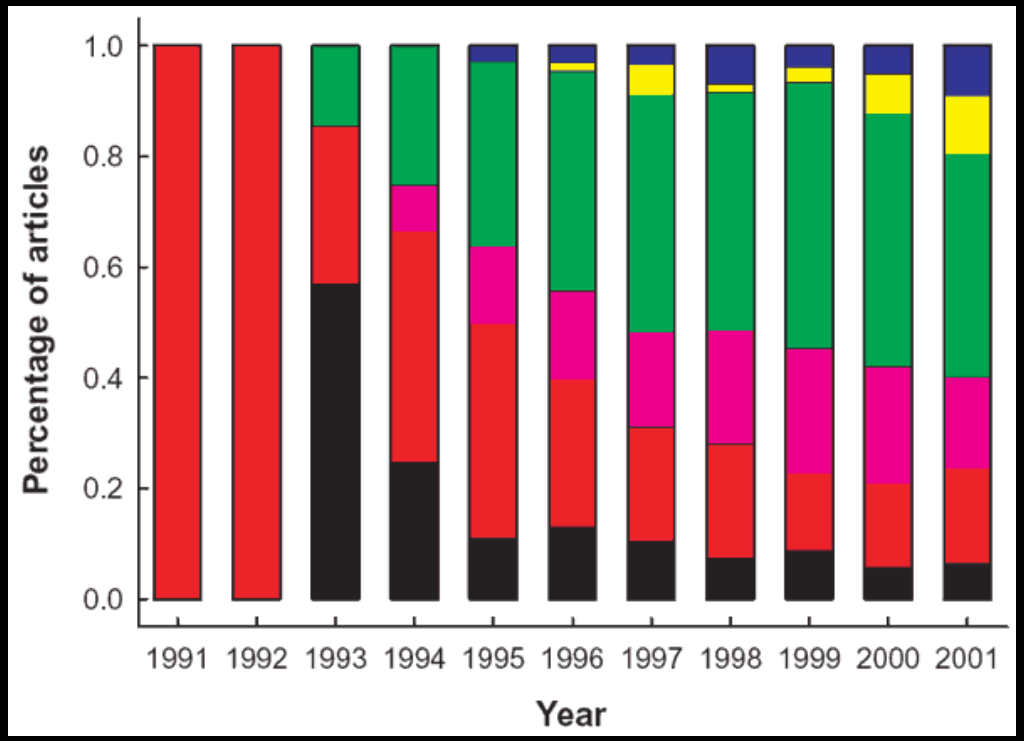
Alternating Left and Right Finger Tapping

~ 1992

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

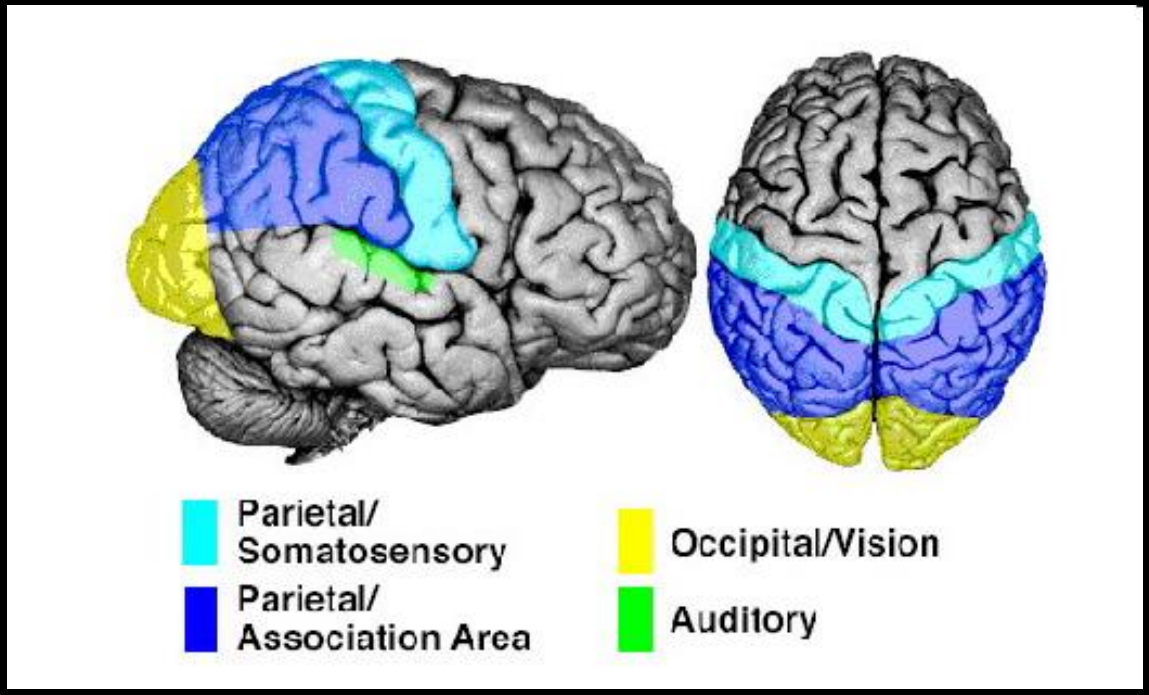
- -utilization of clinical research results

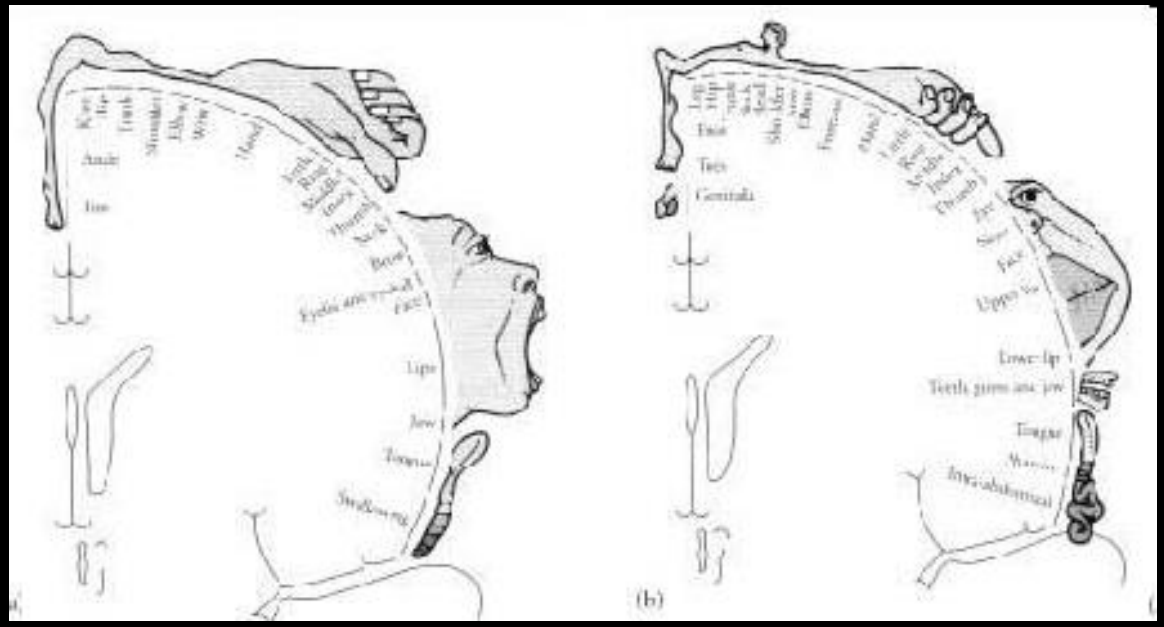
Clinical treatment and assessment

- -drug, therapy, rehabilitation, biofeedback

Non clinical uses

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

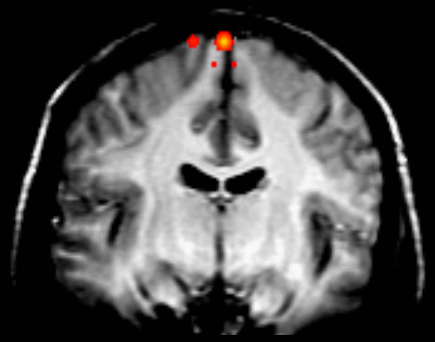

Parietal/
Somatosensory
Parietal/
Association Area
Occipital/Vision
Auditory

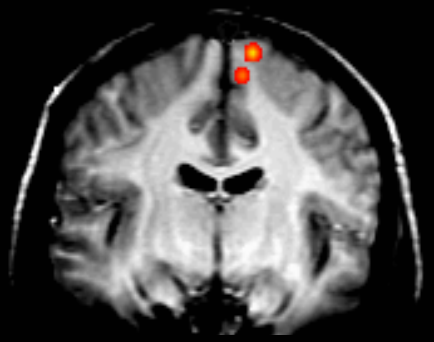

(b)

Left

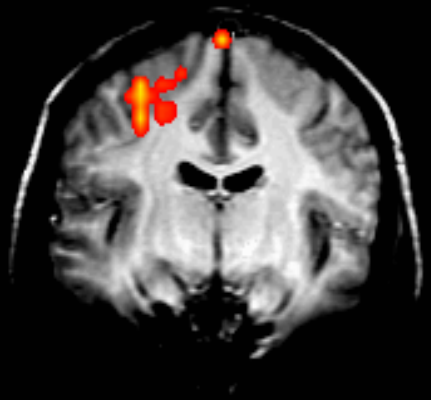
Right

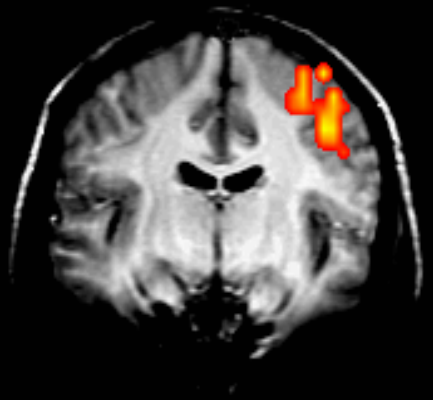
Toe movement



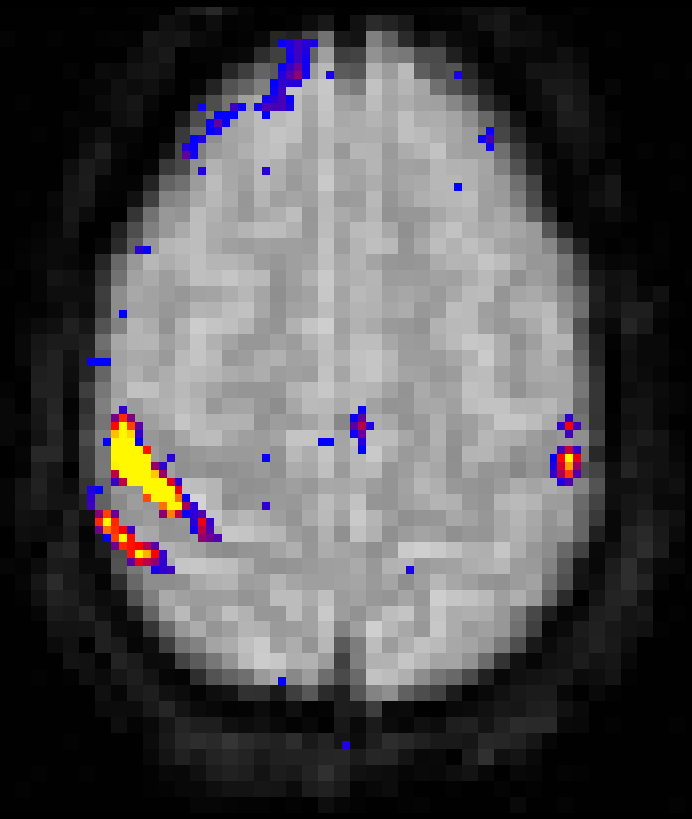


Finger movement

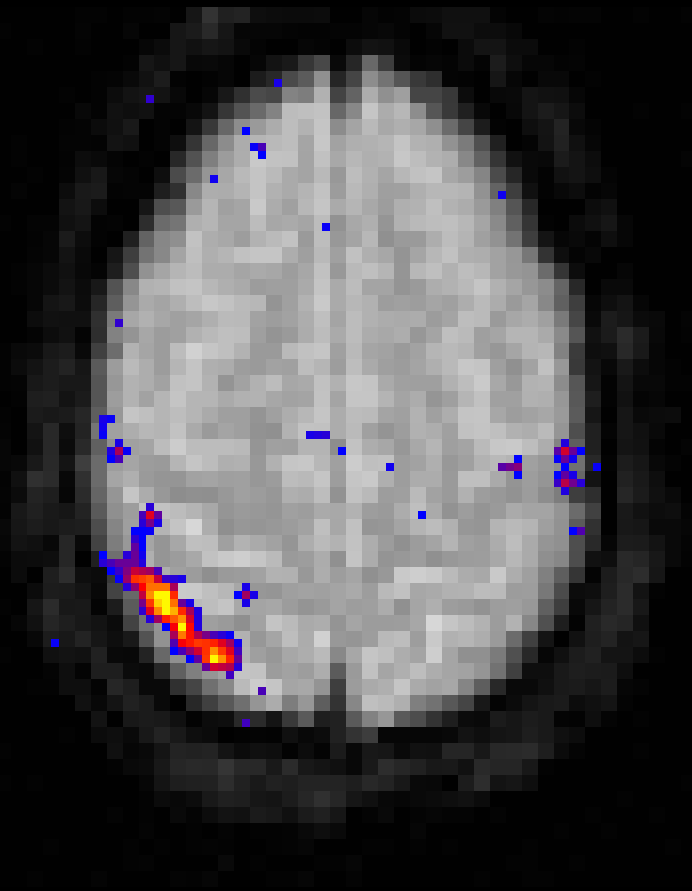


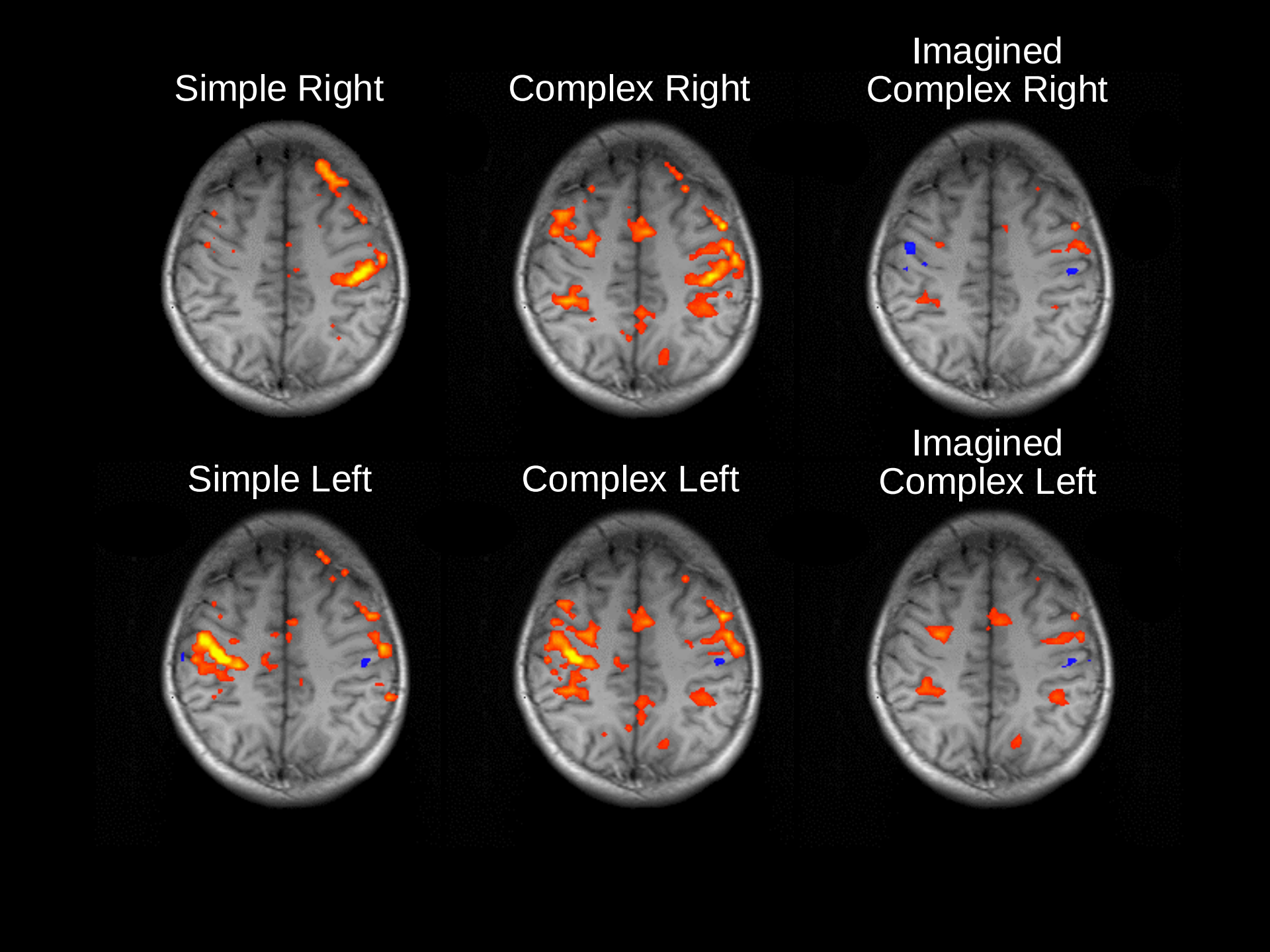


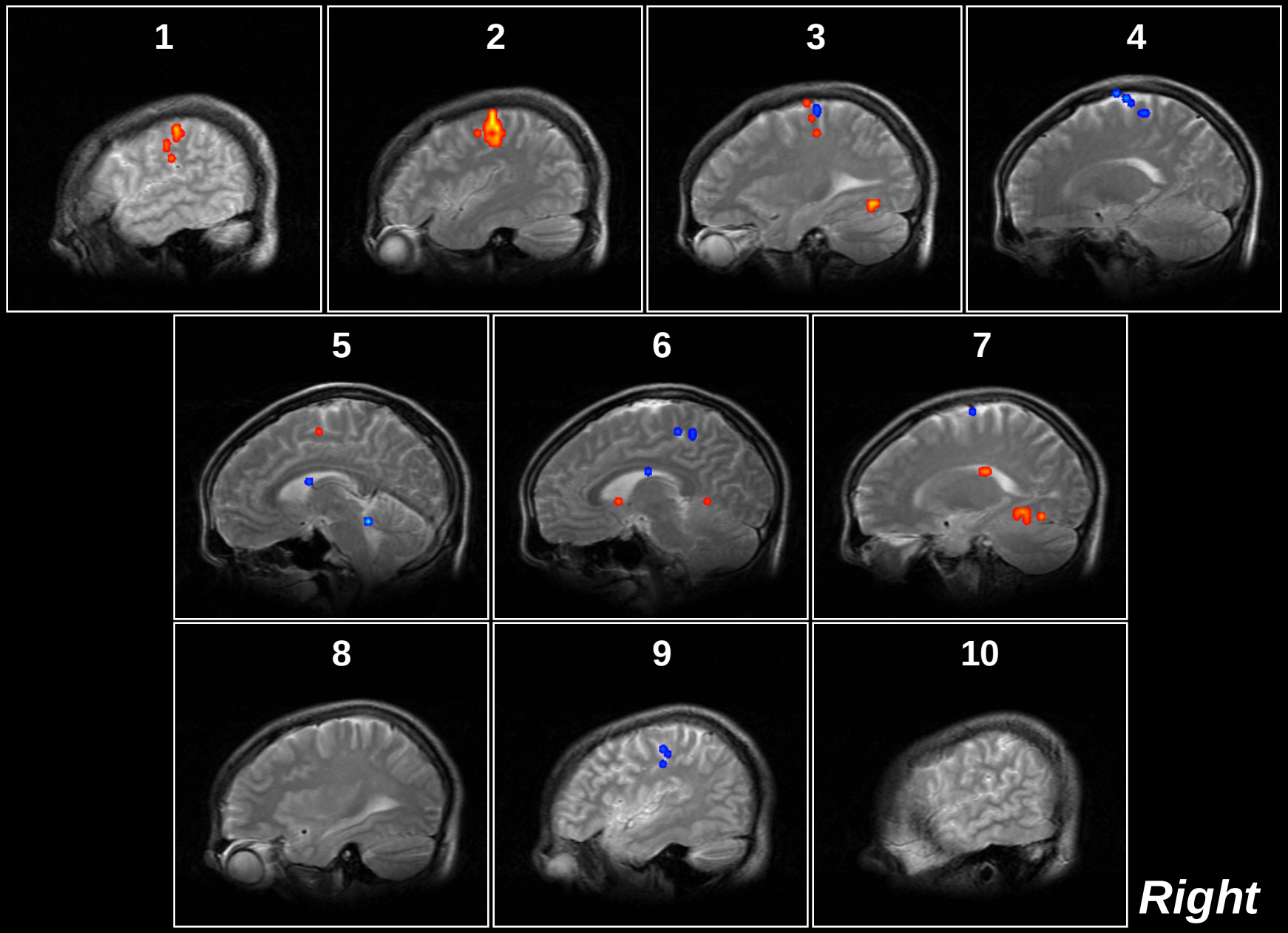
Finger Movement



Tactile Stimulation




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


Left
Simple Finger Movement on the RIght Hand
1
2
3
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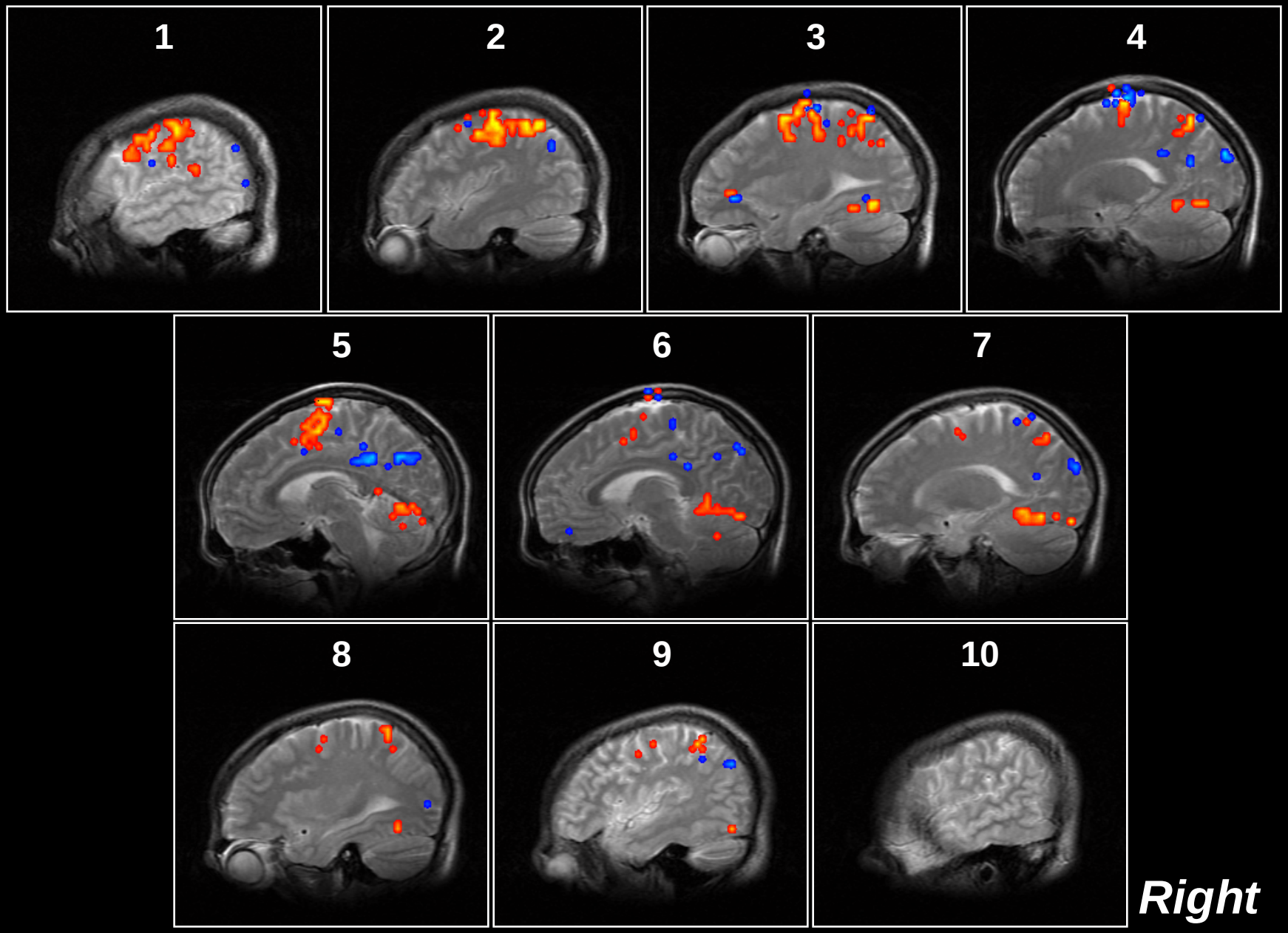
8
9
10
Right


Left
Complex Finger Movement on the Right Hand
1
2
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6
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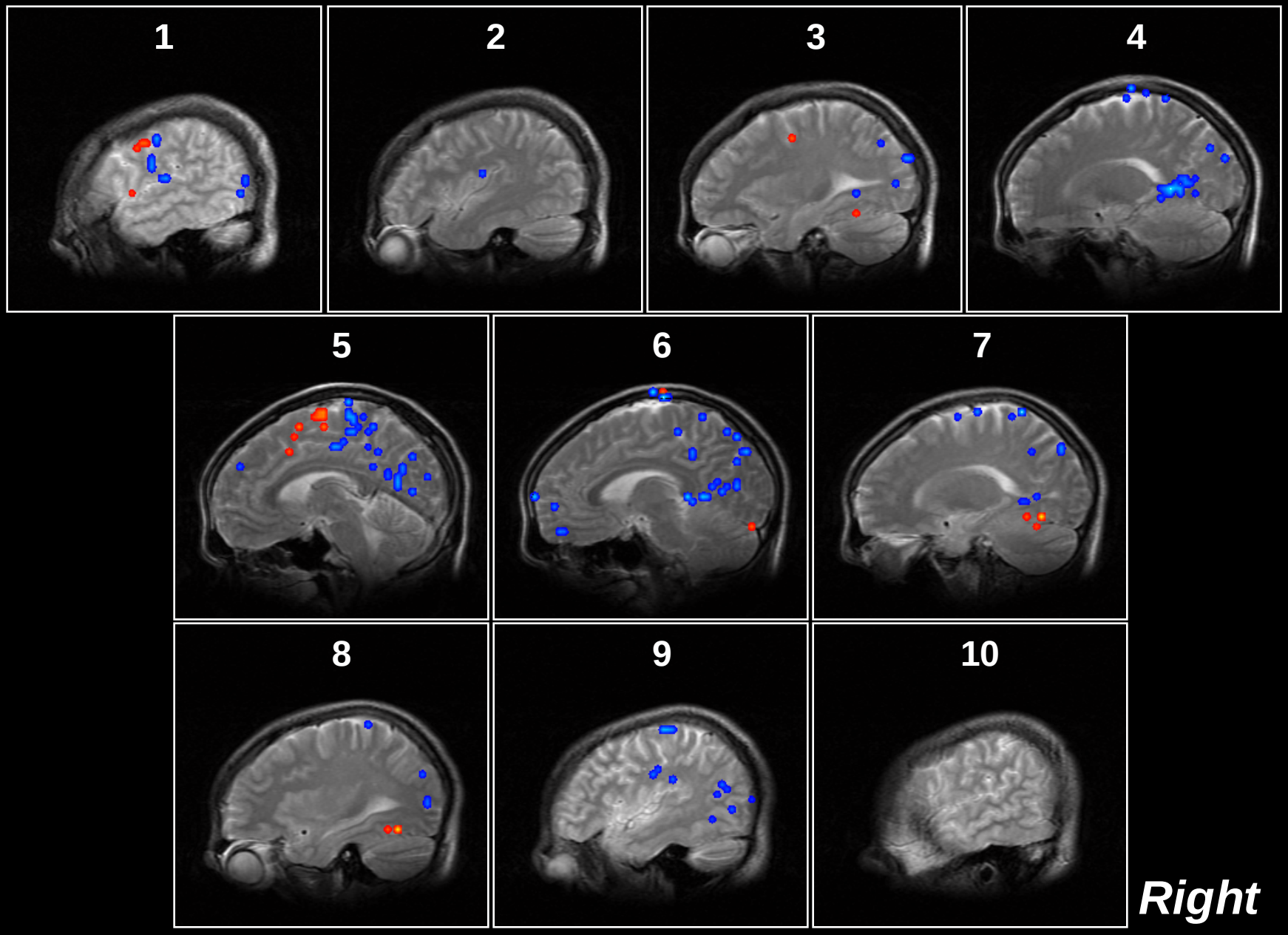
8
9
10
Right


Left
Imagined Complex Finger Movement on the Right Hand
1
2
3
4
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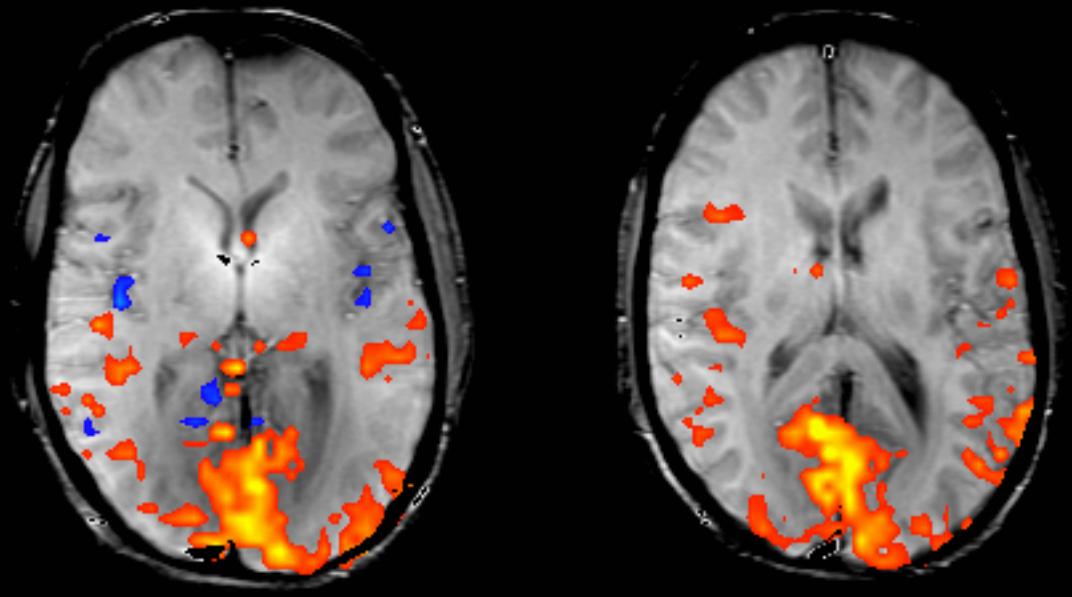
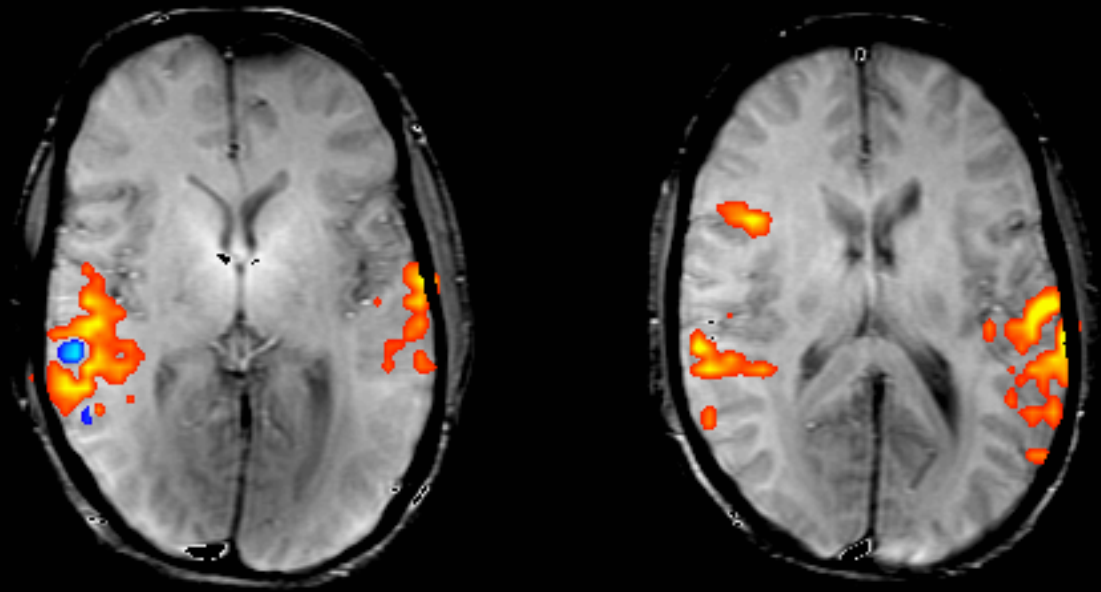
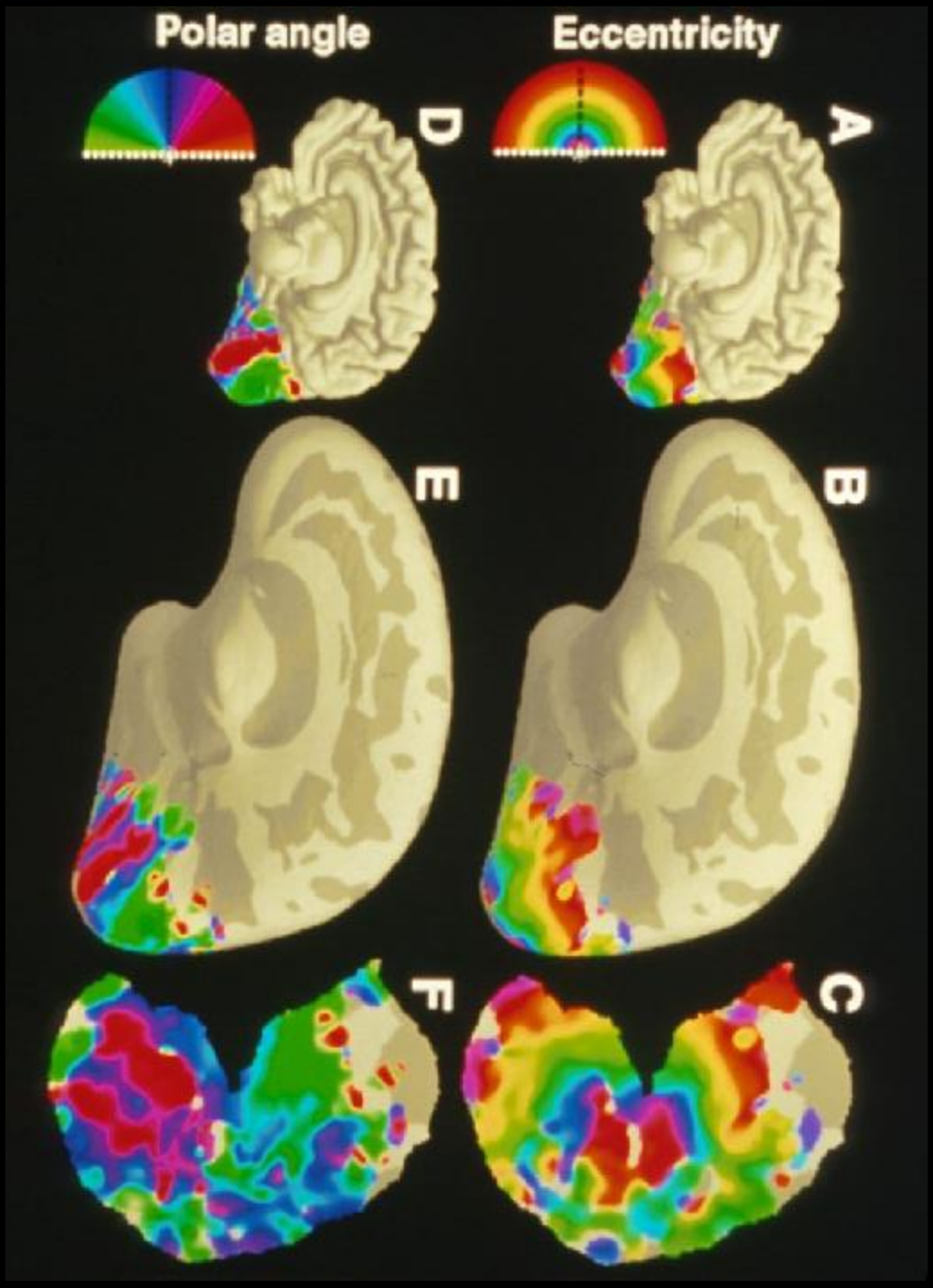
6
7
8
9
10
Right

Reading

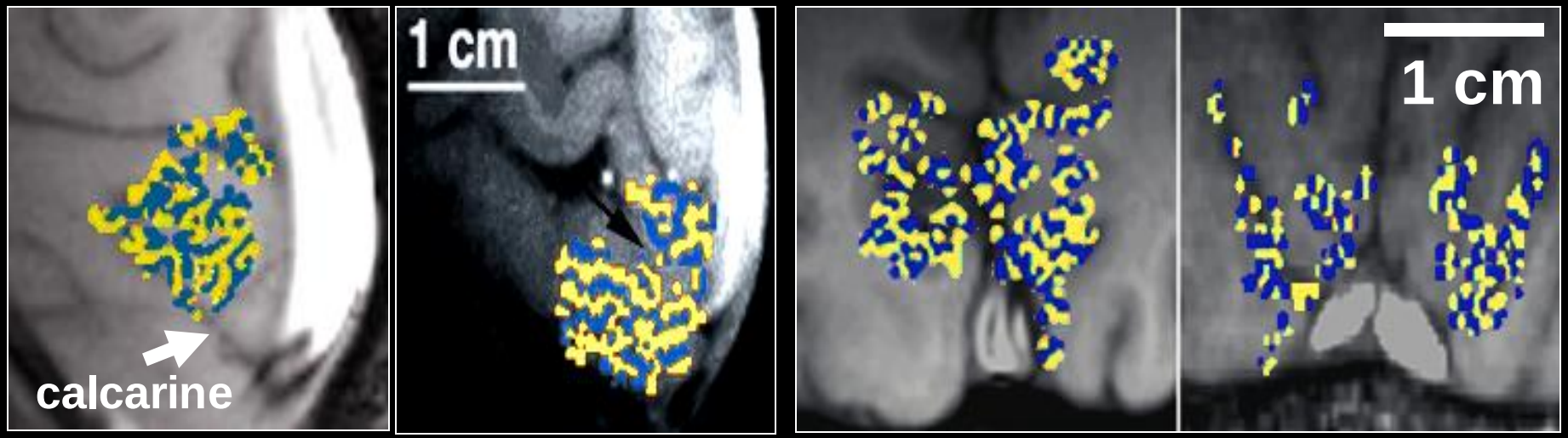


Listening




Polar angle
Eccentricity
D
A
E
B
F
C

ODC Maps using fMRI

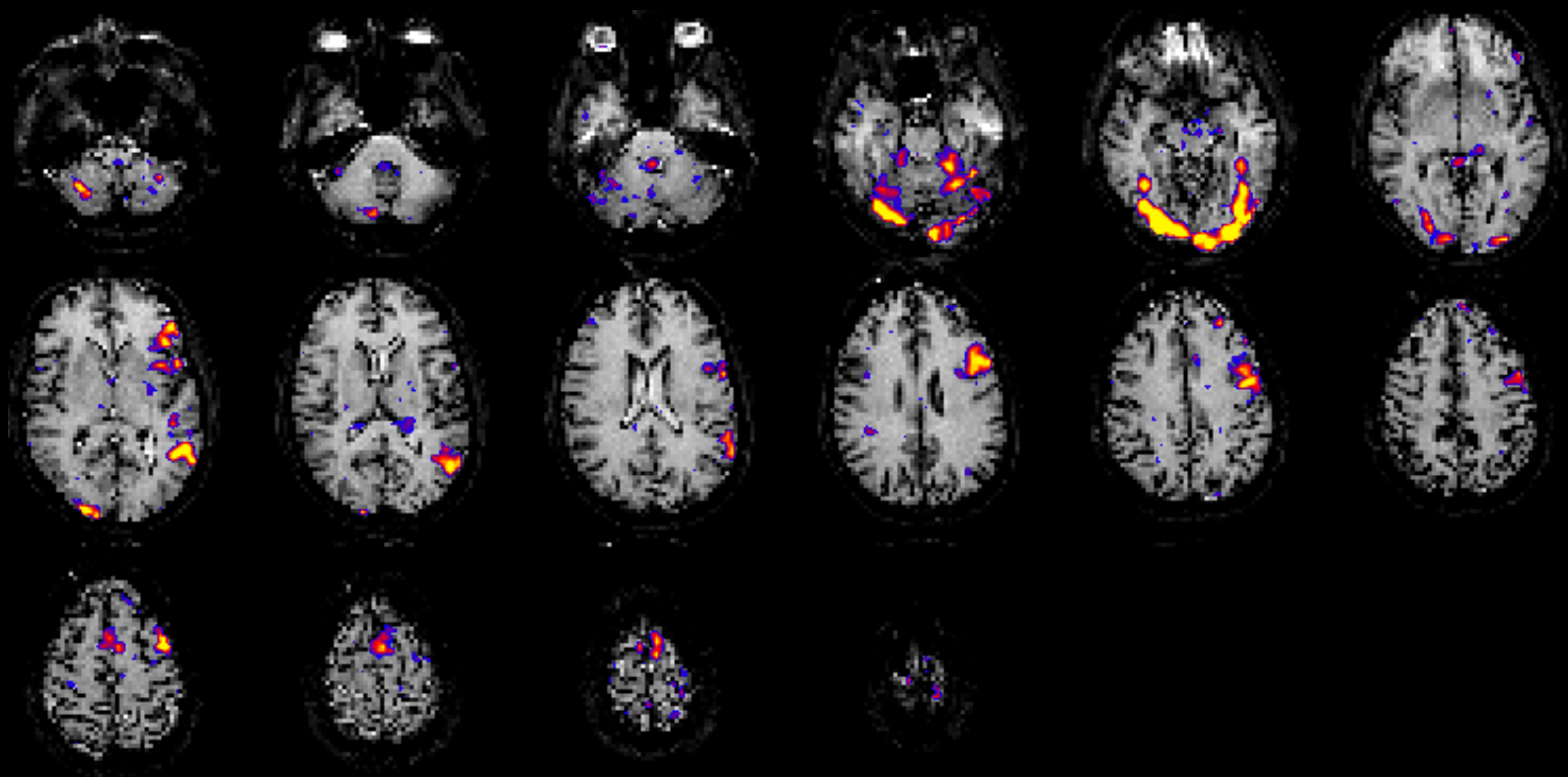


• Identical in size, orientation, and appearance to those obtained by optical imaging[1] and histology[3,4].

Menon et al.

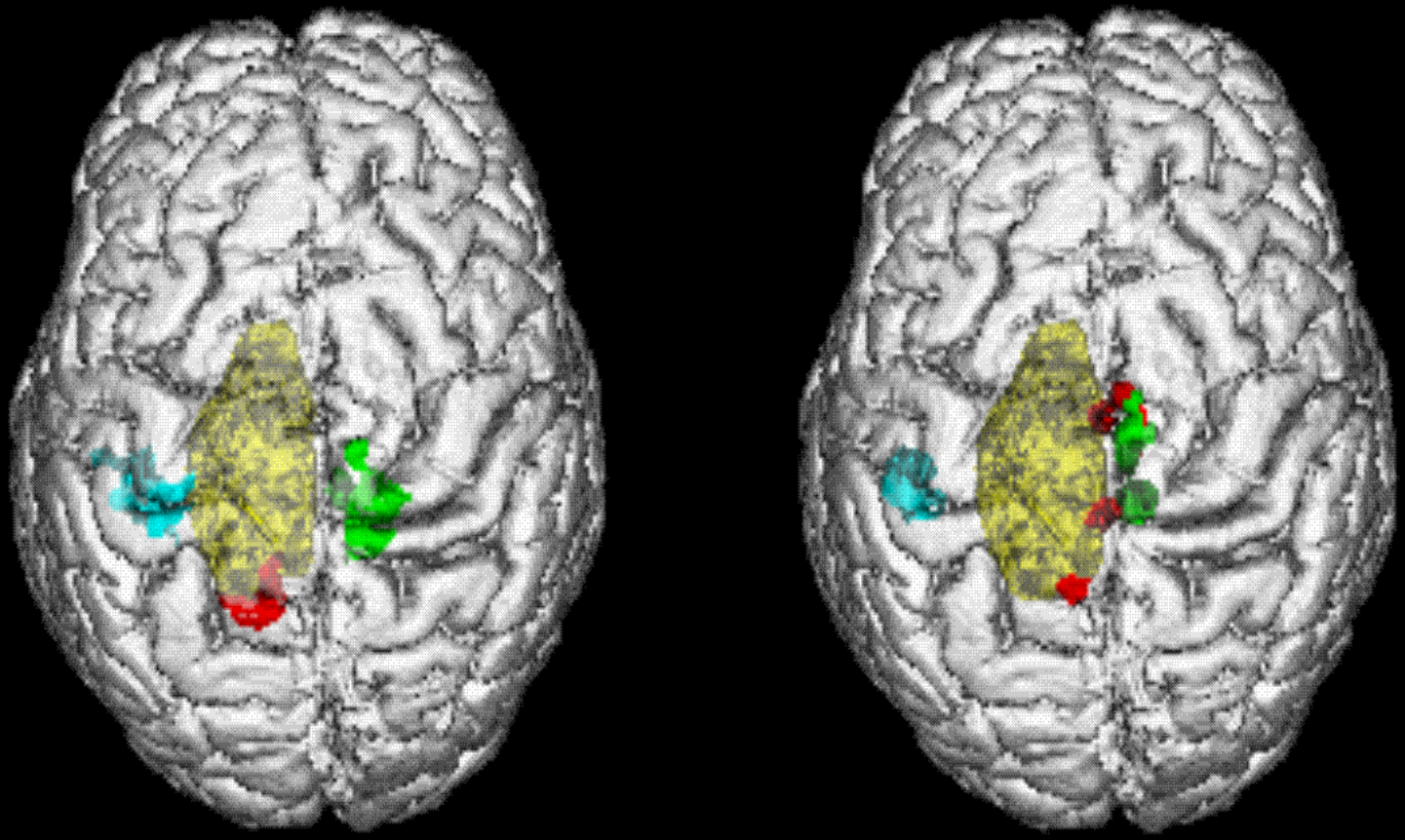
[1]Malonek D, Grinvald A. *Science* 272, 551-4 (1996).
[3]Horton JC, Hocking DR. *J Neurosci* 16, 7228-39 (1996).
[4]Horton JC, et al. *Arch Ophthalmol* 108, 1025-31 (1990).

Word stem completion



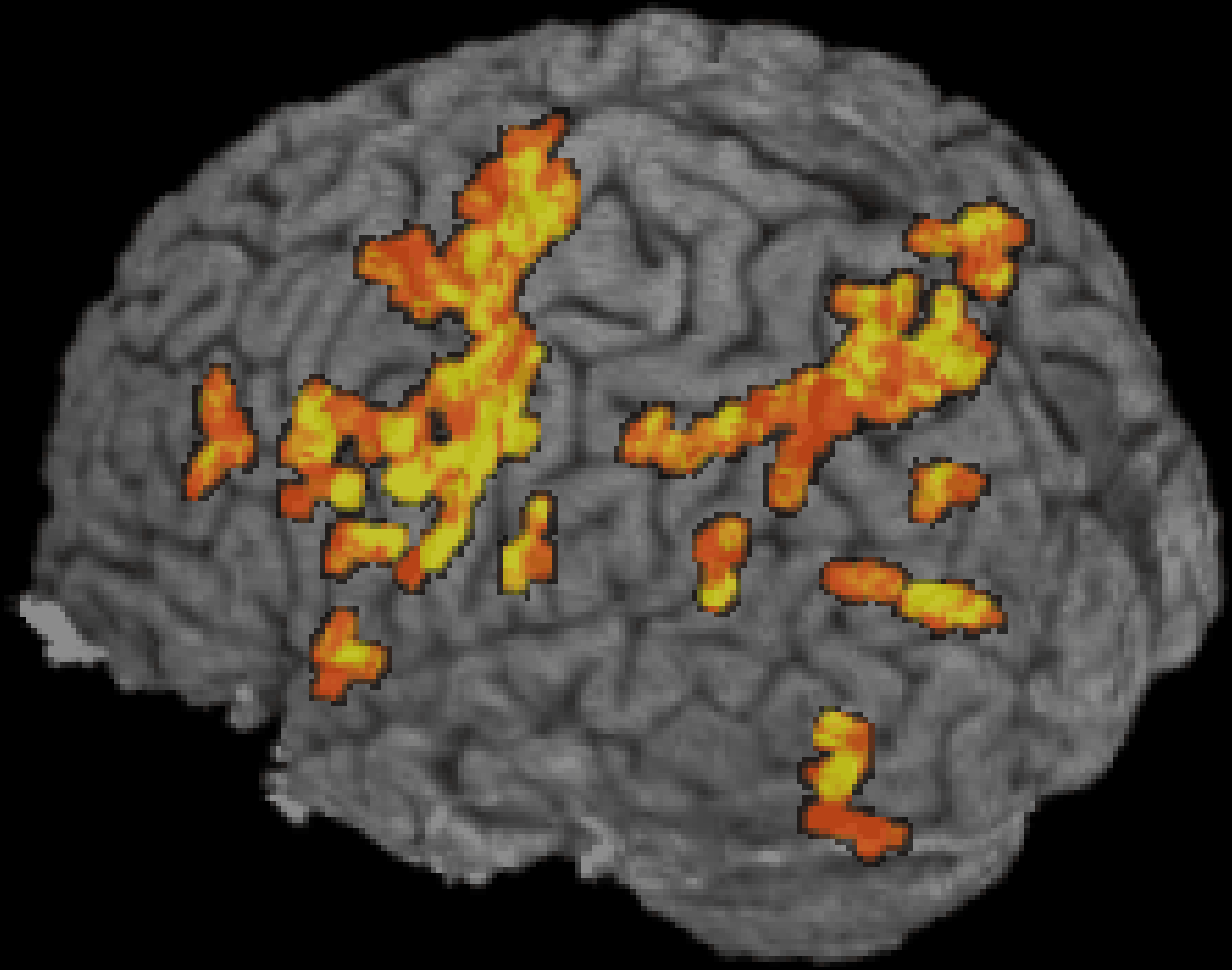
Presurgical Mapping

Left Foot Tumor Right Foot Right Hand



fMRI O-15 PET

End of Acquisition



< 1 s to render

Blocked trials:
20 s on/20 s off
8 blocks

Blocks: 12345678

Color shows
through brain

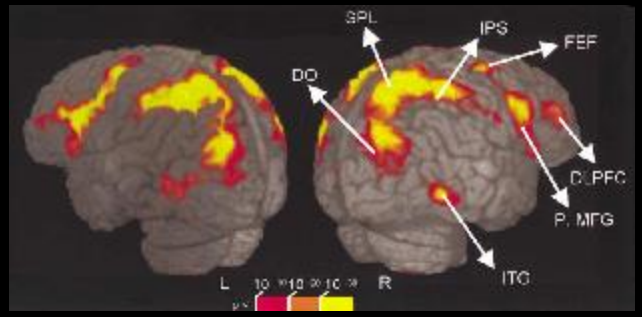
Correlation > 0.45

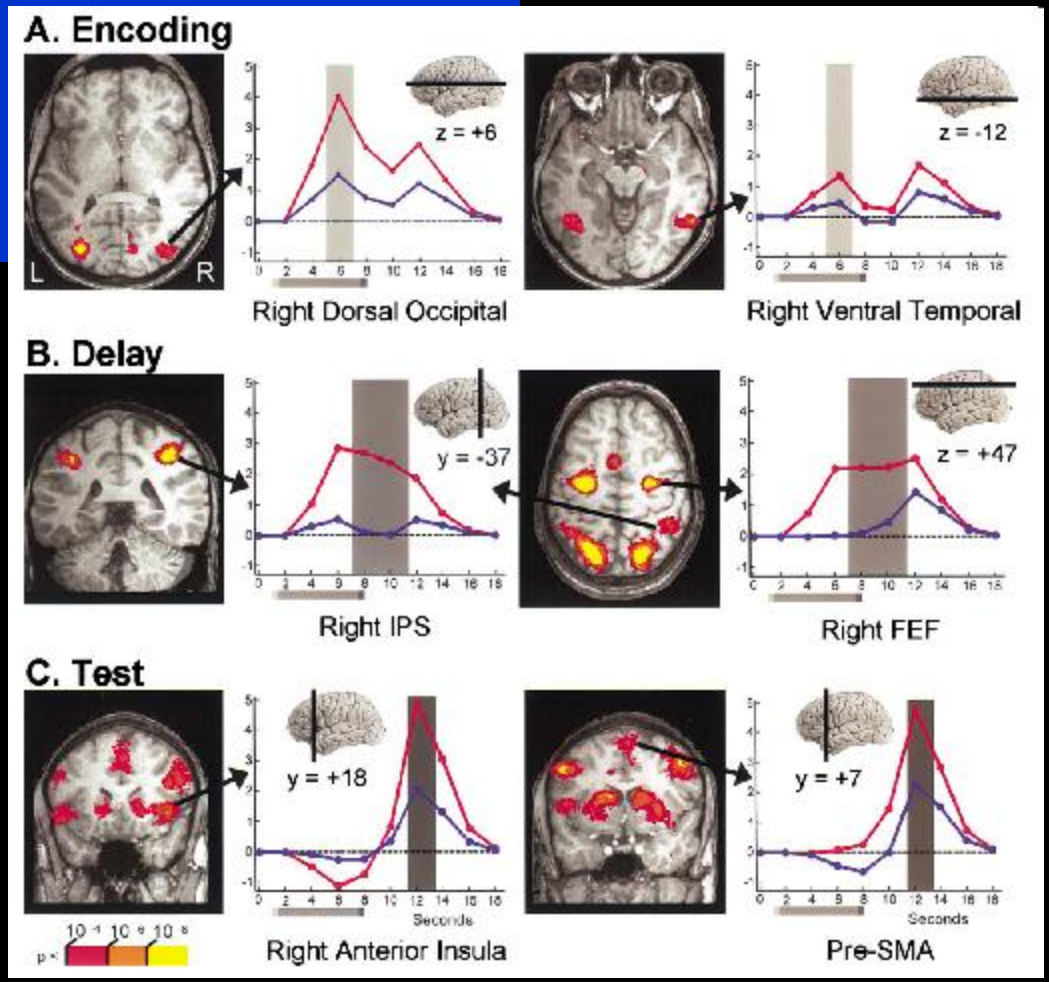
The End

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

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

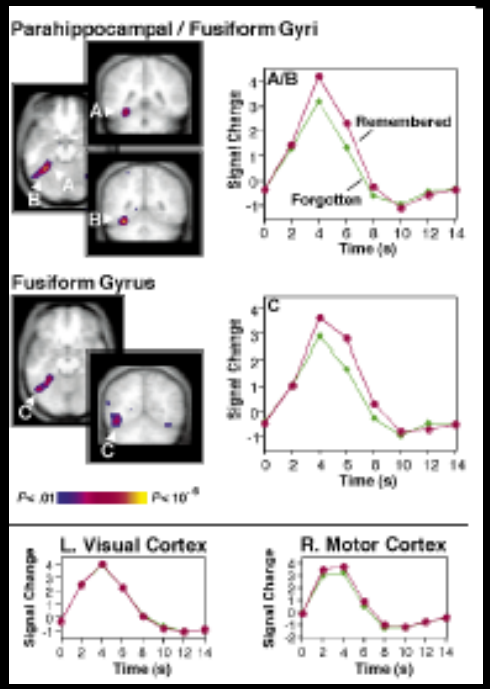
Luiz Pessoa,[1] Eva Gutierrez, Peter A. Bandettini, and Leslie G. Ungerleider
Laboratory of Brain and Cognition
National Institute of Mental Health
National Institutes of Health
Bethesda, Maryland 20892

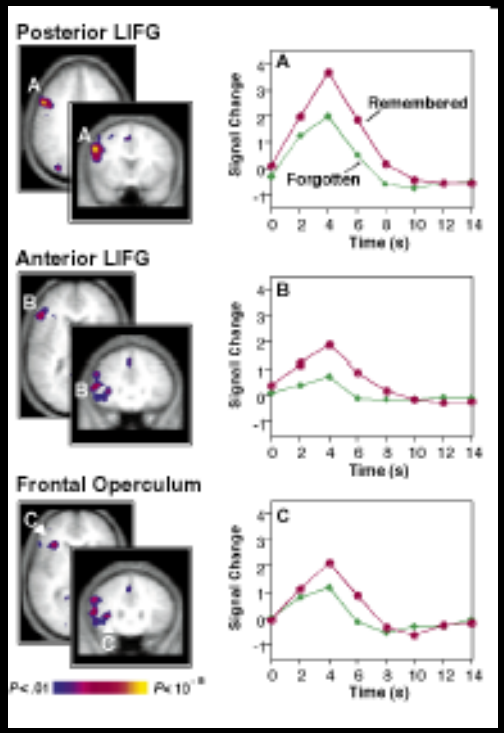




Building Memories: Remembering and Forgetting of Verbal Experiences as Predicted by Brain Activity

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

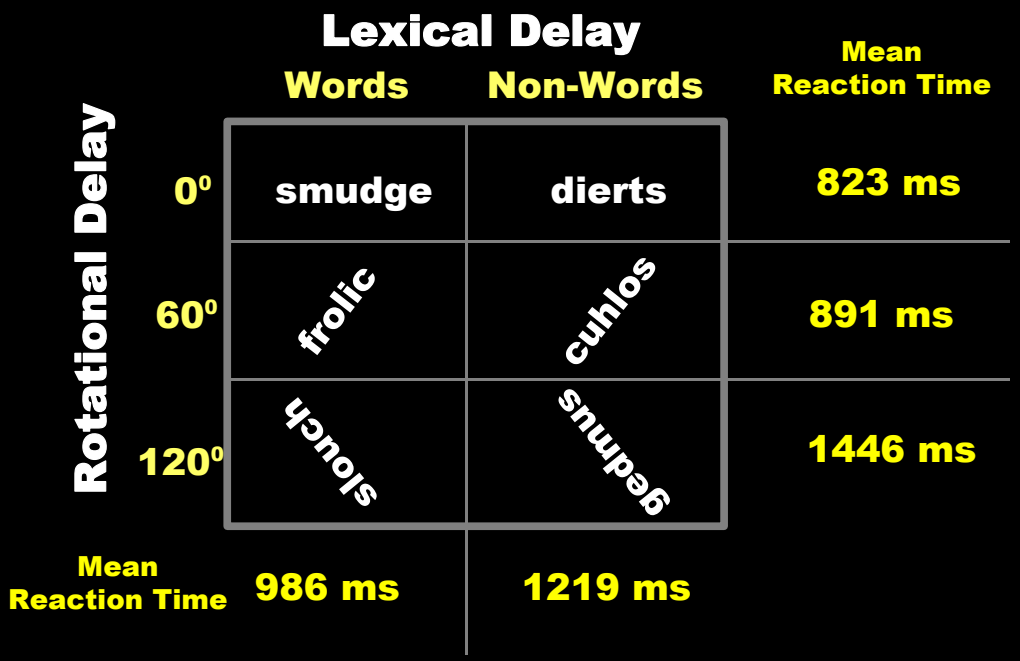
Cognitive Neuroscience Application:

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*

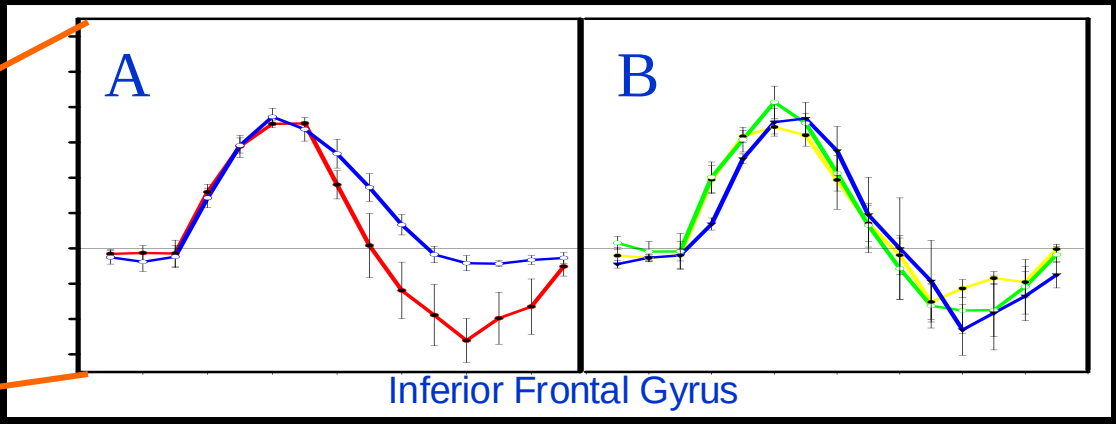
*Laboratory of Brain and Cognition and ‡Scientific and Statistical Computing Core, National Institute of Mental Health, Bethesda, MD 20892

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

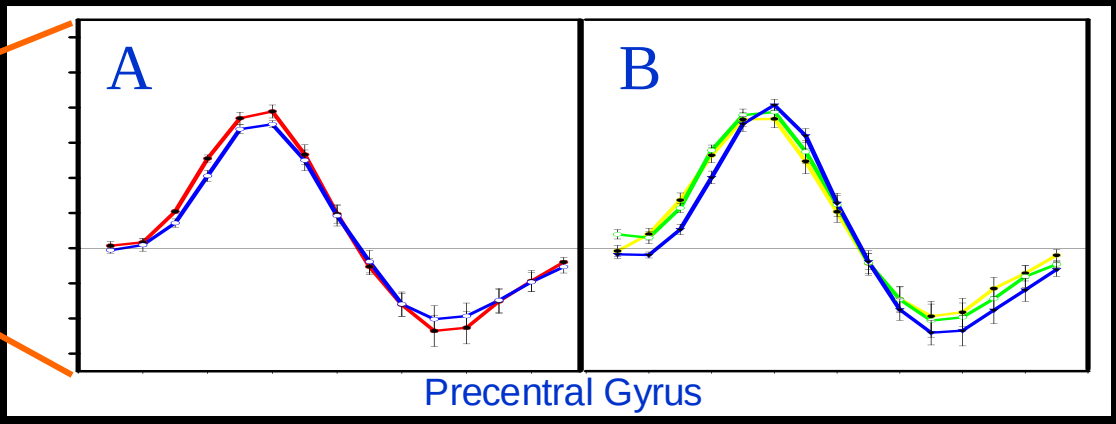


Word vs. Non-word 0°, 60°, 120° Rotation

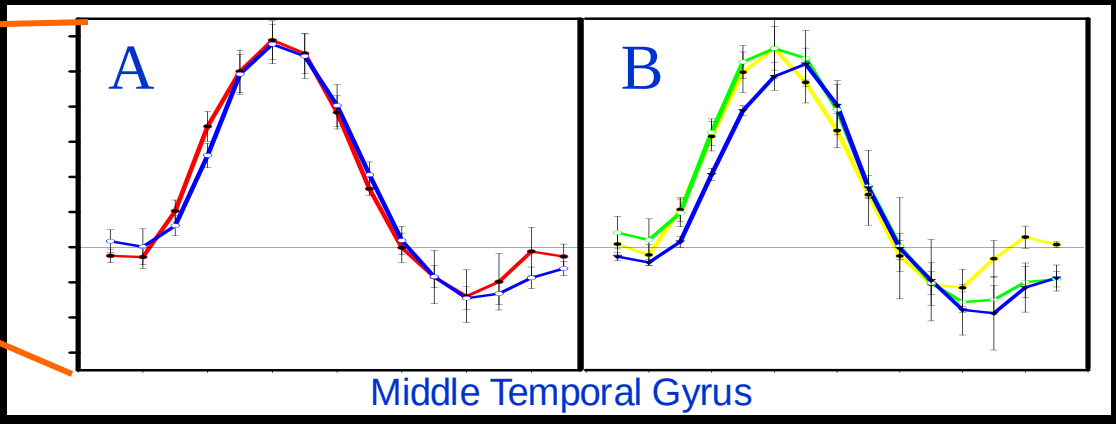
Regions of Interest



Inferior Frontal Gyrus



Precentral Gyrus

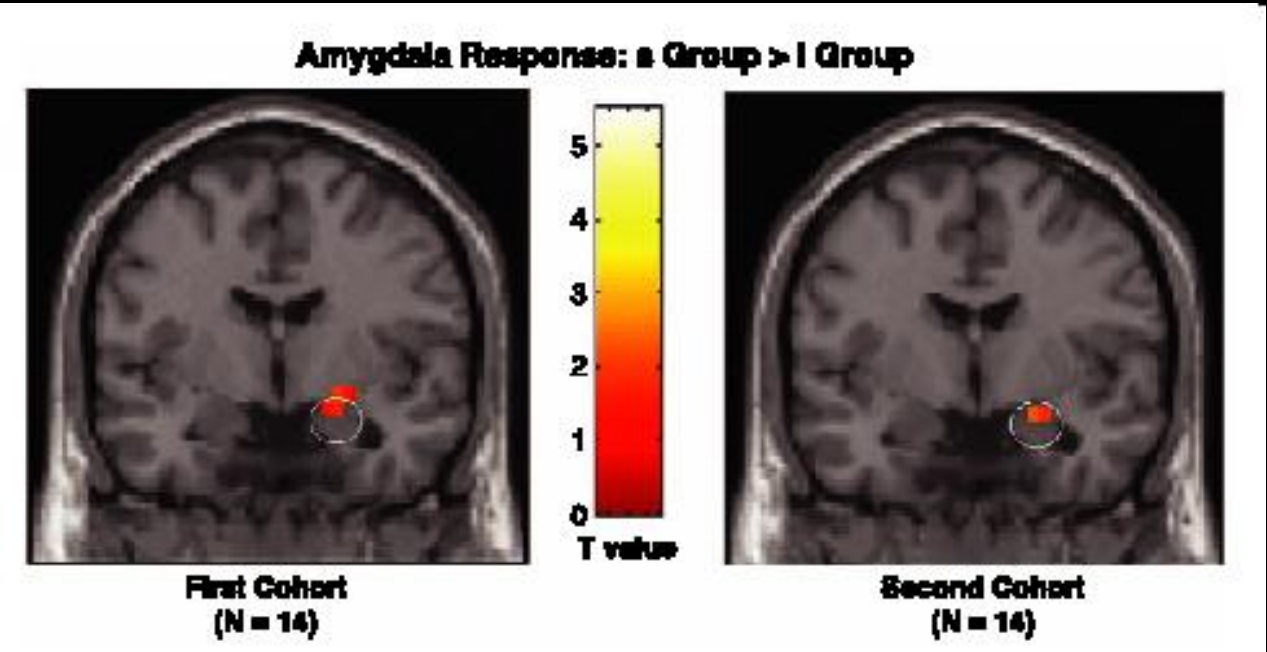


Middle Temporal Gyrus

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) ◆
DOI 10.1002/hbm.10020

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]

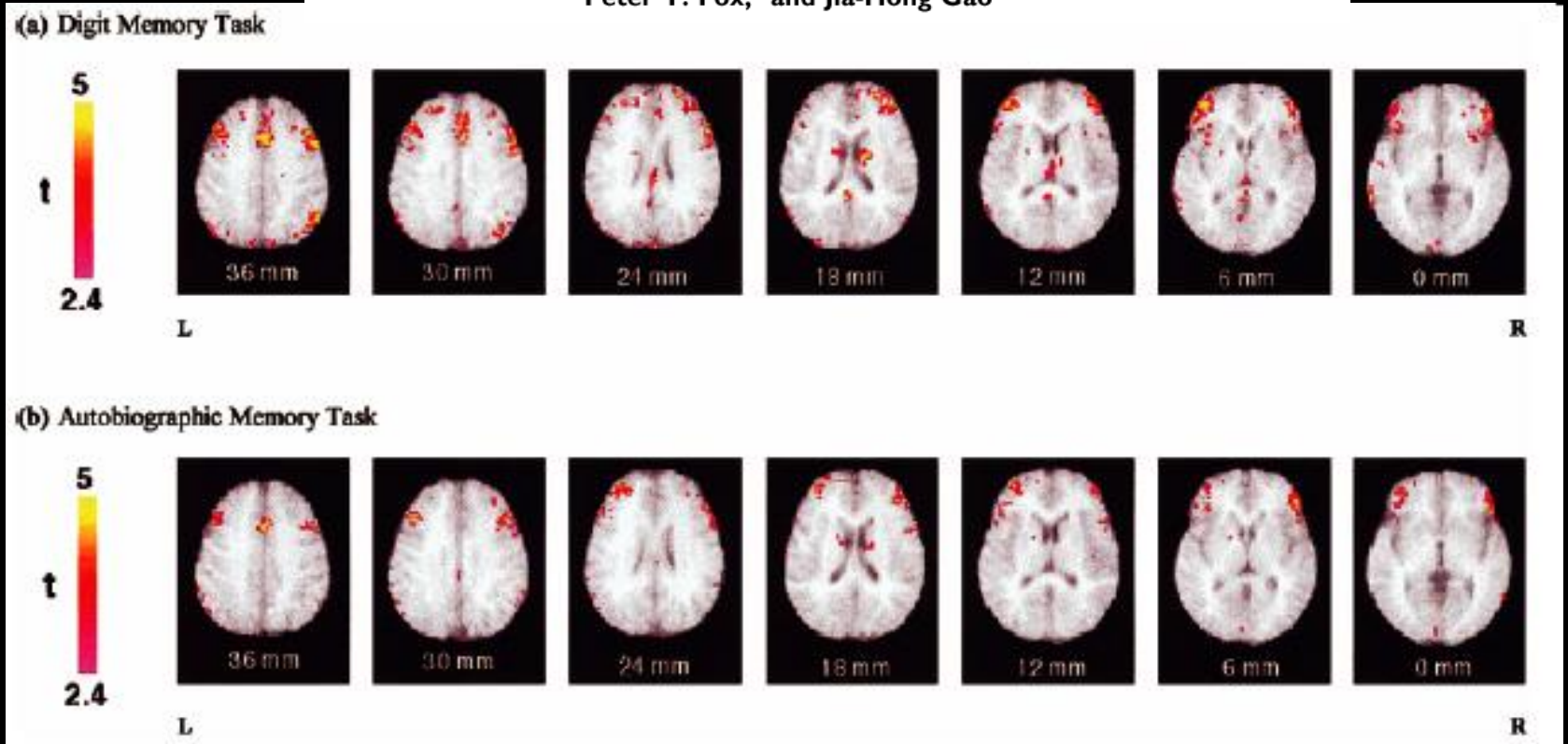


Figure 1.

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.

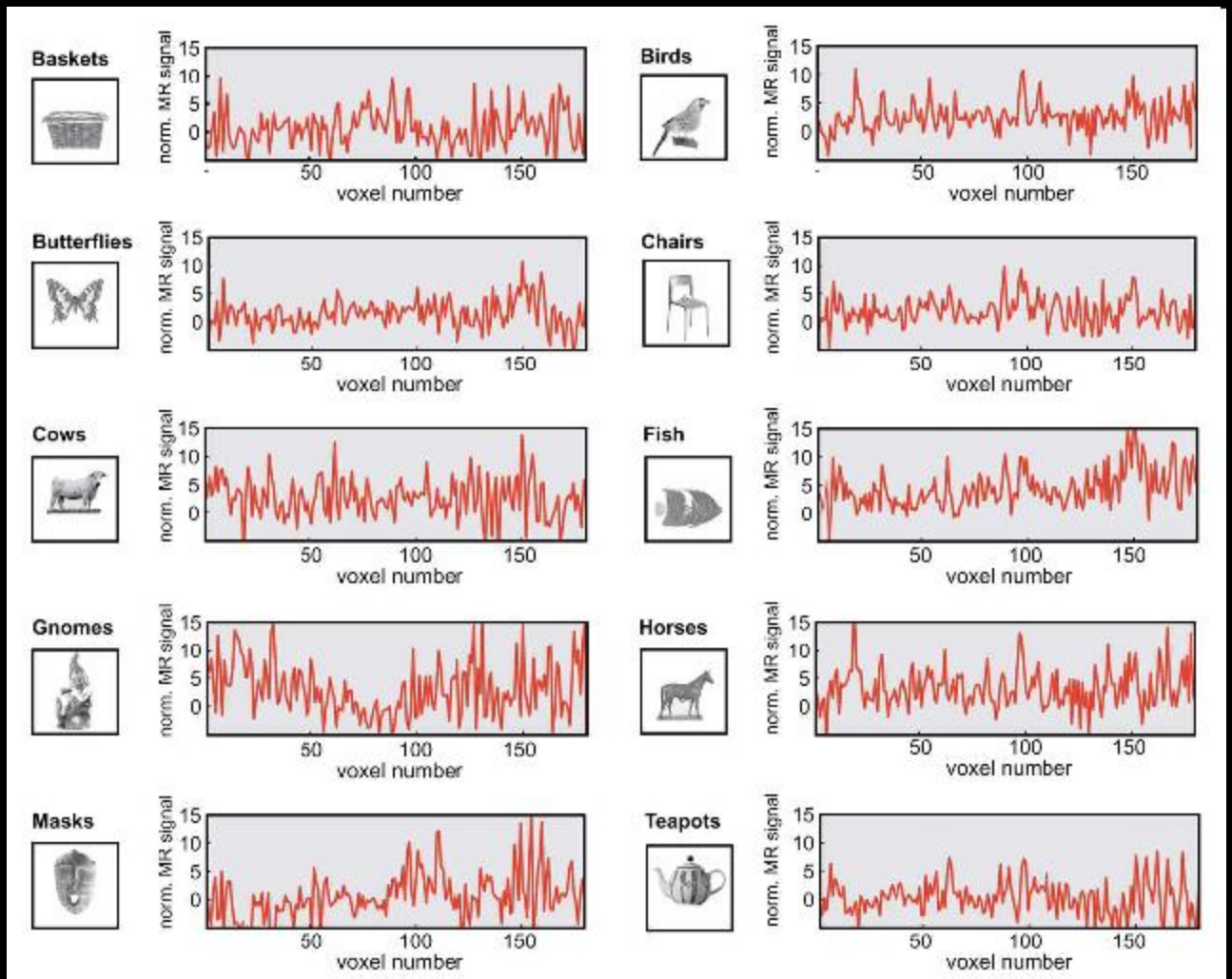
Functional magnetic resonance imaging (fMRI) "brain reading": detecting and classifying distributed patterns of fMRI activity in human visual cortex

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

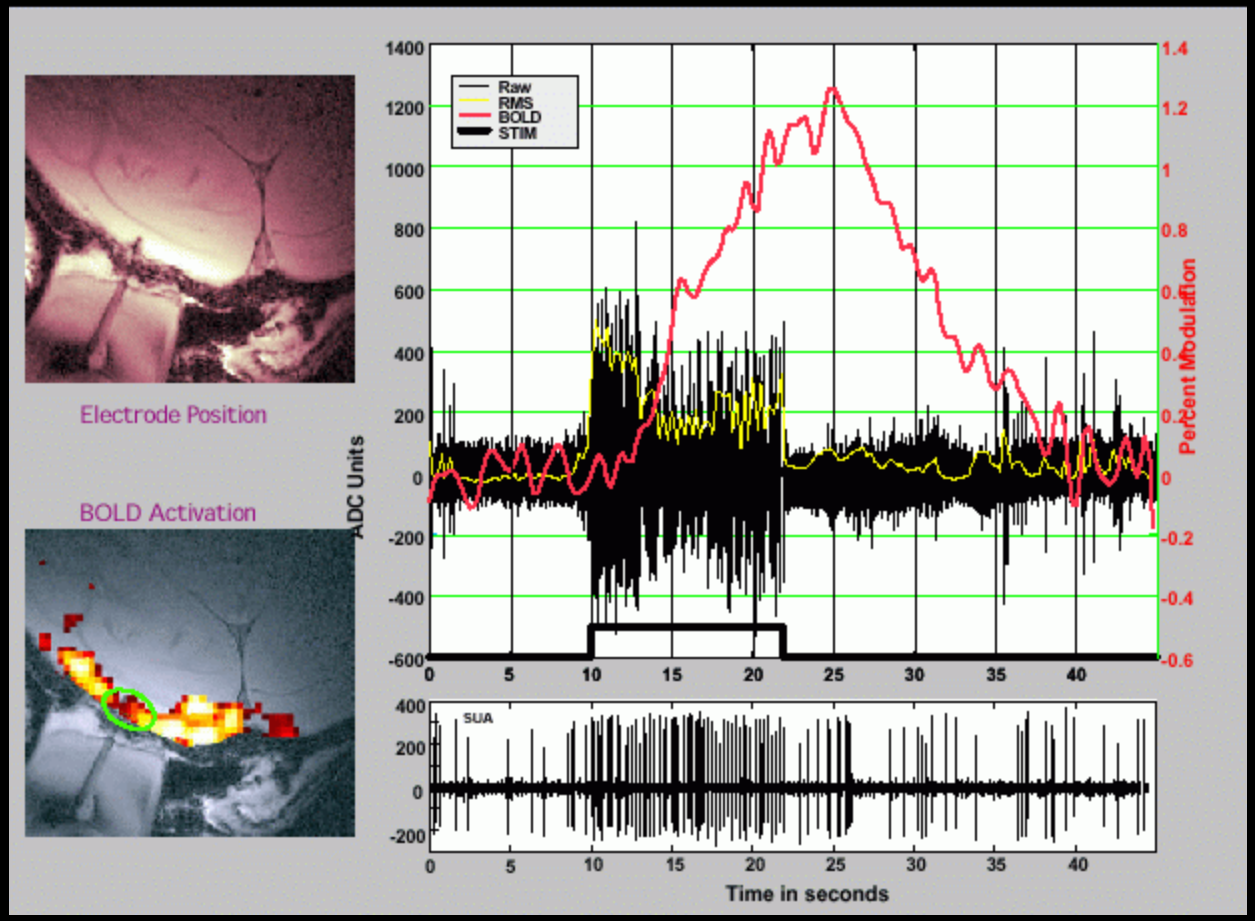
[a] Rowland Institute for Science, Cambridge, MA 02142, USA
[b] Athinoula A. Martinos Center for Structural and Functional Biomedical Imaging, Charlestown, MA 02129, USA
[c] HyperVision, Inc., P.O. Box 158, Lexington, MA 02420, USA

Received 15 July 2002; accepted 10 December 2002

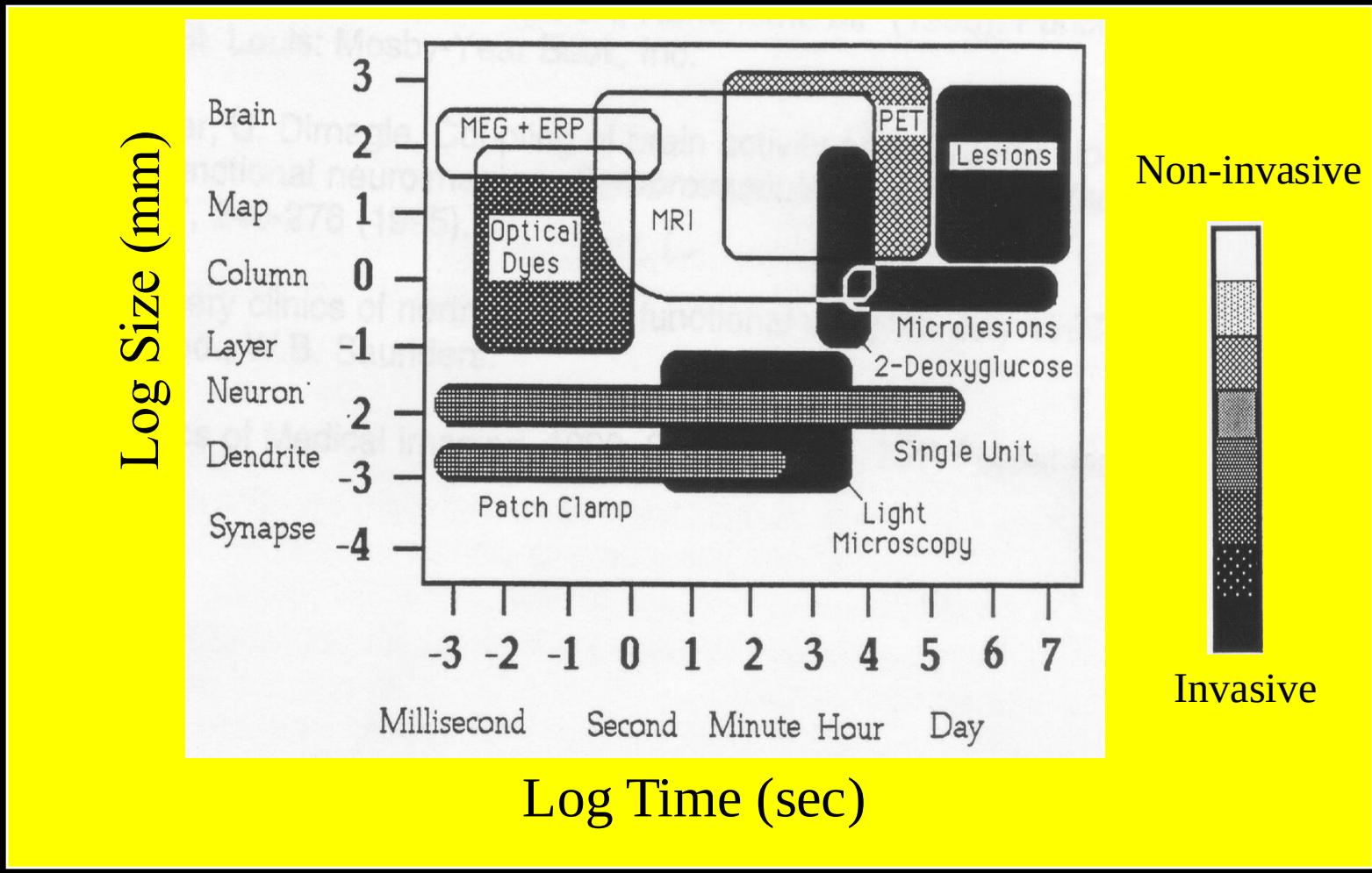
NEUROIMAGE 19 (2): 261-270 Part 1 JUN 2003

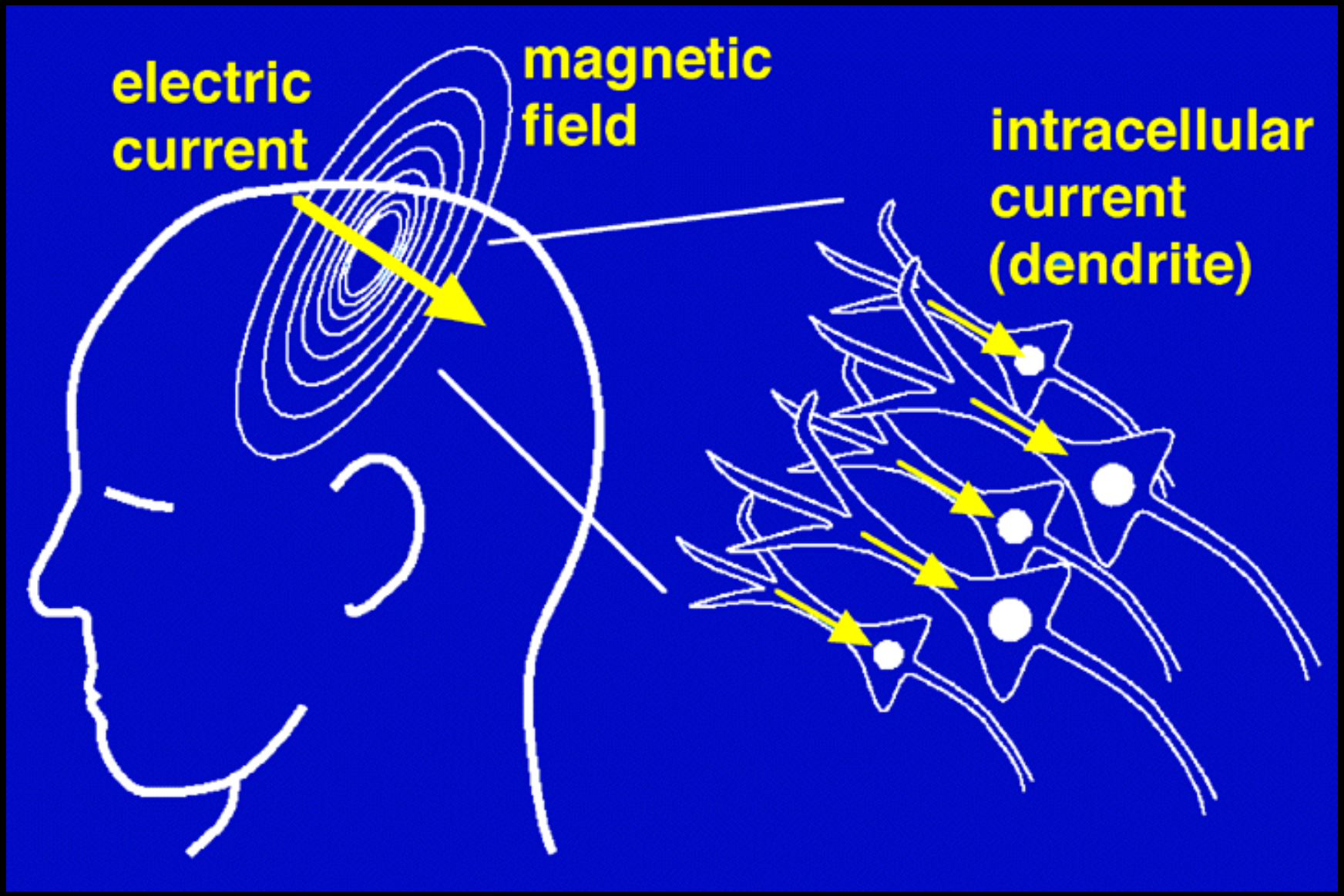


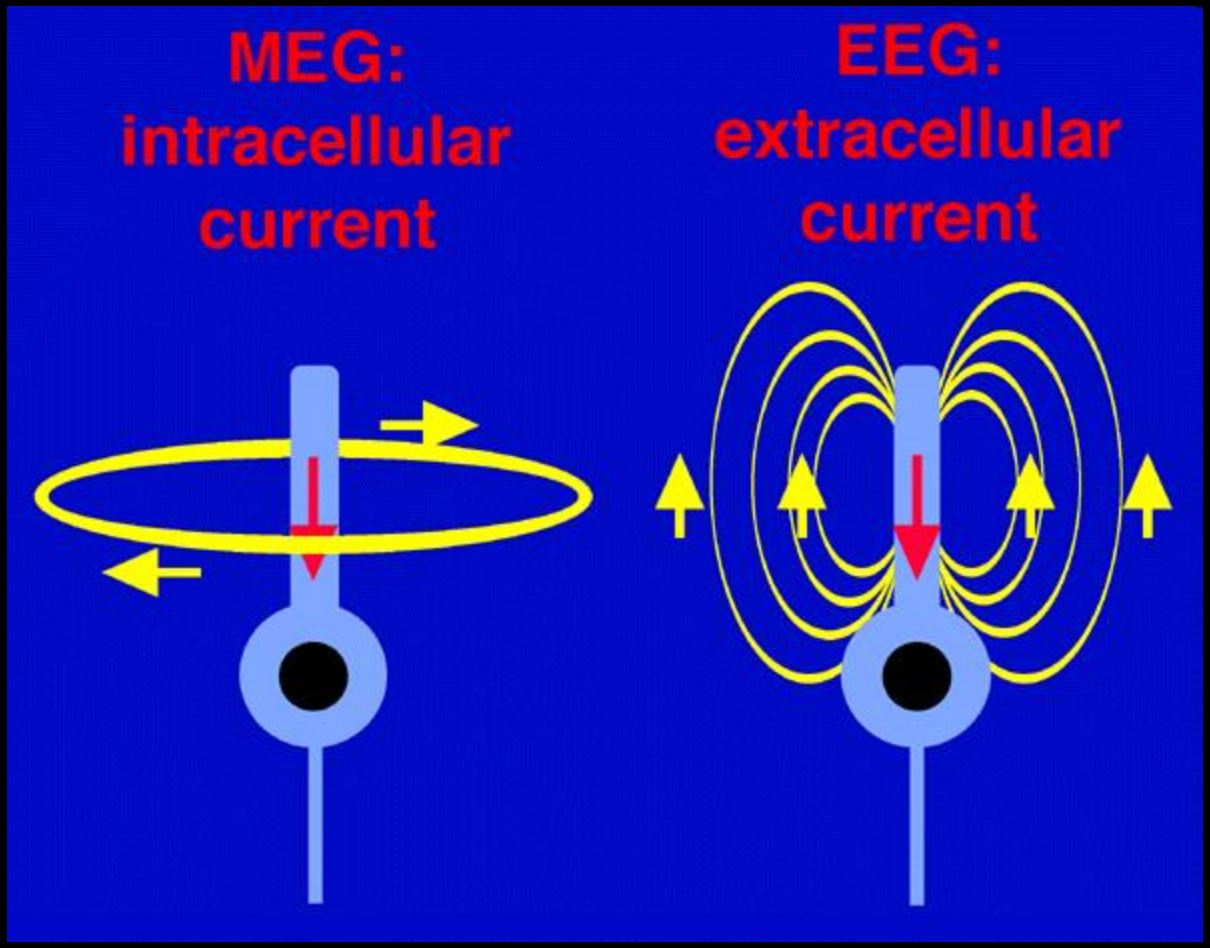
Combined Electrophysiological Measurement and fMRI

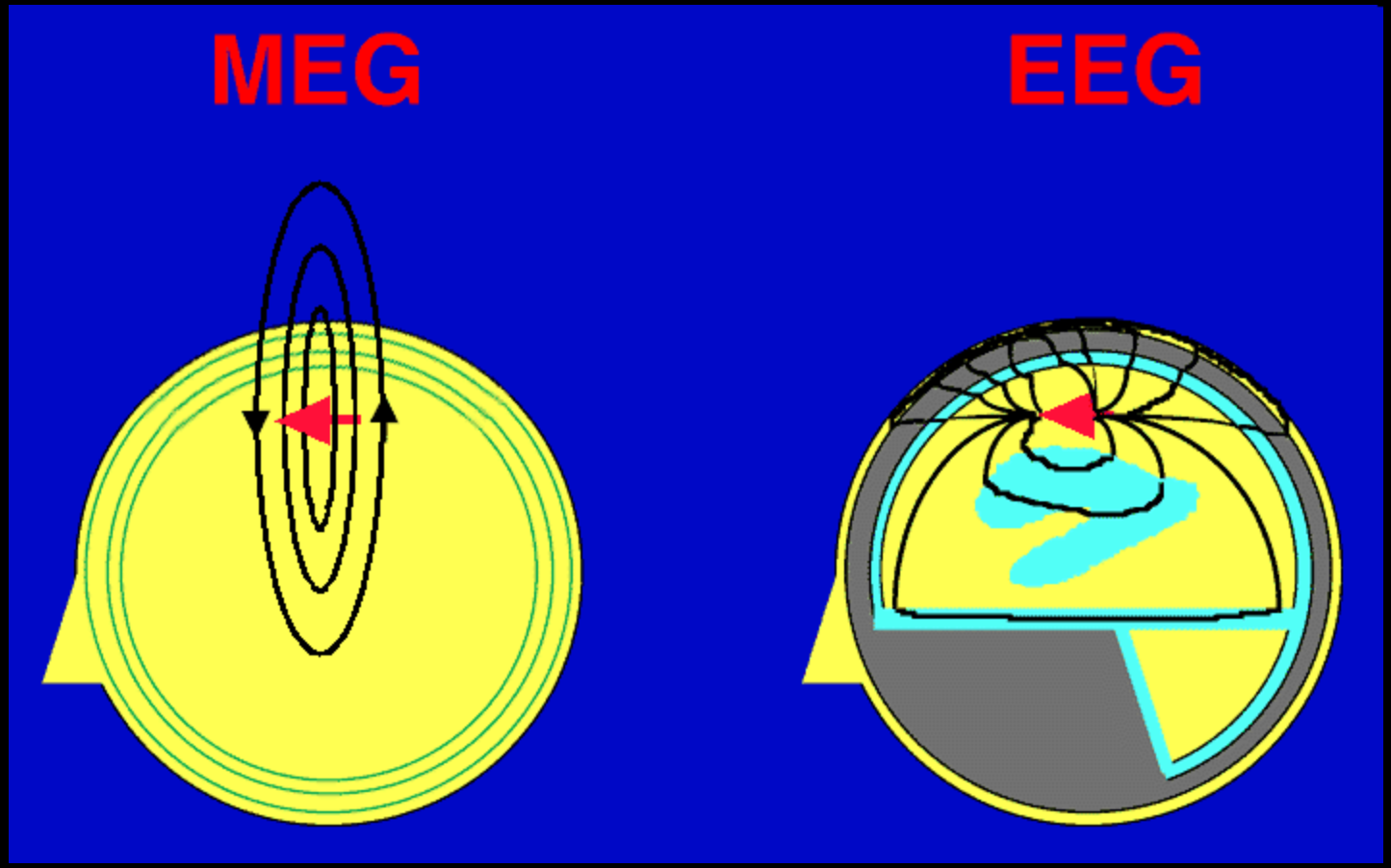


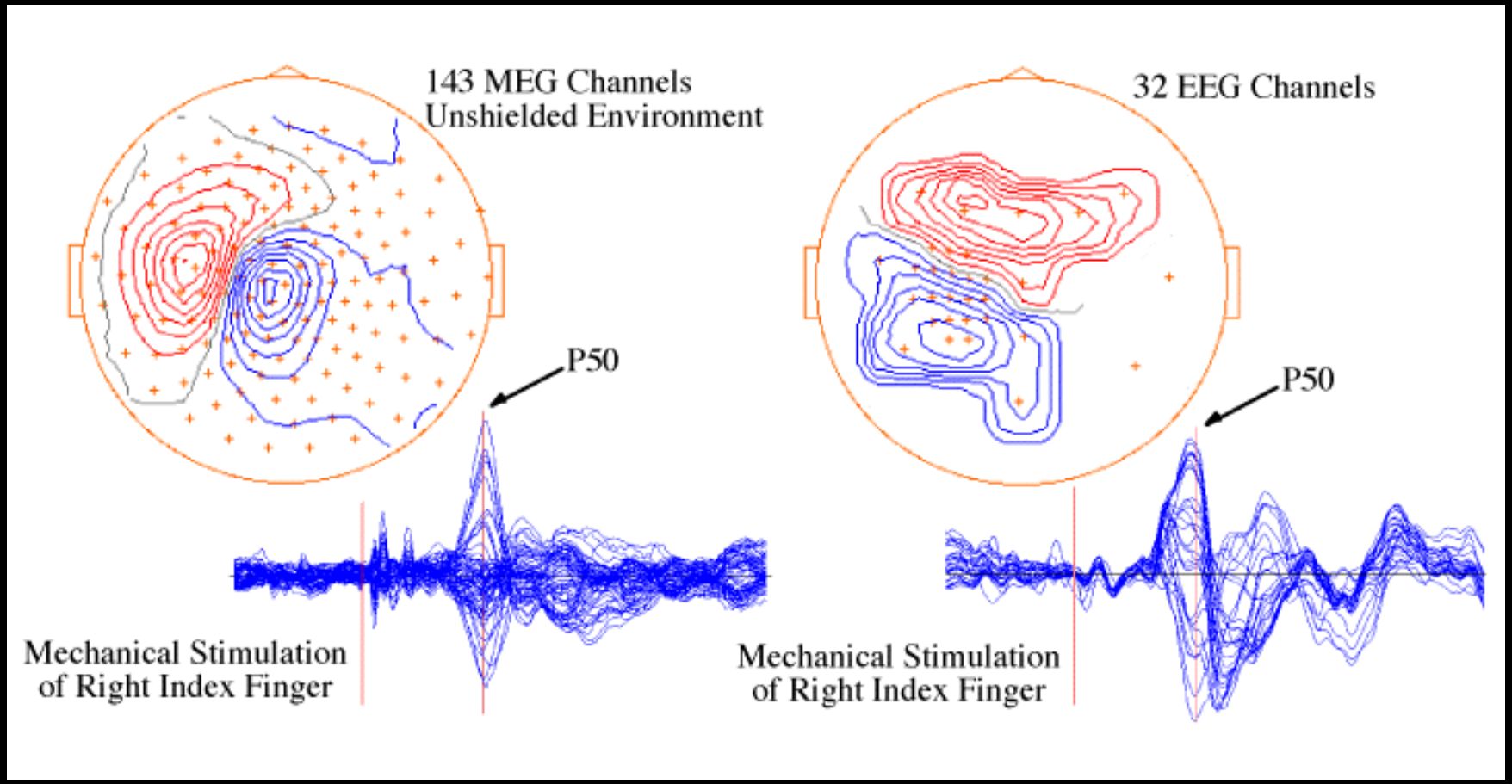
Functional Neuroimaging Techniques

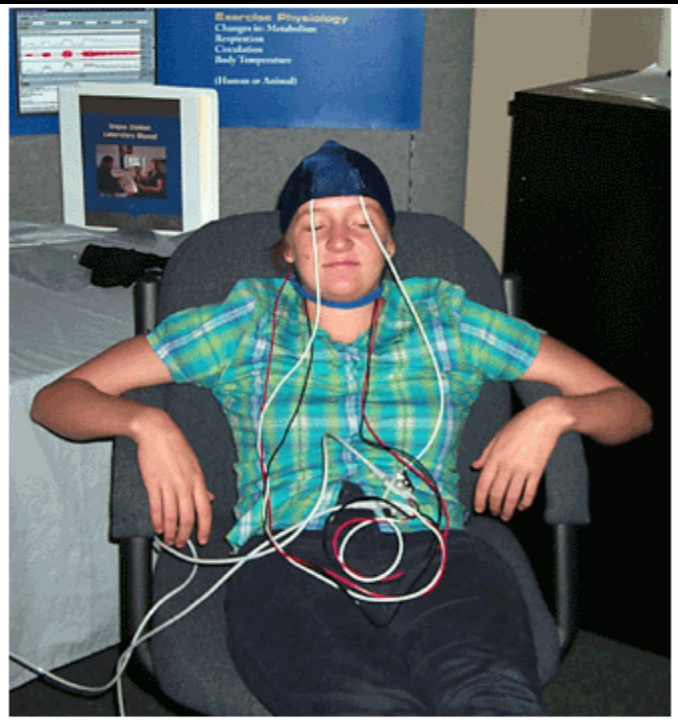


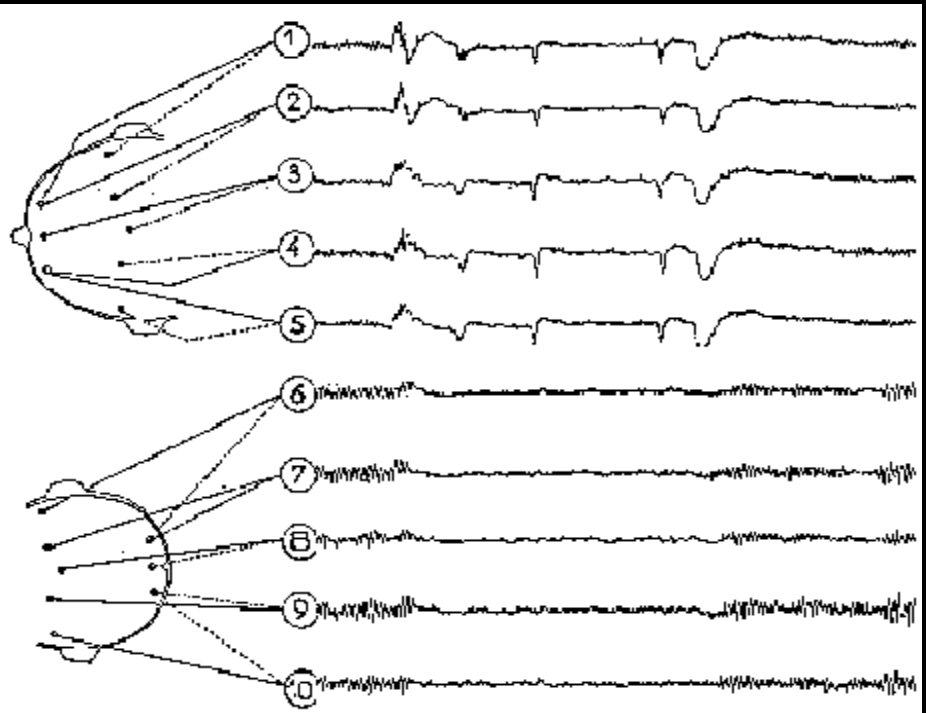

electric
current
magnetic
field
intracellular
current
(dendrite)


MEG:
intracellular
current
EEG:
extracellular
current


MEG
EEG


143 MEG Channels
Unshielded Environment
P50
Mechanical Stimulation
of Right Index Finger
32 EEG Channels
P50
Mechanical Stimulation
of Right Index Finger


Exercise Physiology
Changes in Metabolism
Respiration
Circulation
Body Temperature
(Human or Animal)


1
2
3
4
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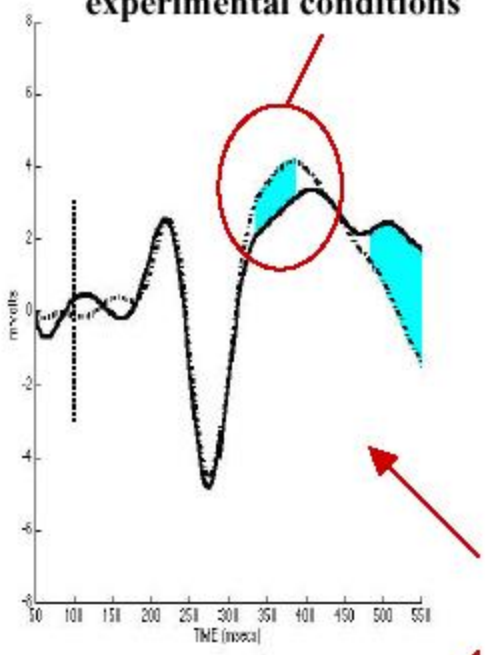
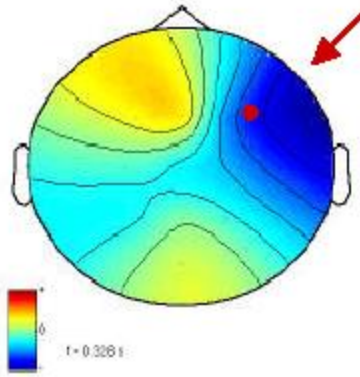
7
8
9
0

Electroencephalograghy (EEG) recording

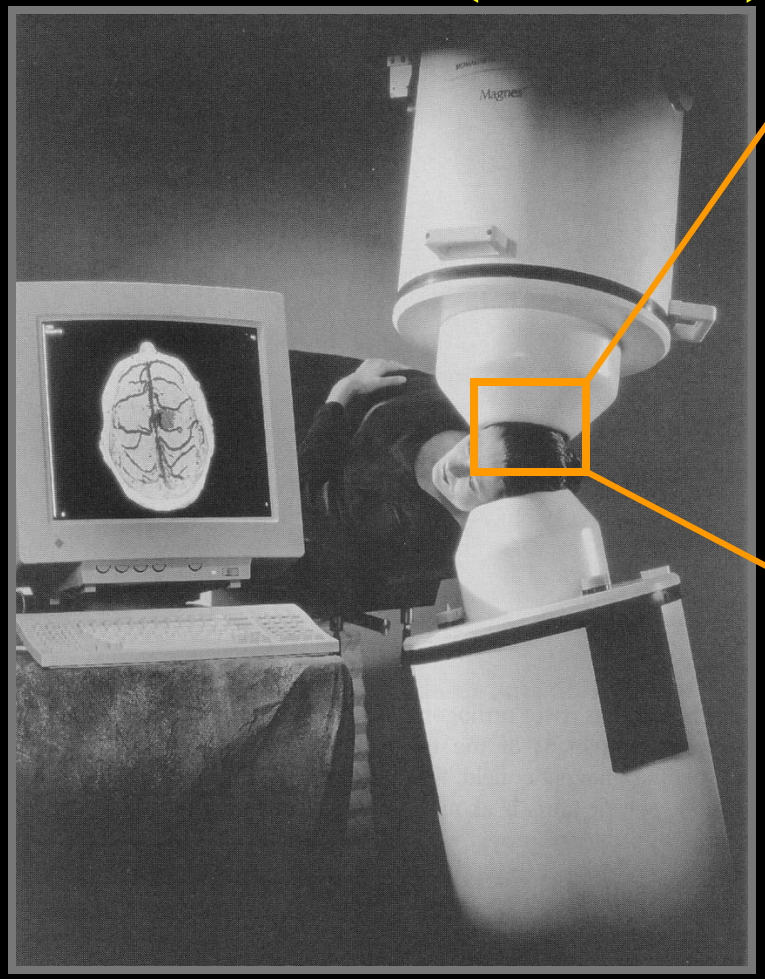
Statistical (T test) between two experimental conditions

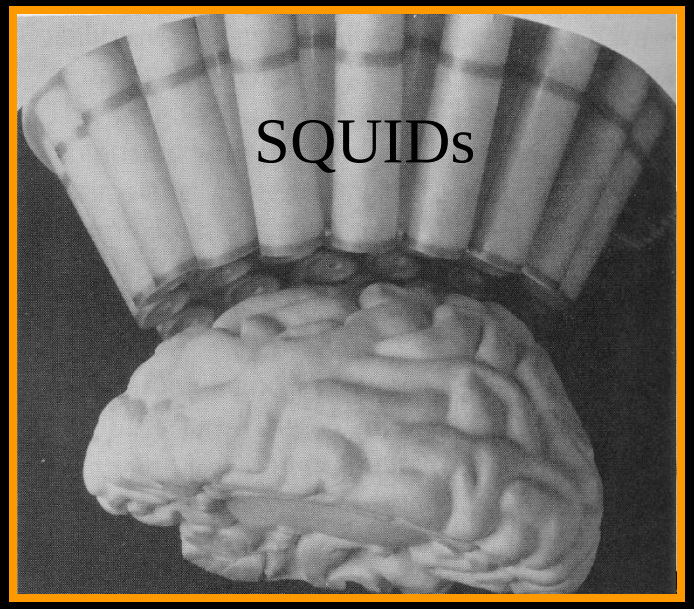


F4



Magnetoencephalography (MEG)

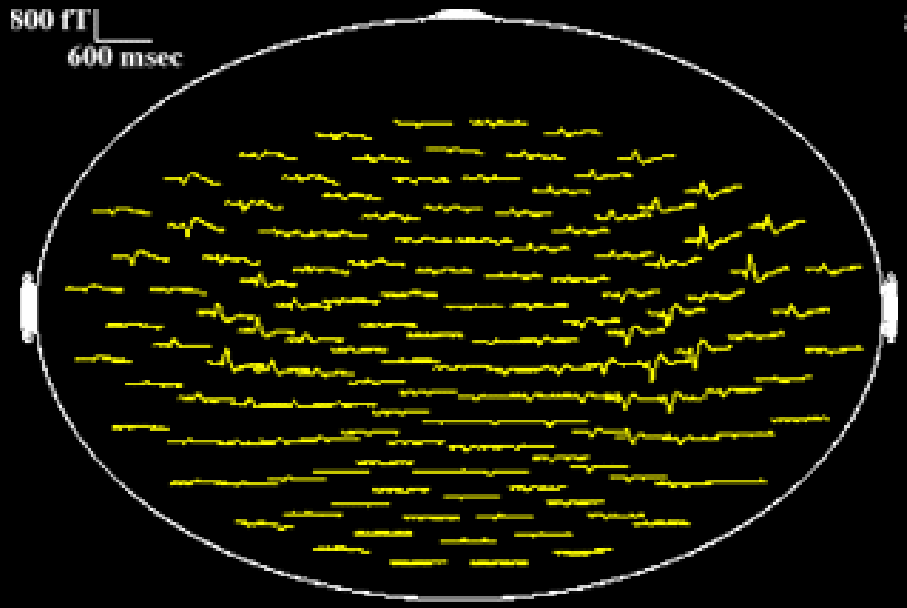


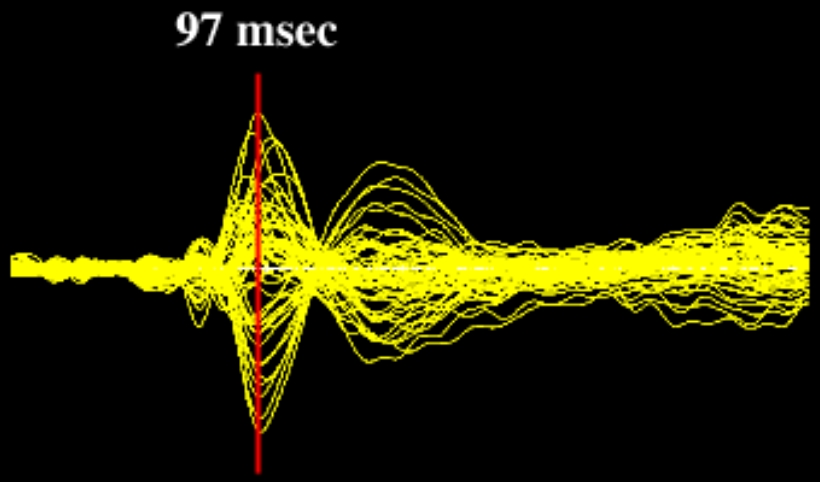


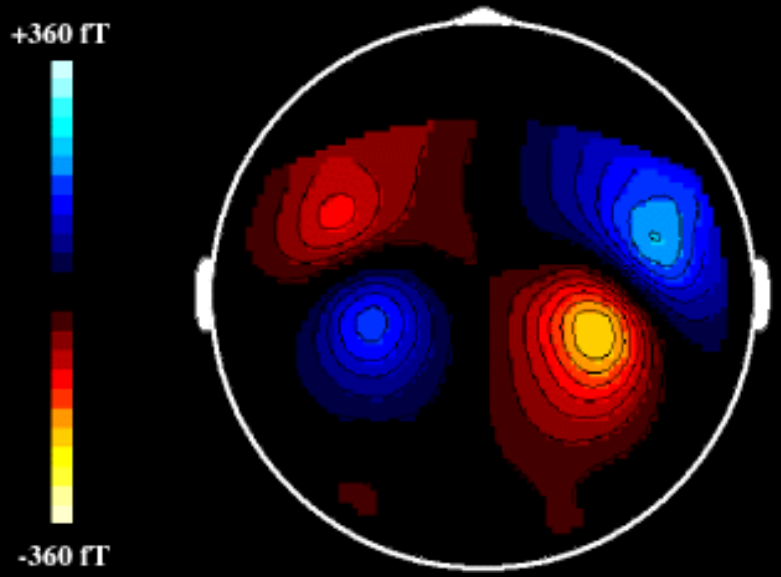
SQUID:
Superconducting Quantum Interference Device

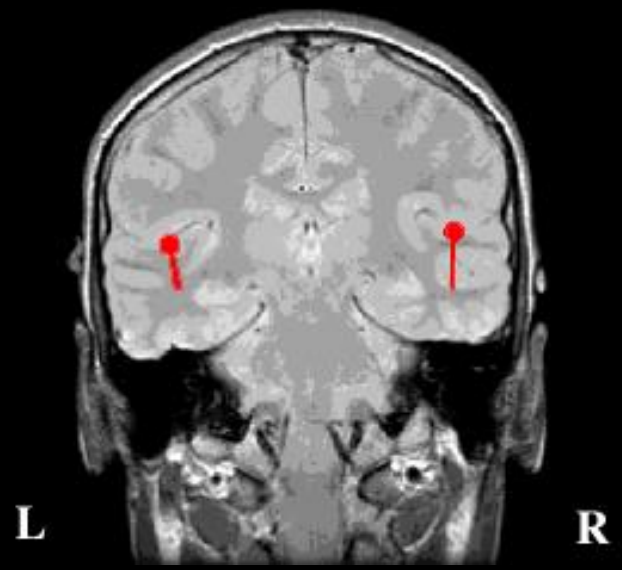
Combined MEG and EEG

MEG Mapping

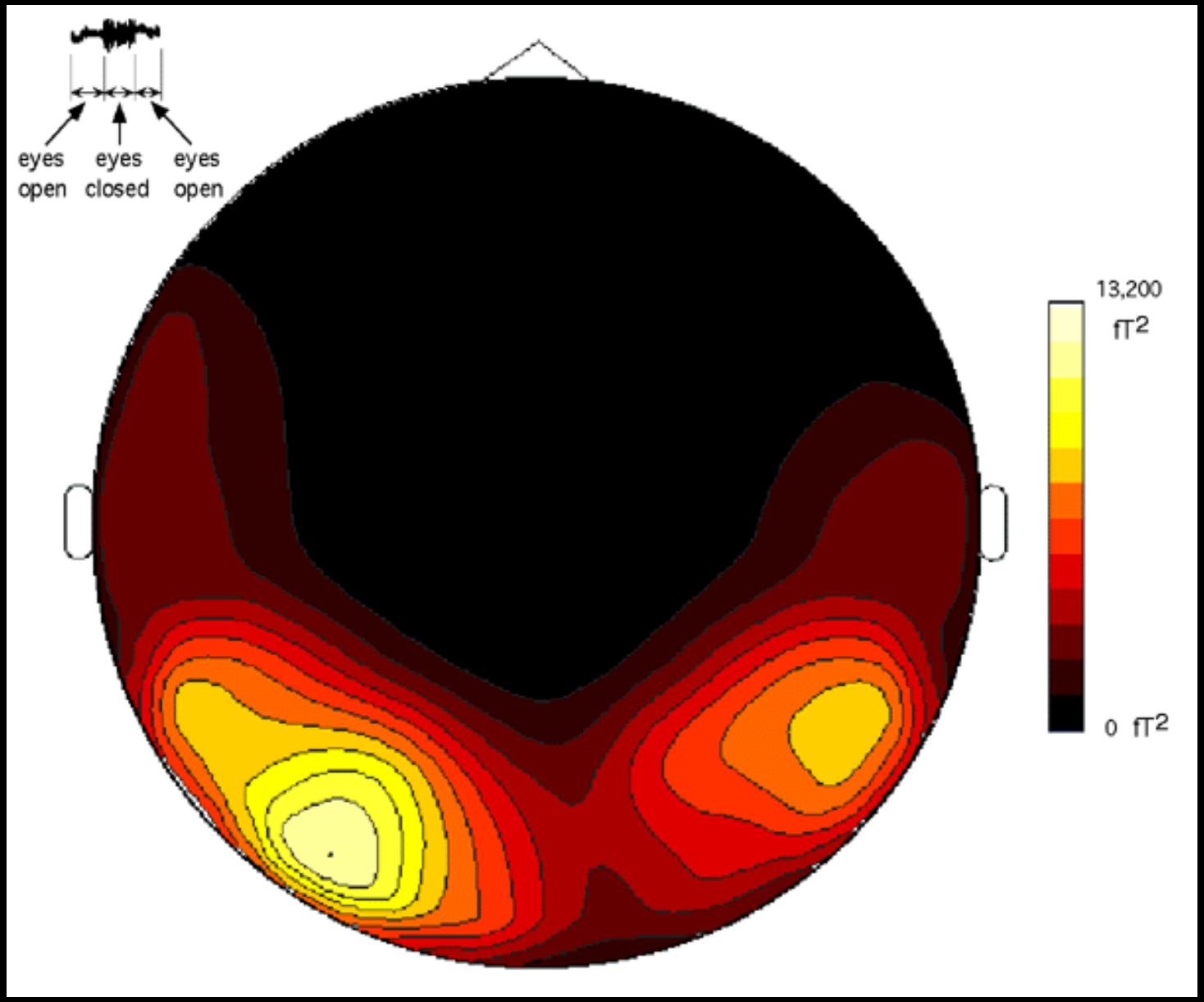




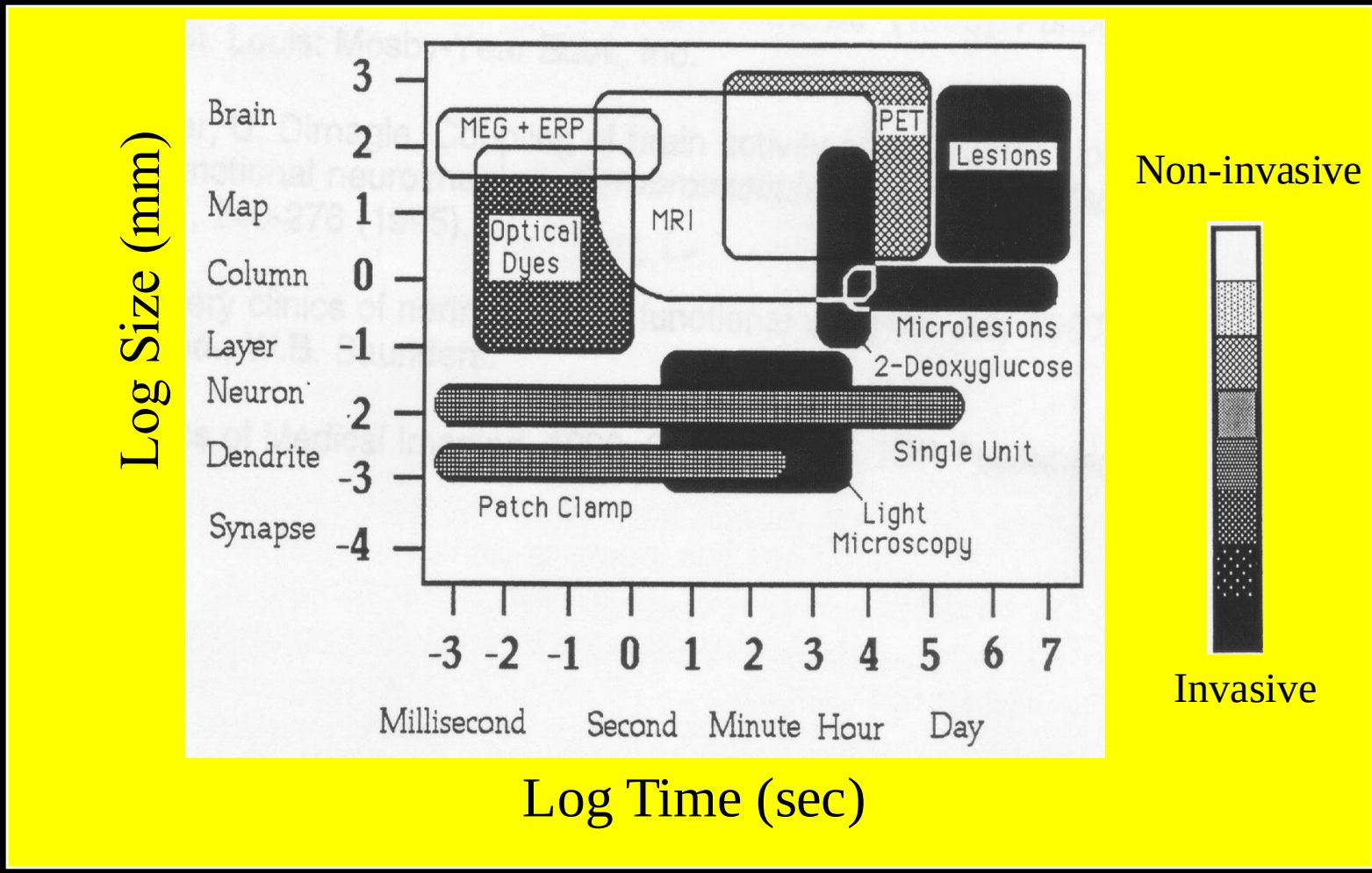




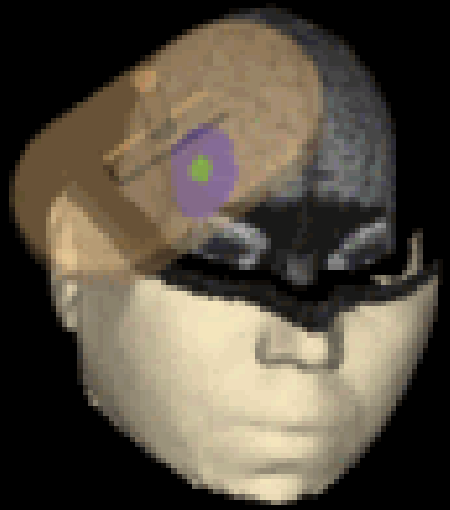
Alpha Wave Activity Mapped with MEG

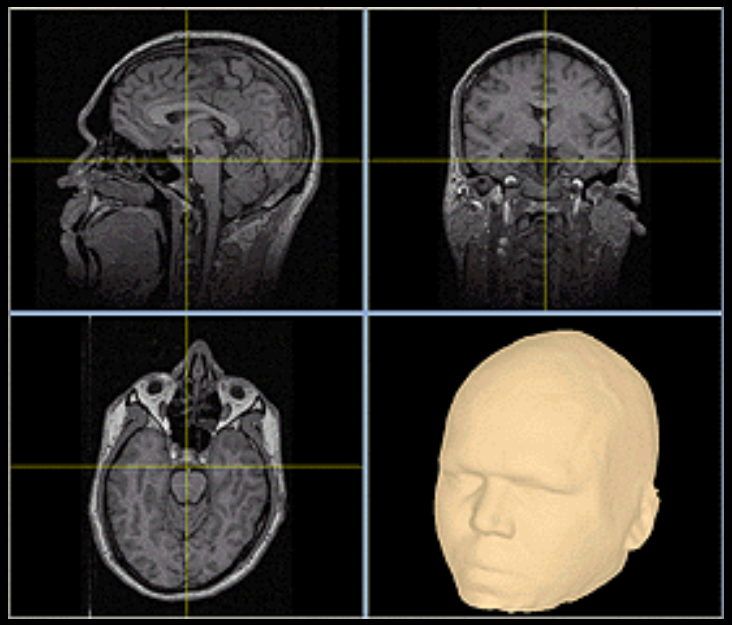


Functional Neuroimaging Techniques



Transcranial Magnetic Stimulation





Transcranial Magnetic Stimulation (TMS)

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