Tutorial on fMRI Methods

Functional magnetic resonance imaging (fMRI) studies are based on the fact that the level of oxygen changes during mental activity. Neurons that are active change their own local blood supply, increasing oxygen more than is actually used and leading to an increase in hemoglobin. The presence of hemoglobin (which has slightly magnetic properties) can be tracked by a strong magnetic field (which is what an fMRI machine is). We can localize the areas of the brain that are active by tracing the level of oxygenation of the blood with MRI. Because of hemodynamic lag—the amount of time it takes for local blood oxygen levels to increase—the temporal resolution of fMRI is limited to several (4 to 6) seconds. In contrast, electroencephalograpy (EEG, or its component responses referred to as ERPs) and magnetoencephalography (MEG) have a temporal resolution of milliseconds. An advantage of fMRI over these other methods is its spatial resolution, which can be an order of magnitude better, allowing researchers to pinpoint *where* in the brain an operation is occurring, with a resolution approaching 1 mm. According to current medical knowledge, MRI is harmless to the patient, using only magnetic fields and nonionizing radiation in the radio frequency range.

The standard method in functional neuroimaging research is known as the subtraction paradigm. If brain regions are activated equally, or not at all, during two experimental conditions, this activation will cancel out in the subtraction of one from the other (referred to in the general case of A – B). Typically, researchers use an experimental condition and a baseline condition that controls for all operations (e.g., sensory and motor), except the one operation of interest. If one region responds more strongly in the experimental condition, compared with the baseline condition, it is said to be activated during the task, and the subtraction will yield signal changes that can then be tested for significance. If a region is activated more during the baseline task than during the experimental task, it is referred to as deactivation. Deactivation is a well-documented phenomenon, occurring most obviously in cases in which the brain must attenuate responses to accomplish a certain task.

It is important to note that in neuroimaging studies one is not studying the amount or extent of activation in the brain for one task only. Because the brain is normally occupied with a number of tasks, including the control and maintenance of homeostasis, respiration, circulation, and so on, as well as random and spontaneous thoughts, a snapshot of blood flow for a single task would yield all sorts of activation that are not directly of interest. The subtraction paradigm, first introduced by Posner and colleagues to neuroimaging, allows us to focus our analysis on brain regions that are active during a particular task or operation of interest.

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