Data Mash-Up: ERPs, EEG/MEG & Neurochemistry

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Target audience: Anyone studying brain activity, connectivity or networks using functional magnetic resonance imaging.

Objective: To introduce fMRI researchers to the breadth of information that can be obtained using other neuroimaging techniques, including electrophysiological and neurochemical metrics

Overview: This lecture will focus on the relationship between the fMRI measured haemodynamic response, and measureable manifestations of electrophysiological and neurochemical activity in the human brain. The lecture will be split into four parts:

1) What is brain activity?

The term 'brain activity' is used often in neuroimaging and can relate to anything from spiking of a single neuron to the measurement of significant changes in haemodynamics across large brain volumes. In this opening section of the lecture, the wide range of measurable effects captured by the collective term 'activity' will be reviewed. I will begin with haemodynamics including BOLD and also the more quantitative MRI derived metrics such as cerebral blood flow (CBF) or cerebral blood volume (CBV). I will then move on to invasive (e.g. ECoG) and non-invasive (e.g. MEG and EEG) measures of electrophysiology including event related potentials (ERPs) and neural oscillations. Finally I will review measurable neurochemical effects accessible to techniques such as magnetic resonance spectroscopy (MRS) and positron emission tomography (PET). This will set haemodynamic metrics in context with other available neuroimaging data.

2) Electrophysiological 'correlates' of fMRI

In the second section of the lecture, I will review the findings from key papers that have attempted to relate measurable electrophysiological effects to the haemodynamic response. I will focus specifically on neural oscillations which have been shown to exhibit strong spatial and temporal correlation to measurable BOLD effects. I will show convincing evidence for a close relationship between these disparate metrics. However, I will also highlight the complex nature of this relationship, by showing that there is no simple one-to-one relationship between oscillations in any one frequency band, and the measurable BOLD response.

3) The neural origins of functional connectivity

The last decade has seen a paradigm shift in fMRI. Traditional analyses which rely on temporal models of haemodynamic activity based on task timing are increasingly complemented by approaches which seek to elucidate spatial structure within temporally correlated patterns of spontaneous BOLD fluctuations. These so called functional connectivity approaches, which are often applied to task independent (or 'resting state') data have led to the surprising discovery of a relatively small number of large scale distributed functional networks across the brain, some associated with sensory action (e.g. the sensorimotor network) and others associated with cognition and attention (e.g. the dorsal attention network). Recent work in electrophysiology has attempted to seek electrophysiological correlates of these networks, and in particular to characterise the electrophysiological mechanisms underlying connectivity. In this section of the talk I will review this evolving area of research, introducing the key papers in this area and summarising their principal findings.

4) What can neurochemistry tell us?

The final section of the talk will move towards neurochemistry; in particular the recent evidence of correlations between neurotransmitter concentration, electrophysiology, and the BOLD effect. I will review the non-invasive methodologies that can be used to measure neurochemistry, focussing largely on MRS. I will then summarise the experimental data available. Specifically, I will show the measured relationships between, for example, the concentration of gamma aminobutyric acid (GABA), the amplitude of the BOLD response, and the frequency of neural oscillations in the visual cortex.