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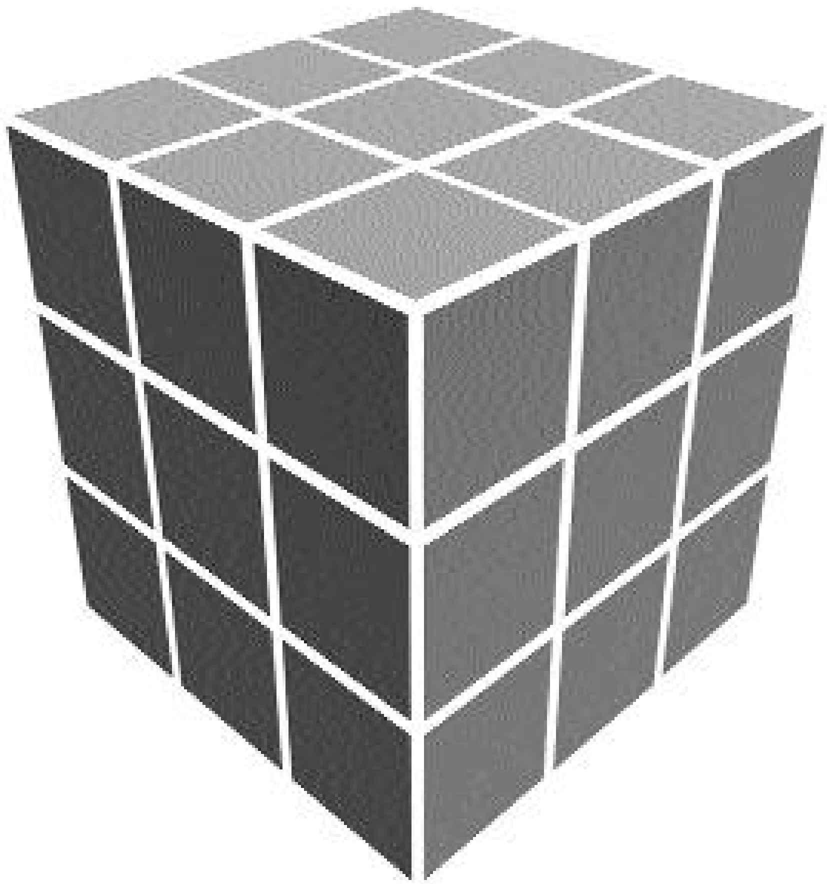


Brain Imaging Made Easy

Figure 1 : A typical MRI machine

by Chris Furmanski

New technology that was once used for clinically diagnosing torn-knee cartilage and brain tumors is now giving scientists insights into how the human brain operates. MRI, a common technique used by doctors to produce images of anatomical structures, can be specially adapted to help map the activity of the brain. This cutting-edge scientific tool is called functional MRI (*fMRI*). Researchers can now noninvasively study the cortical activity underlying human perception, cognition, and memory.

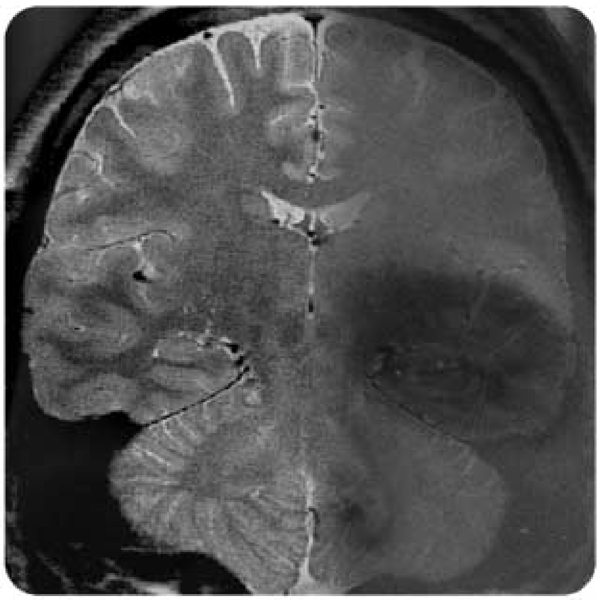


Figure 2 : A horizontal MRI of my brain

ABC's of MRI

MRI stands for magnetic resonance imaging. *Magnetic* because the cylinder patients are put in is actually a giant electromagnet and *resonance* because images are formed by the resonance (or altering the oscillation) of atoms. Conventional MRI is used to image anatomical structures, such as knees, shoulders, and brains, while *fMRI*, or *functional* MRI, is used to map the function of the brain.

MRI is sometimes (and more descriptively) referred to as NMR, or nuclear magnetic resonance. *Nuclear* is more descriptive because it is the nuclear part of an atom (the proton) that is resonated and is responsible for producing the image. Yet, the moniker NMR is seldom used in clinical or hospital settings because the general public often associates *nuclear* with nuclear radiation. This leads to unnecessary fear and apprehension; NMR/MRI is one of the few brain-imaging techniques that does not use radiation to produce images.

What's all the buzz about?

Thousands of clinical MRIs are performed every day in hospitals across the country. As anyone that has had an MRI will attest, the procedure from the patient's point of view is remarkably simple: patients are placed in a large, horizontal cylinder and are instructed to lay still as the machine knocks, buzzes, and beeps for about 30 minutes. The procedure is entirely painless, and except for the loud noises, the patient experiences no other physical sensations; however, some claustrophobic participants may feel uncomfortable being in a confined space.

In the few seconds it takes to remove the patient from the machine, doctors are ready to examine a collection of anatomical images—and compared to more conventional X-rays, the image quality of MRI is extraordinary. These images resemble a series of consecutive slices through the patient's body—resembling actual cuts through bone and tissue.

The acquisition procedure for *fMRI* is virtually identical to that of MRI. In fact, the same machine, when fit with the correct equipment, can perform both MRI and *fMRI*. However, *fMRI* images typically require hours of post processing to analyze; the colorful brain images found in journals and magazines are actually color-coded statistical maps depicting how the brain changes over time. Supercomputers are required to handle the statistical comparisons of the huge *fMRI* data sets, commonly larger than 30 million data points. For anatomical localization, these maps are superimposed on brain anatomy taken with conventional MRI.

Why study brain function?

Researchers aim to understand how the physical brain can control such a vast array of different functions like respiration, perceiving the visual world, and solving analogies. Up to now, much of what we know about the human brain has been inferred from research on animals. Now, noninvasive brain imaging techniques allow researchers to confirm or revamp animal-based theories of basic brain function, especially in modalities that are similar between human and other primate brains, such as vision or audition.

Imaging techniques, like *fMRI*, also allow researchers to develop new theories and test theoretical cognitive models on uniquely human characteristics, such as speech or reading, which were previously untestable with animal models. Further, the mapping of an individual's brain function has practical applications for surgical planning by greatly reducing the loss of cognitive function following brain resection. In the future, understanding the dynamics of the human brain will also be critical for improving artificial intelligence and bioengineering.

A quick neuroanatomy lesson

The adult brain is made up of approximately 125 billion individual cells called neurons. Most of the neurons responsible for higher cognitive function exist in the outer folds of the brain called the cortex. Distinct subpopulations of these cortical neurons are specialized to perform a specific type of processing, such as audition or memory. Each subpopulation is comprised of several "functional areas" believed to be responsible for processing distinct portions of the stimulus.

For example, the rear eighth of the brain (occipital cortex) is specialized for processing vision. The occipital cortex can be broken down into a collection of functional areas believed to be responsible for processing distinct aspects of vision, such as motion and object shape. Similarly, functional specialization has been found throughout the brain in other areas responsible for memory, movement, tactile sensation, and audition.

Functional brain imaging is ideally suited for understanding the function of, and interplay, between these various brain areas. Other techniques are much better for studying the behavior of a single neuron or interaction between a few neurons. But functional brain imaging, specifically *fMRI*, excels at studying how the large collections of neurons work as a unit.

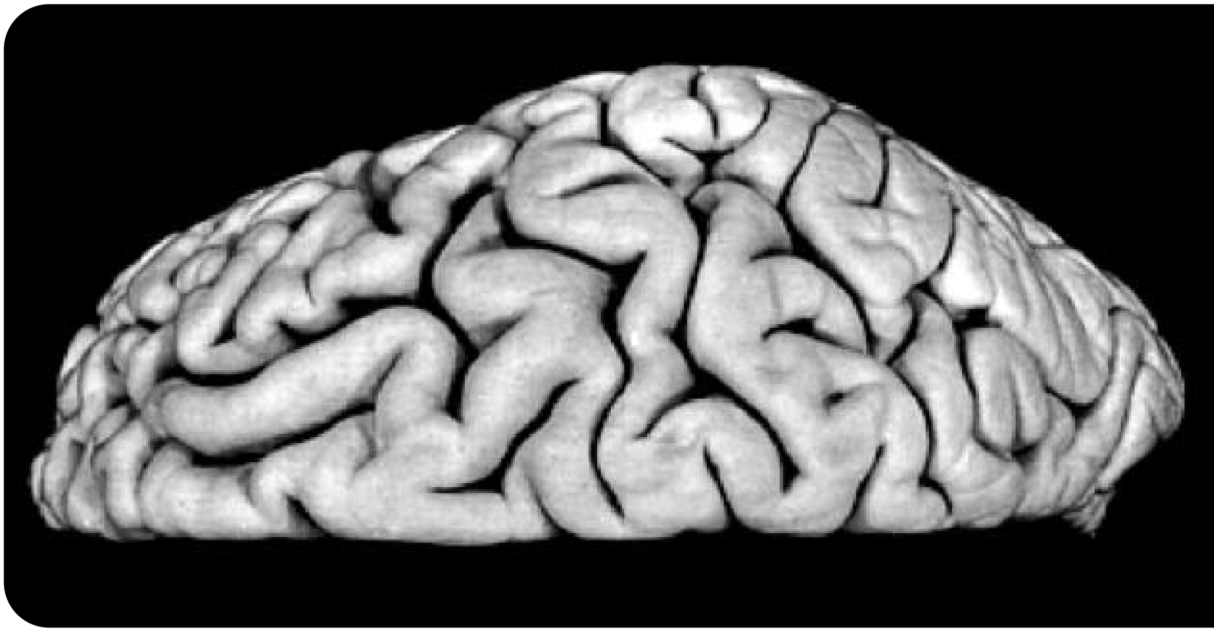
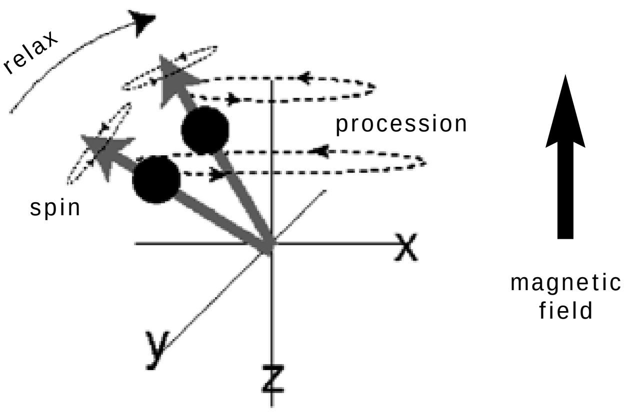


Figure 3 Photo of the top surface of a real brain

Figure 4: Protons in an external magnetic field.



Not your parent's X-ray

MRI is very different from the other imaging techniques. X-rays, for example, is one of the oldest techniques for imaging human skeletal anatomy. X-ray images are formed when X-ray radiation is passed through the body to expose film on the other side of the patient. As the radiation passes through the body, it is preferentially absorbed by dense material, such as bone or metal, leaving those areas on the film unexposed.

The resulting images are similar to photographic negatives where exposed film remains dark and unexposed film becomes light. X-ray images convey a gradient of tissue density collapsed through space. Because X-rays are passed through the body onto a 2-dimensional surface, all depth information is lost.

These images are ideal for rapidly and cheaply imaging bone, but cannot adequately image soft tissue such as muscle, blood vessels, or brain tissue. X-rays also have certain limitations as they use potentially dangerous radiation, albeit in small doses.

CAT scan—a better X-ray

CAT (computer-aided tomography) is a more modern technique that also uses X-ray radiation. Unlike X-rays, however, CAT employs sophisticated computers and a more complicated X-ray delivery system to produce selective anatomical images.

Such technological differences allow multiple images of distinct brain slices. This greatly increases anatomical localization because information about depth is preserved. CAT scans are ideal for clinical brain imaging, but have limited neuroscience utility as they cannot be used to study brain function.

PET scans reveal brain function

PET (positron-emission tomography) is another common imaging technique. Like CAT, PET uses sophisticated computers to image particular brain slices and requires the use of radioactive elements. However, unlike CAT, PET uses a different type of radiation, internal radioactivity, which allows brain function to be studied.

Radioactive isotopes attached to certain molecules, such as water, can be either inhaled or injected. These isotopes travel in the blood to the brain and are absorbed in larger doses by more active brain tissue. Over the period of many minutes, special arrays around the head collect positron emissions, tiny electrical by-products of colliding radioactive isotopes. Computers are then used to triangulate the location of the collision.

However, because the collection and triangulation of positrons is not precise, the spatial resolution is often greater than many centimeters. Such an area may be 1/10th to 1/5th of the entire brain, which may be too coarse to localize the underlying functional areas. The temporal resolution is also limited by the long positron collection time (on the order of 10's of minutes).

The resulting PET images are only an average of brain activity over many minutes, instead of the millisecond to second range of actual brain activity. And while PET has many advantages, such as being able to study different aspects of cellular metabolism, the use of radioactivity limits the number of scans each subject can participate in safely.

MRI & fMRI—brain imaging without radiation

MRI and *fMRI* have several advantages to other brain imaging techniques. Like PET, *fMRI* can study brain function and localize images to specified slices. But unlike those techniques, *fMRI* has greatly increased spatial and temporal resolution without requiring the use of radioactive elements.

Instead, MRI uses magnetic fields and pulses of radio waves to produce images. When patients are placed in the giant electromagnetic cylinder, all of the protons in the subject's body align with the magnetic field. A focal pulse of radio waves is then sent to disrupt the alignment of the protons. Because of subtle differences in the magnetic properties of different tissue types, the protons of various tissues, such as bone, blood and muscle, will "relax," or return to alignment at different rates. These return rates are the basis for delineating different tissue types in the MRI image.

Functional MRI uses these same principles as MRI to produce images, but instead of imaging brain structures, *fMRI* images measures changes in brain activity. But *fMRI* (or PET) cannot quantify neuronal activity directly.

BIO

Chris Furmanski is a fifth-year graduate student in Cognitive Psychology. His primary research uses *fMRI* as a tool to study the human visual system. To learn more, visit the website:

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Instead, *fMRI* uses a second order measure of neuronal activity: changes in blood oxygenation. Proteins in the blood (hemoglobin) which carry oxygen to brain tissue have subtly different magnetic properties with and without oxygen. Local changes in neural activity in different functional brain areas produce local changes in blood oxygen content that, in turn, produces modulations in the *fMRI* signal.

fMRI has several distinct advantages to PET. First, *fMRI* has exceptional resolution: subsecond temporal resolution (compared to many minutes) and submillimeter spatial resolution (compared to many centimeters). This allows for greatly improved anatomical localization. Second, *fMRI* doesn't use radioactivity, so subjects are not limited to a small number of scans, thus improving the researcher's statistical power.

With this technology, researchers are able to determine which brain areas preferentially respond to particular stimuli. For example, researchers studying color can map which brain areas prefer chromatic stimuli; memory researchers can figure out if the same brain structures are responsible for long and short term memory; schizophrenia researchers can understand if hallucinations activate the same neural mechanisms as actual sensations. *fMRI* also has many clinical applications. For example, doctors can employ *fMRI* to map out a patient's unique language areas, which will greatly increase the chance of sparing vital cognitive brain regions during tumor surgery.

Brain imaging at UCLA

UCLA has recently completed construction of one of the premier brain imaging centers in the world. The Ahmanson-Lovelace Brain Mapping Building is located near the medical center and houses the UCLA Human Brain Mapping Division, which is a collection of M.D./Ph.D.'s and Ph.D.'s focused exclusively on human brain research.

This cutting-edge scientific laboratory houses new PET and *fMRI* scanners. Typically, *fMRI* researchers must share scanner access with clinicians, as most *fMRI* machines are just adaptations of conventional hospital MRI machines. Under these circumstances, research time is very limited as clinicians take precedence. However, UCLA boasts one of the few research-only *fMRI* magnets in the country, which allows for around-the-clock research.

The Brain Mapping Division is an extensive research group that collaborates with professors and students in the Psychology, Neuroscience, and Medicine departments. A multitude of different research projects are ongoing, including studies of: memory, object and face recognition, Alzheimer's disease, child development, color perception, and language development, just to name a few.

Visit UCLA's Human Brain Mapping Division's website to learn more: http://www.brainmapping.org