

Functional Magnetic Resonance Imaging

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What is fMRI

- Functional magnetic resonance imaging, or fMRI, is a technique for measuring brain activity.
- It works by detecting the changes in blood oxygenation and flow that occur in response to neural activity – when a brain area is more active it consumes more oxygen and to meet this increased demand blood flow increases to the active area.

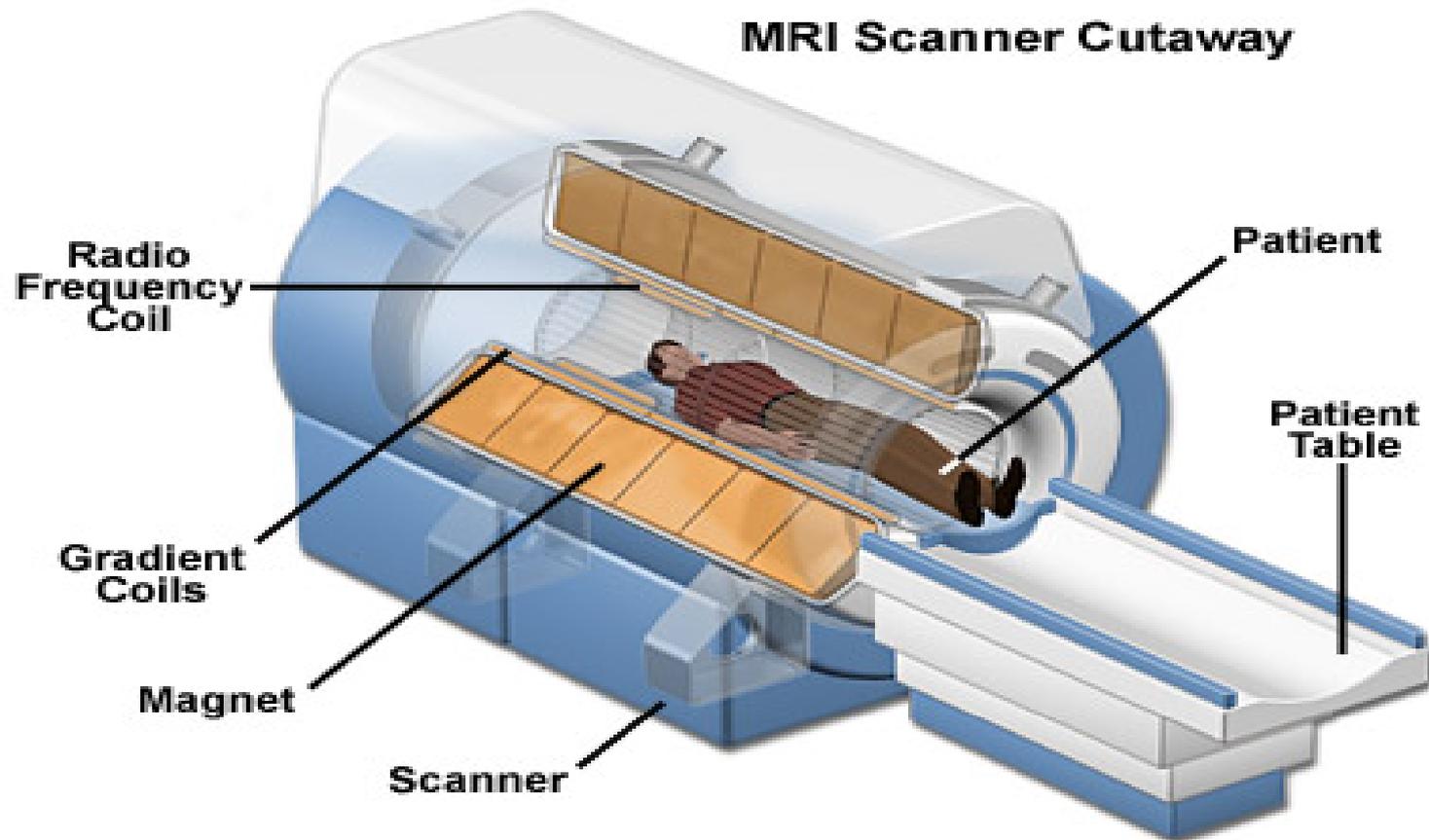
MRI



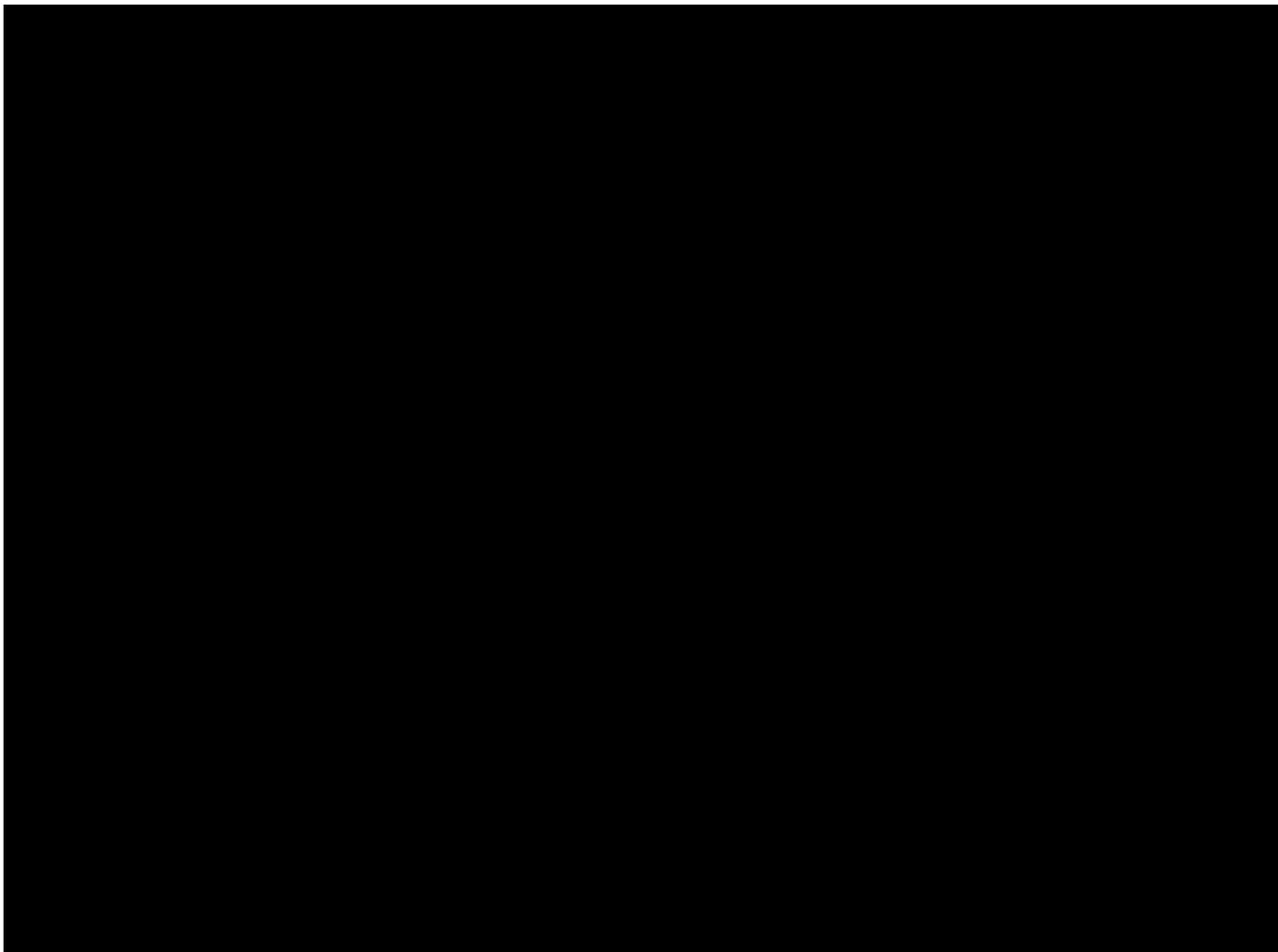
fMRI



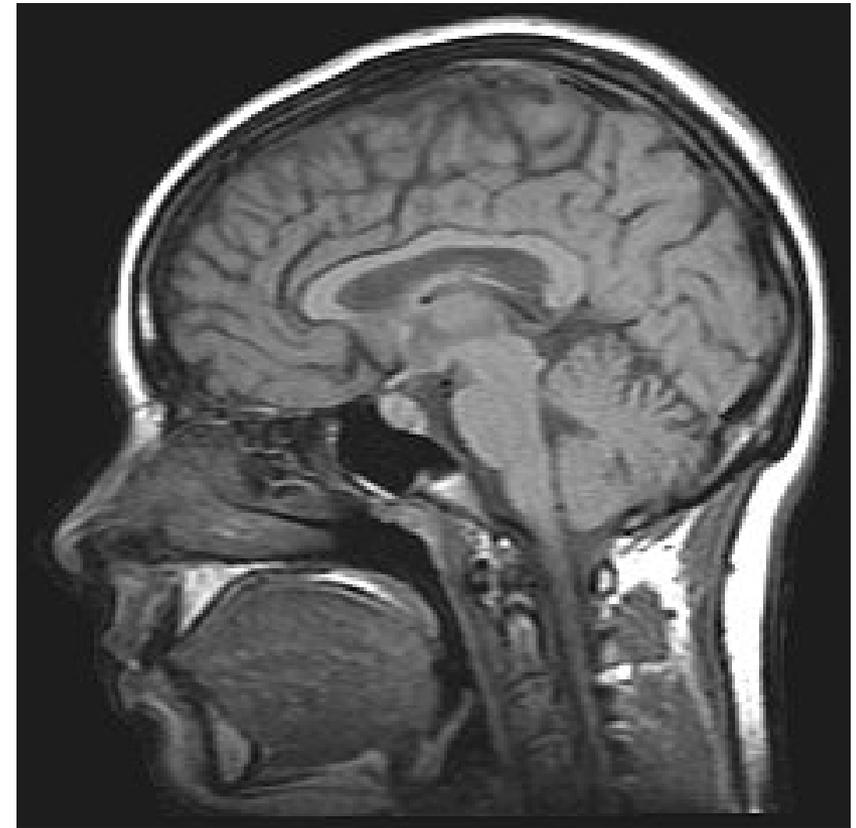
Scanner



How MRI works

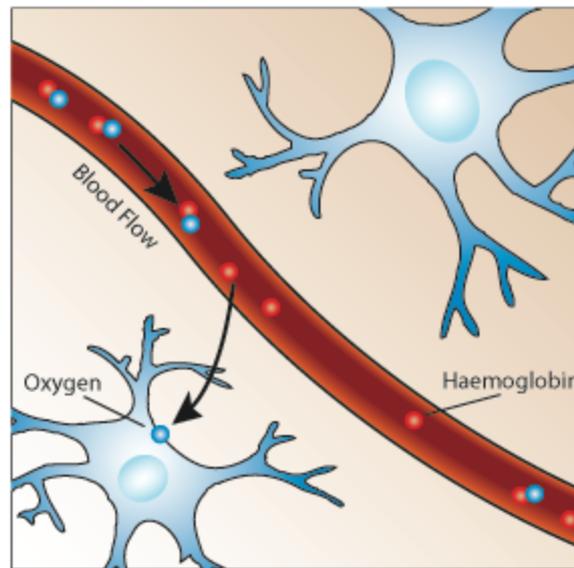


What does MRI Measure?

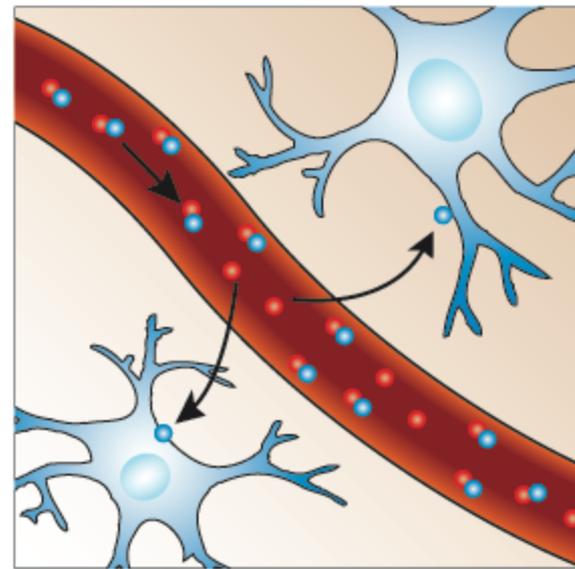


What does fMRI Measure?

- Oxygen is delivered to neurons by haemoglobin in capillary red blood cells.
- Haemoglobin is diamagnetic when oxygenated
- Haemoglobin is paramagnetic when deoxygenated.
- Blood oxygenation level dependent (BOLD) imaging.

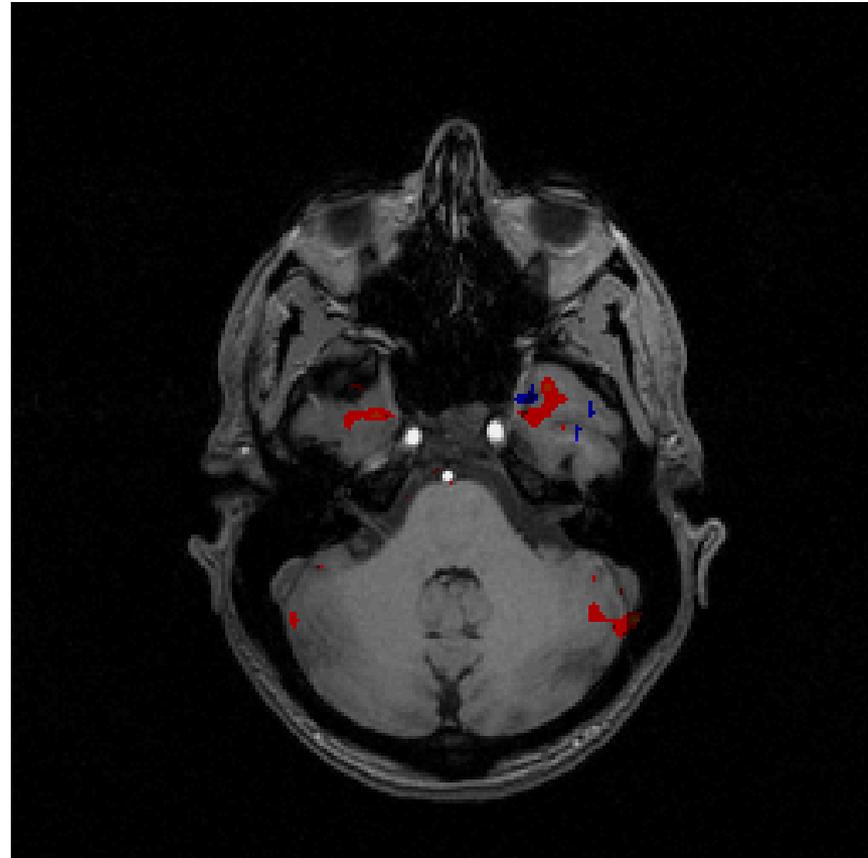


Resting



Activated

What does fMRI Measure?



fMRI...What is it good for?

- fMRI is used to monitor brain functions of both healthy and ailing individuals
- Used on healthy individuals to study and understand brain anatomy and cognition
- Used on ill individuals to diagnose neurological problems as well as pre-surgical diagnosis and risk analysis

fMRI as a diagnostic tool

- **BOLD fMRI is used a part of pre-surgical procedure to identify risks and to plan for the performance of aggressive procedures to the central region of the brain**
- **Also has a role in identifying patients who are not ideal candidates for surgery and should opt for less invasive therapeutic methods**

BOLD fMRI for Brain Tumor Surgery

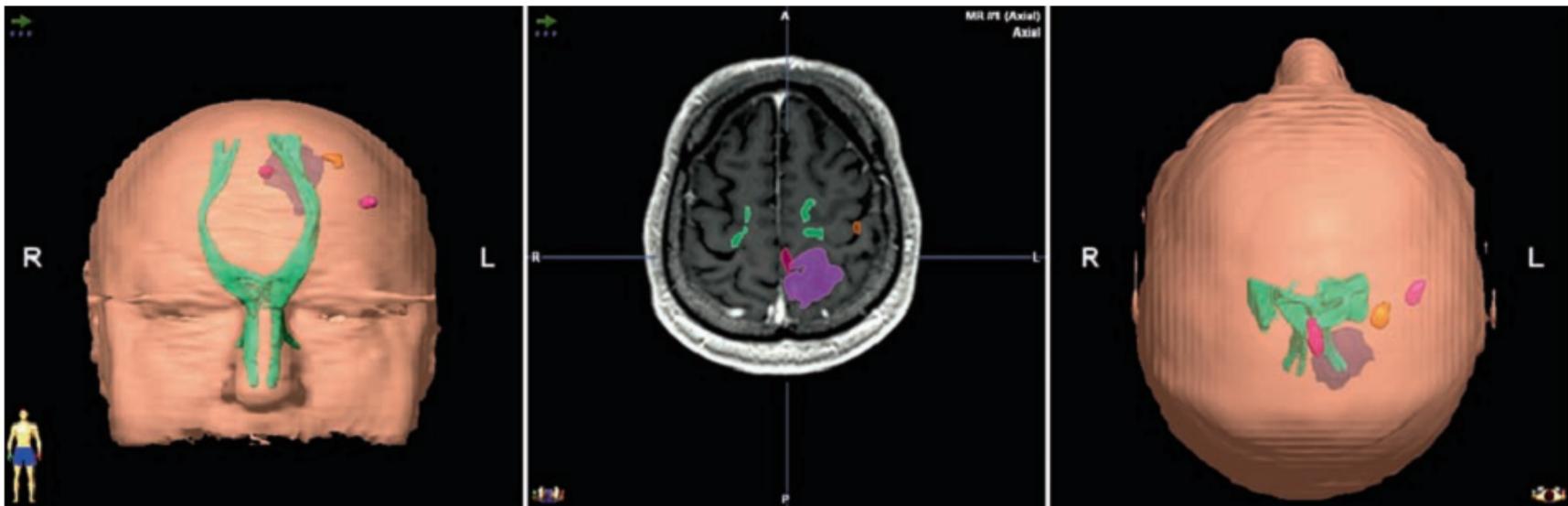


Fig. 7.2 Integration of BOLD-fMRI and DTI-tractography for functional neuronavigation. 3D-surface projections (left: anterior – posterior, right: top – down) and 2D-navigation view (*middle*). The spatial relationship of the cortical toe (*red*), finger (*orange*) and tongue (*pink*) motor representations and of the

pyramidal tract (*green*) to the segmented brain tumor (*purple*) is clearly depicted. The tumor affects the superior parietal lobule, invades the postcentral gyrus extending towards the cortical motor representation of the lower extremity

What the picture really looks like

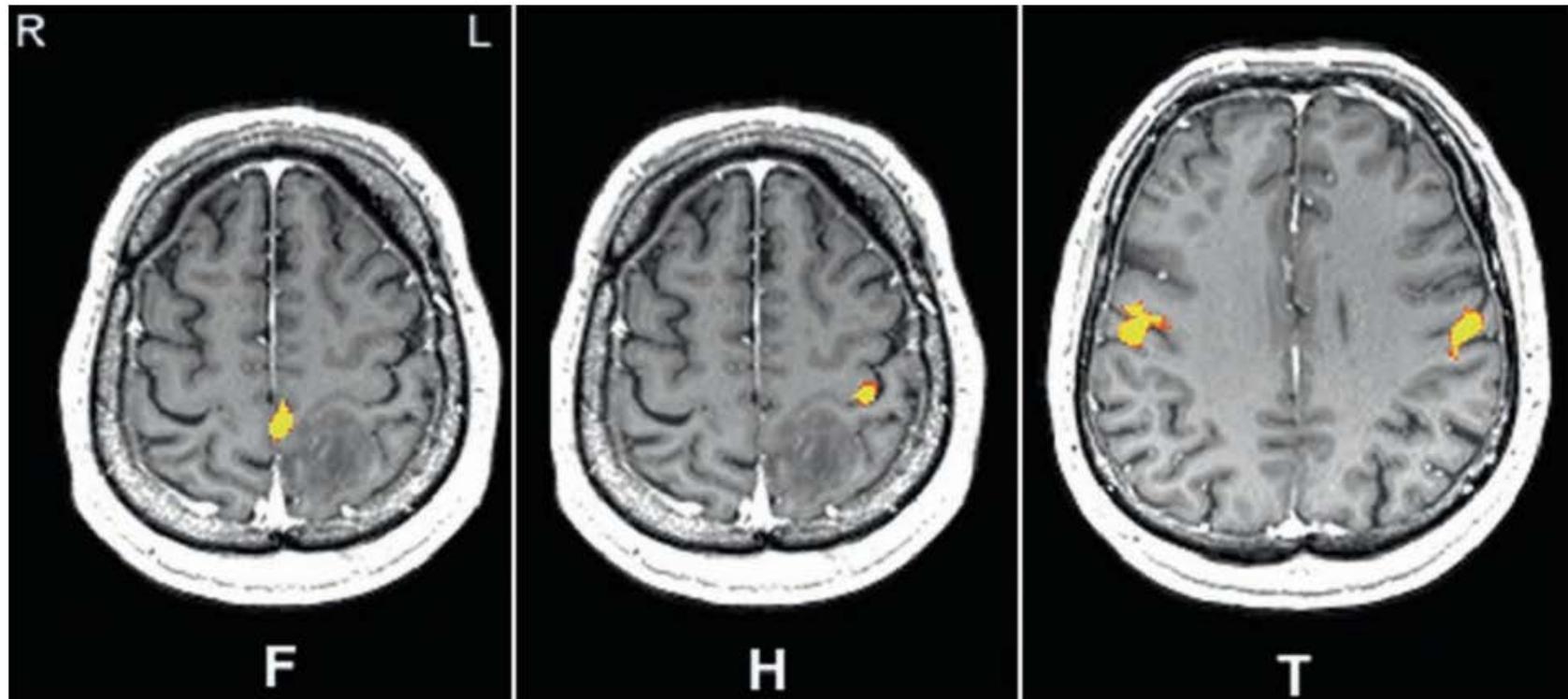


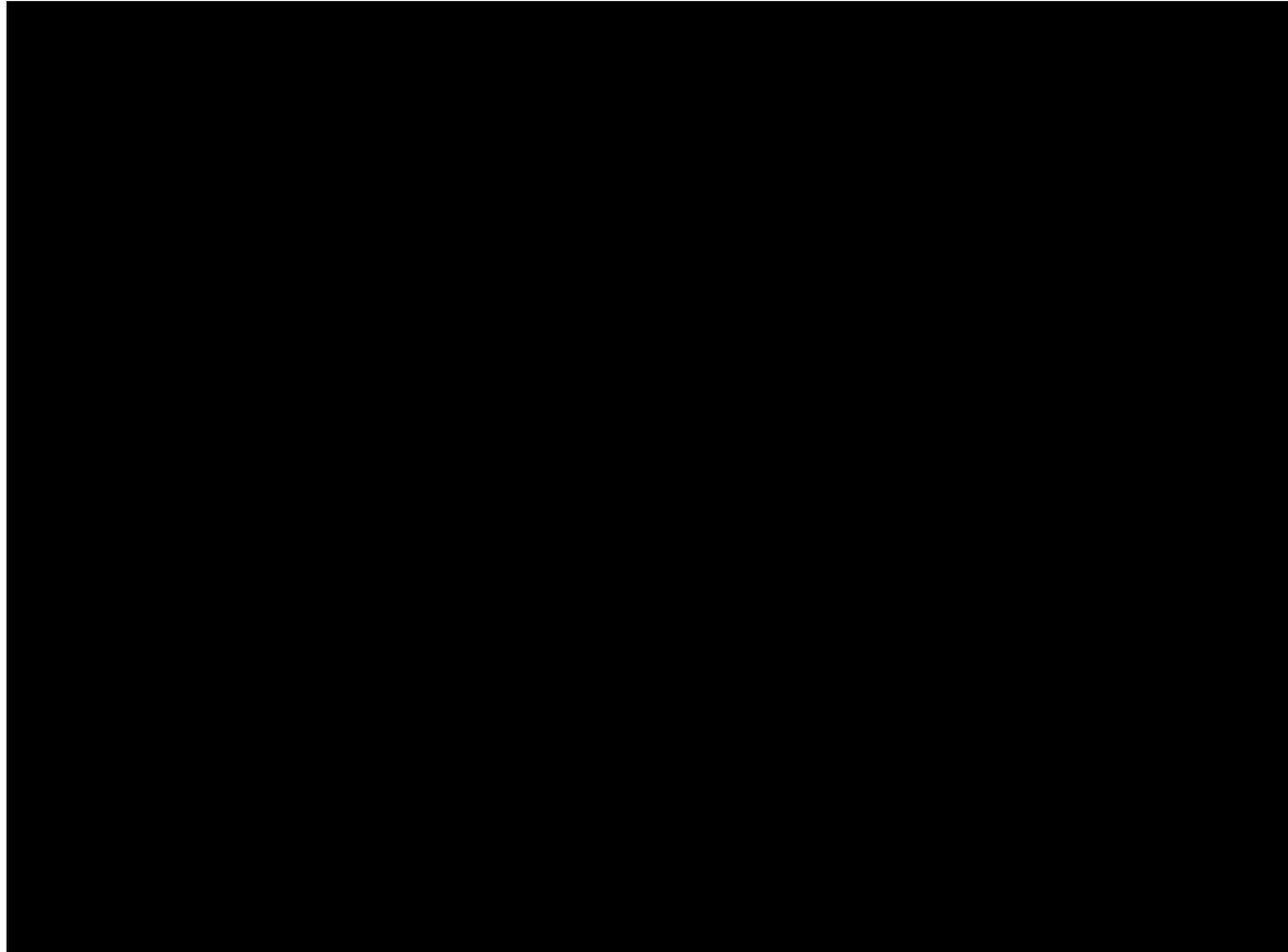
Fig. 7.8 Standard presurgical fMRI protocol: Somatotopic mapping of the motor cortex (same patient as in Fig. 7.2). The cortical foot representation (*F*) is closely related to the left pari-

eto-postcentral anaplastic glioma. BOLD-activation of the motor hand area (*H*) is localized at the hand knob and the bilateral tongue representations (*T*) at the level of the ventricular roof

fMRI in cognitive research

- fMRI is used to map the brain in order to understand brain function during cognitive activity
- An example of this is a study done at the Stanford School of Medicine into brain behavior while listening to classical music

This is your brain on music



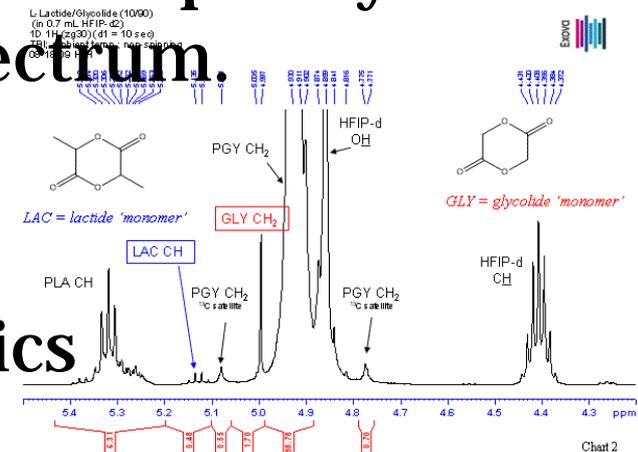
http://med.stanford.edu/news_releases/2007/july/music.html

History: NMR spectroscopy

- Nuclear magnetic resonance (NMR): precursor to MRI technology
- Effect: They found that when certain naturally-occurring nuclei were placed in a magnetic field they absorbed energy in the radio frequency range of the electromagnetic spectrum.

- Used extensively in chemistry
- Felix Bloch and Edward Purcell

won the 1952 Nobel Prize in Physics



History: The beginnings of MRI

- **Feb. 9, 1974:** Dr. Raymond V. Damadian patents a method for distinguishing normal from cancerous tissue by what was then called nuclear magnetic resonance.
- **1977:** First MRI exam performed on human patient; procedure long and complicated
- **March 17, 1985:** New York Times runs an article explaining that most doctors were calling both the procedure and the machines “magnetic resonance imaging”

History: Advancing MRI

- 1973: Paul Lauterbur described his research on the high level of contrast that could be realized in nuclear magnetic resonance imaging
- Sir Peter Mansfield developed methodology to analyze the signals and assemble them rapidly into three-dimensional images.



Paul C. Lauterbur



Sir Peter Mansfield

The Nobel Prize in Physiology or Medicine 2003 was awarded jointly to Paul C. Lauterbur and Sir Peter Mansfield *"for their discoveries concerning magnetic resonance imaging"*

History: The dawn of fMRI

- **BOLD fMRI arose from the discovery that there is a change in blood oxygenation levels with brain activity by Seiji Ogawa, who reported his team's findings in 1990**
- **Robert Turner then showed the utility of blood oxygenation characteristics by using cats with induced hypoxia (inadequate oxygen supply)**
- **The first movies of human visual cortex activation were produced at the Massachusetts General Hospital in May of 1991**
- **Perfusion fMRI uses measurements of blood flow in the brain to determine brain activity; Dr. John Detre published his paper on this subject in 1992.**

fMRI T1/T2 Mechanism

- The two fundamental MRI relaxation rates T1 and T2 are used to describe fMRI signal
- T1 is the rate at which nuclei approach thermal equilibrium, and is used to measure perfusion
- T2 is more important to BOLD as it represents the rate of decay of MRI signal due to magnetic field inhomogeneities, and thus can be used to measure blood oxygenation change
- An observed increased signal on T2 weighted images during activation reflects a decrease in deoxyhemoglobin content

Signal Intensity of BOLD fMRI

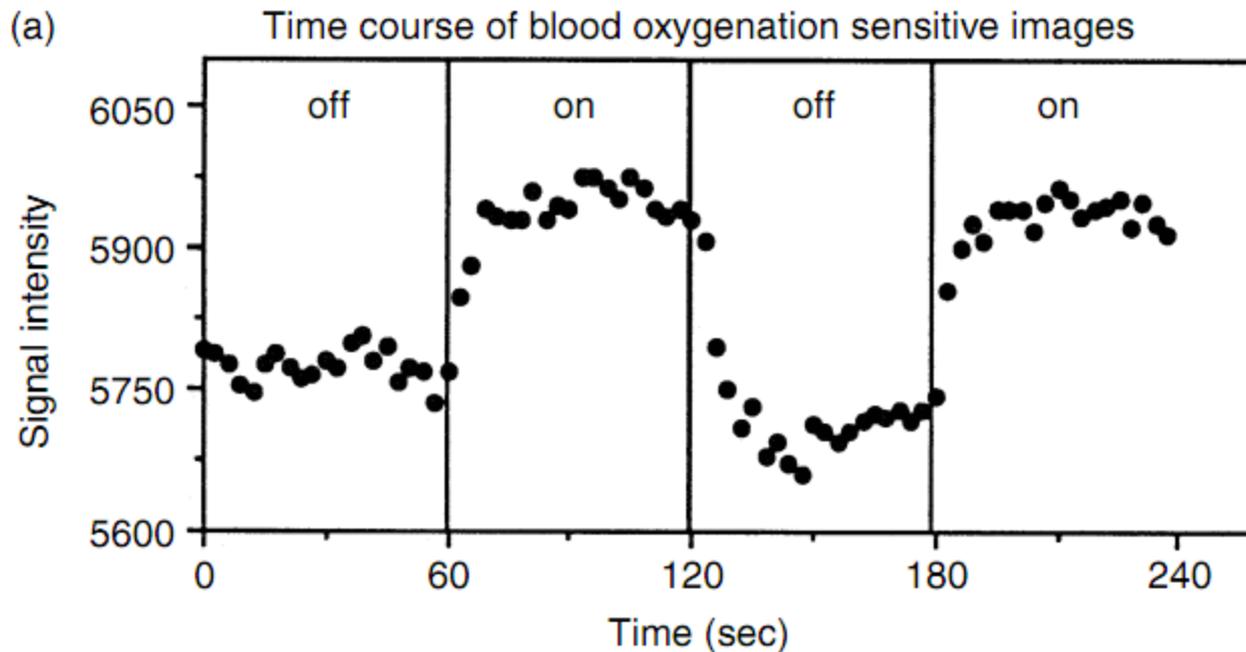


FIGURE 12.16 Signal intensity changes for a region of interest ($\sim 60 \text{ mm}^2$) within the visual cortex during darkness and during 8-Hz photic stimulation. Results using oxygenation-sensitive (*top graph*) and flow-sensitive (*bottom graph*) techniques are shown. The flow-sensitive data were collected once every 3.5 sec, and the oxygenation-sensitive data were collected once every 3 sec. Upon termination of photic stimulation, an undershoot in the oxygenation-sensitive signal intensity is observed.

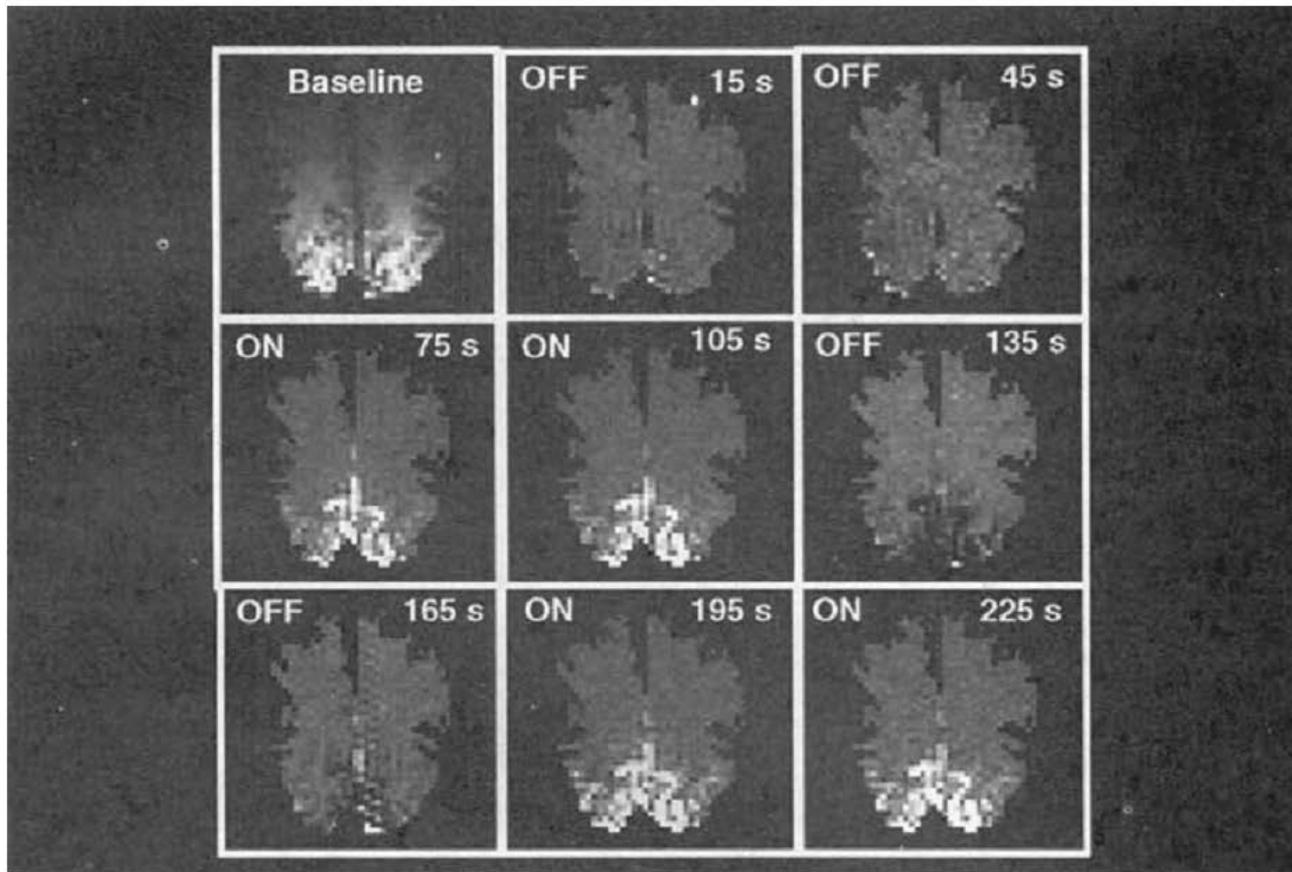


FIGURE 12.15 Movie of fMRI mapping of primary visual cortex (V1) activation during visual stimulation. Images are obliquely aligned along the calcarine fissures with the occipital pole at the bottom. Images were acquired at 3-sec intervals using a blood oxygenation-sensitive MRI sequence (80 images total). A baseline image acquired during darkness (*upper left*) was subtracted from subsequent images. Eight of these subtraction images are displayed, chosen when the image intensities reached a steady-state signal level during darkness (OFF) and during 8-Hz photic stimulation (ON). During stimulation, local increases in signal intensity are detected in the posteromedial regions of the occipital lobes along the calcarine fissures.

The current state of fMRI

- Current MRI systems can use BOLD techniques to acquire whole head images with a spatial resolution of 1.5x1.5 mm in plane and 3 mm slice thickness
- “Siemens MAGNETOM Verio is the first MRI system to offer 3T field strength combined with a 70cm bore and Tim (Total imaging matrix) technology” (Siemens fMRI brochure)

fMRI software

- Siemens MRI machines can utilize their proprietary *syngo* Neuro Suite
- “It includes techniques such as single-shot epi (echo planar imaging) as well as MPRAGE used to acquire the anatomic information that will later be fused with the fMRI data.”

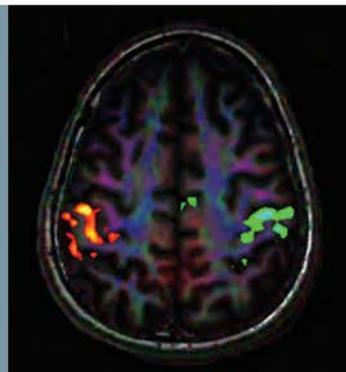


Figure A. Bilateral finger tapping paradigm.

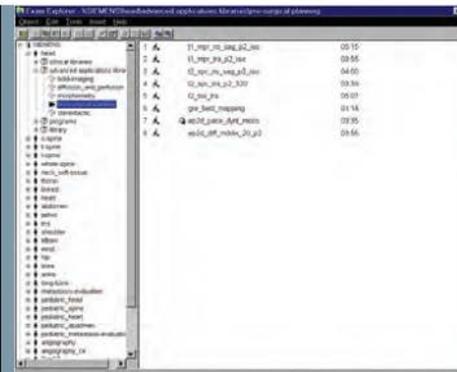


Figure B. The *syngo* Neuro Suite (Standard).



Figure C. *syngo* 3D Neuro Evaluation.

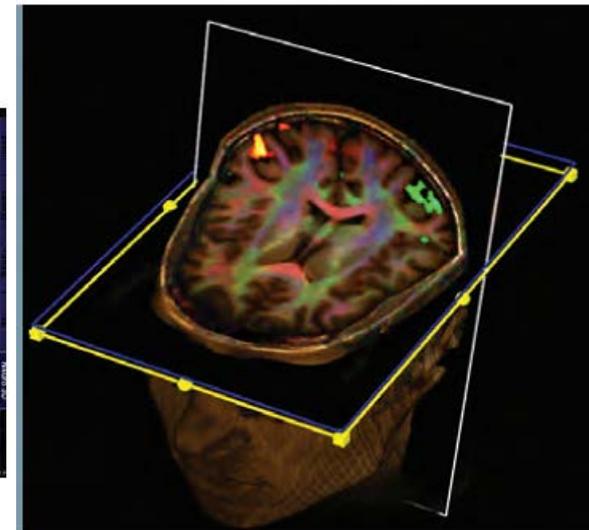


Figure D. fMRI fused with fractional anisotropy and MPRAGE.

Advantages

- No radiation.
- No injection.
- High spatial resolution. Typical 2–3 mm, 1mm possible.
- Oversee all regions of the brain.
- Compelling images of brain “activation” regions.

Disadvantages

- Expensive
- Influence by non-neural changes in the body.
- Poor temporal resolution. The BOLD response peaks approximately 5 seconds after neuronal firing begins in an area. EEG have higher temporal resolution but worse spatial resolution.
- Minimizing the distributed nature of processing in neural networks.
- The BOLD response can be affected by a variety of factors, including: drugs, age, brain pathology, attention, amount of carbon dioxide in the blood.

Limitations

- High-quality images are assured only person remain perfectly still
- A person who is very large may not fit.
- MRI generally is not recommended for patients who have been acutely injured.
- Examination takes Long time.
- Pregnant women are advised not to have an MRI exam unless medically necessary.
- Cost
- Additional tests for confirmation is required.

Future

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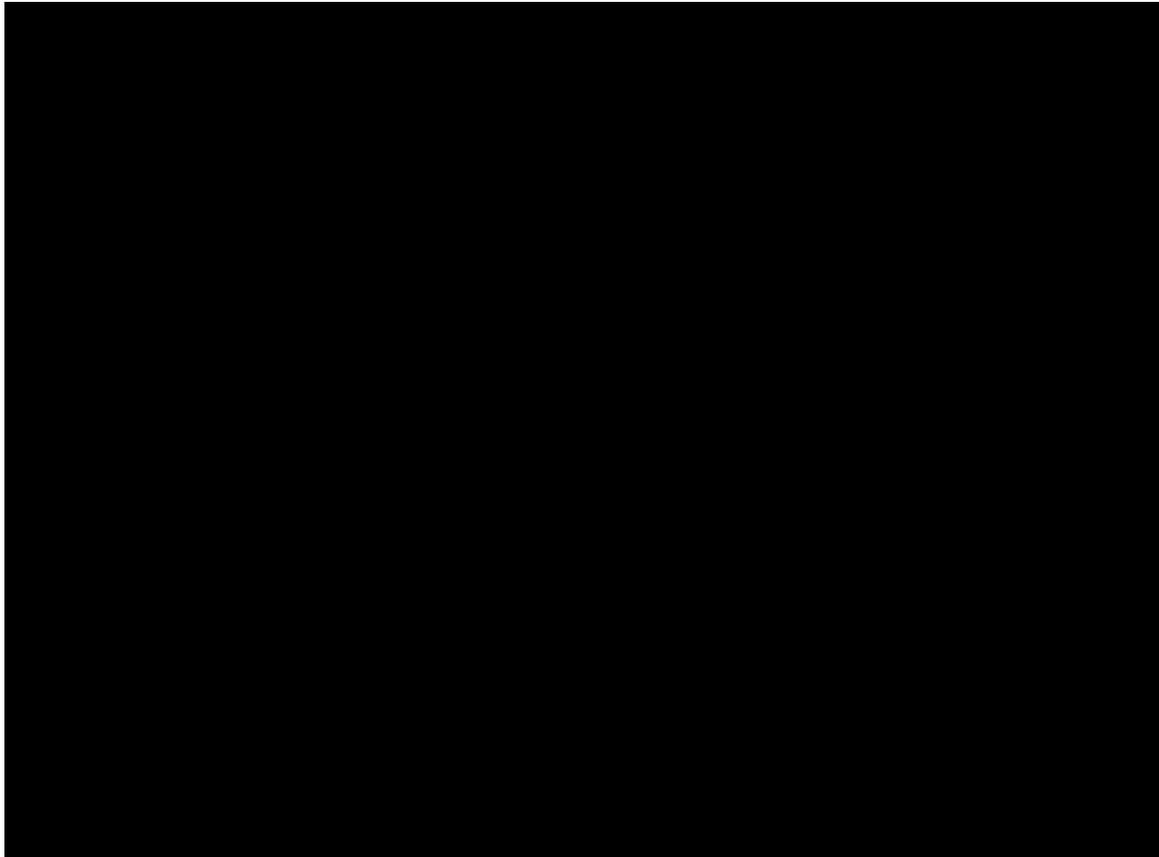
Read your mind



The Future of Mind Reading



Questions?



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