NEUROIMAGING

at the NIH

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Functional MRI Facility

&

Unit on Functional Imaging Methods

Laboratory of Brain and Cognition, NIMH

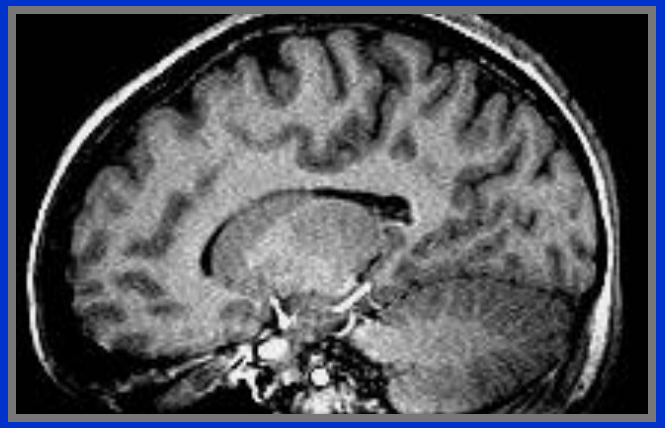
NIMH
National Institute of Mental Health

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.

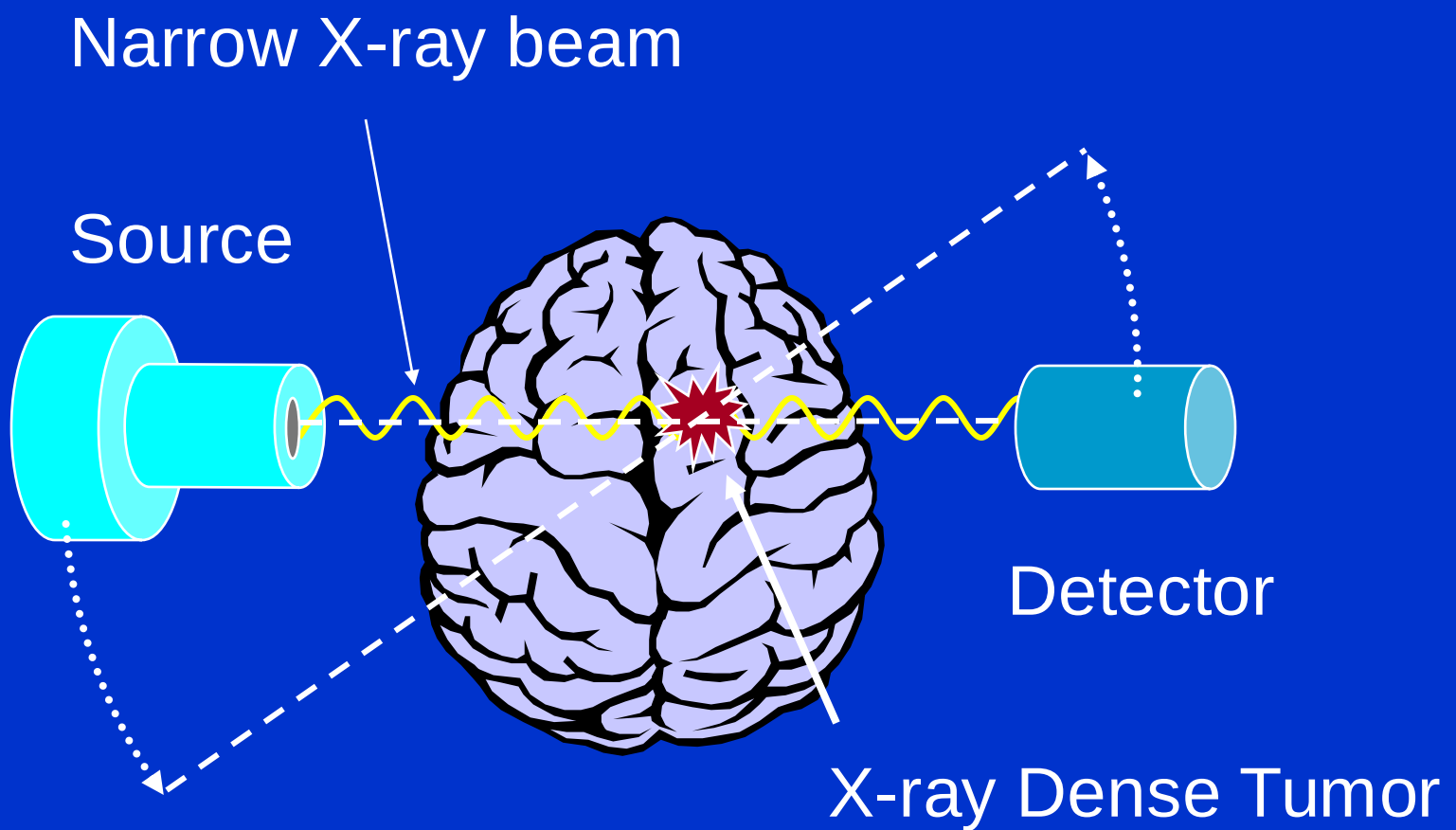


- Structural/Anatomical Imaging
  - X-ray
  - Computerized Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
    - Angiography
    - Venography
    - Perfusion
    - Diffusion Tensor Imaging

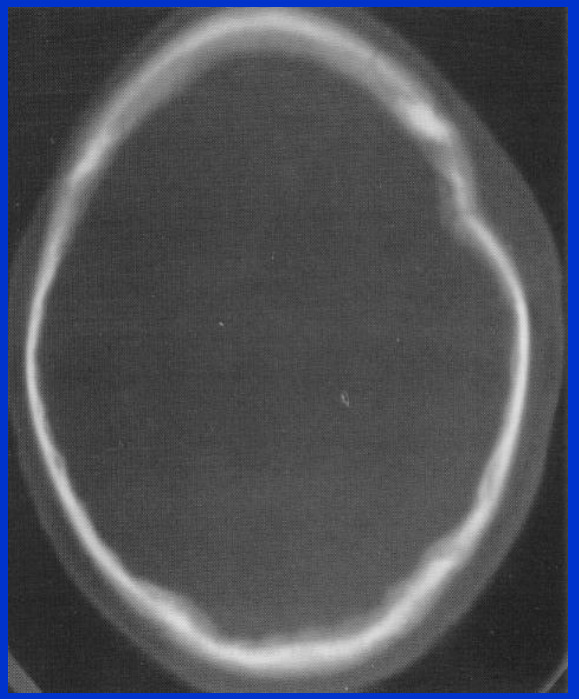
- Functional Imaging
  - –Xenon Computerized Tomography (Xe CT)
  - –Positron Emission Tomography (PET)
  - –Single Photon Computed Tomography (SPECT)
  - –Functional MRI (fMRI)
  - –Electroencephalography (EEG)
  - –Magnetoencphalography (MEG)
  - –Transcranial Magnetic Stimulation (TMS)

Computerized Tomography (CT)

Creation of images in slices or sections.

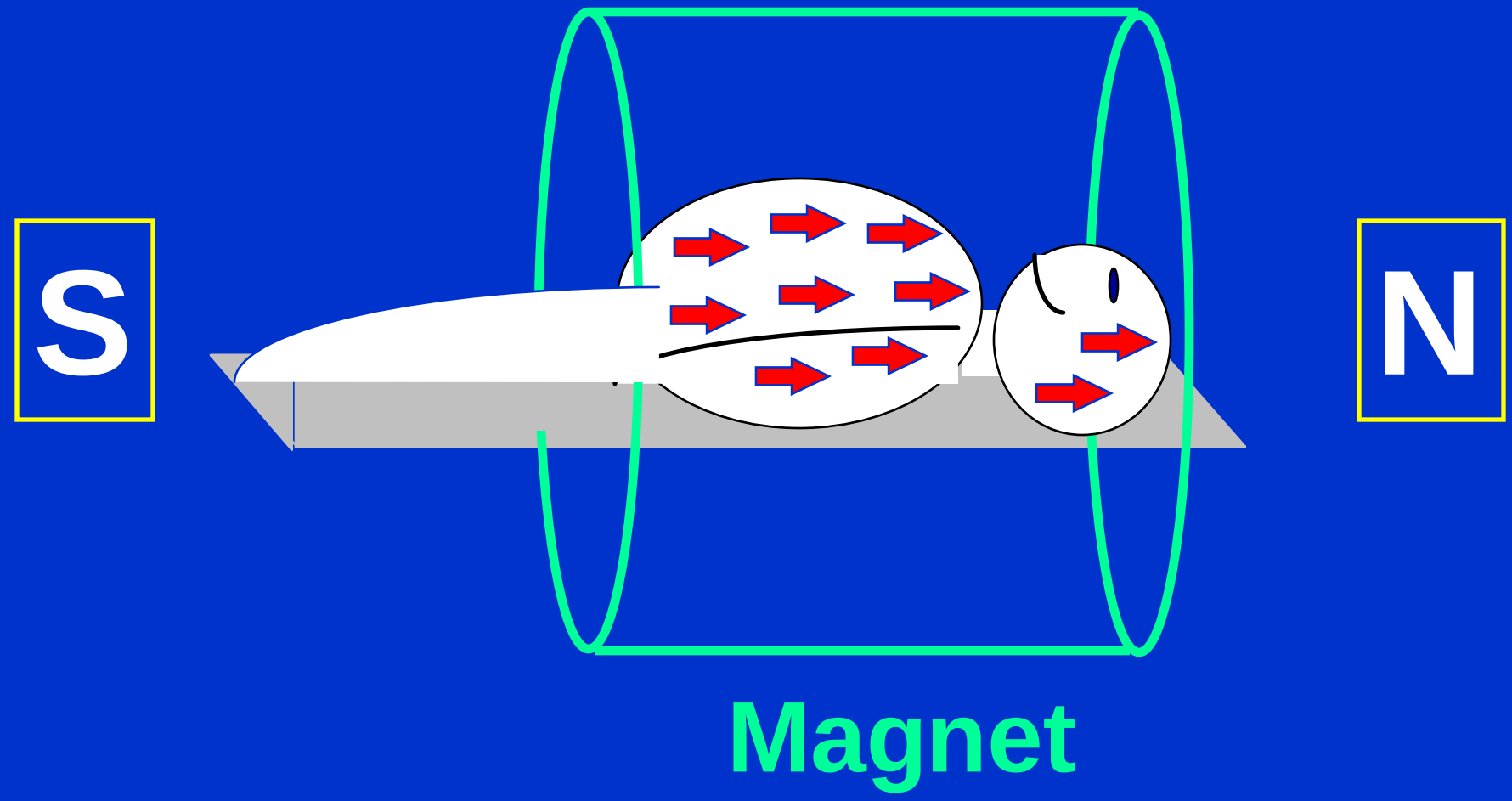


CT Images

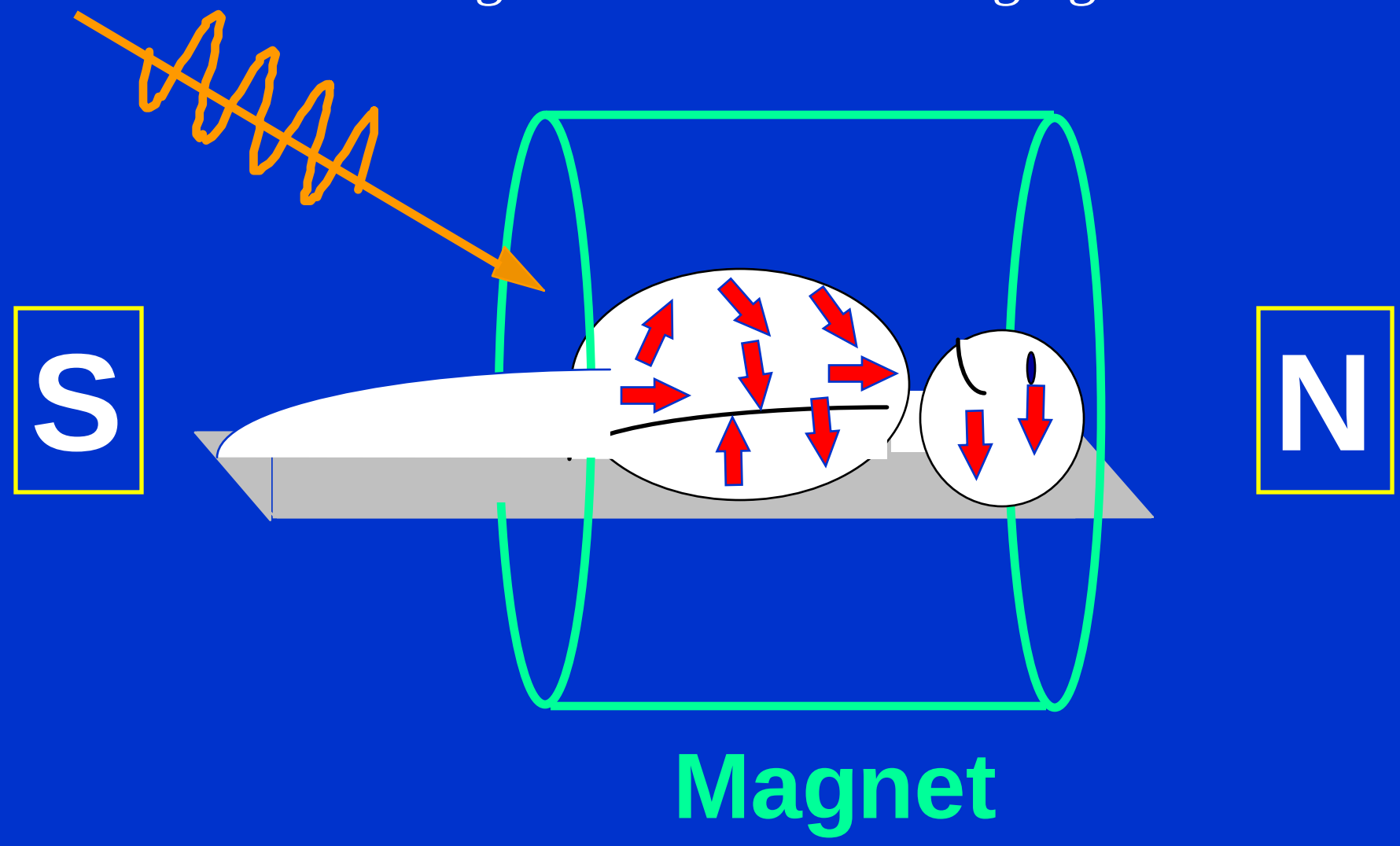


Magnetic Resonance Imaging

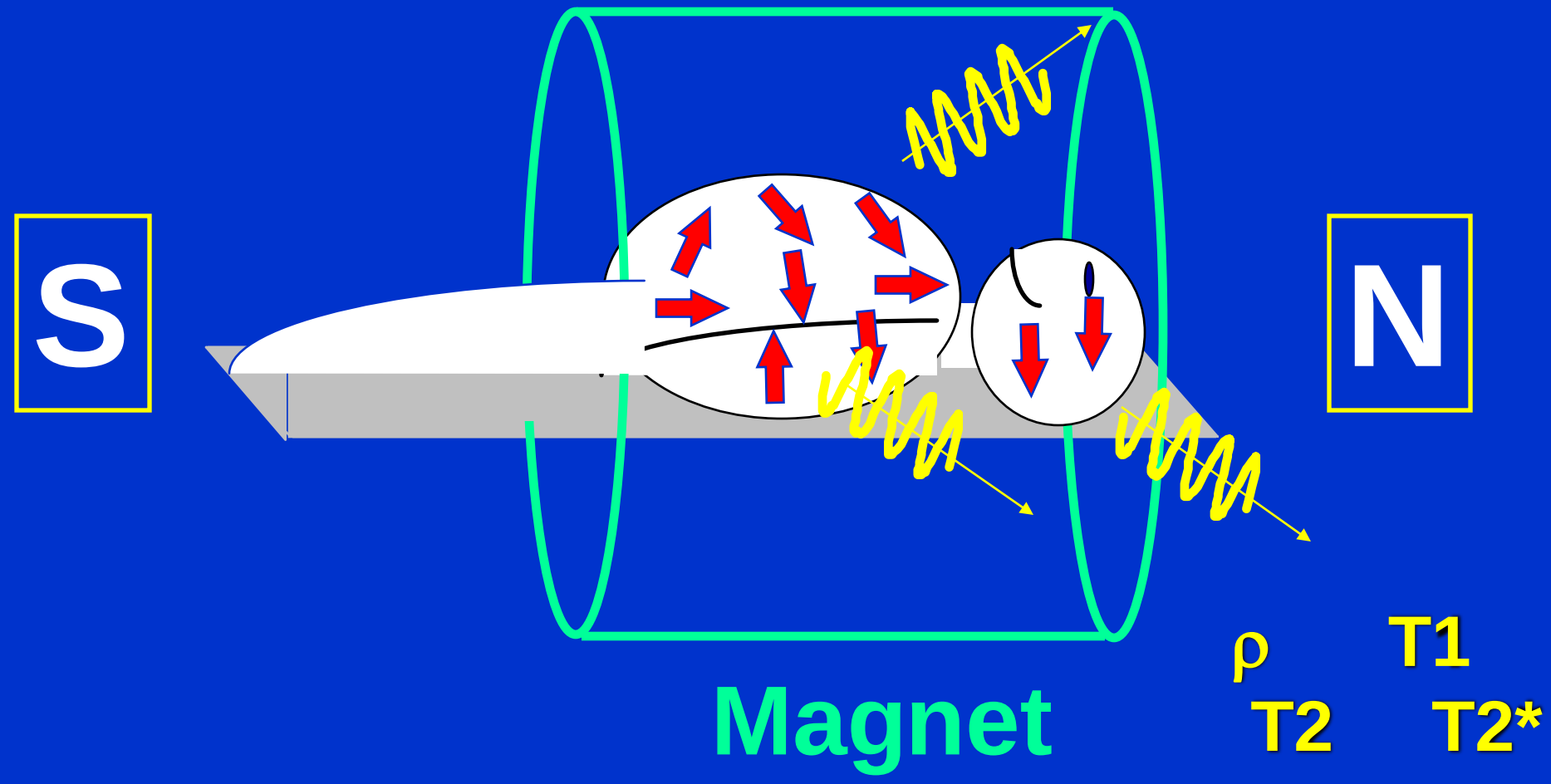
Magnetic Resonance Imaging



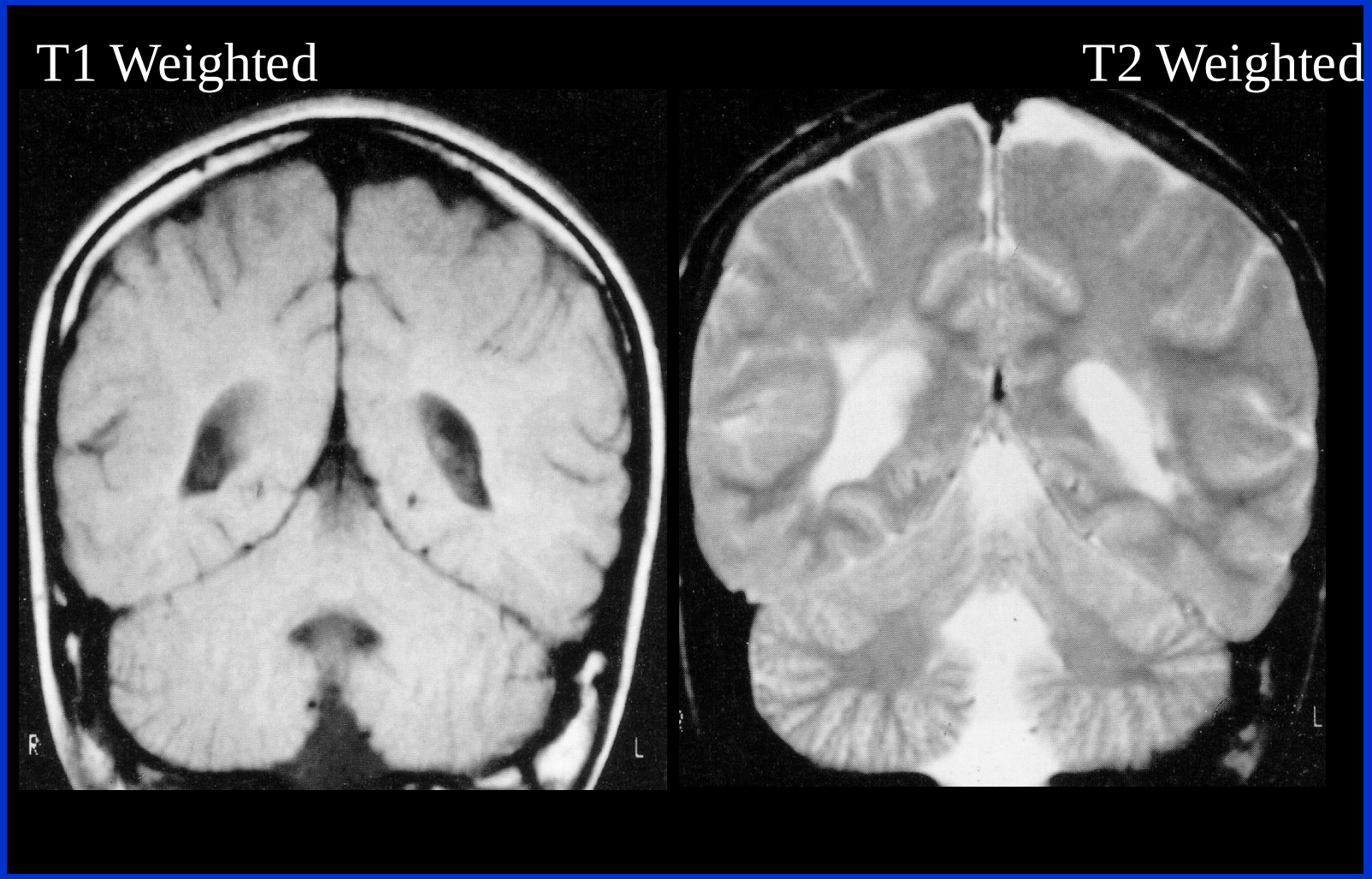
Magnetic Resonance Imaging

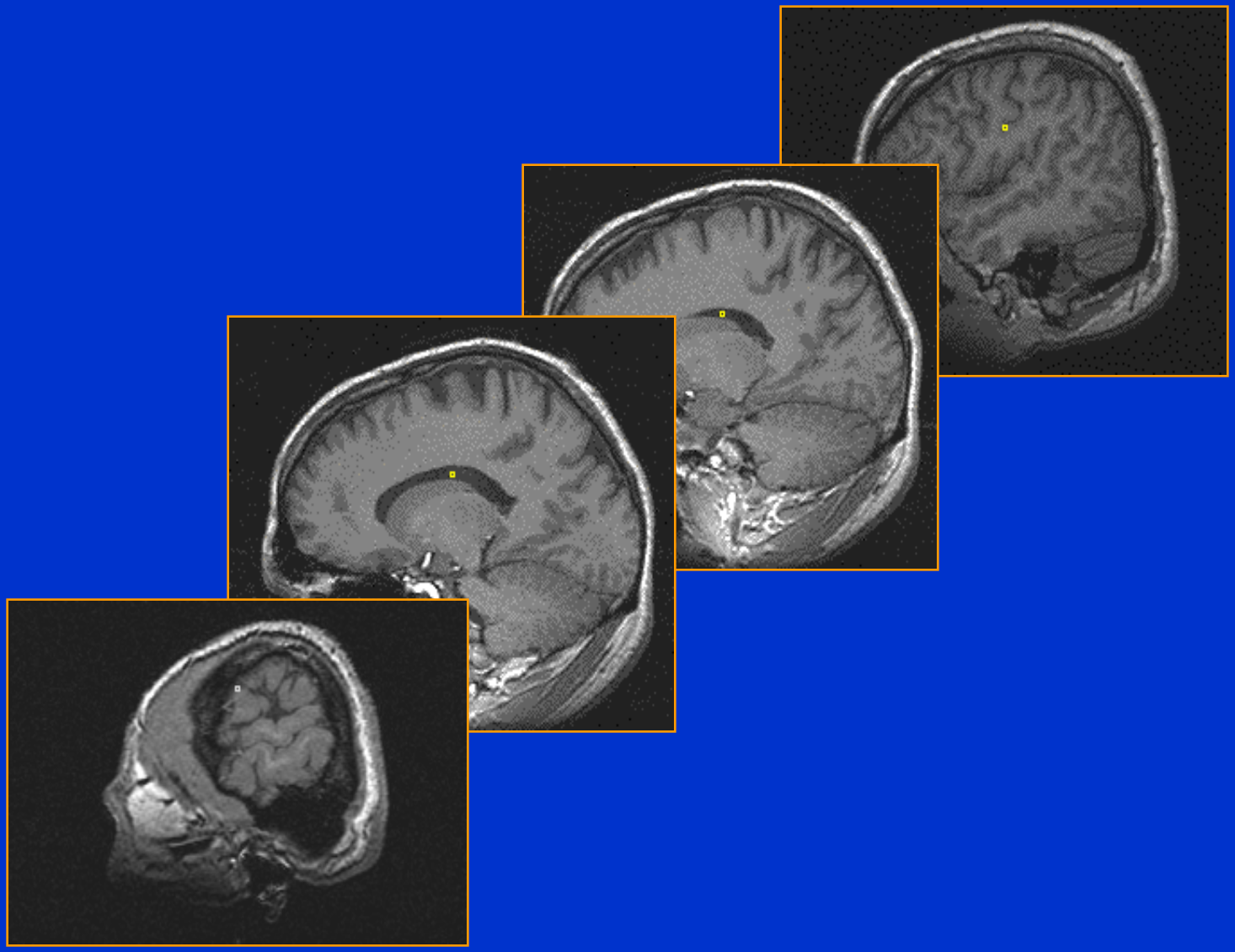


Magnetic Resonance Imaging

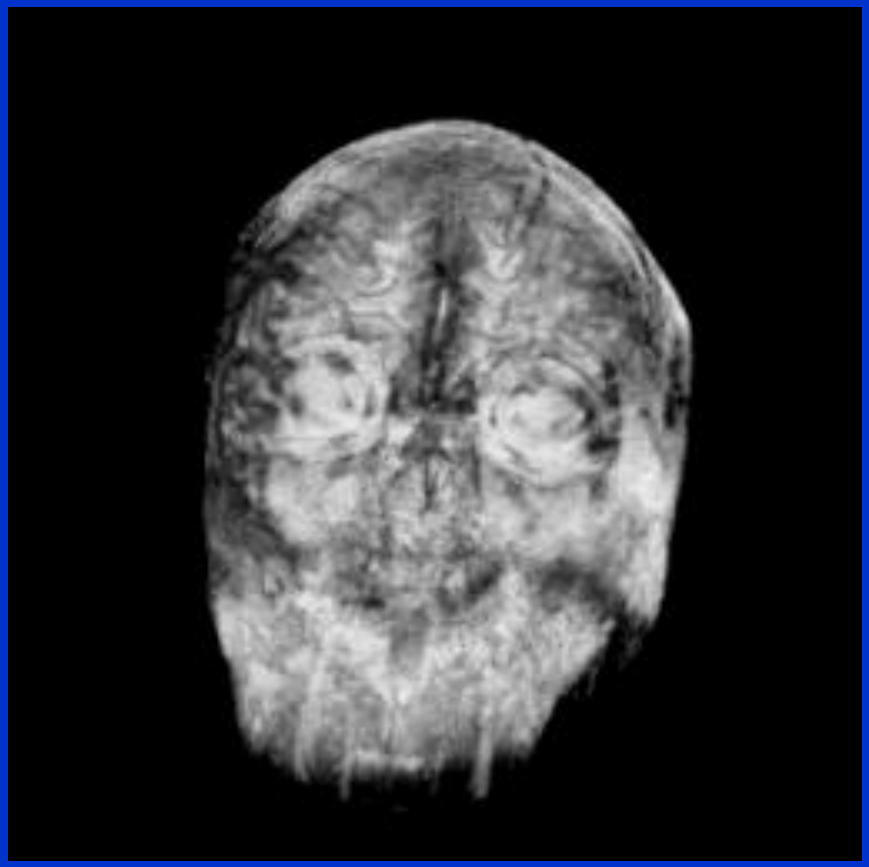


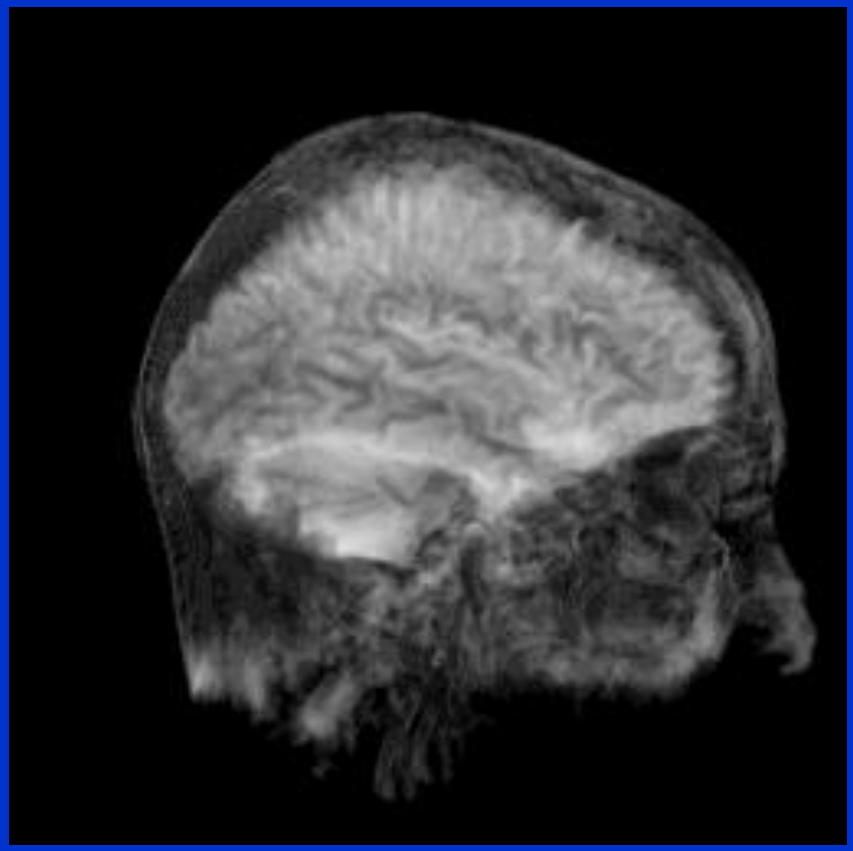
MRI Images with Different Contrast Weighting





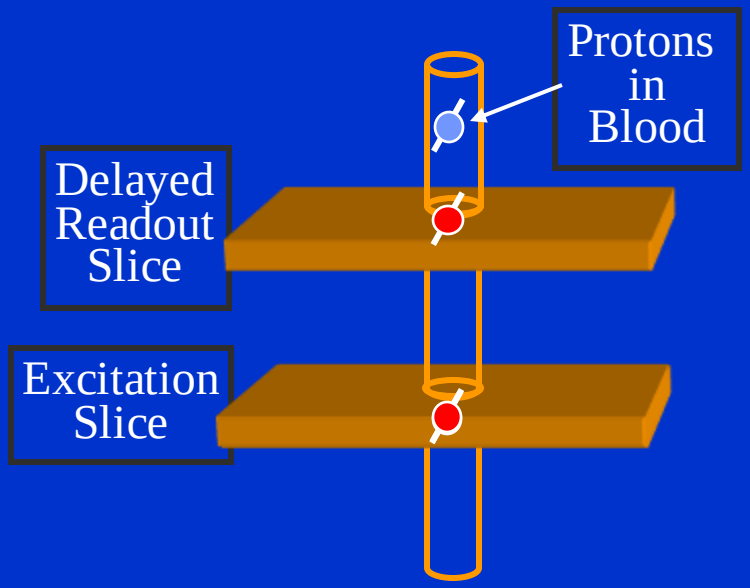
3D Rendered MRI

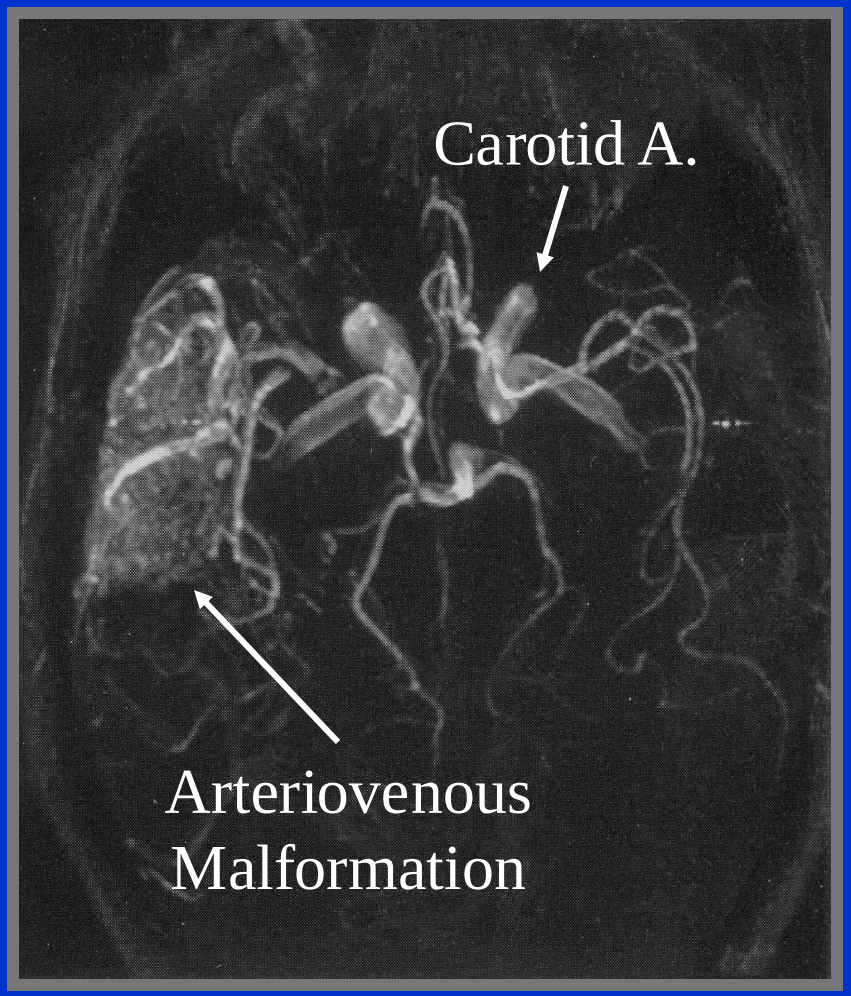




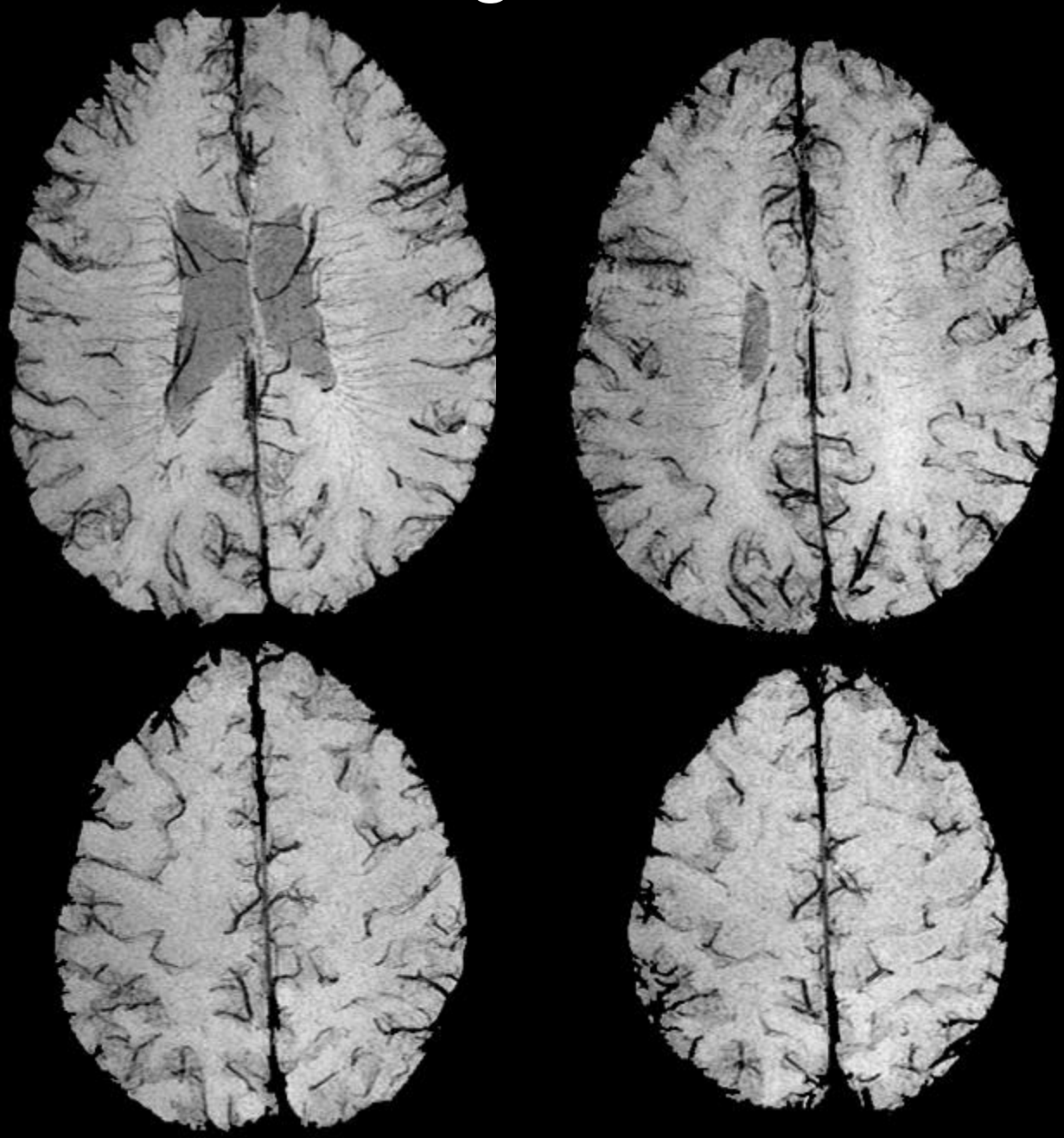
MR Angiography Shows Blood Vessel Structure

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

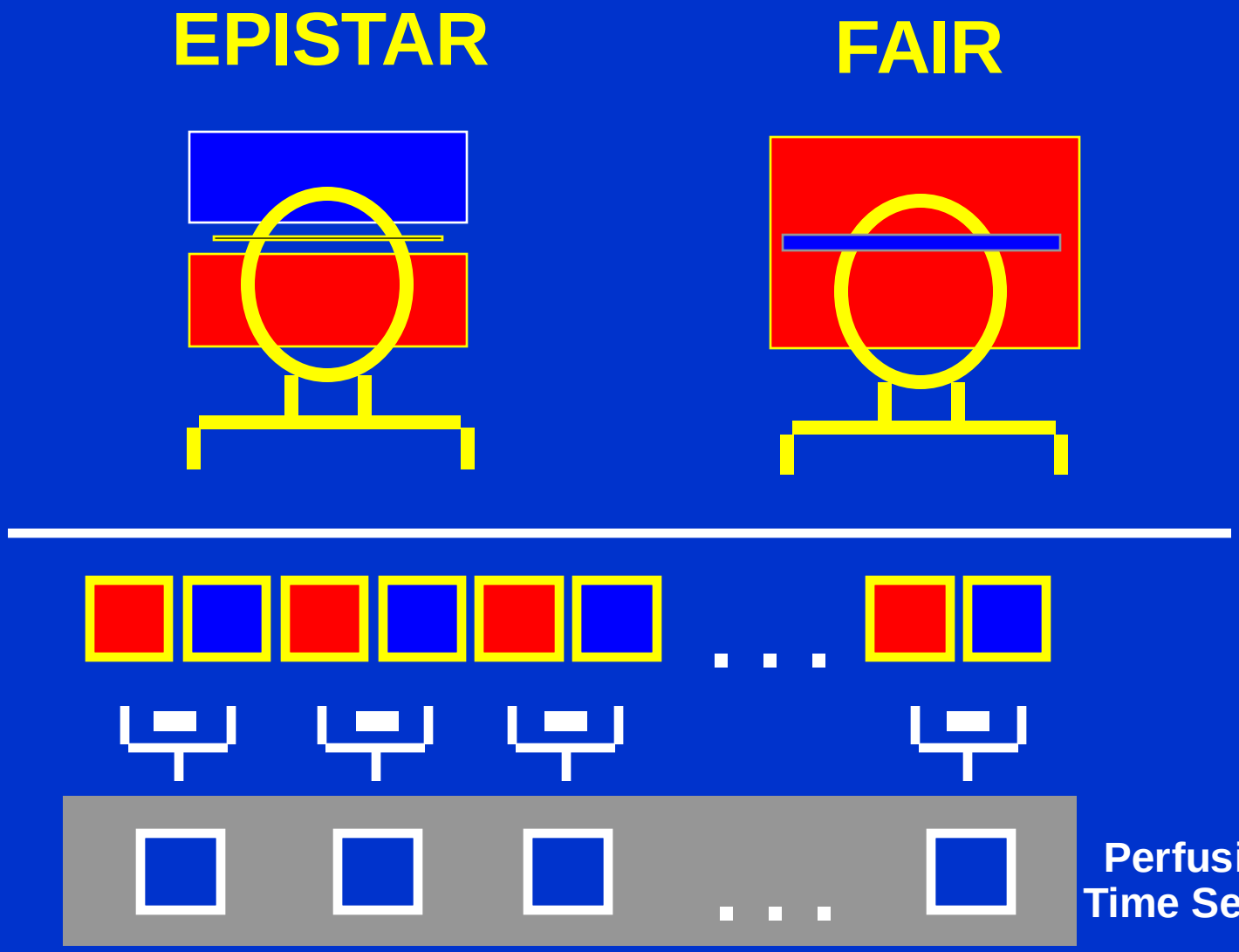




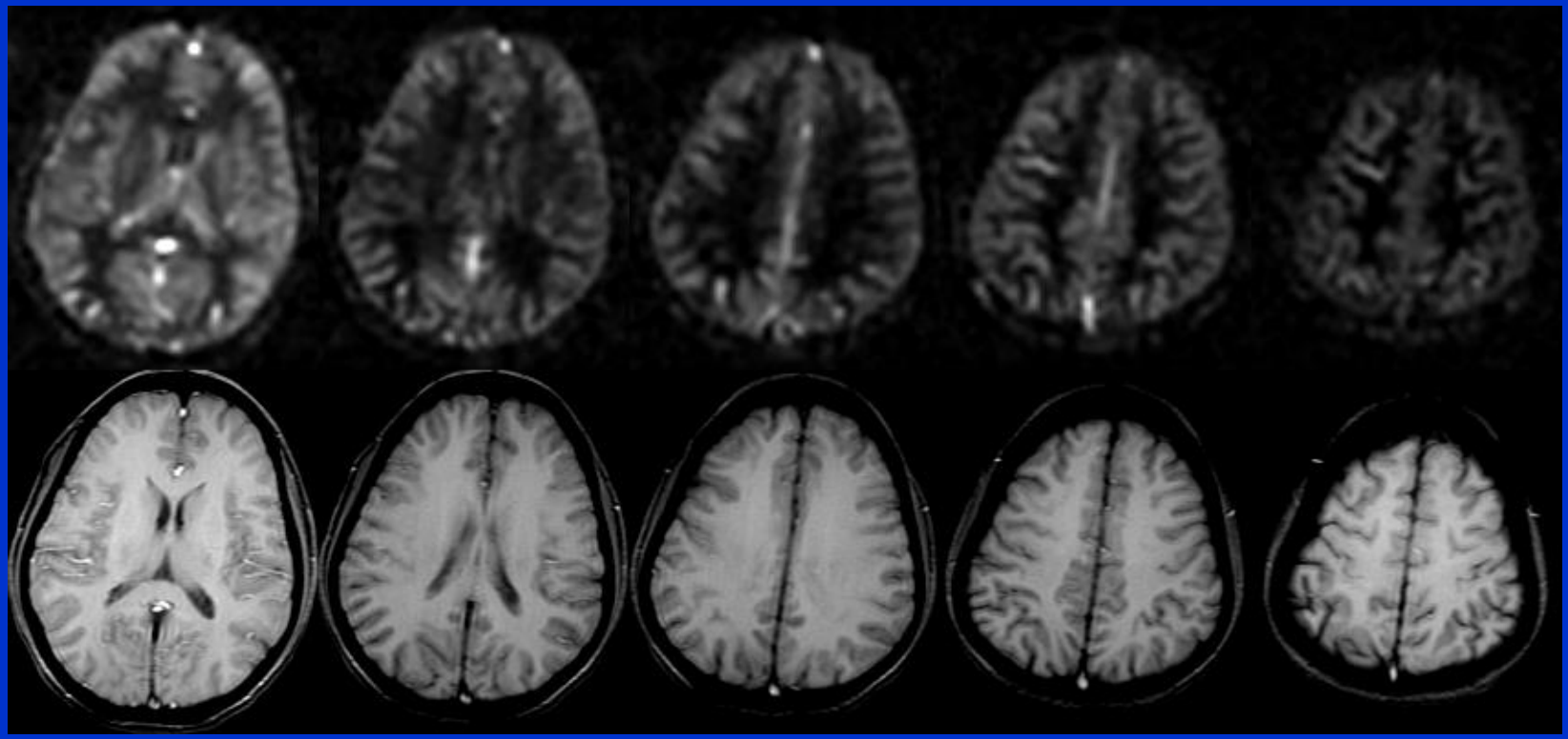
Venograms



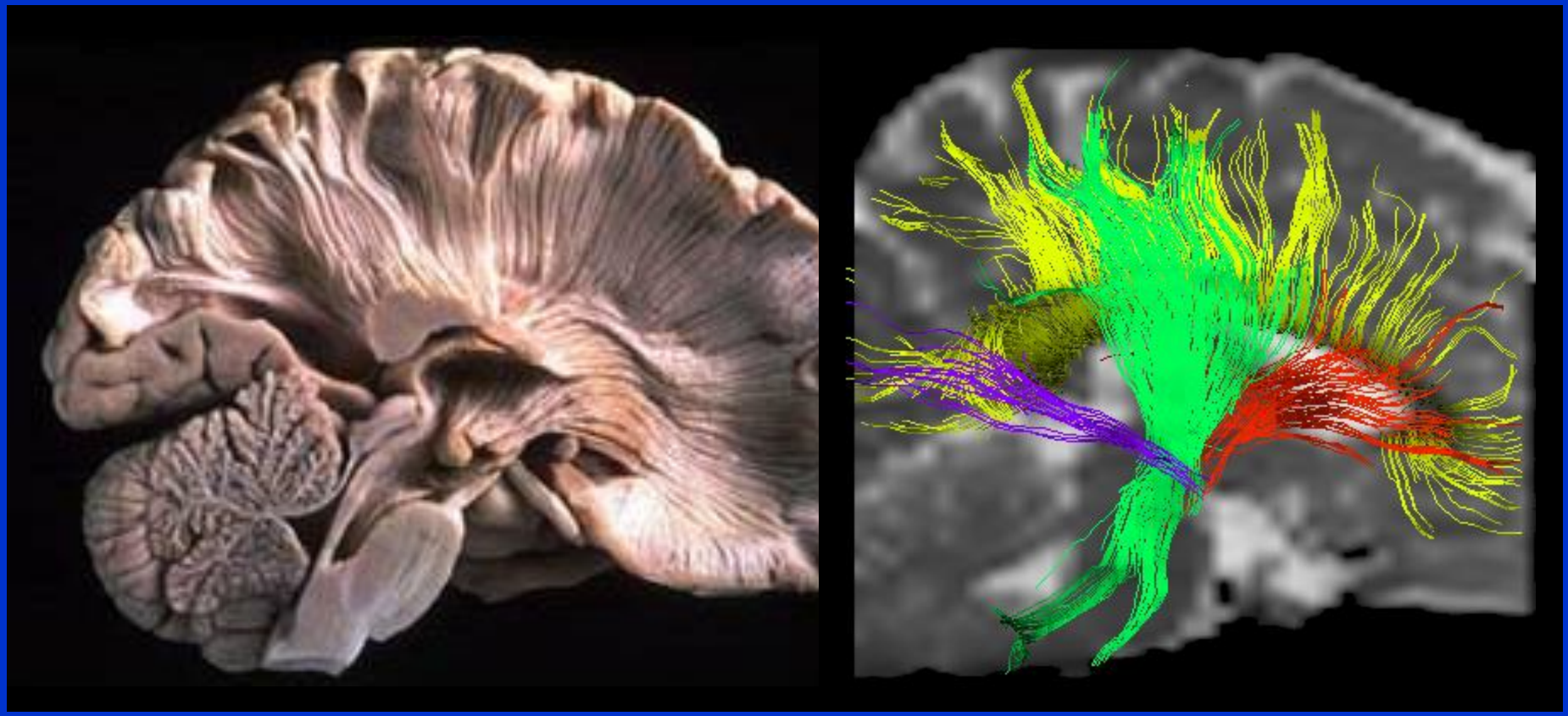
Perfusion / Flow Imaging



Perfusion Imaging with MRI

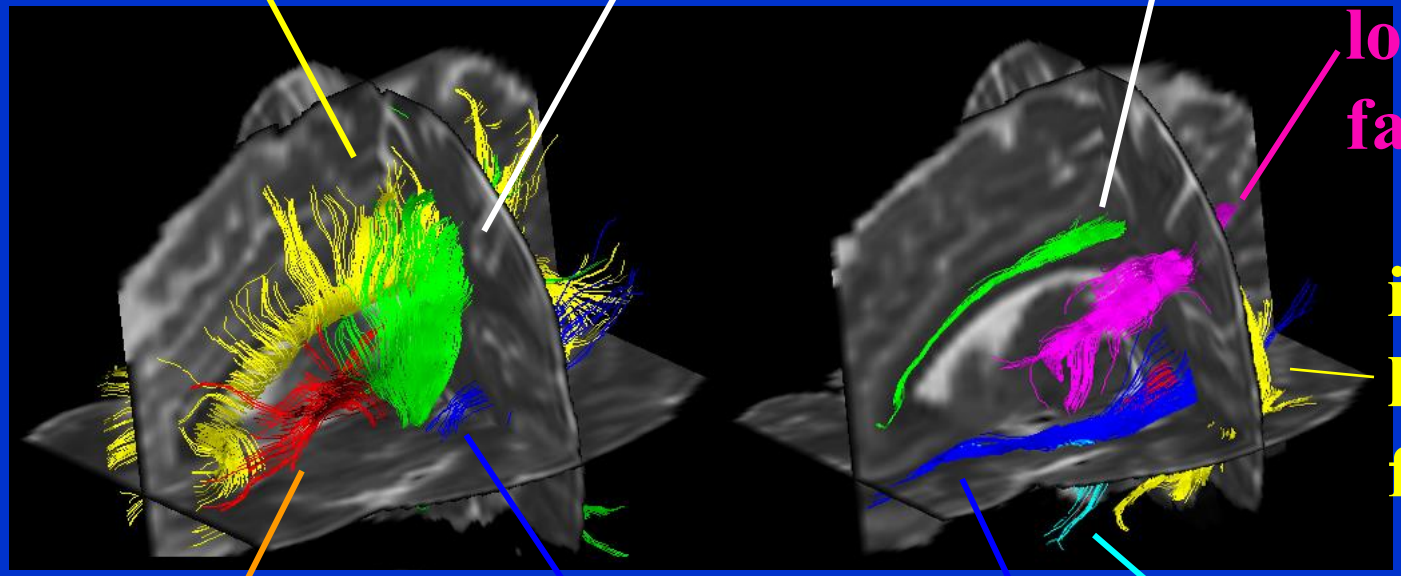


Diffusion Tensor Imaging



S. Mori – Johns Hopkins

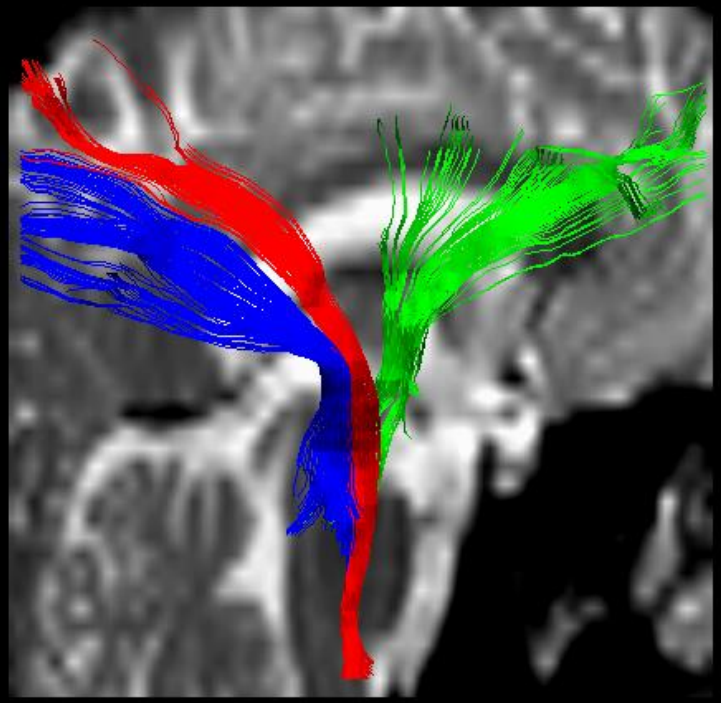
Diffusion Tensor Imaging

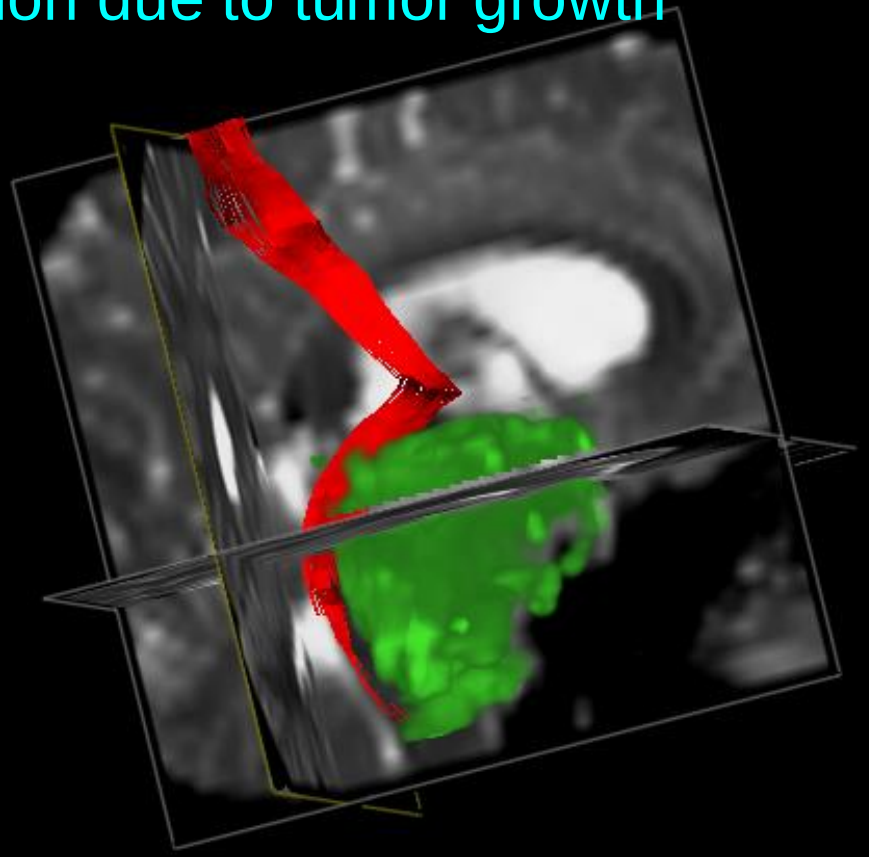


S. Mori - JHU

Anatomical guidance with DTI:

Example: Anatomical deformation due to tumor growth





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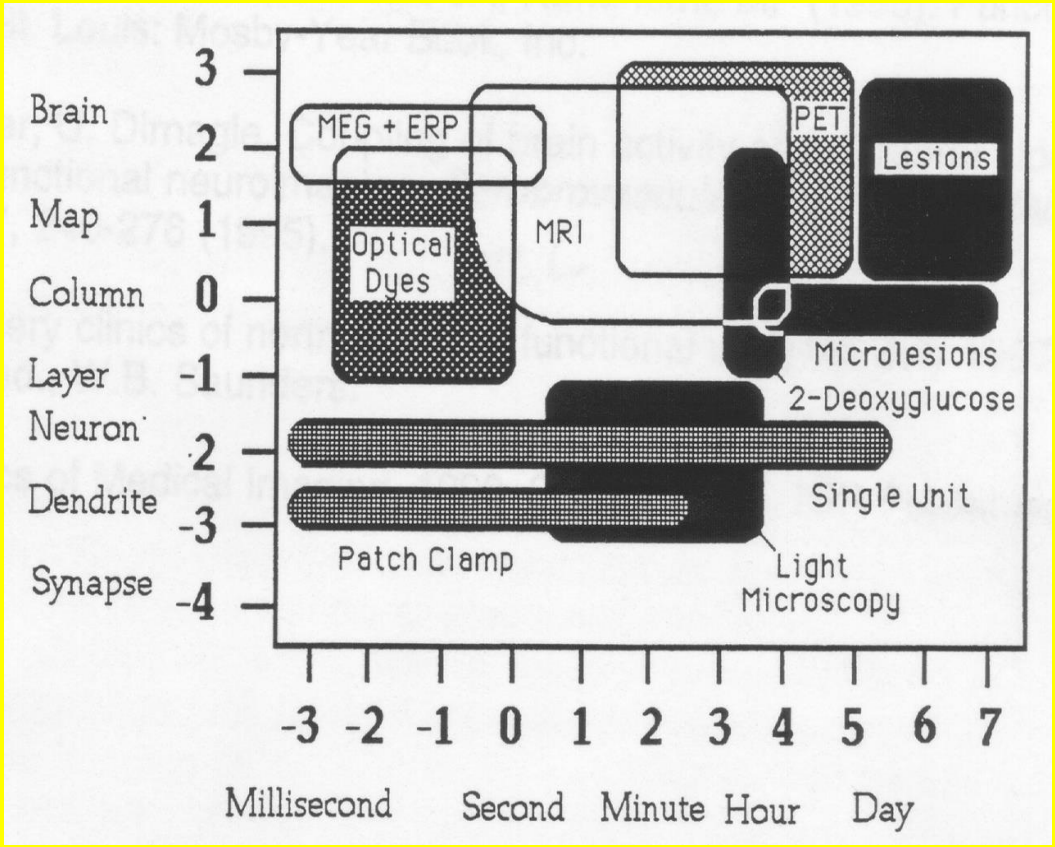
Functional Imaging

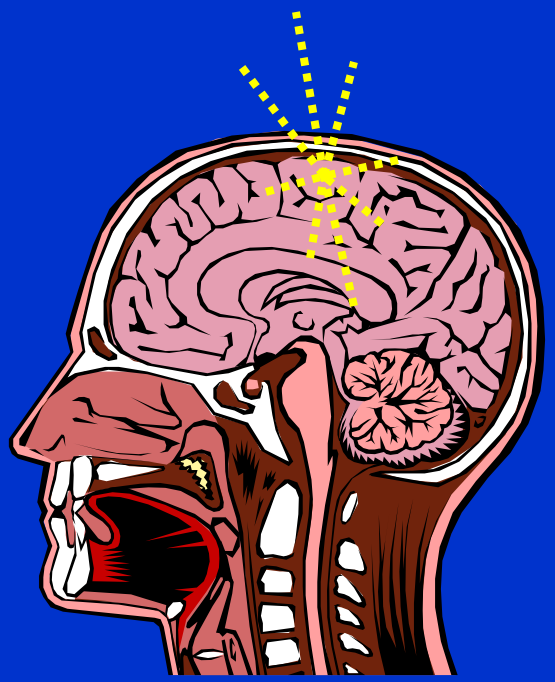
- Unlike structural imaging, functional imaging provides pictures of brain physiology or chemistry.
- By targeting factors that are related to brain activity (eg. blood flow and oxygenation), images of brain activation can be obtained.
- Functional imaging has been used for pre-surgical mapping of function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

Functional Neuroimaging Techniques

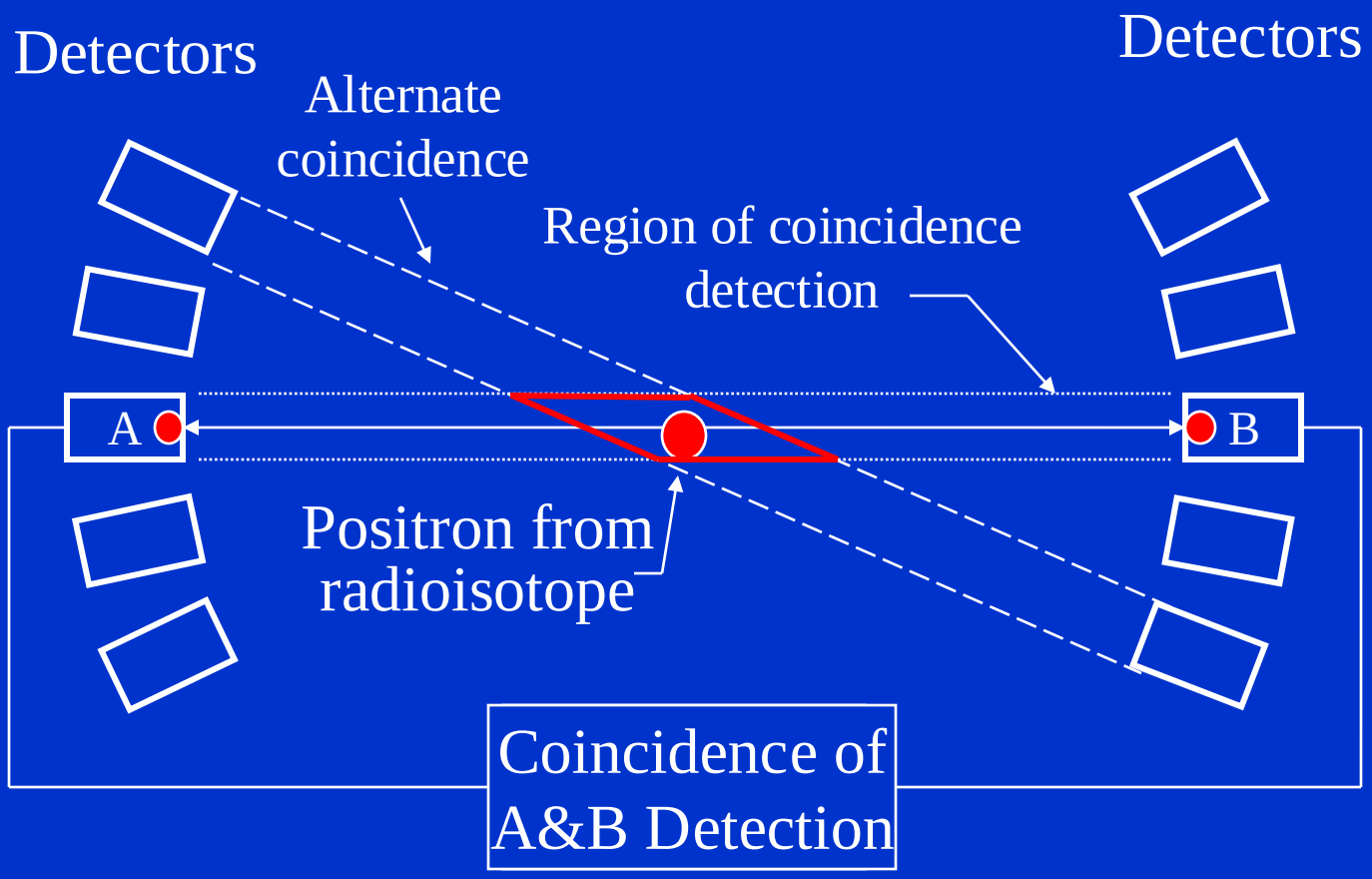


Positron Emission Tomography (PET)

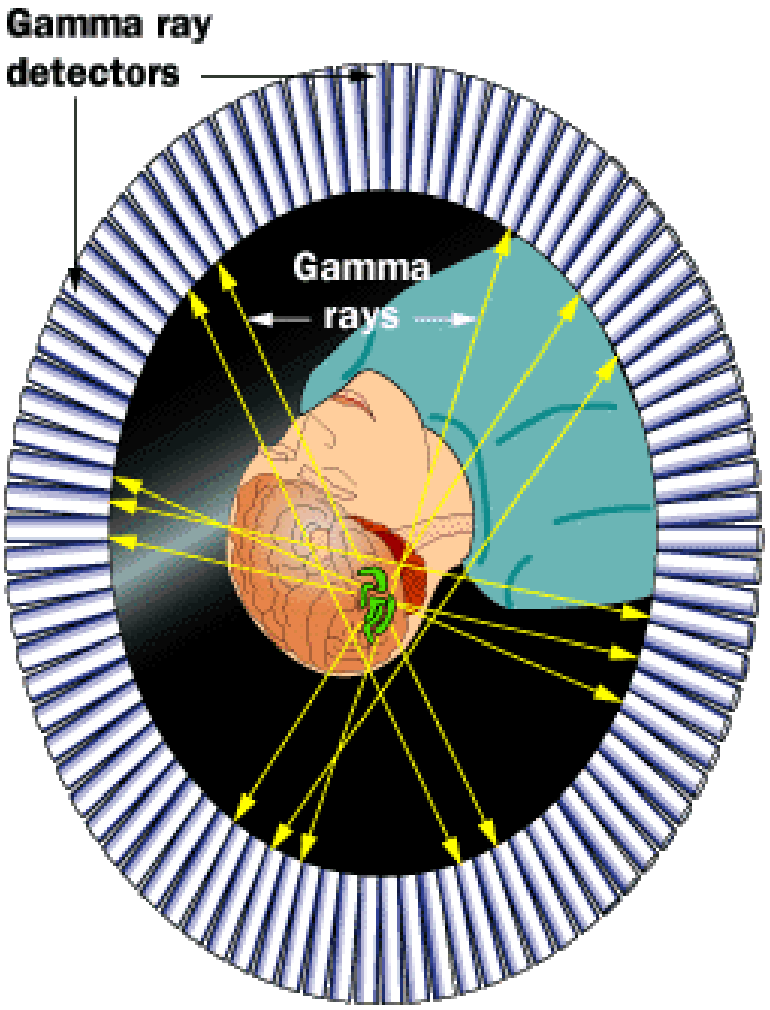
- Positron emission tomography (PET) is a technique for studying functional processes *in vivo* by measuring the concentrations of positron-emitting radioisotopes within the subject.
- PET is primarily used to study biochemical and physiological processes within living organs with 3-dimensional spatial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

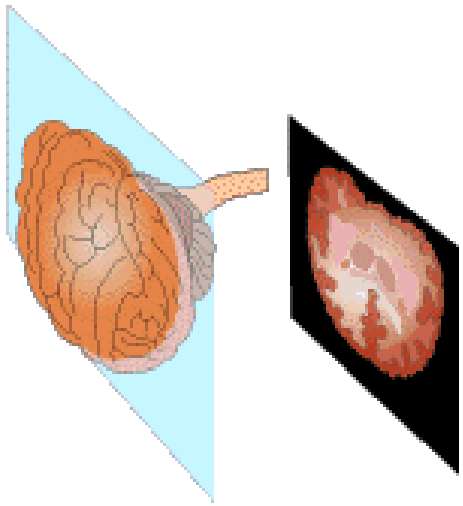


PET mechanism

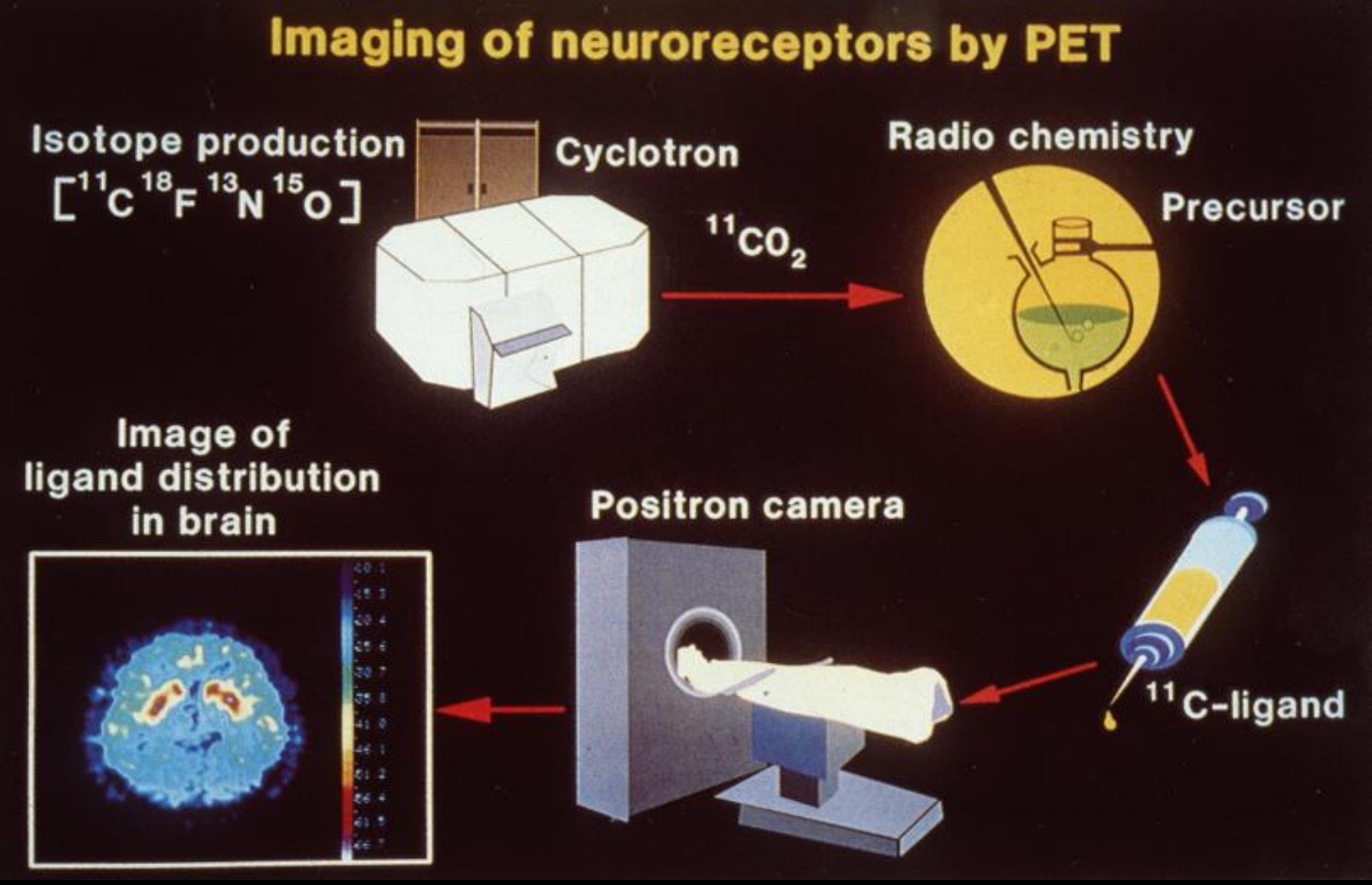


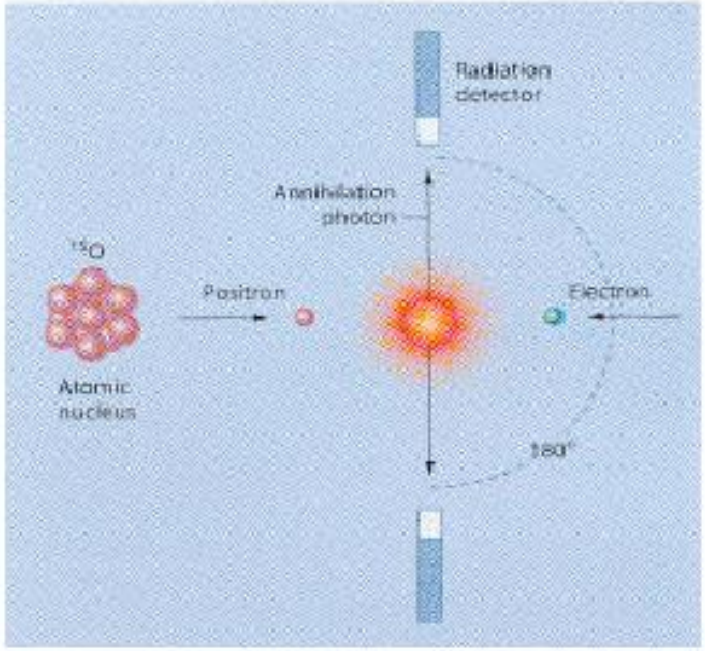
Positron Emission Tomography

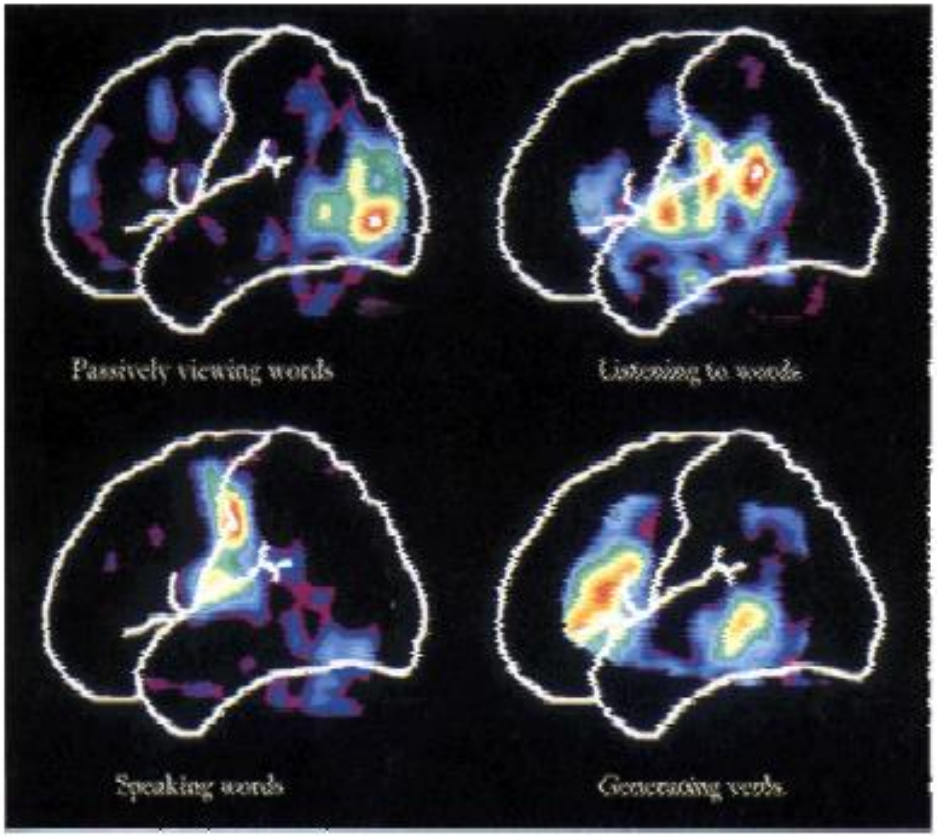




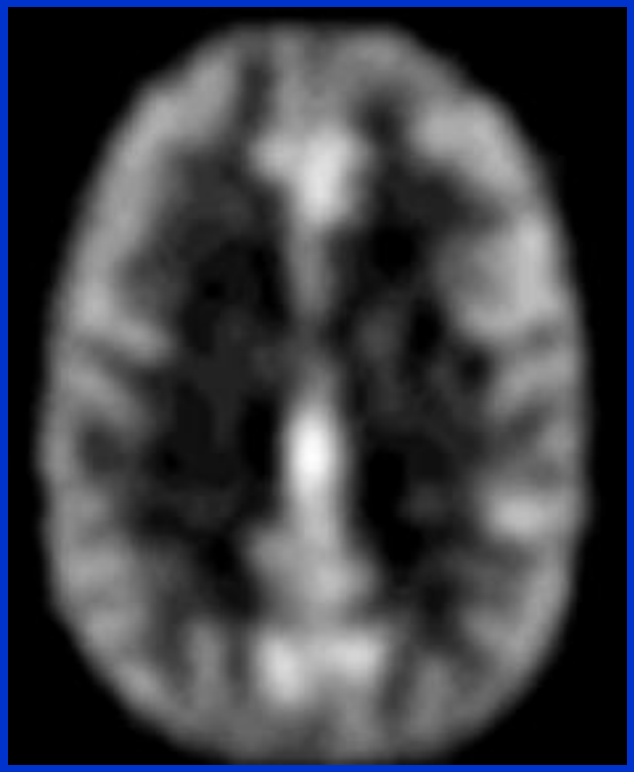
Imaging of neuroreceptors by PET



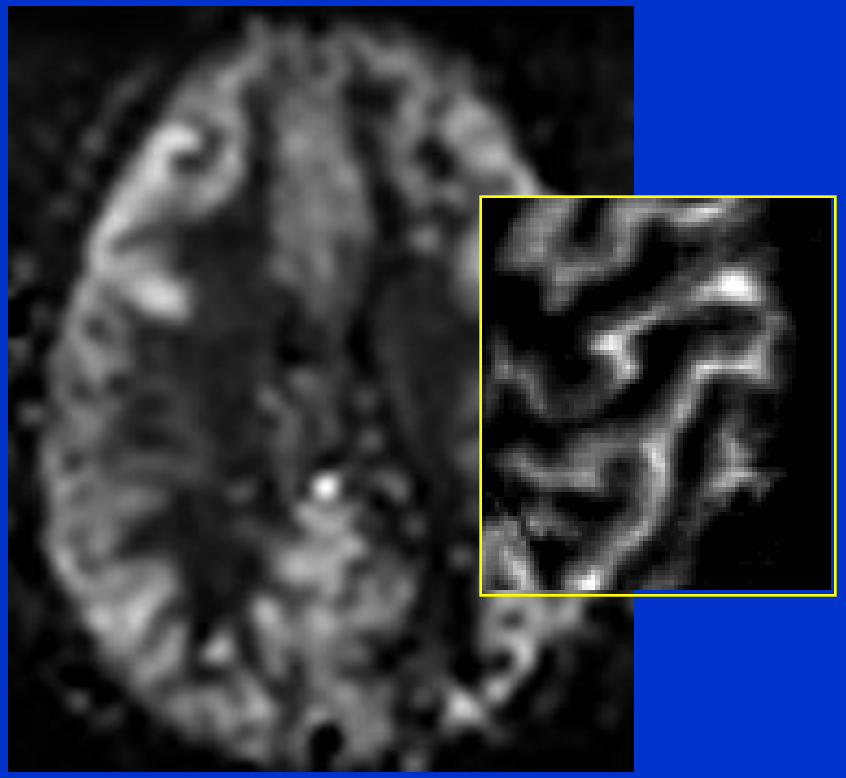

Radiation detector
Annihilation photon
^{15}O
Positron
Electron
Atomic nucleus
180°


Passively viewing words
Listening to words
Speaking words
Generating verbs

Comparison with Positron Emission Tomography

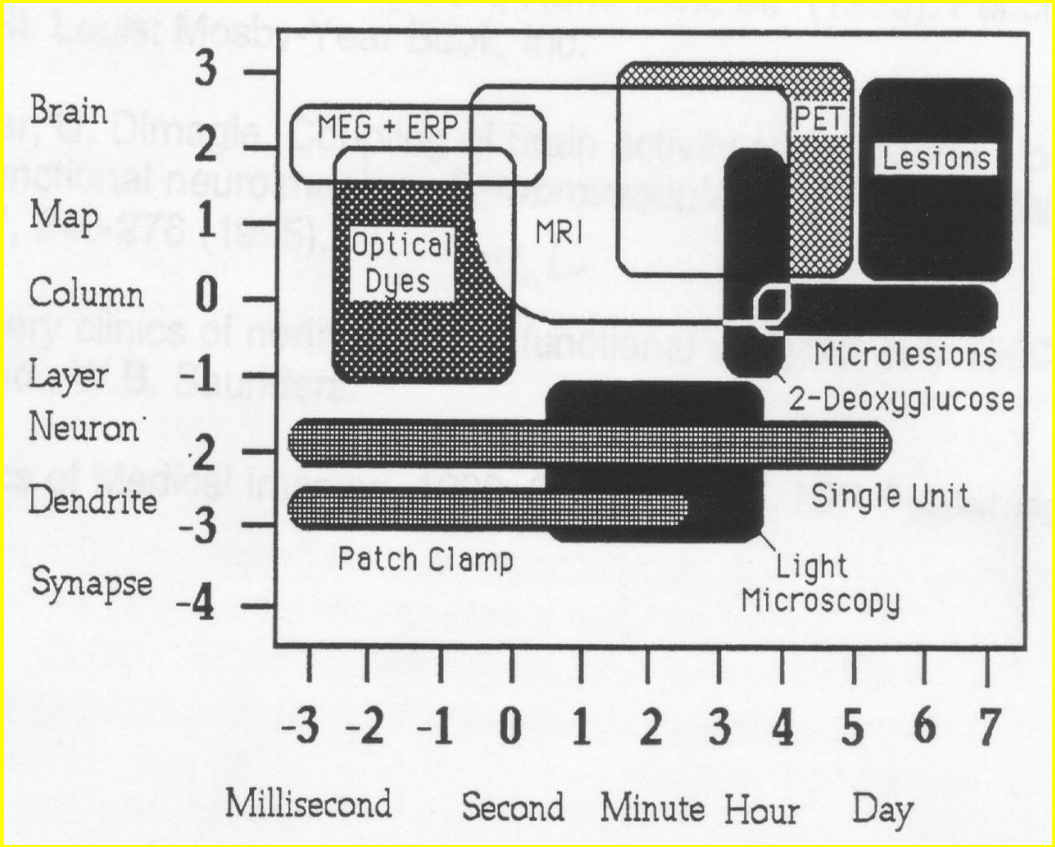


PET: $H_2{}^{15}O$



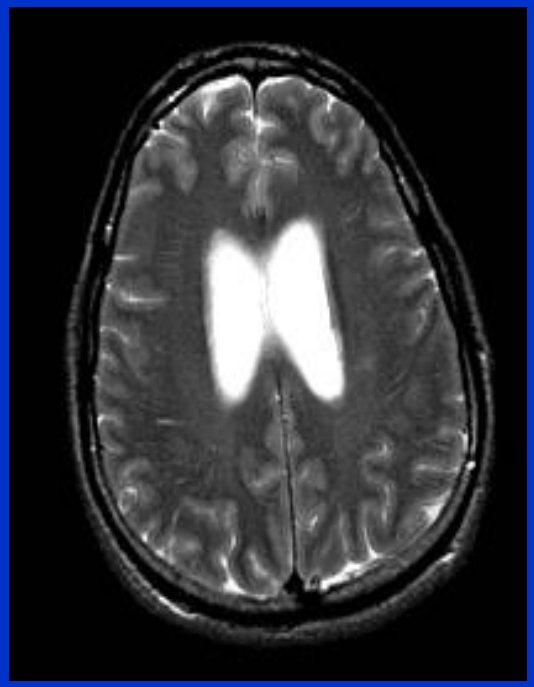
MRI: ASL

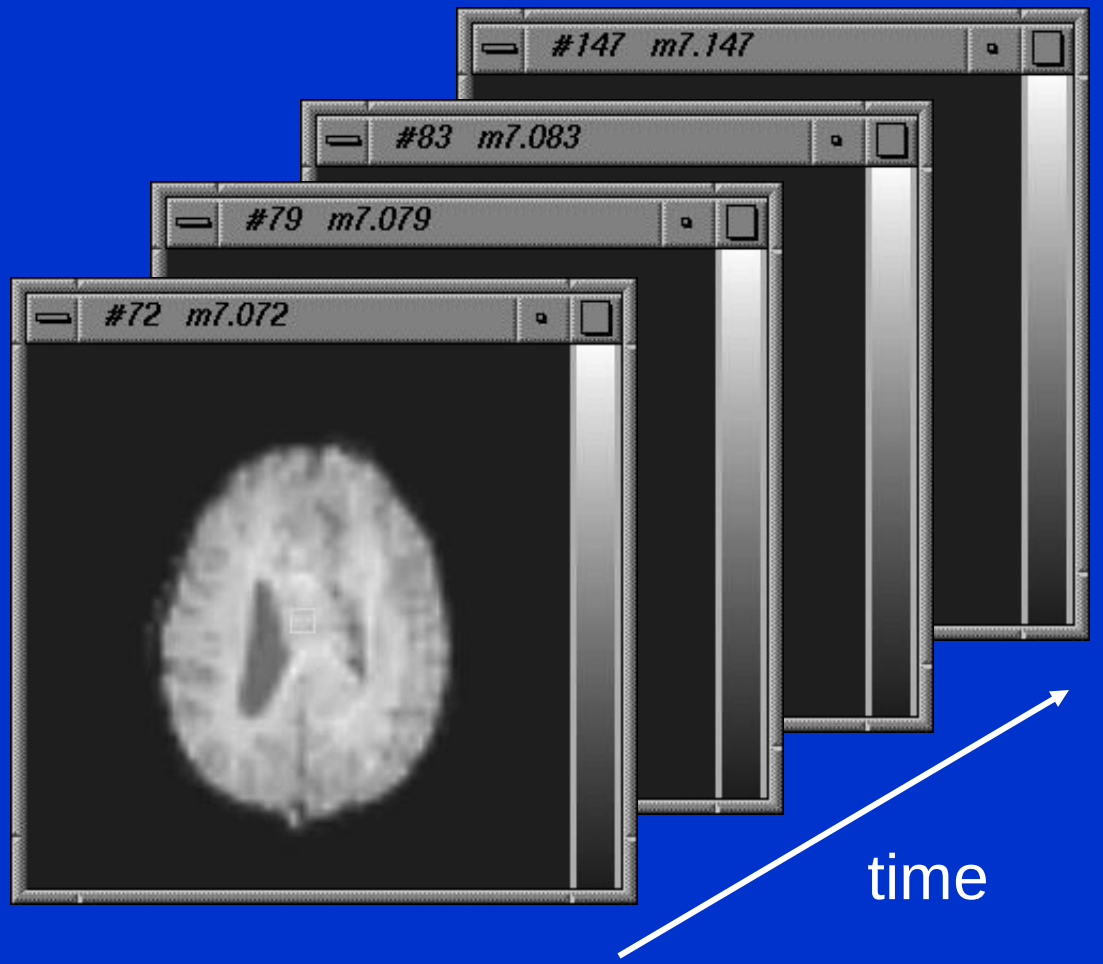
Functional Neuroimaging Techniques



Contrast in Functional MRI

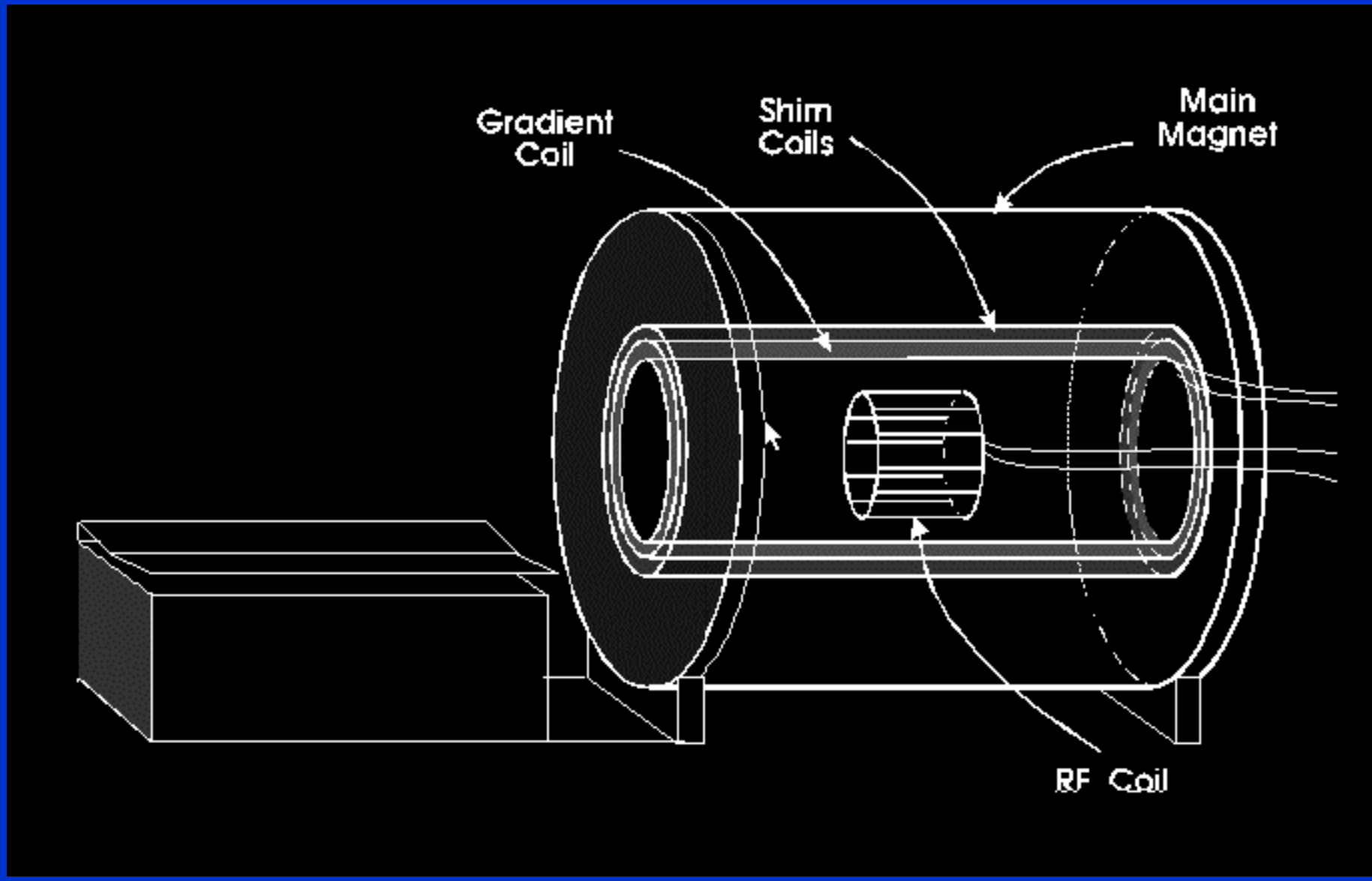
- **Blood Volume**
- **BOLD (Blood Oxygenation Level Dependent Contrast)**
- **Perfusion**





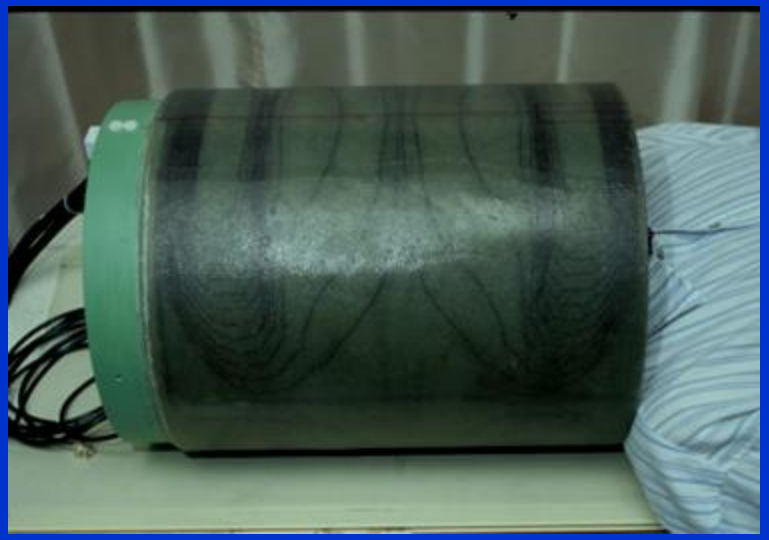
Anatomic

Functional

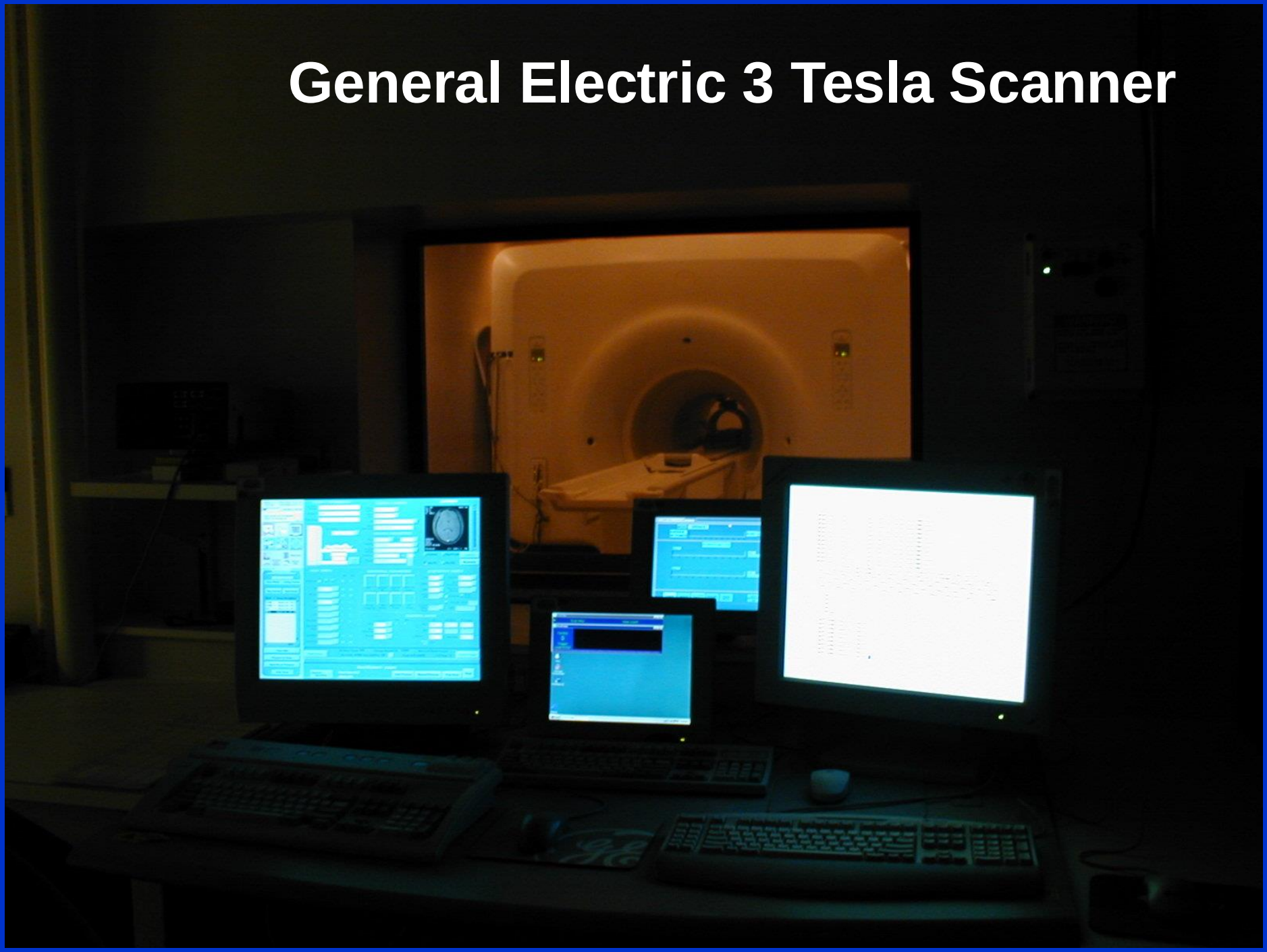

Gradient Coil
Shim Coils
Main Magnet
RF Coil

1991-1992

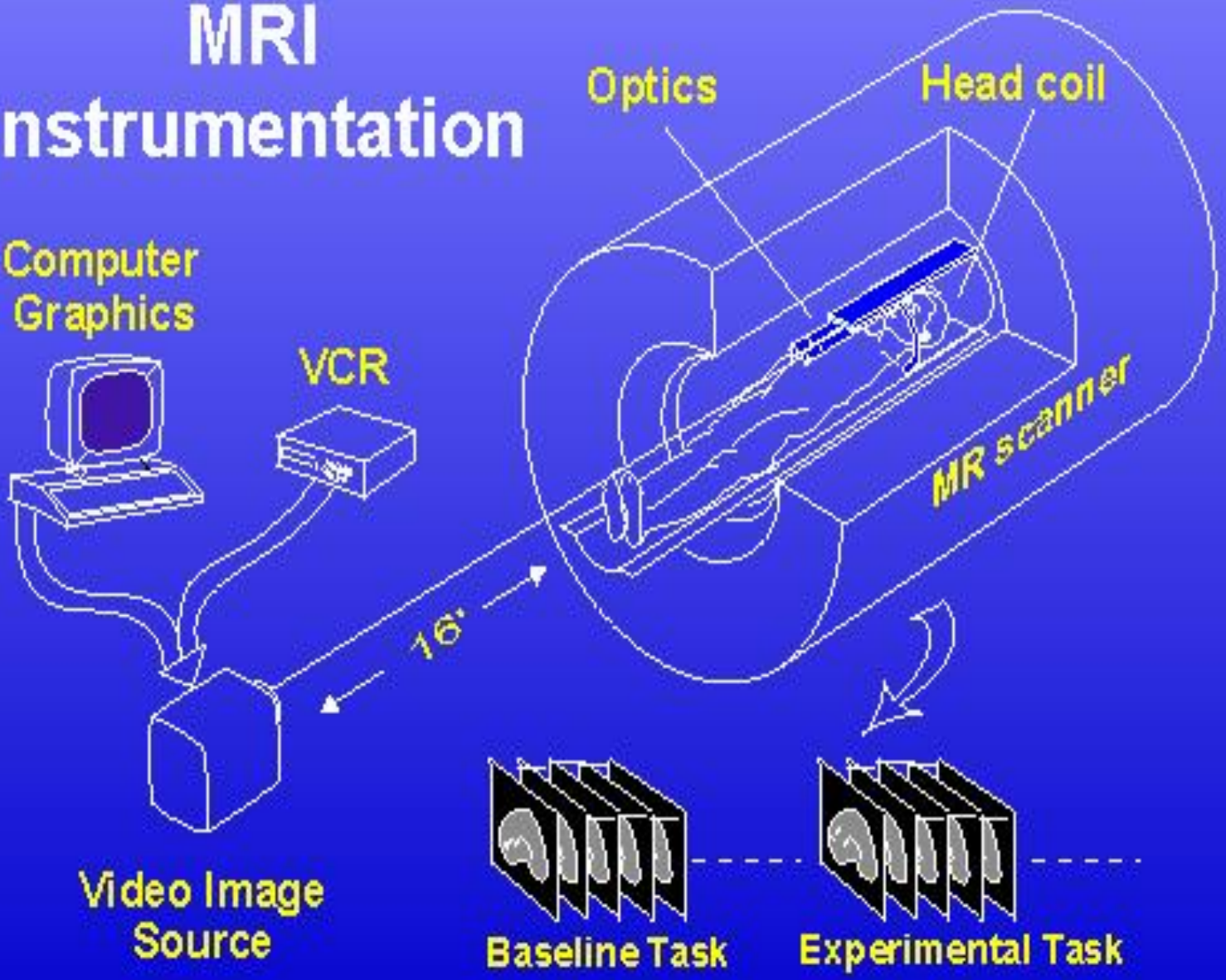
1992-1999



General Electric 3 Tesla Scanner

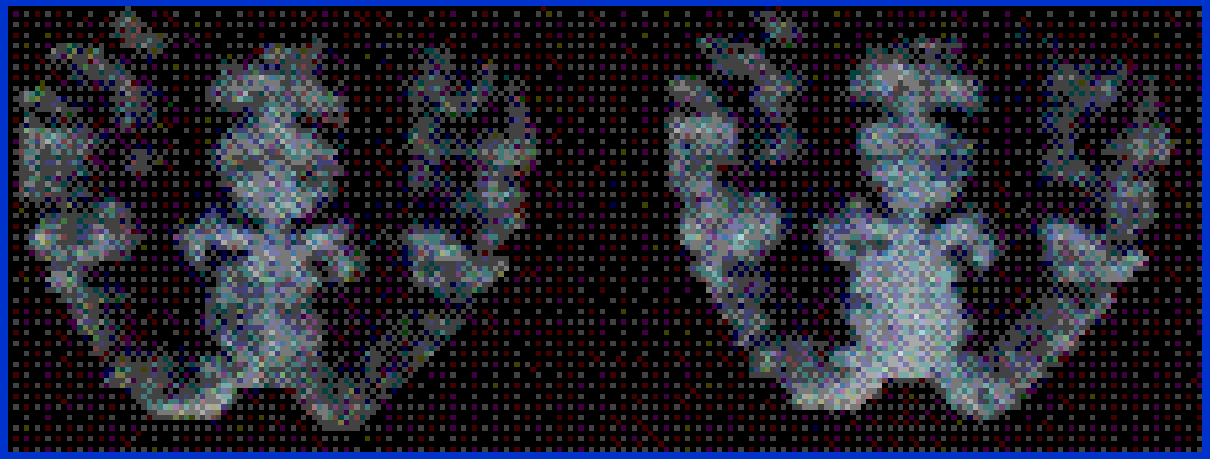


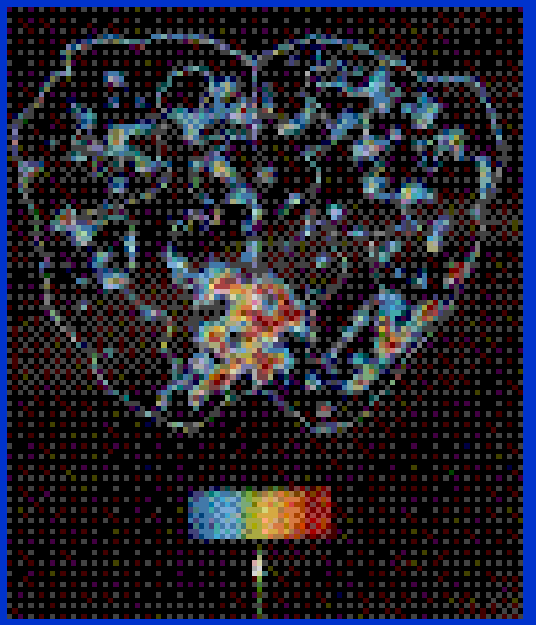
MRI Instrumentation

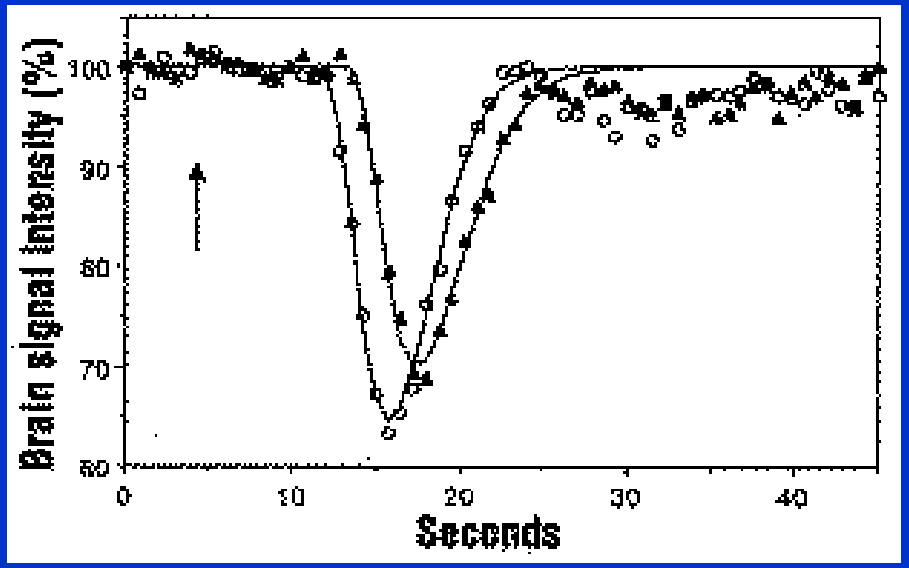


Blood Volume Changes with Brain Activation

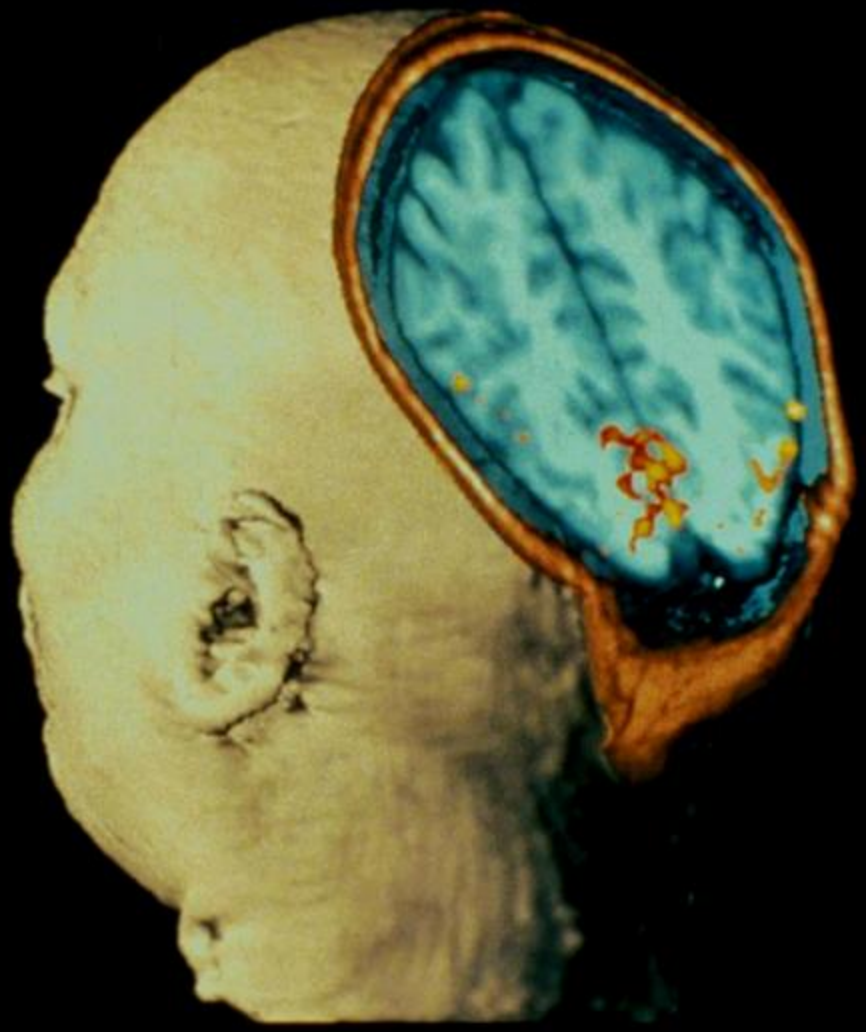
Resting **Active**







Photic Stimulation



MRI Image showing activation of the Visual Cortex

From Belliveau, et al. Science Nov 1991

BOLD

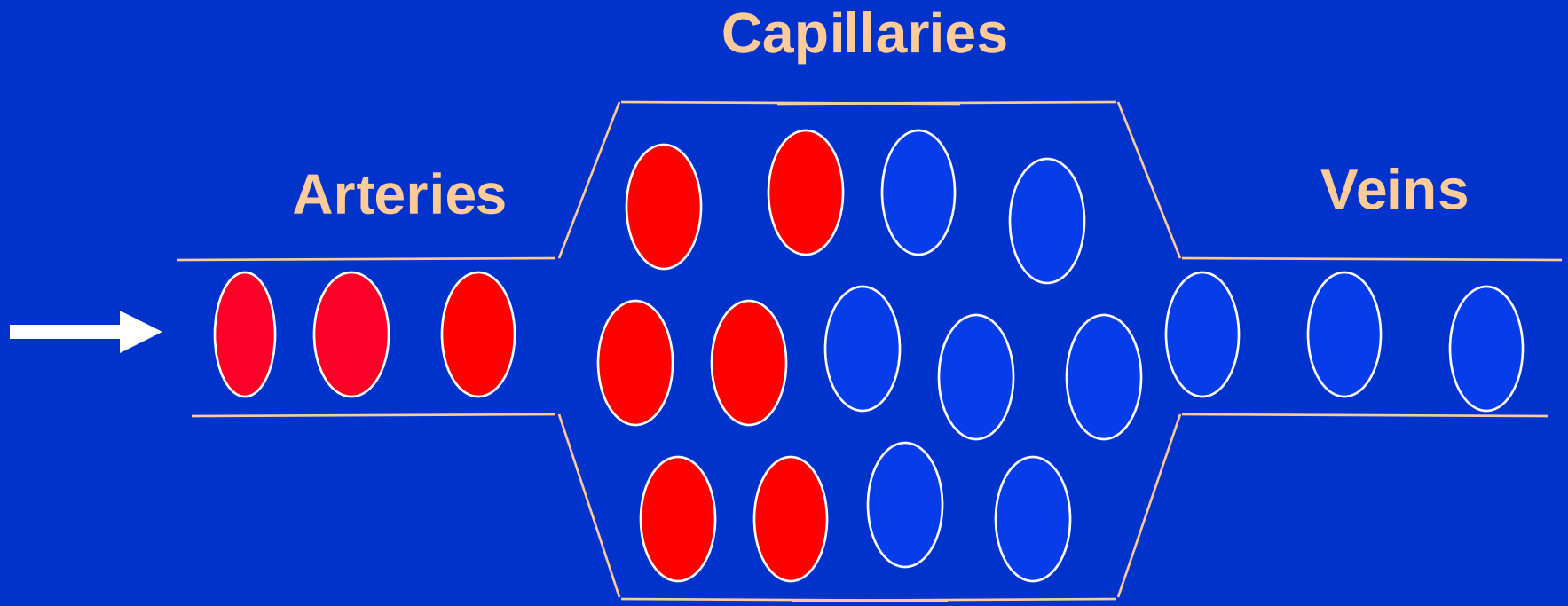
(blood oxygenation level dependence)

blood flow ↑

oxygenated-blood ↑

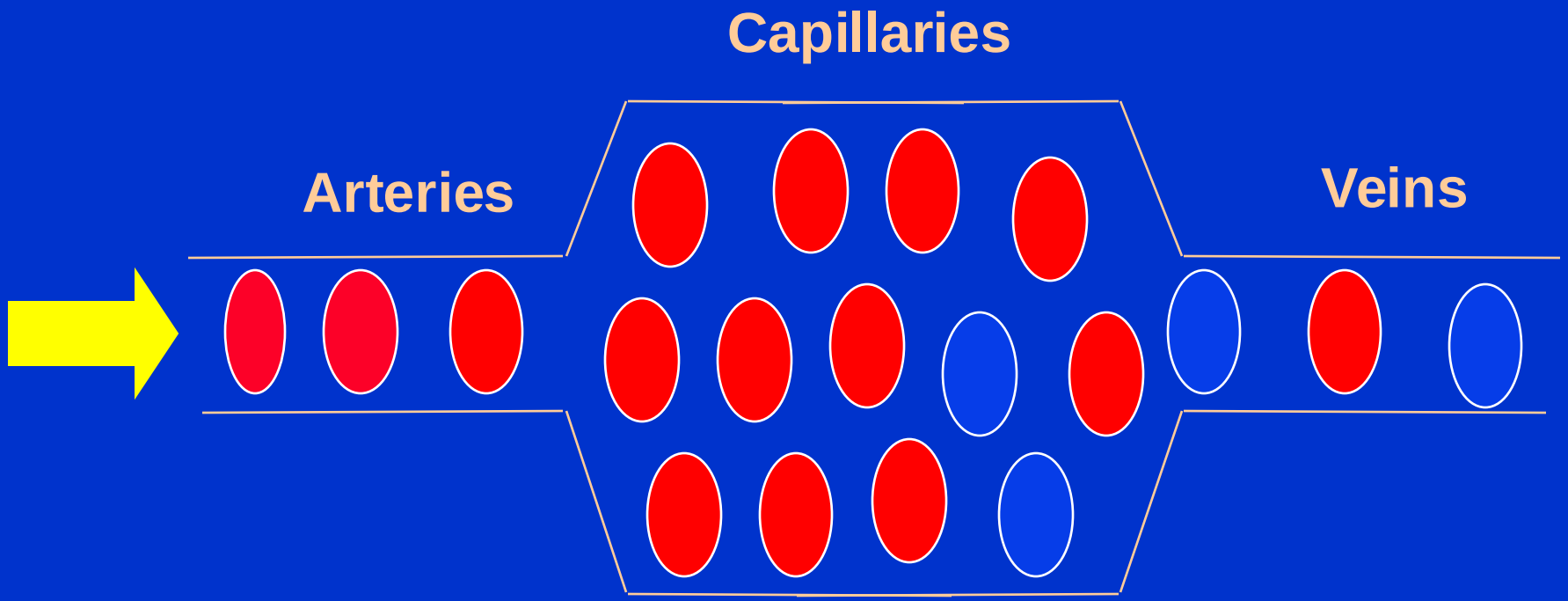
MR signal ↑

BOLD: Resting Perfusion



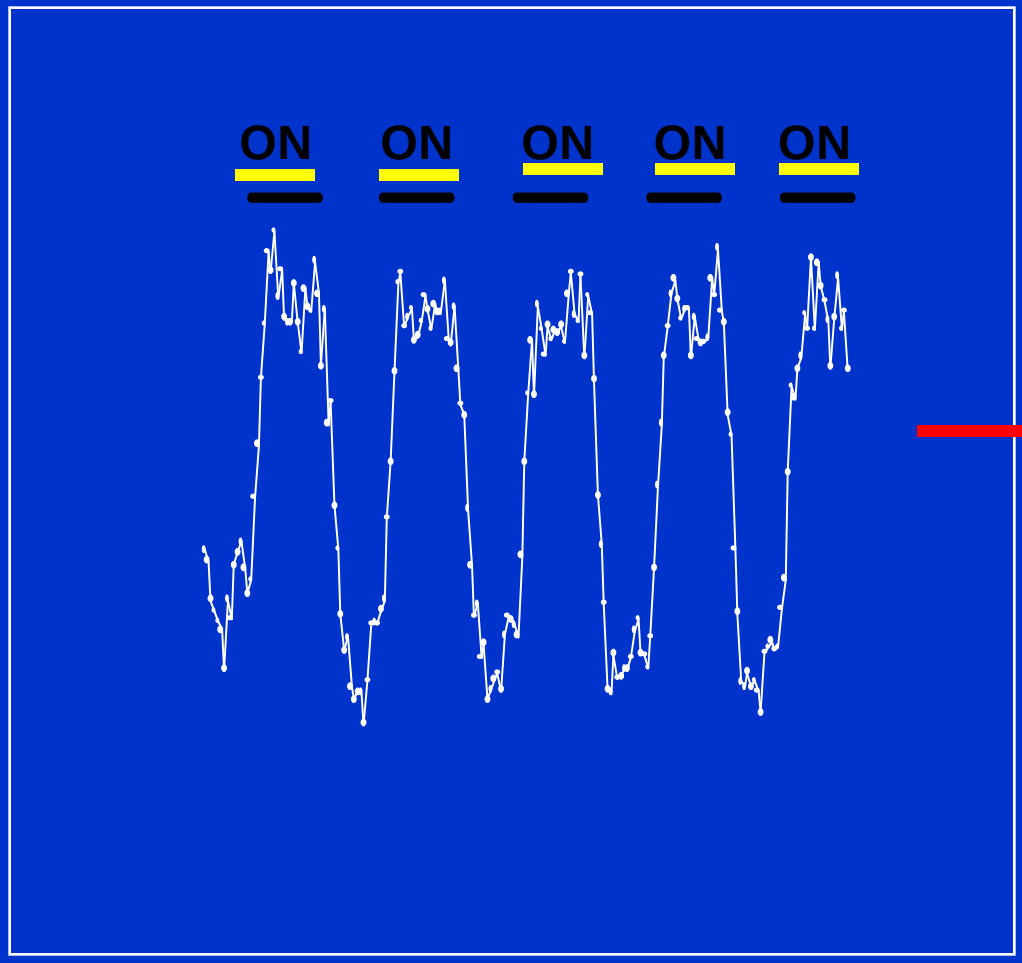
SIGNAL

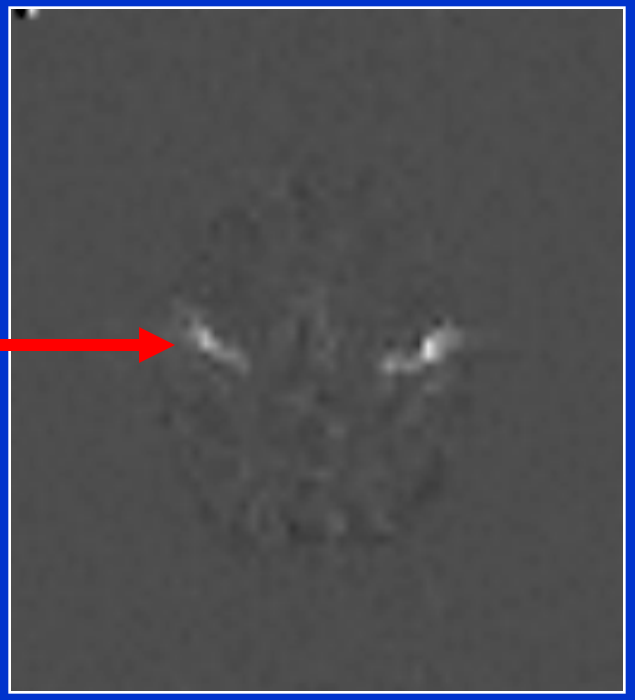
BOLD: Activated Perfusion



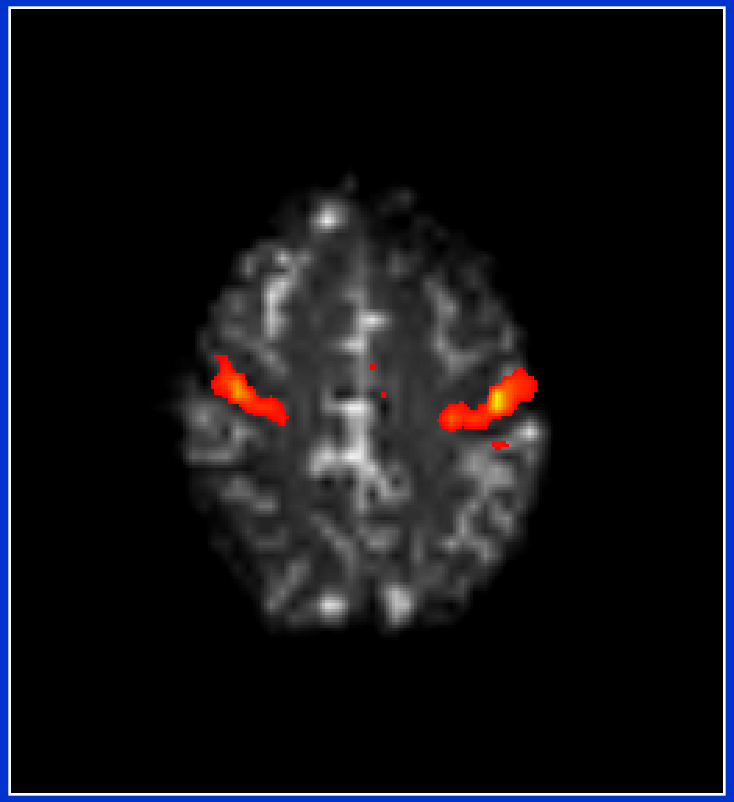
SIGNAL

BOLD: Motor Cortex Activation

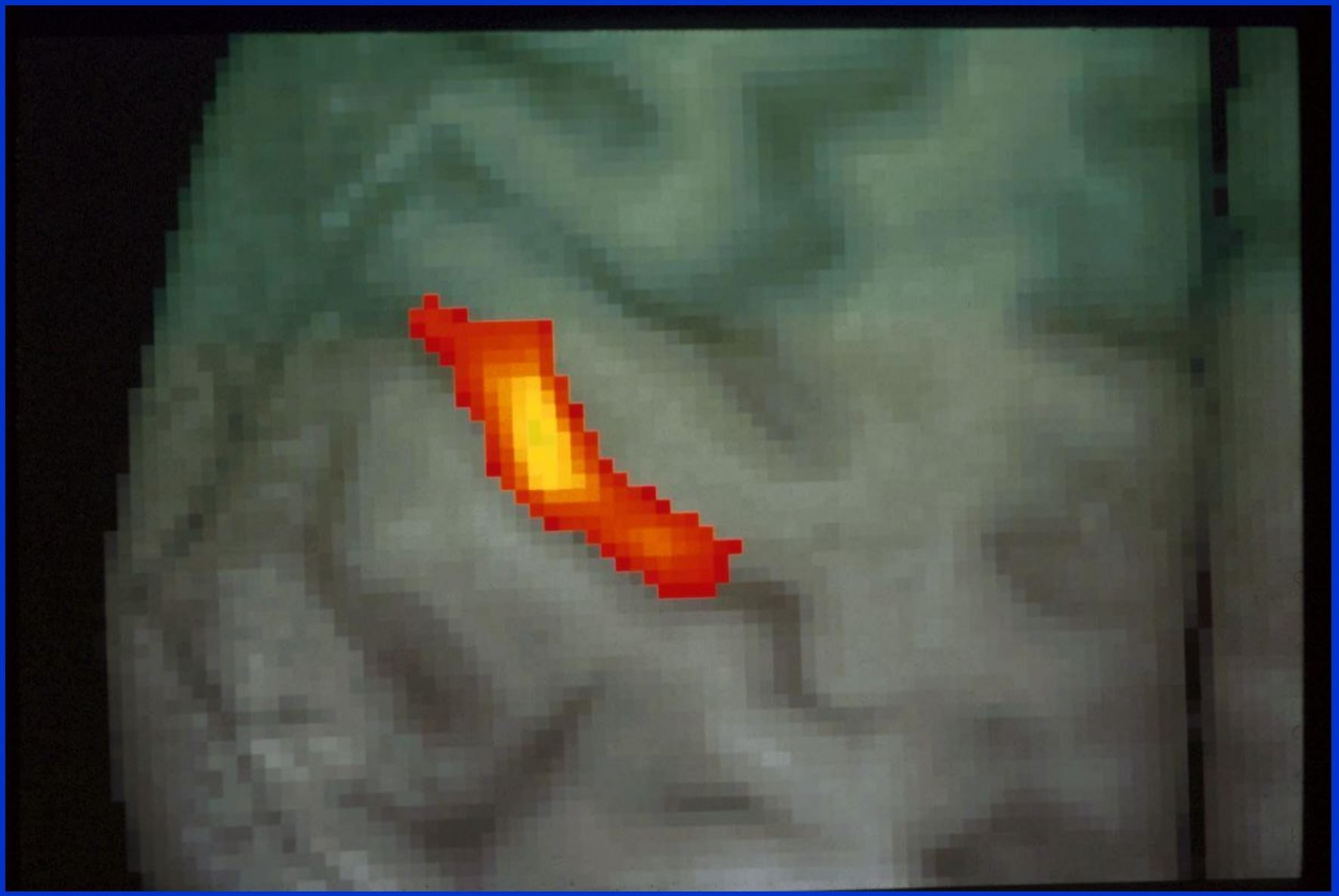




Cross Correlation Image

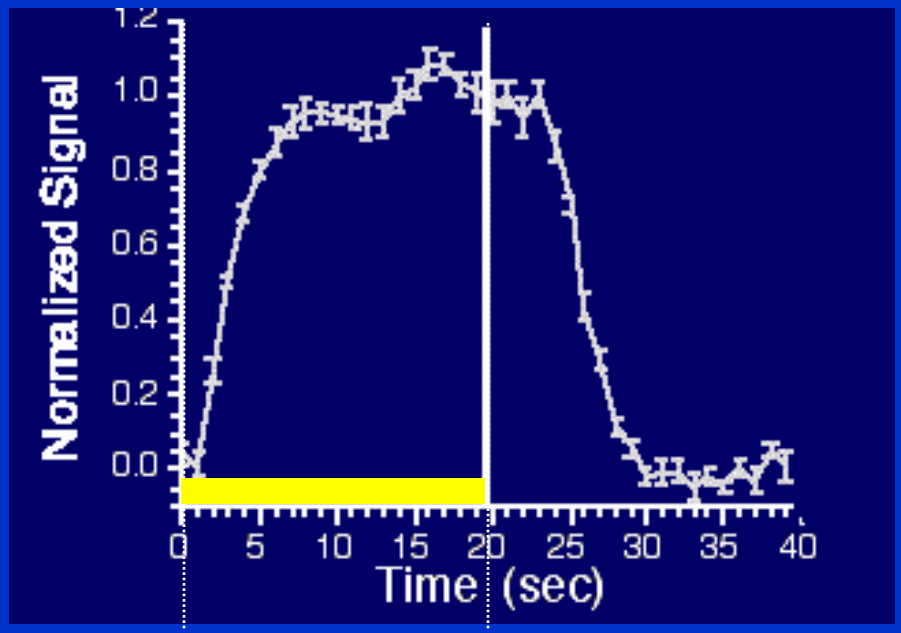


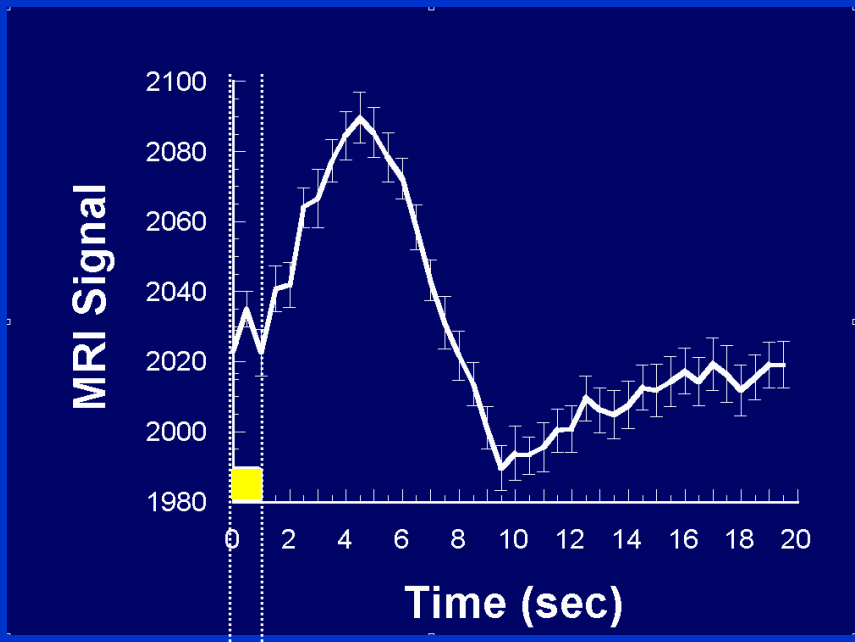
Cross Correlation Image
Anatomical Image



The BOLD Signal

Blood Oxygenation Level Dependent (BOLD) signal changes



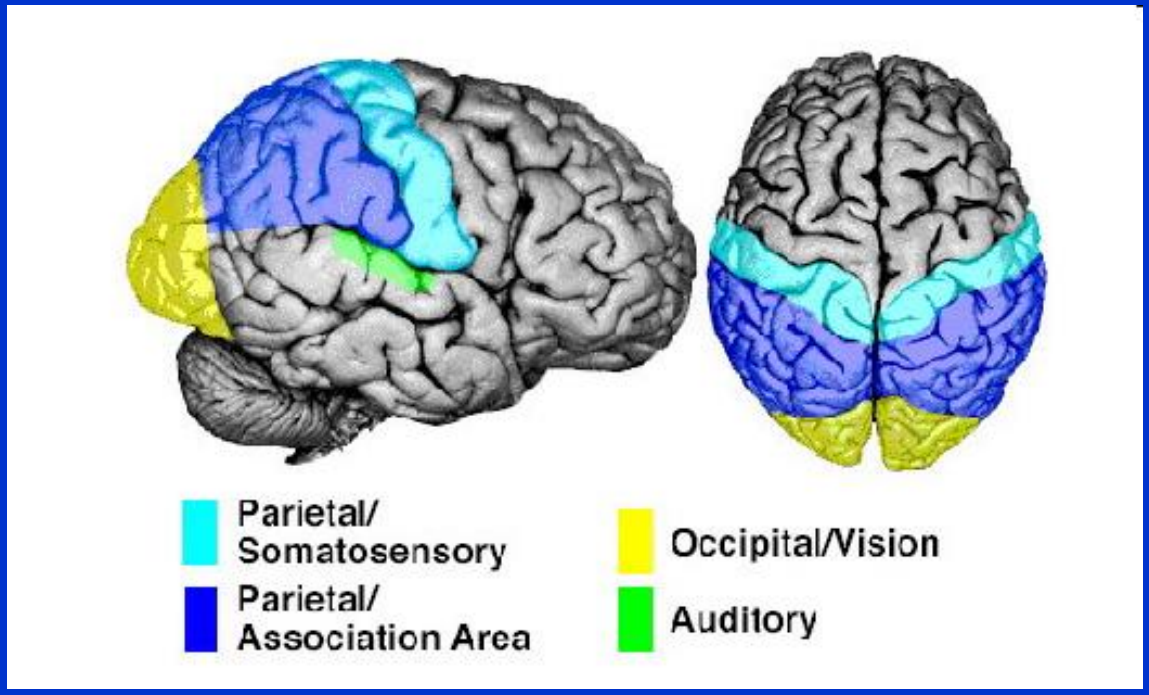


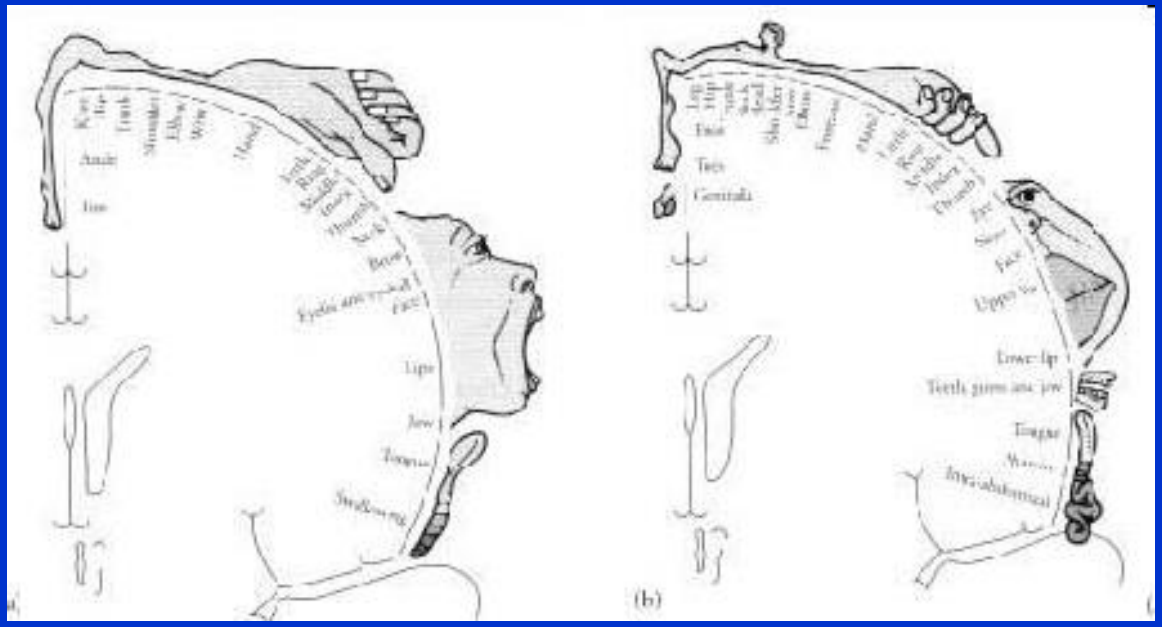
task

task

Alternating Left and Right Finger Tapping

~ 1992

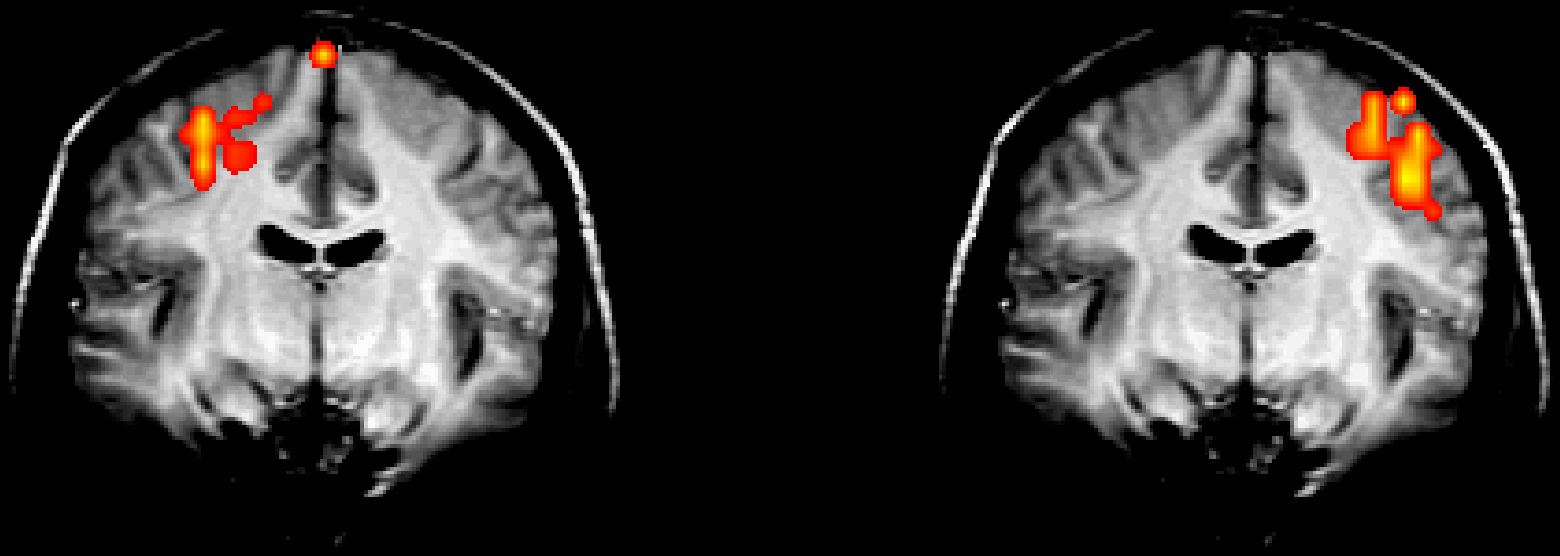

Parietal/
Somatosensory
Occipital/Vision
Parietal/
Association Area
Auditory


(b)

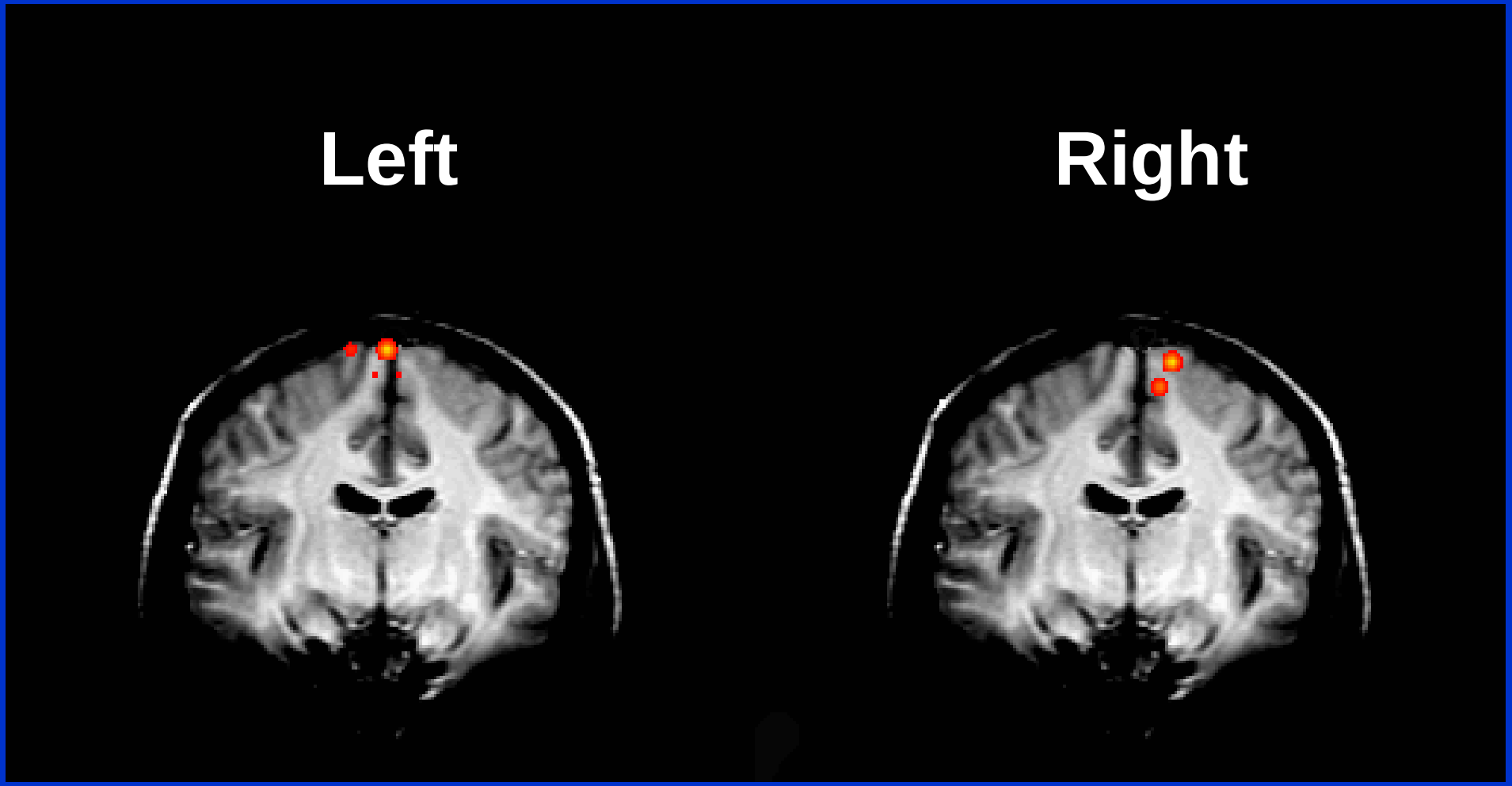
Finger Movement

Left

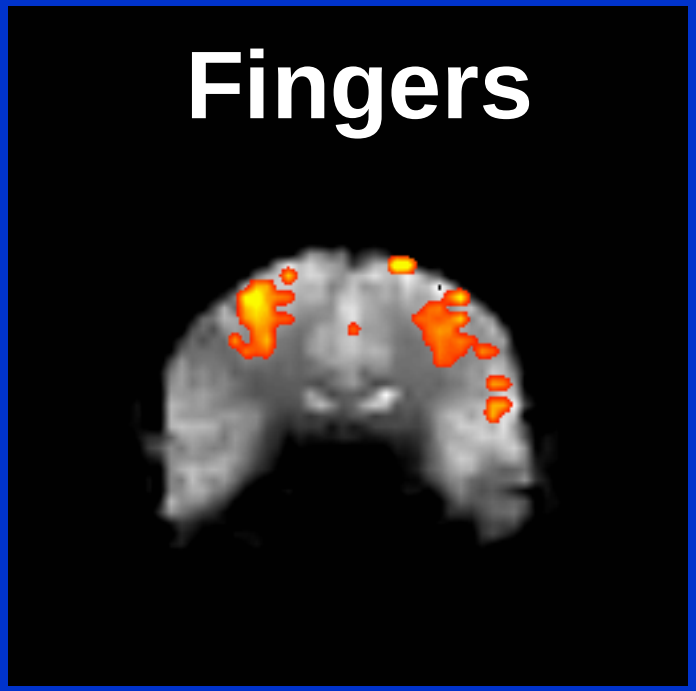
Right



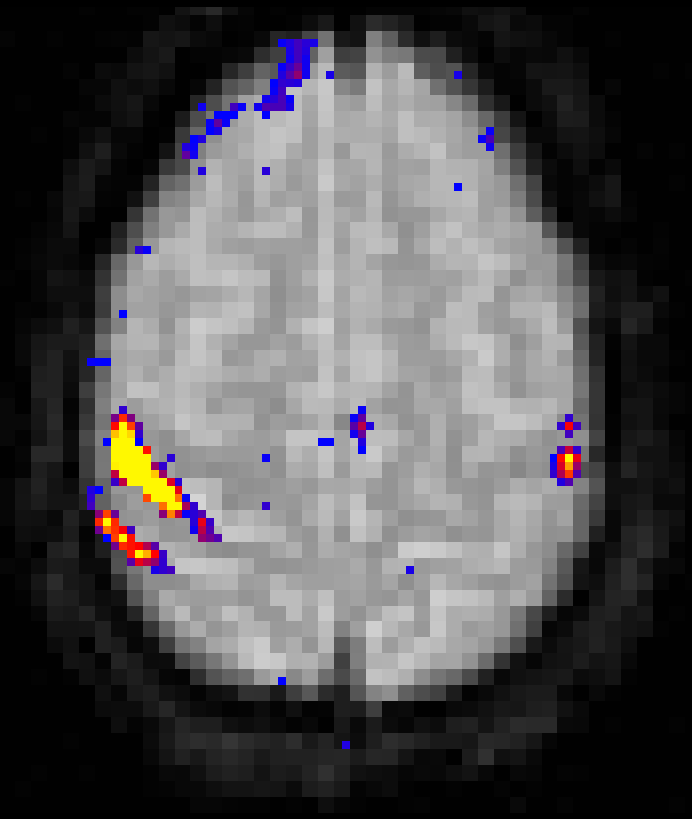
Toe Movement



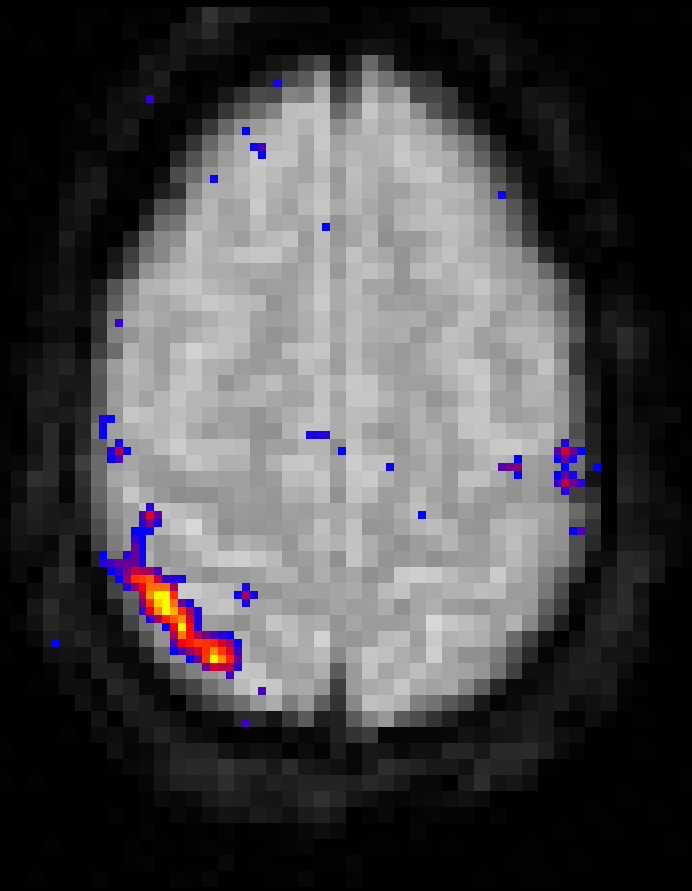

Wrist

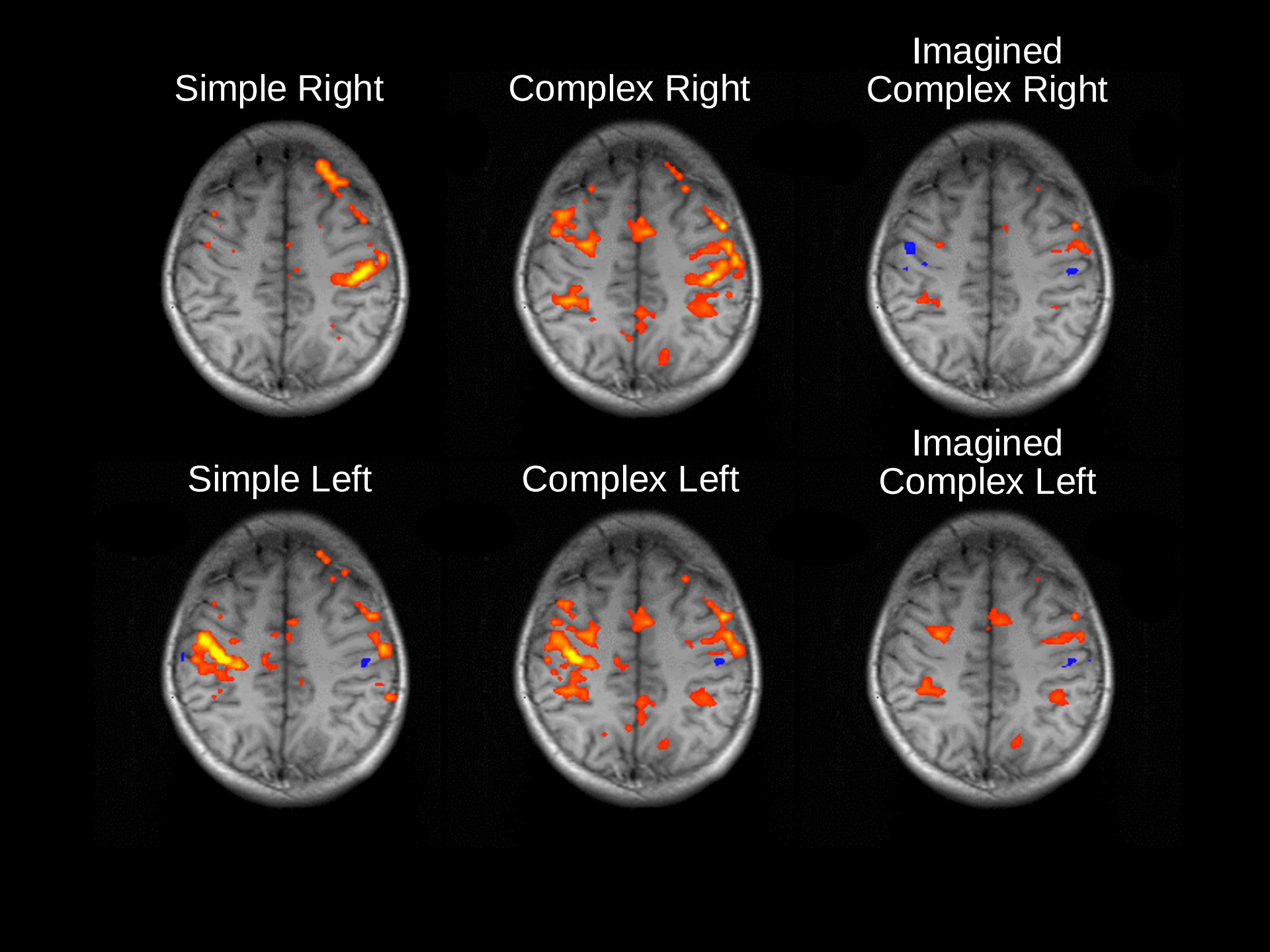

Fingers

Finger Movement



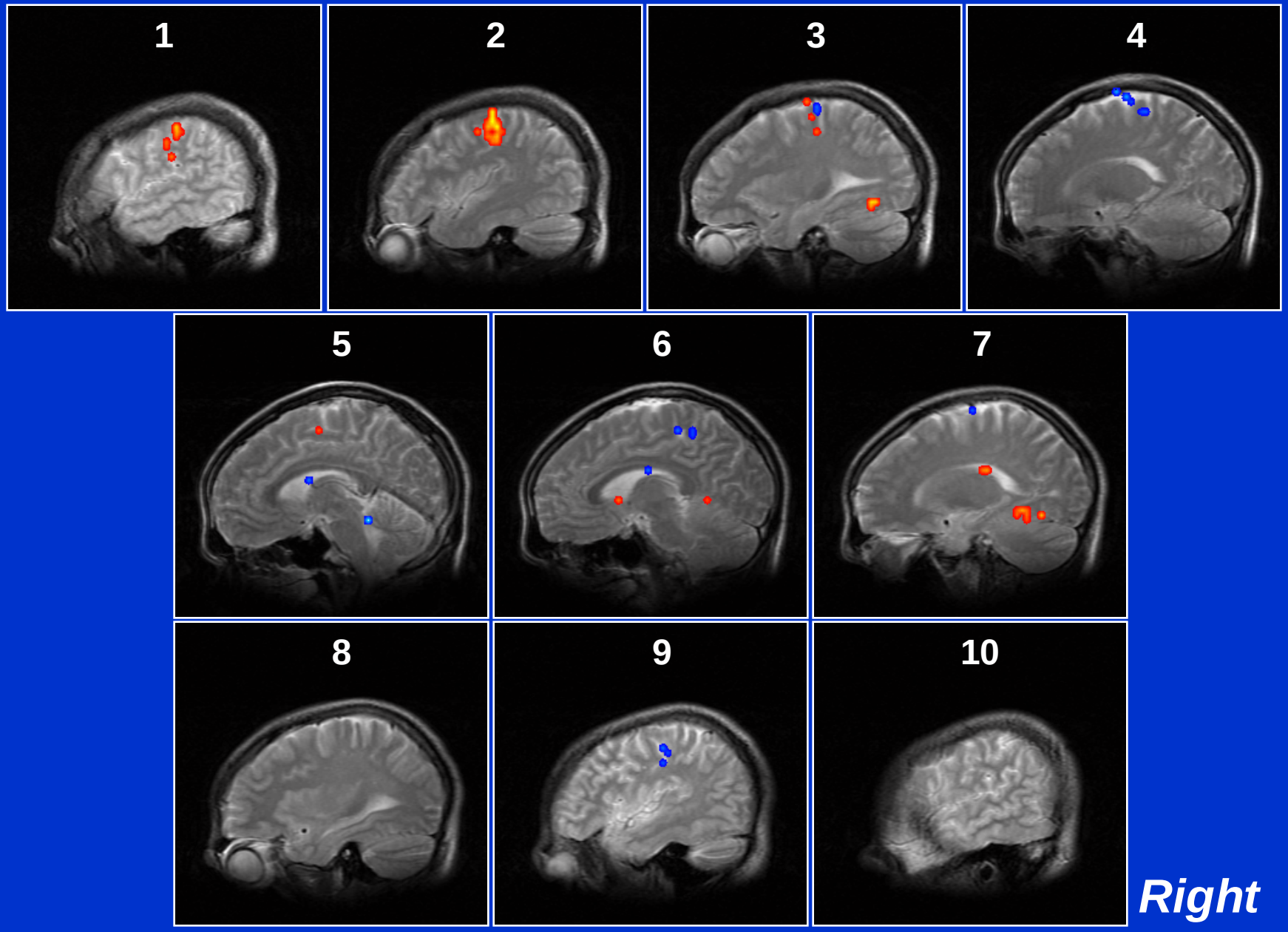
Tactile Stimulation




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

Left

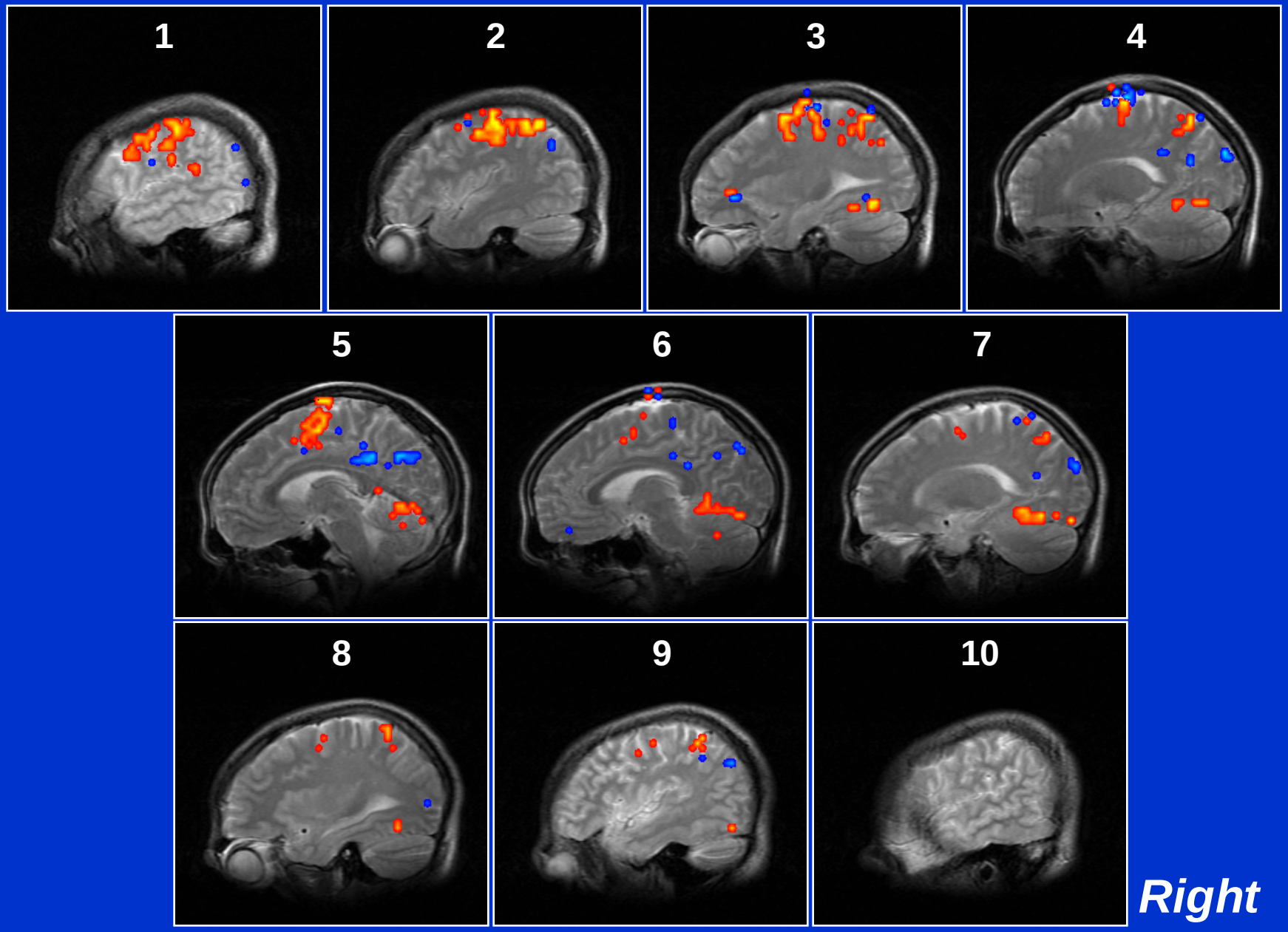
Simple Finger Movement on the RIght Hand



Right

Left

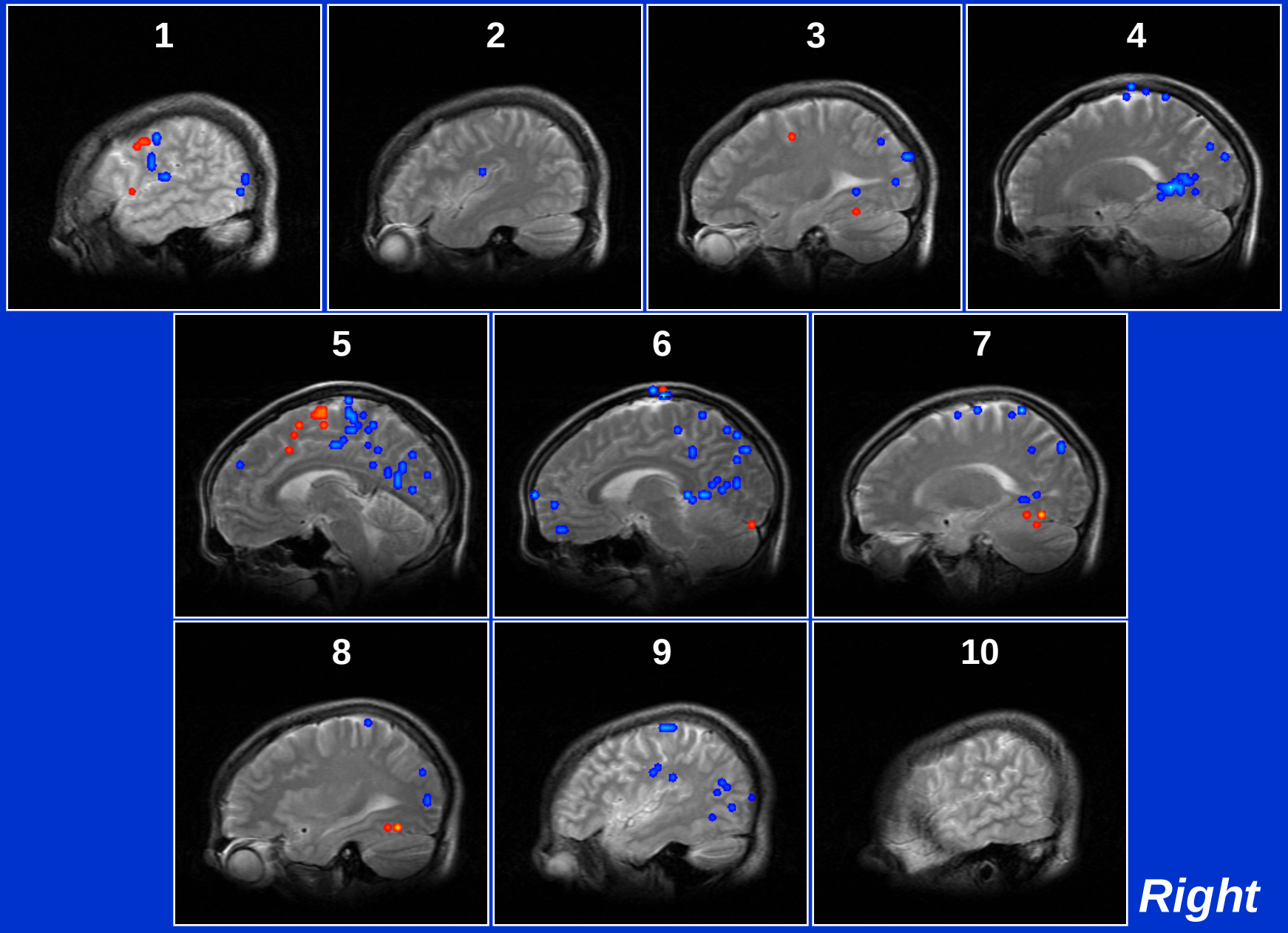
Complex Finger Movement on the Right Hand



Right

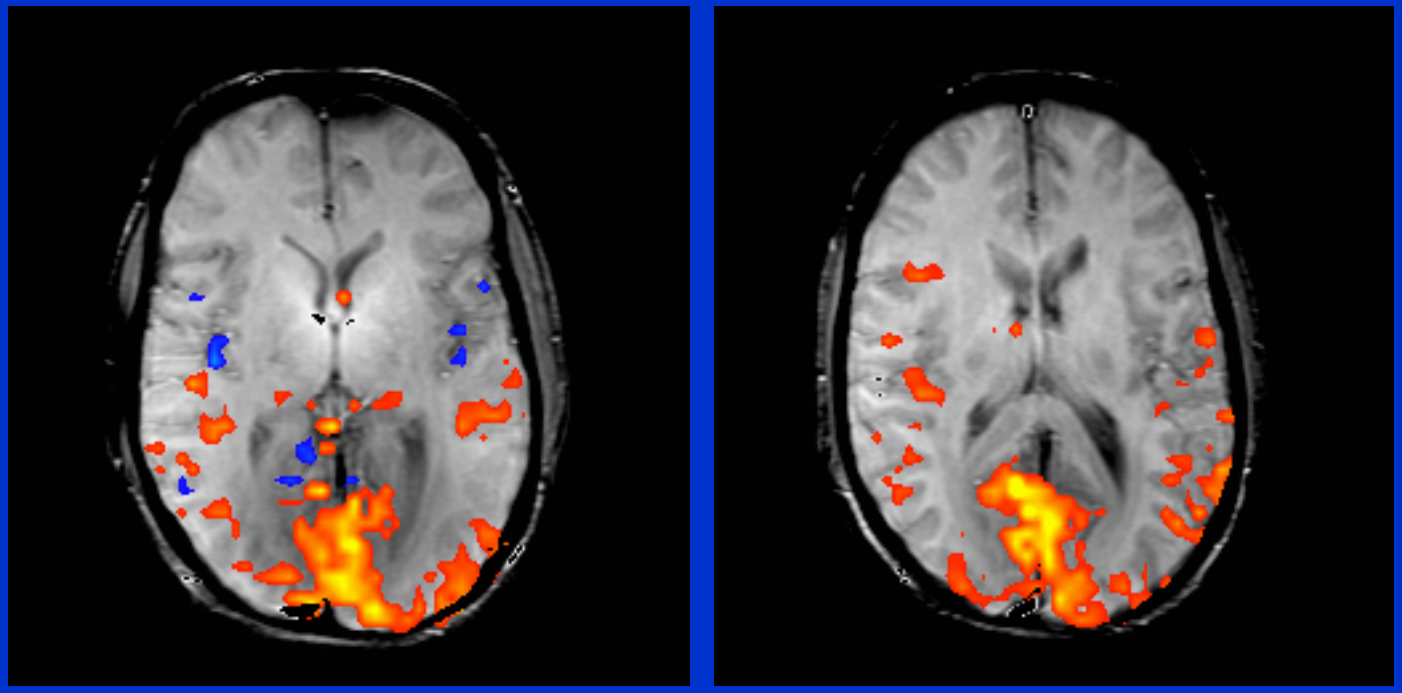
Left

Imagined Complex Finger Movement on the Right Hand

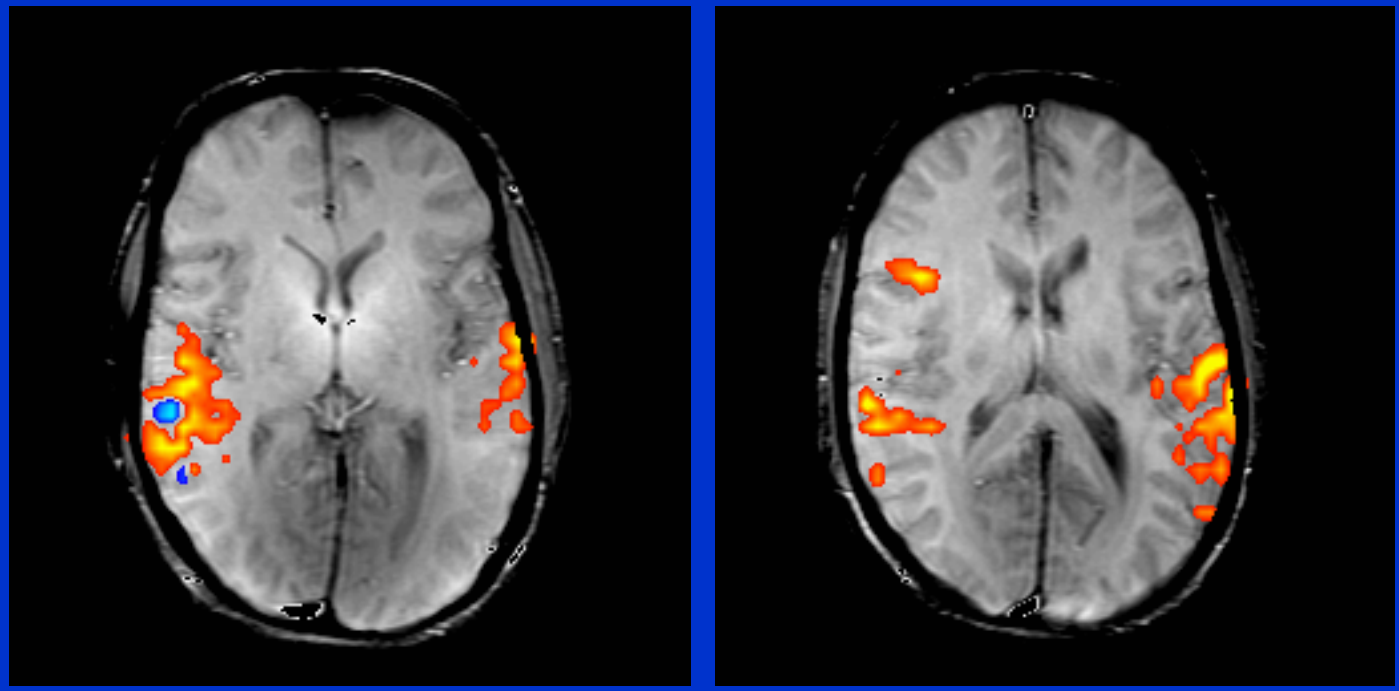


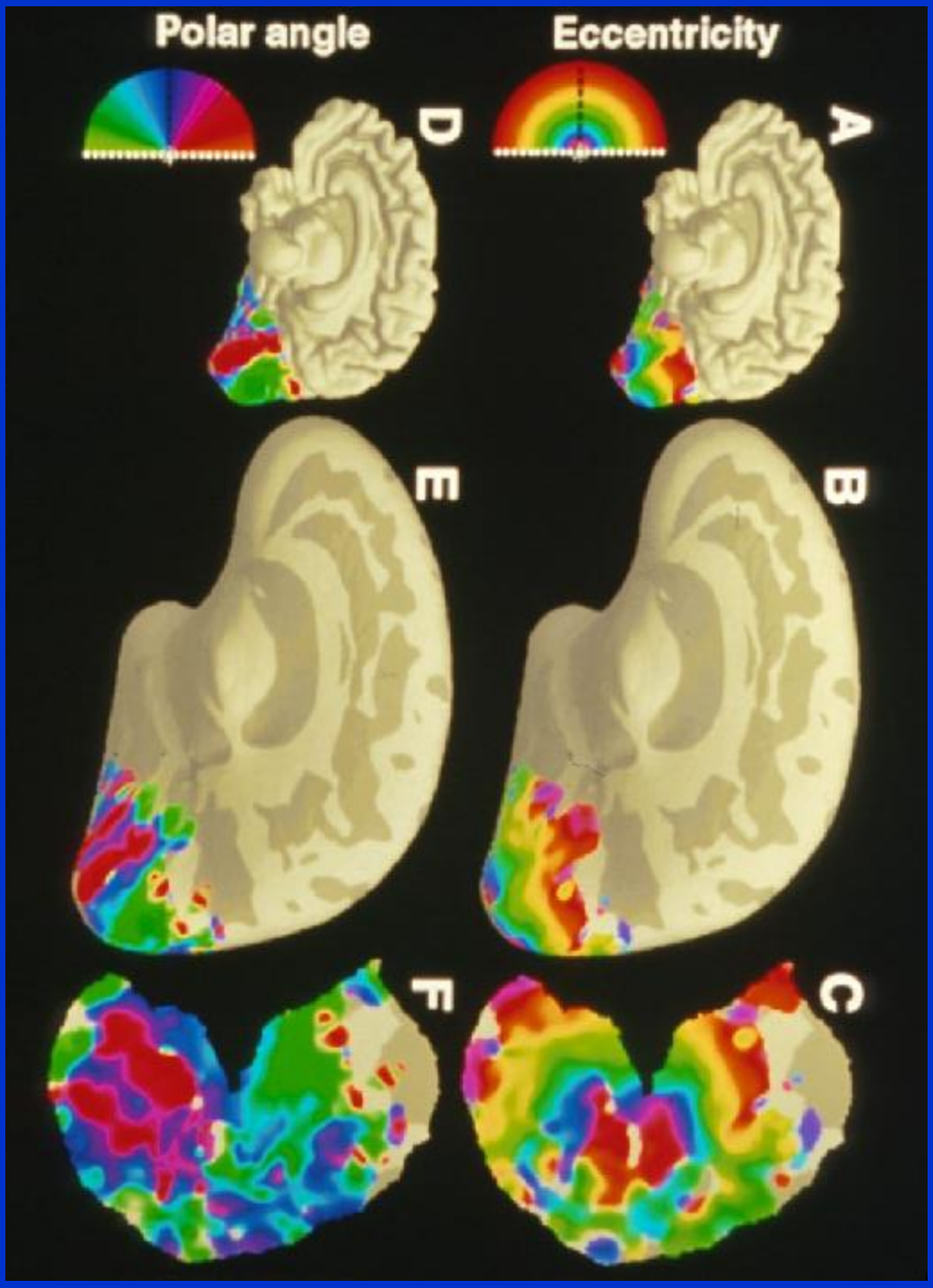
Right

Reading

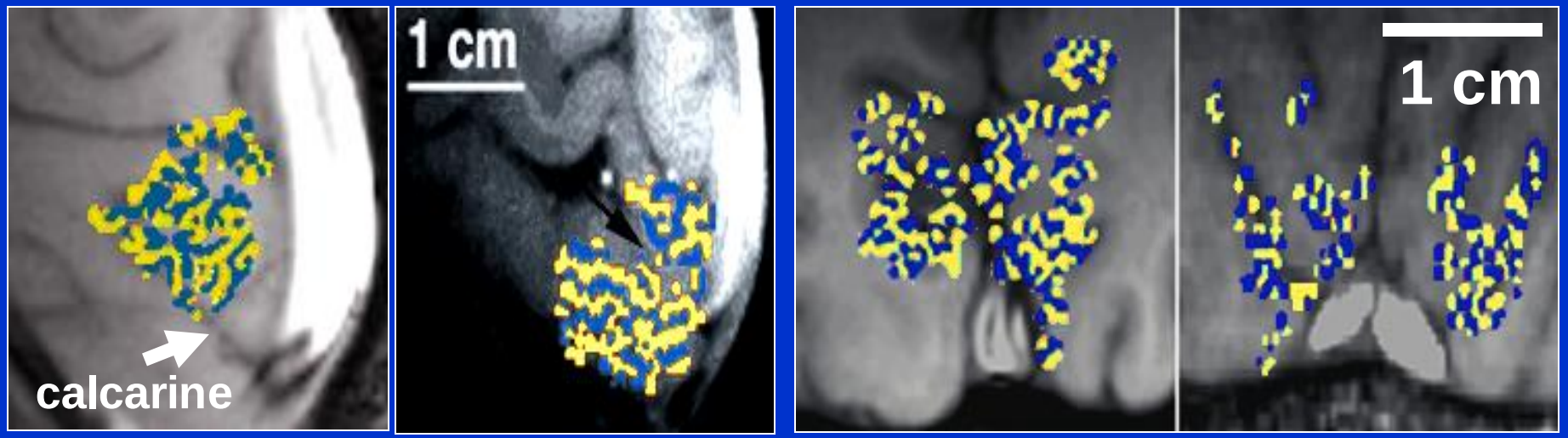


Listening to Spoken Words




Polar angle
Eccentricity
A
B
C
D
E
F

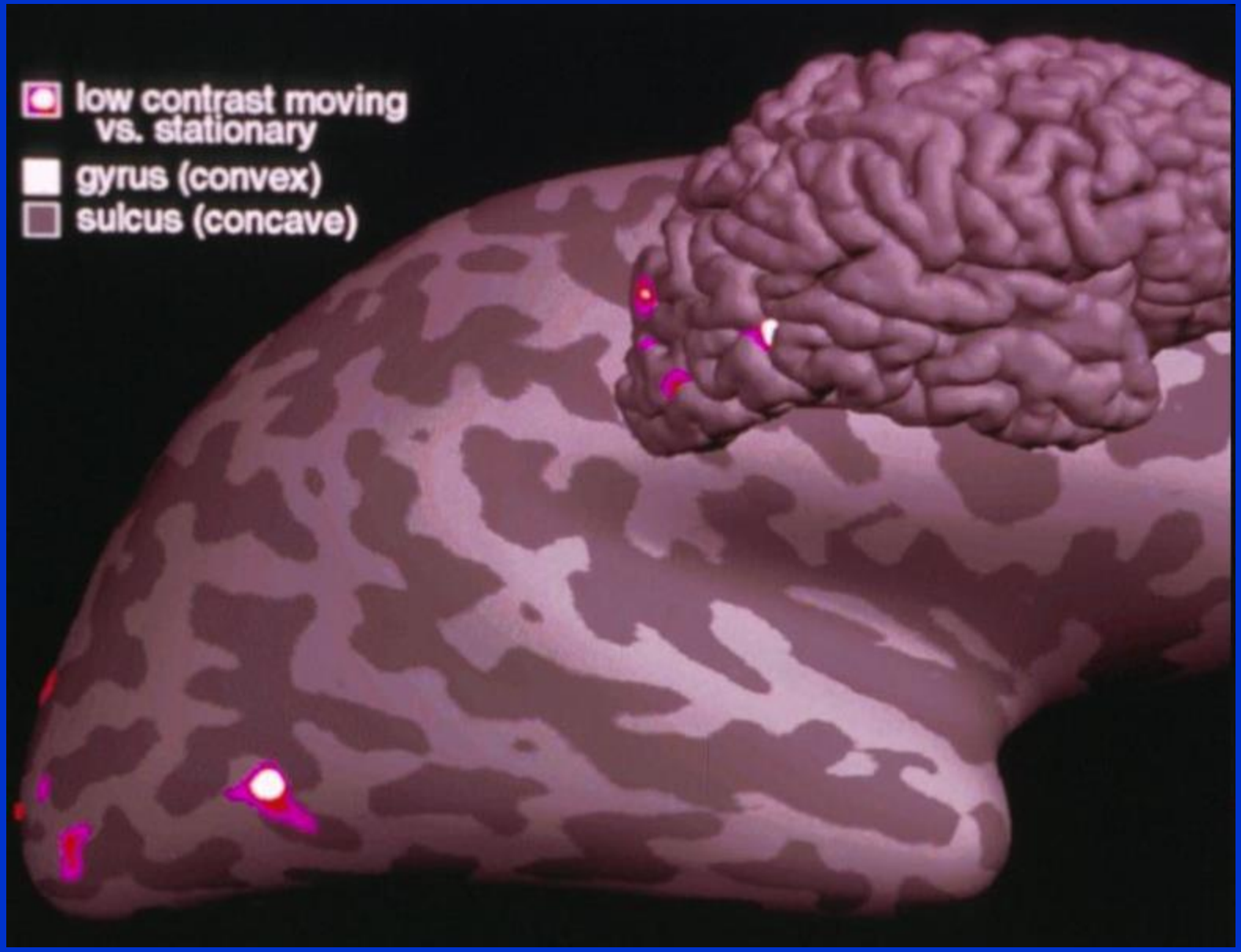
ODC Maps using fMRI



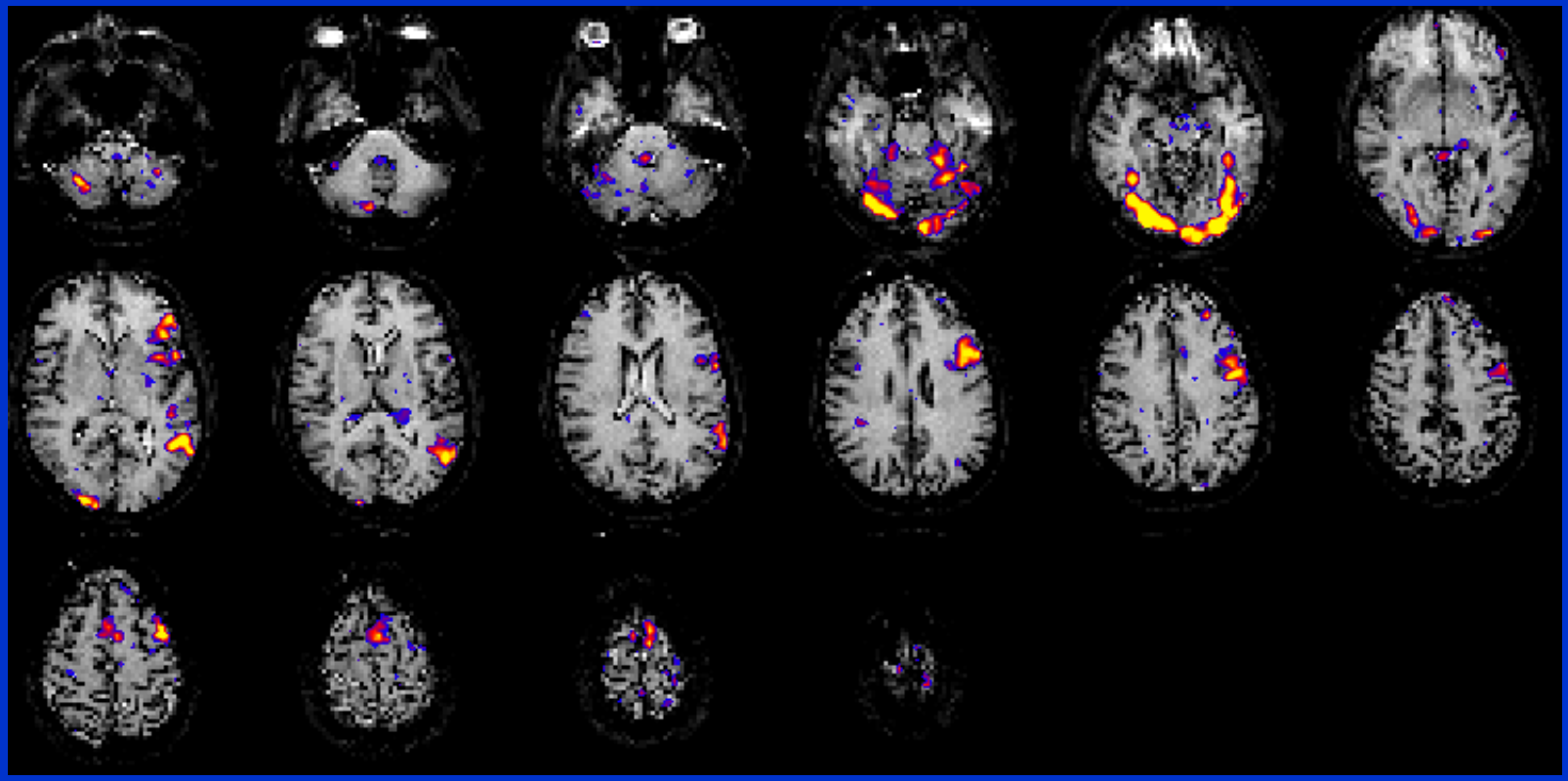
• Identical in size, orientation, and appearance to those obtained by optical imaging[1] and histology[3,4].

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).

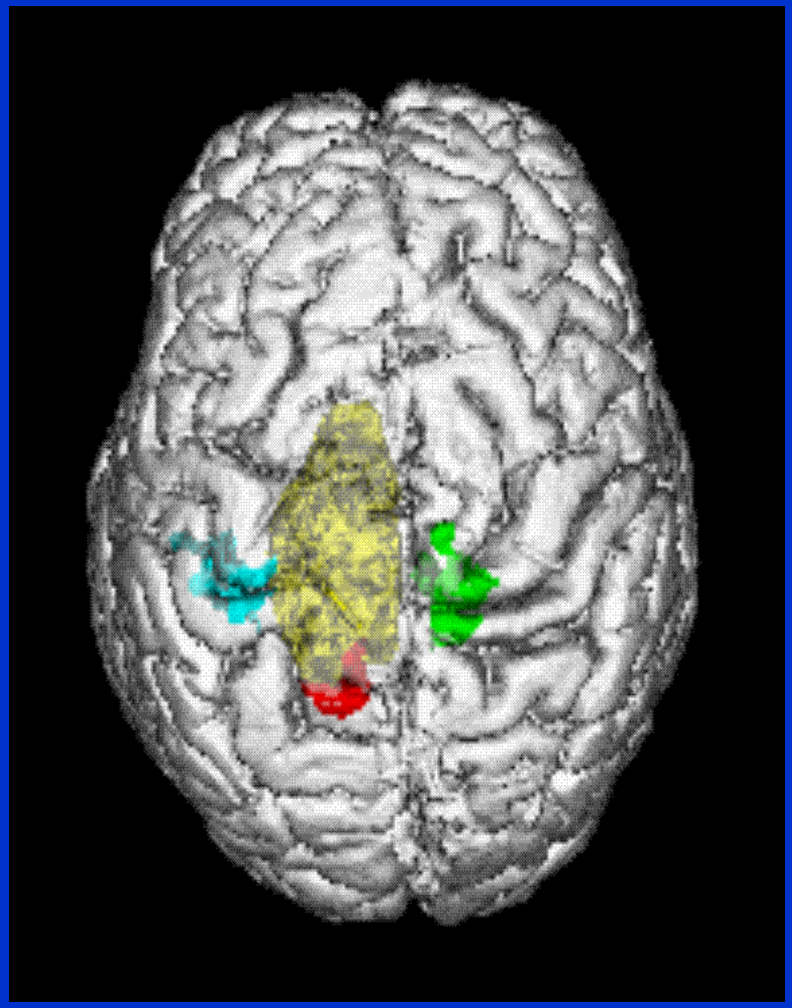

low contrast moving
vs. stationary
gyrus (convex)
sulcus (concave)

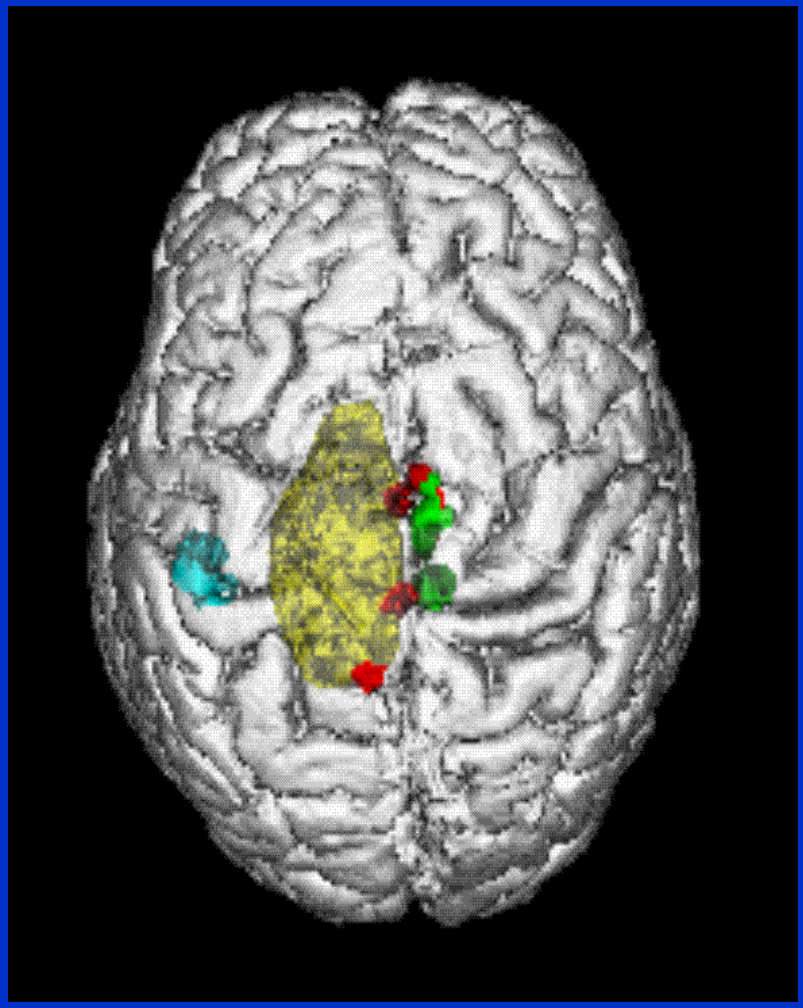
Word stem completion



Presurgical Mapping

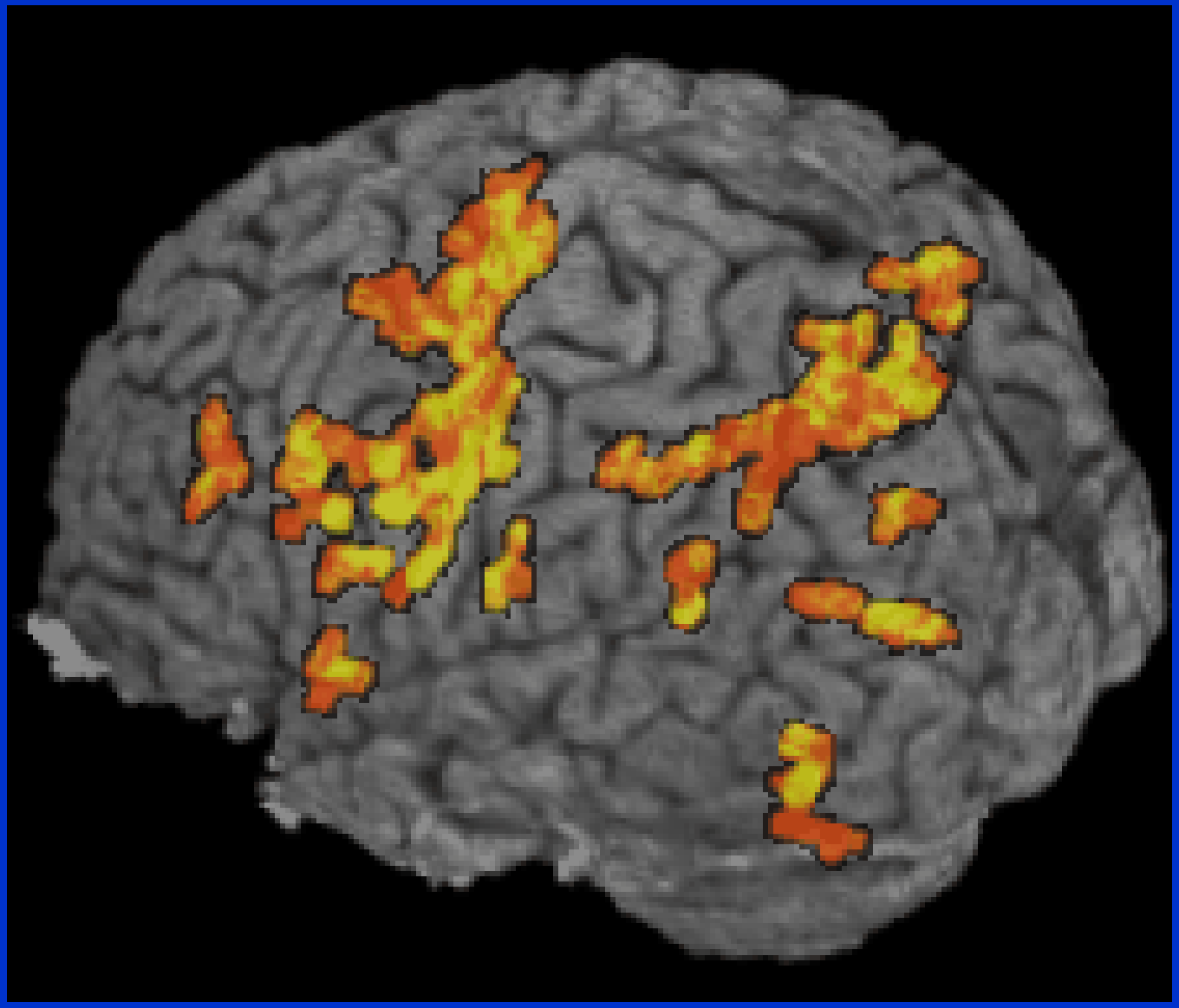
Left Foot Tumor Right Foot Right Hand





fMRI O-15 PET

End of Acquisition



< 1 s to render

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

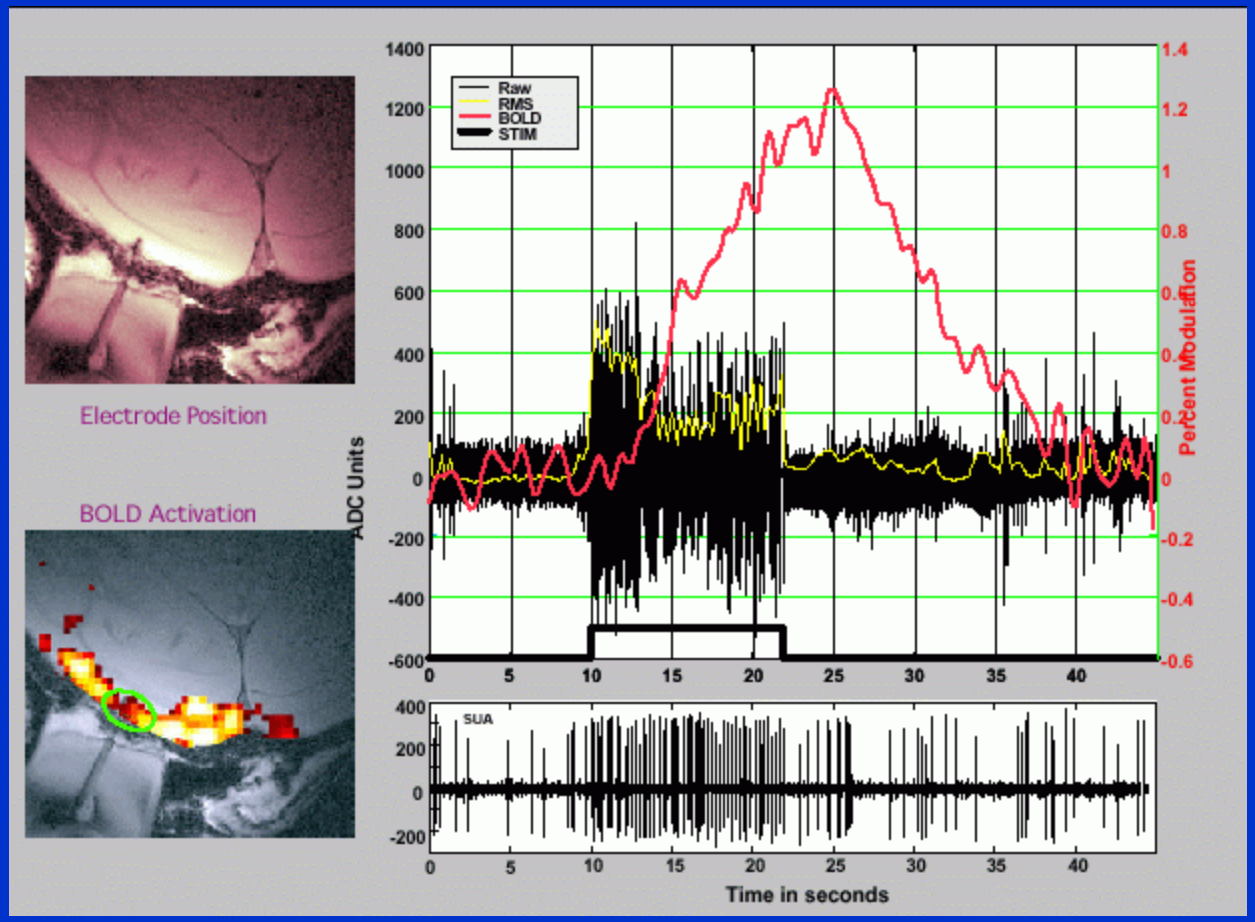
Blocks: 12345678

Color shows through brain

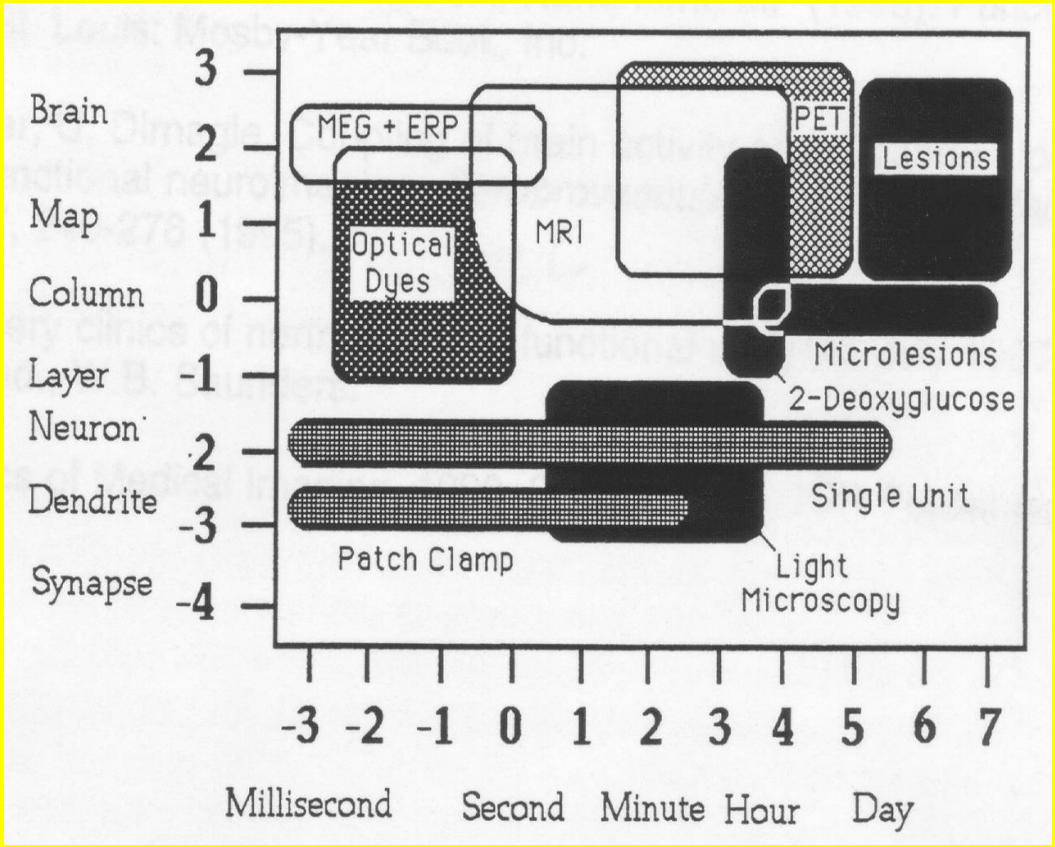
Correlation > 0.45

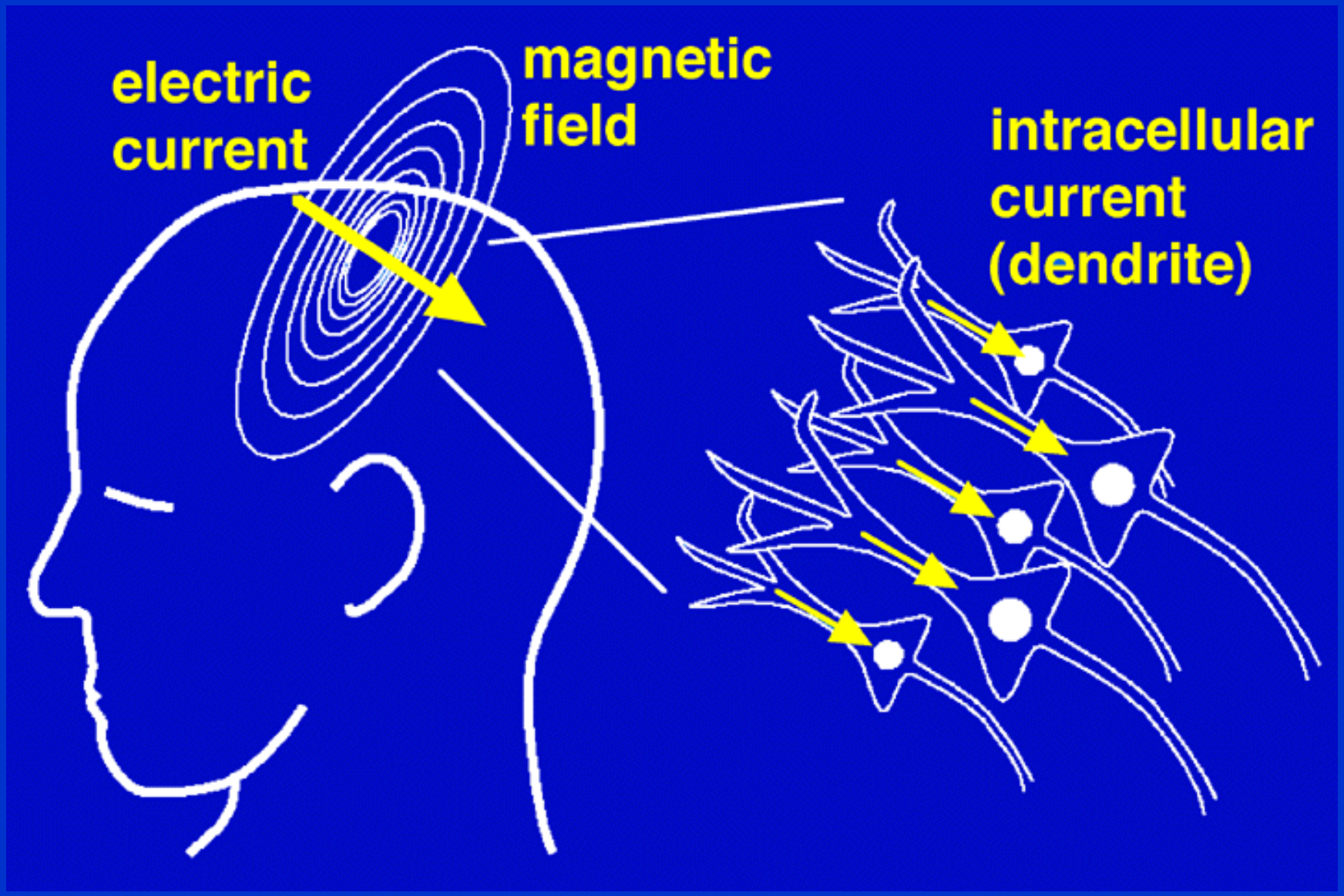
The End

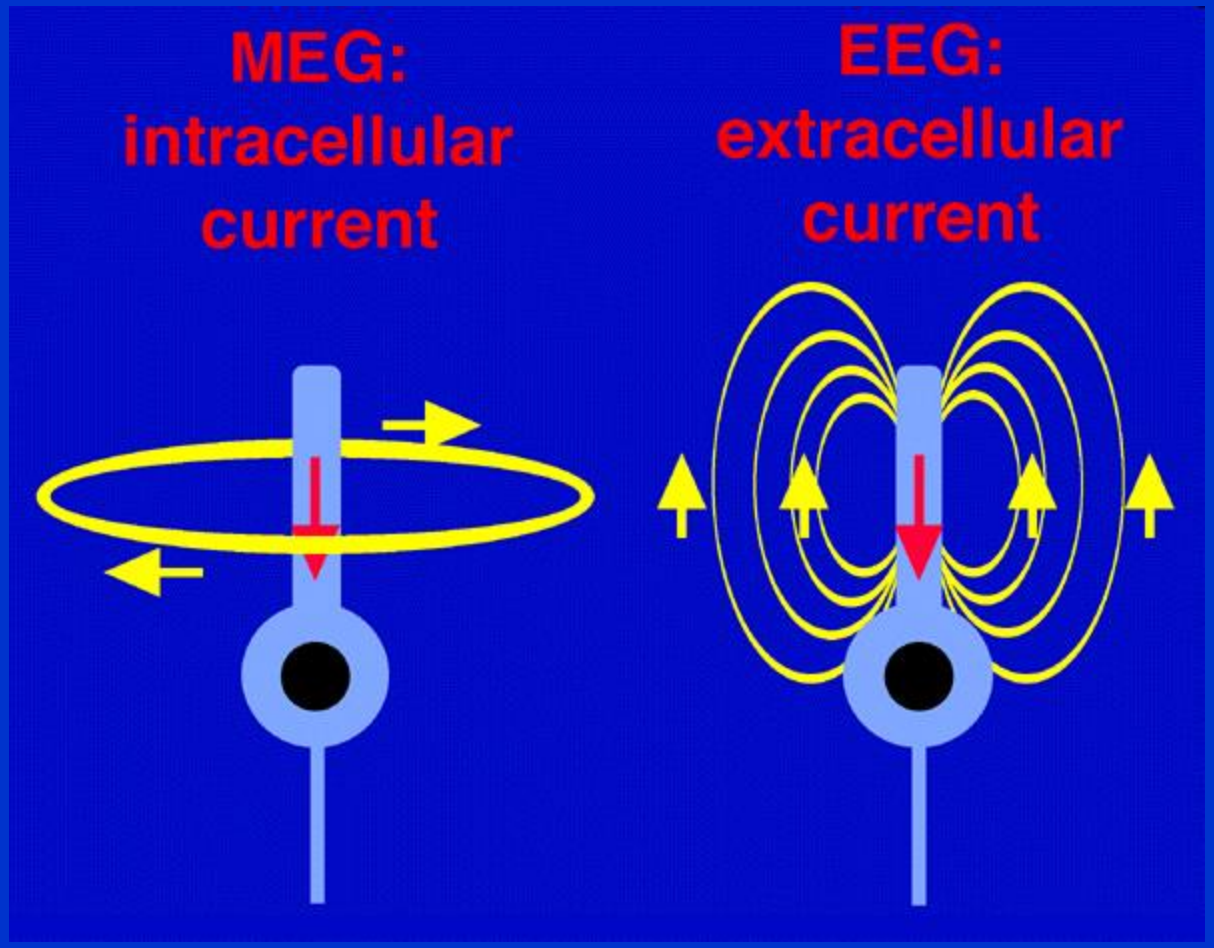
Combined Electrophysiological Measurement and fMRI

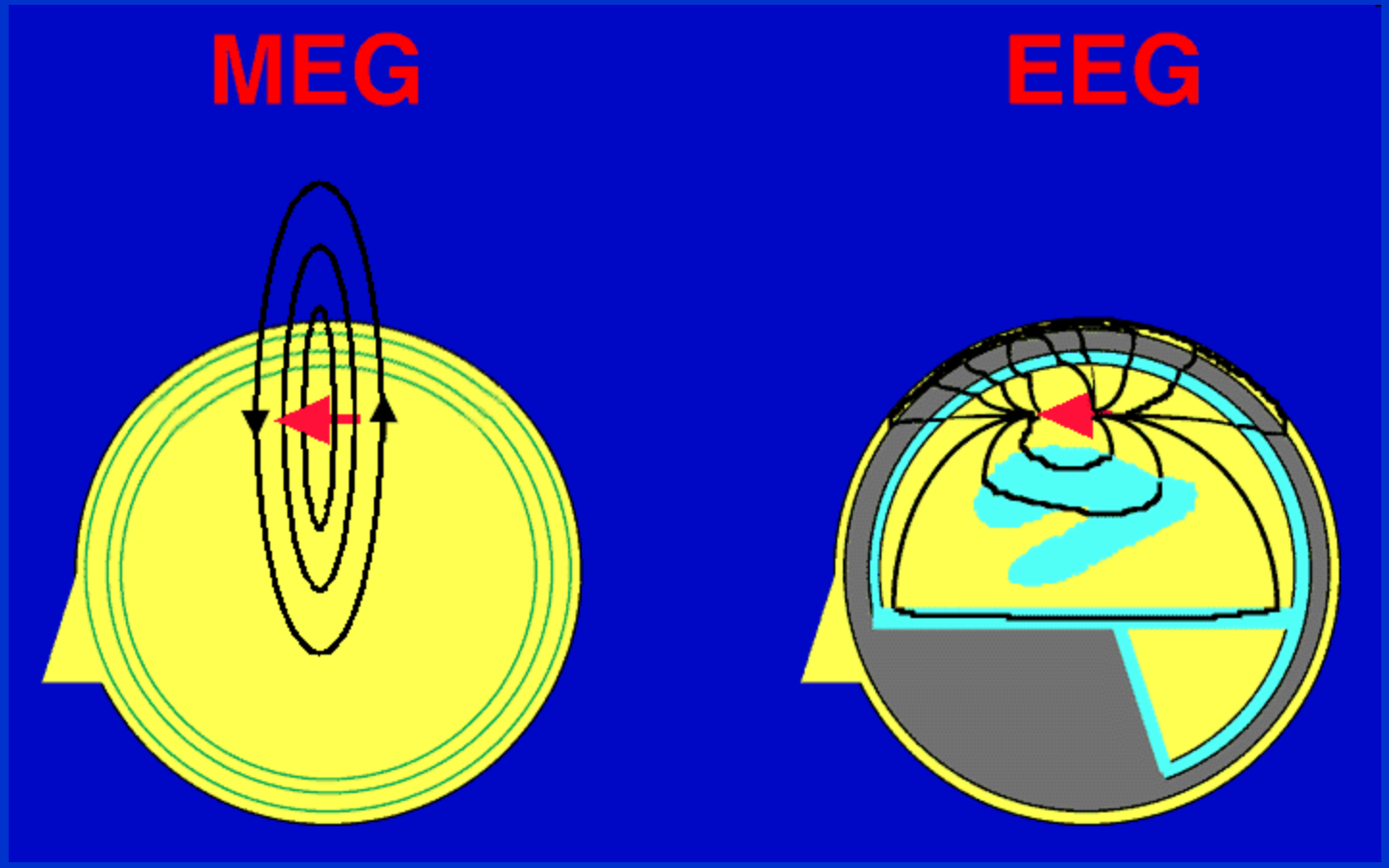


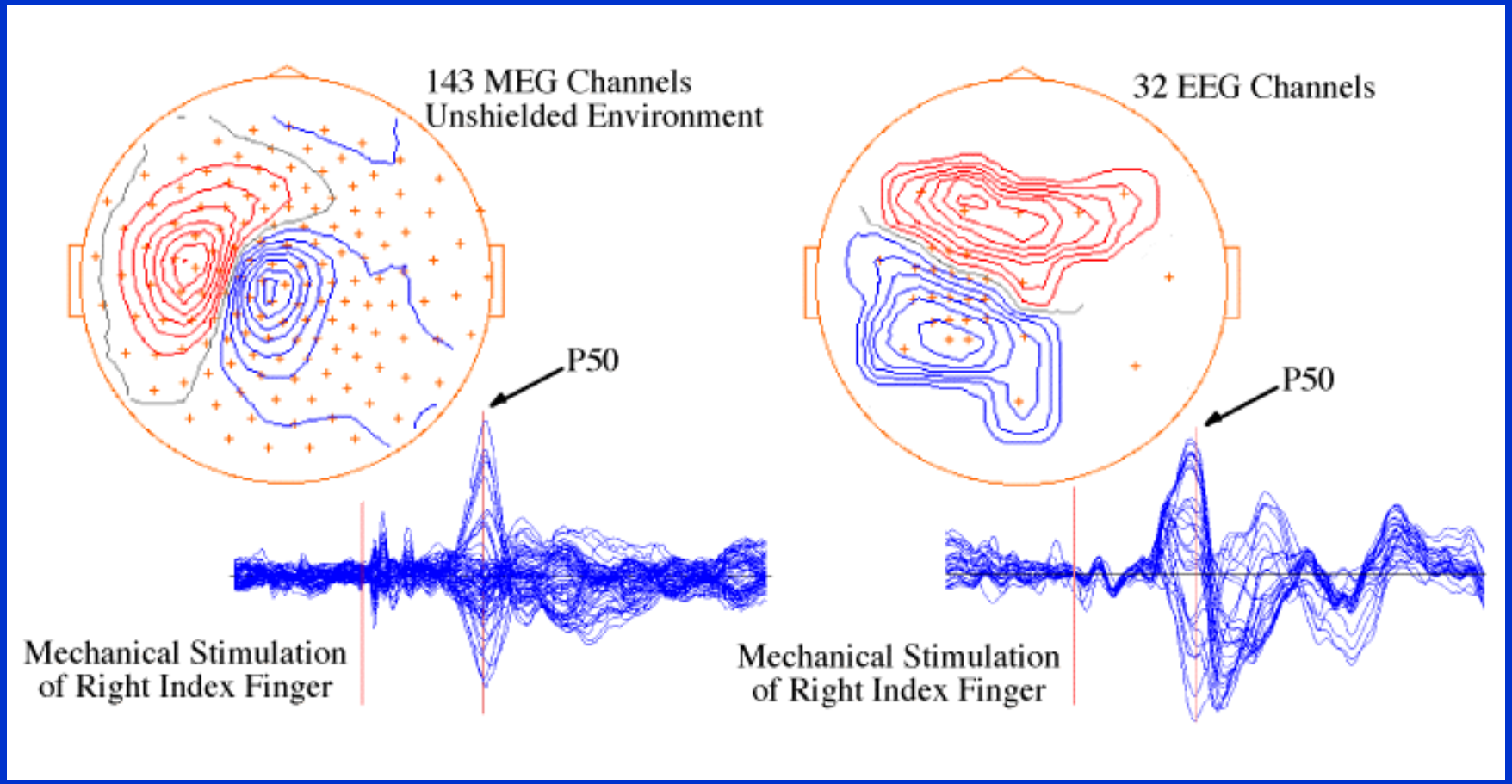
Functional Neuroimaging Techniques

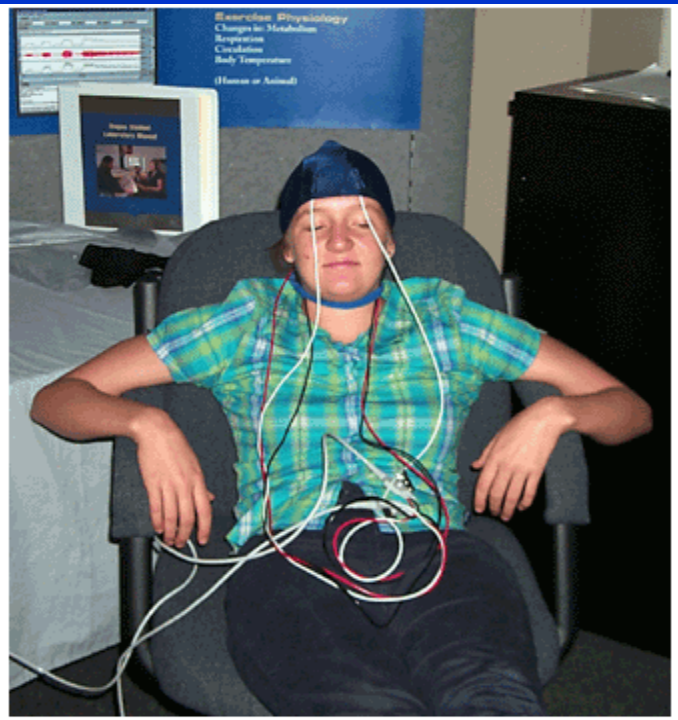


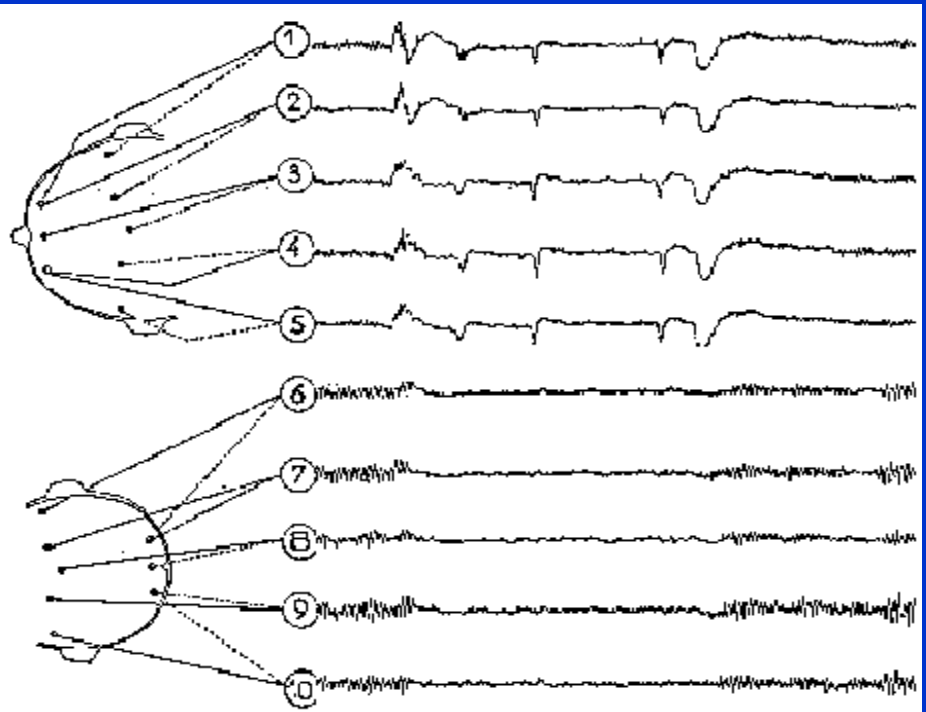

electric
current
magnetic
field
intracellular
current
(dendrite)


MEG:
intracellular
current
EEG:
extracellular
current


MEG
EEG

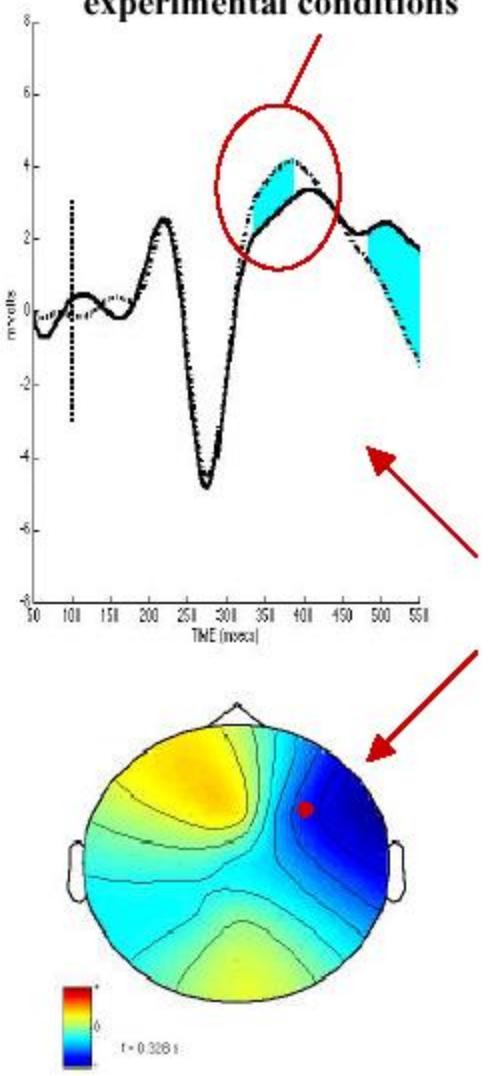

143 MEG Channels
Unshielded Environment
P50
Mechanical Stimulation
of Right Index Finger
32 EEG Channels
P50
Mechanical Stimulation
of Right Index Finger


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

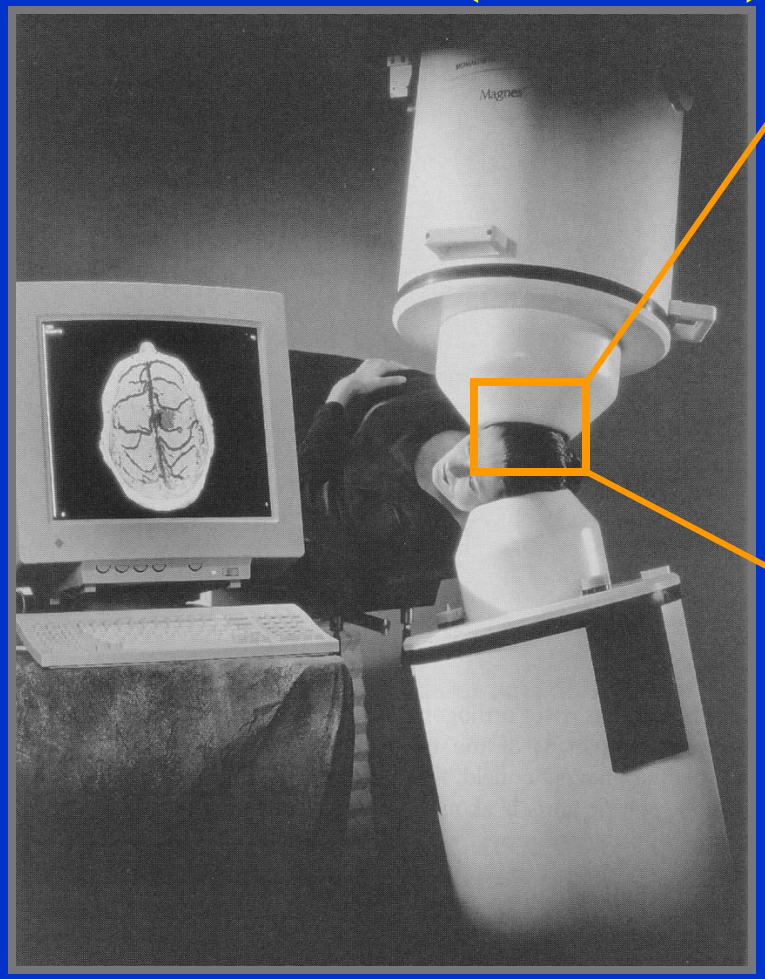

1
2
3
4
5
6
7
8
9
0

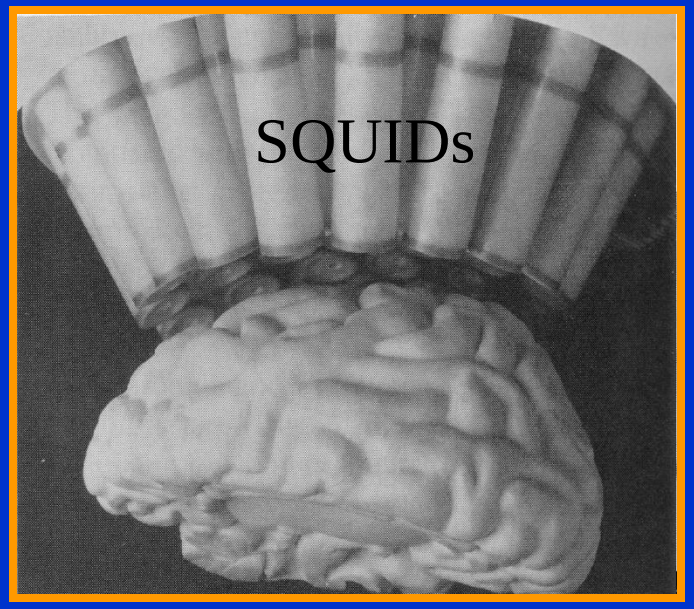
Electroencephalograghy (EEG) recording

Statistical (T test) between two experimental conditions



Magnetoencephalography (MEG)

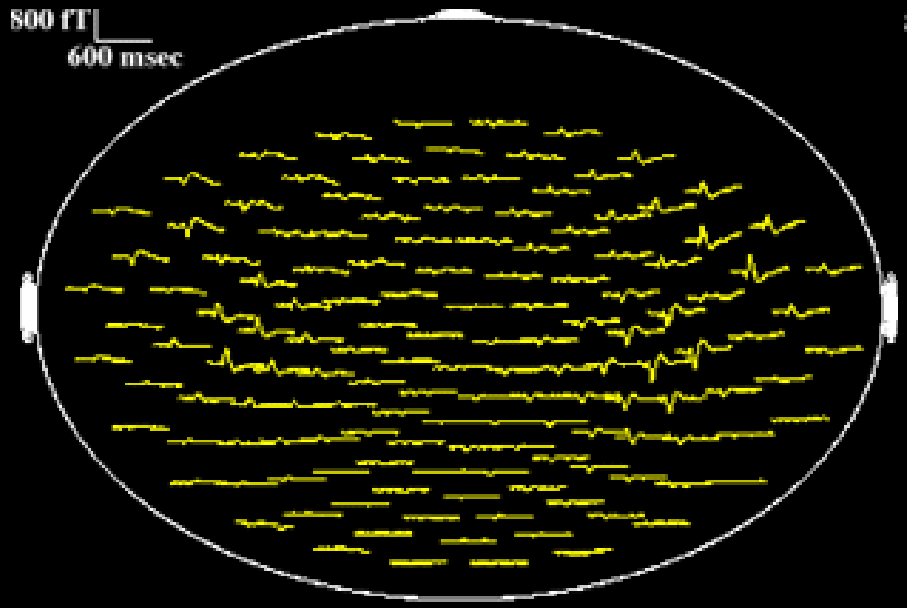


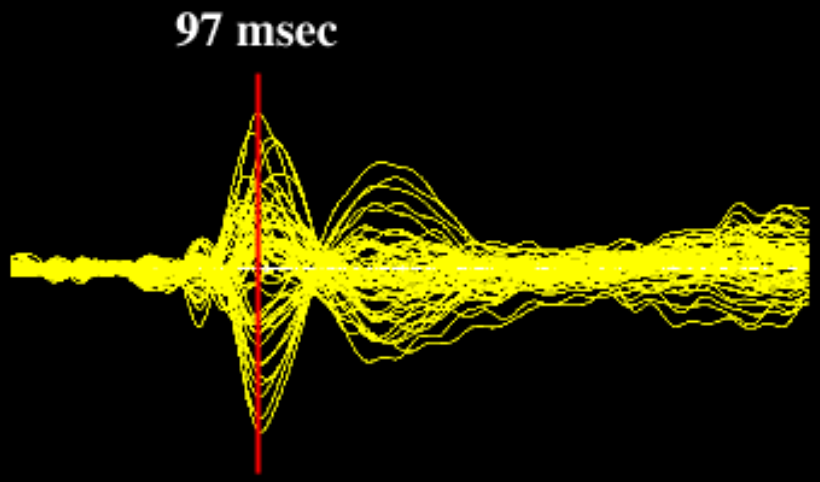


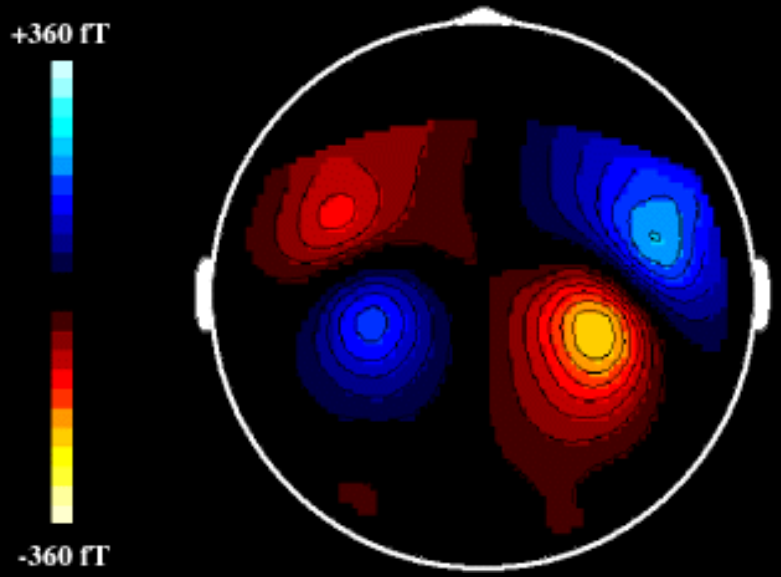
SQUID:
Superconducting Quantum Interference Device

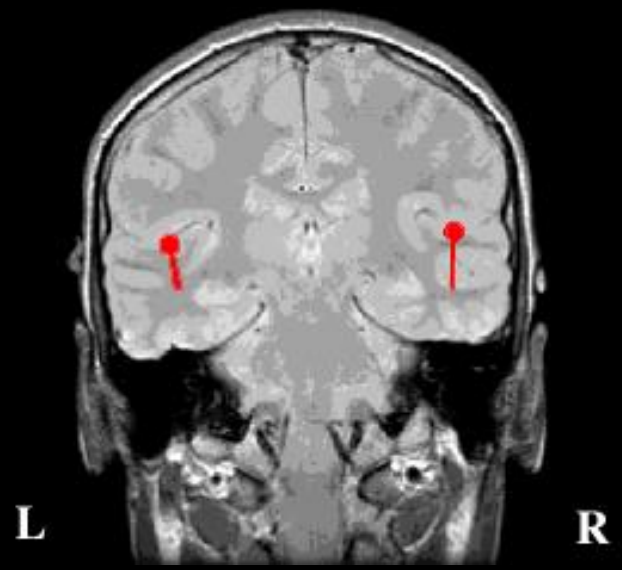
Combined MEG and EEG

MEG Mapping

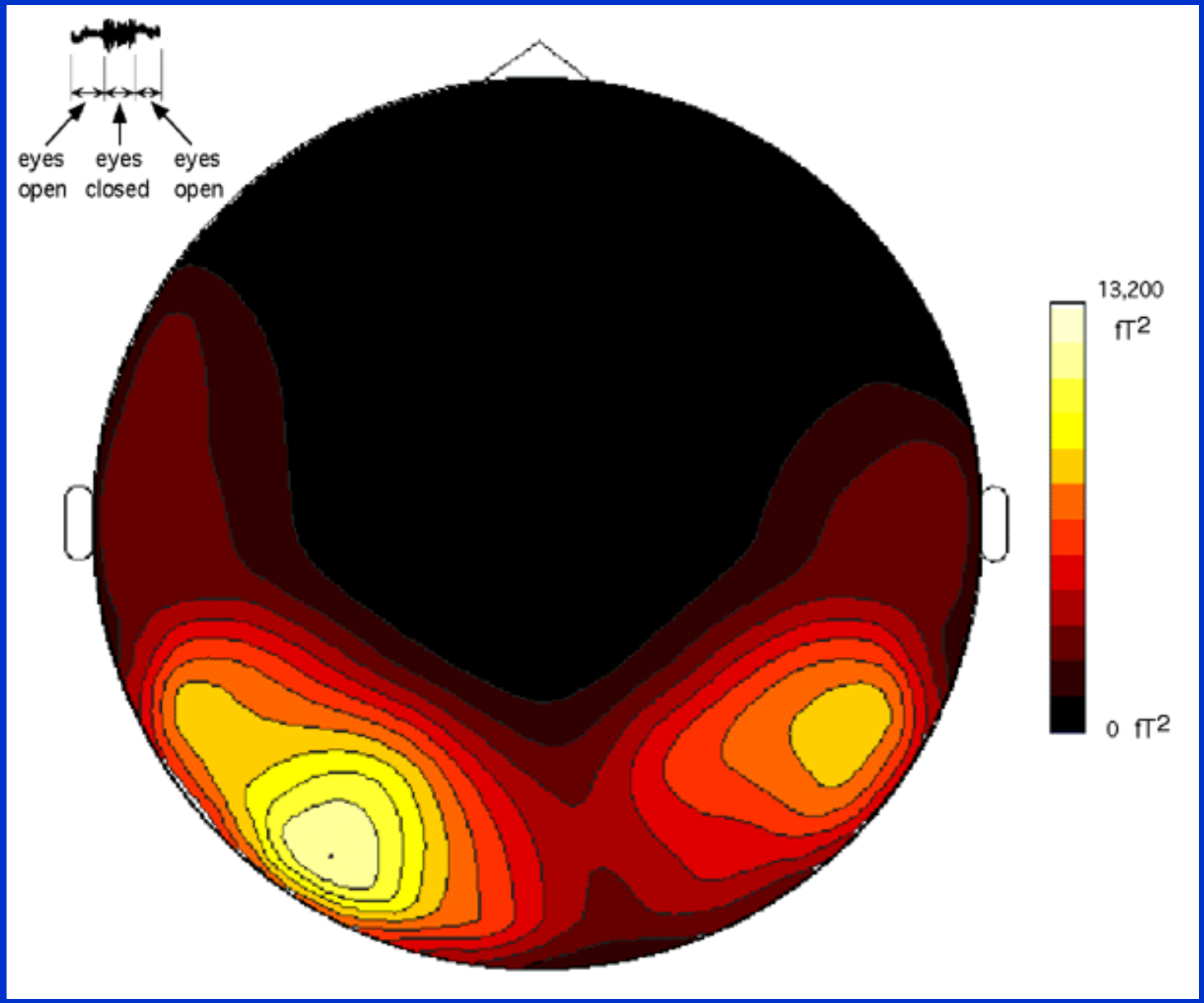




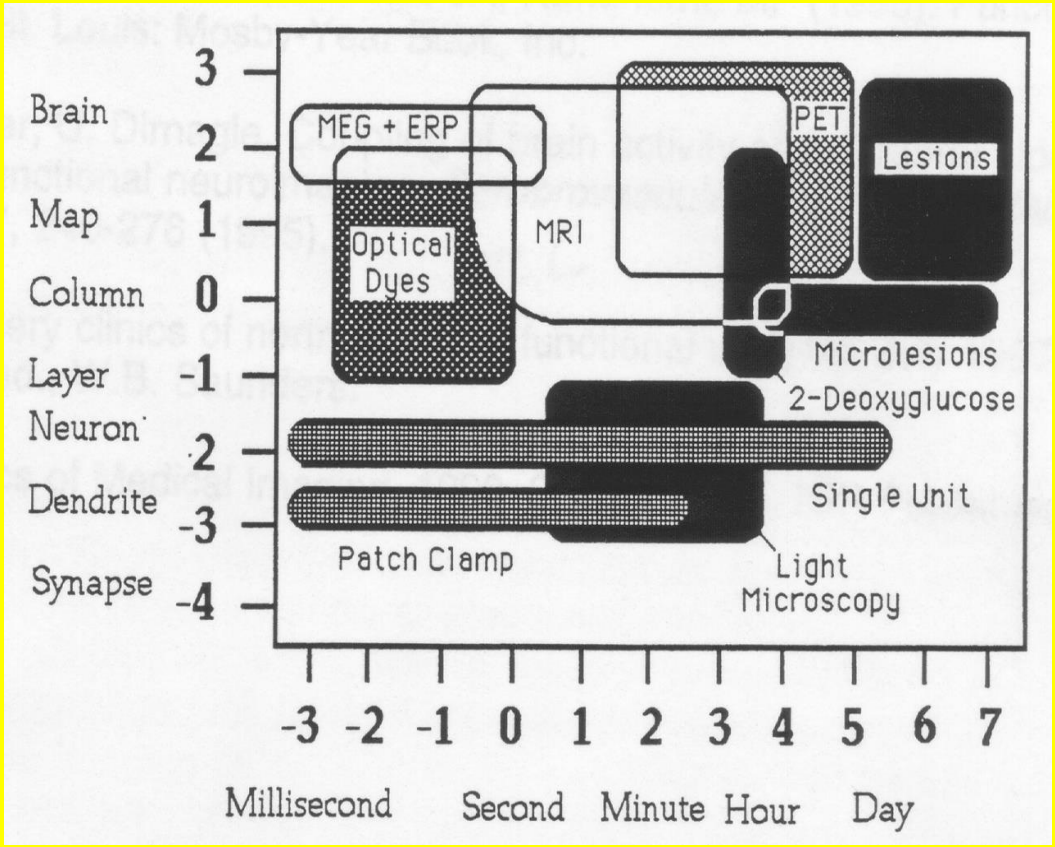




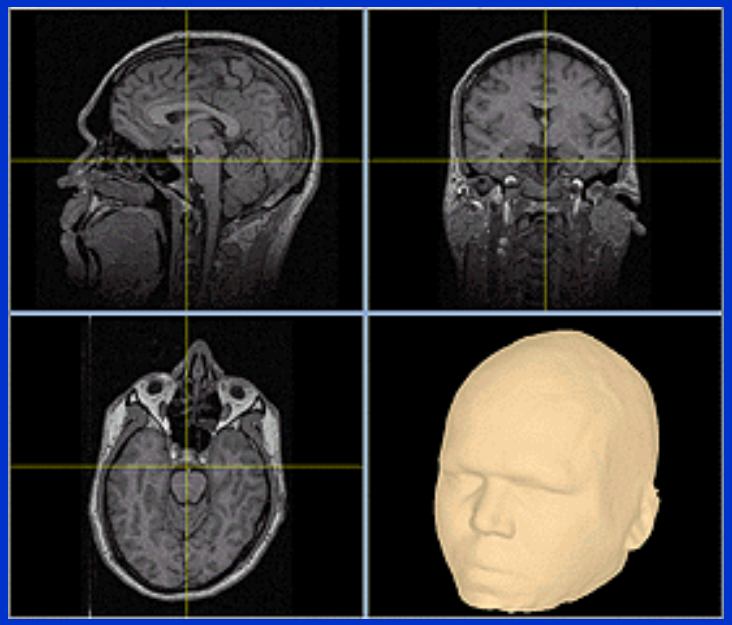
Alpha Wave Activity Mapped with MEG



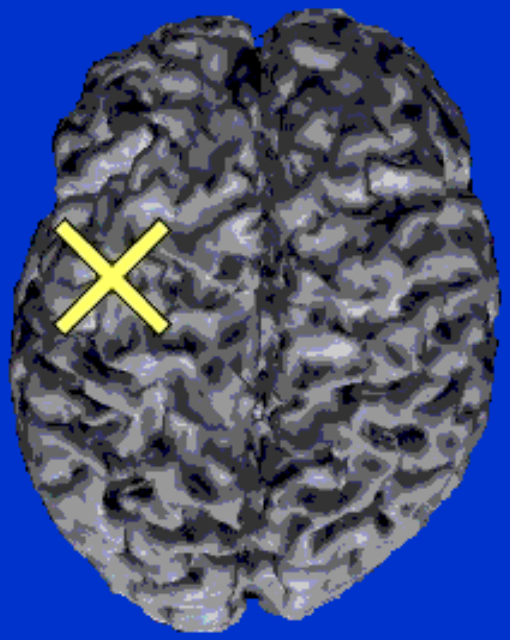
Functional Neuroimaging Techniques



Transcranial Magnetic Stimulation



Transcranial Magnetic Stimulation (TMS)



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