Functional MRI (fMRI) is a new tool which utilizes fast MRI methods to non-invasively map the functioning, intact brain. As opposed to conventional MRI which provides high-resolution images of brain anatomy, functional MRI identifies only those brain structures that are actually performing, controlling or monitoring specified functions.

The principle of fMRI is that the signal used to construct MR images increases by a small amount (typically a few percent) in regions of the brain cortex that are activated by appropriate sensory, cognitive or even pharmacological stimuli. With current MRI systems, it is possible to monitor changing regional activation patterns in response to stimuli with temporal resolution on the order of 1 second and spatial resolution on the order of 2mm.

The signal used to construct an MR image is derived from the net magnetization of hydrogen nuclei within tissue water which results from the polarizing effect of the field of the MRI magnet on the human body. Specifically, the MR signal is produced when the magnetization is manipulated by means of electromagnetic pulses applied at radiofrequencies to induce an alternating current in a receiver coil placed near the body-part of interest. The rate of decay of the alternating current signal is known to be a function of the uniformity of the magnetic field strength within the tissue, i.e. the more uniform the field the longer the signal duration. fMRI relies on the fact that capillaries and red cells within tissues induce microscopic field gradients that shorten the signal duration to a degree that depends on the precise value of the magnetic susceptibility of blood, which in turn depends on the local oxygen tension. Because of this, fMRI is also referred to as BOLD (Blood Oxygenation Level Dependent) imaging. Blood containing oxhemoglobin has a susceptibility close to that of tissue water, whereas deoxygenated blood is significantly different. An increase in neuronal activity produces a flow increase locally that introduces oxygenated blood to a degree that is greater than the increased metabolic demand, with the results that the tissue oxygen tension increases, and venous blood becomes more oxygenated. The intravascular magnetic susceptibility then more closely matches the surrounding tissue than it does when the vessels contain deoxyhemoglobin, and the MR image intensity increases. As the stimulus is cyclically applied and removed the activated area will show a similar pattern of increased and decreased signal intensity.

fMRI pulse sequences are specifically chosen to be sensitive to the small field uniformity effects (T2*) which result from regional differences in blood flow produced by the brain activation. The fMRI study is typically presented as a color overlay to a high resolution MR image allowing correlation of the “activated” regions with brain anatomy. fMRI protocols frequently use gradient-echo imaging sequences with long echo-times (TE).

Educational Objectives:

1) To understand the theoretical basis of fMRI and BOLD contrast.
2) To present typical pulse sequences and task protocols used in fMRI.
3) To present typical fMRI study results.