Syllabus Outline
Specialty area: An Update on fMRI
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Date/Time: 10th May 2014/Morning session

Highlights

- Recent scanner hardware improvements that assist spatial resolution
- Biophysics of neurovascular coupling
- Layer-dependent fMRI: difficulties and potential

TALK TITLE : High-resolution fMRI in Humans: What is the Limit?

TARGET AUDIENCE – Grad students, post-docs and staff scientists involved in brain research.

OUTCOME/OBJECTIVES – Enabling more widespread and better-informed high resolution MR imaging of human brain function, with a good understanding of practical and theoretical limitations.

PURPOSE – Recent studies have shown that fMRI can depict brain activity at spatial scales much finer than those commonly considered in experimental cognitive neuroscience. This clearly allows much more direct correlation of brain activity with its neural substrate (Turner 2013), and may enable discrimination of cortical columnar structure, and assignment of layer-specific functional roles across the cortical thickness. It may also improve our understanding of the spatial correlations observed in task-independent spontaneous fluctuations of brain activity. Robust findings from such studies, and the quality of ensuing theories of brain mechanisms, require optimal data. Attainable fMRI spatial resolution is limited both by neurophysiology and by MRI physics. The lecture will explain each of these limitations and suggest optimal approaches to data collection and interpretation.

METHODS – The recommendations to be presented are built on a large neuroscience literature on animal models using a variety of methodologies, and on recent improvements in MRI hardware data acquisition. These comprise: increased B_0 field strength, improved gradient coil performance, multichannel RF coils, parallel imaging, simultaneous multi-slice acquisition, and inner-volume imaging. Functional brain imaging is normally performed using BOLD contrast, but new methods to using measure cerebral blood volume changes have been shown to compete with BOLD at ultra-high field strength, and are expected to provide far better spatial specificity. Better methods of dealing with head motion, such as prospective motion correction, open the door to many more potentially high resolution, high sensitivity fMRI acquisition techniques. Improved image analysis methods are also required to reap the harvest of insights available from the much better data.

RESULTS – Results to be discussed will include Harel (2006), describing an early ultra-high resolution animal study of BOLD cortical layer dependence; Zhao (2006) and Jin (2008), comparing layer-dependency of animal CBV and BOLD signals; Polimeni (2010), Koopmans (2010, 2011), Olman (2012) and Chen (2013), showing layer-dependent BOLD sensitivity; Satpute (2013), showing discrimination of functional areas within periaqueductal grey matter; Sanchez-Panchuelo (2013) and Kuehn (2013), describing discrimination of Brodmann areas within somatosensory cortex; Siero (2013), discussing relative spatial specificity of gradient echo and spin echo BOLD; Goense (2012) and Moon (2013), discussing intracortical variations in neurovascular coupling; Heidemann (2012), describing zoomed and accelerated EPI to obtain very high spatial resolution BOLD signal; Petridou (2013) showing the benefits for spatial resolution of high-density multi-element small RF receive coils; Olman (2011) describing strategies for obtaining high spatial resolution BOLD; Yu (2013), showing that laminar-specific neural inputs can be deciphered with line-scanning fMRI; van der Zwaag (2013) demonstrating digit-specific BOLD activation in cerebellum; Huber (2013), showing excellent sensitivity at 7T for VASO CBV functional MRI; de Martino (2013), showing tonotopic gradients within human inferior colliculus; Moerel (2012), analysing auditory cortex tonotopy in detail; Schulz (2013) showing that prospective motion correction can dramatically reduce false positive activations in fMRI; and Waehnert (2013), describing a cortical contouring model that respects the anatomical layer structure suitable for analysing high resolution fMRI data by cortical layer.

DISCUSSION – The correlation between the vascular changes observed with MRI techniques and the underlying neural activity requires very careful understanding before ultra-high resolution fMRI data can be properly interpreted. Analysis of such data needs improved tools and better conceptualization of typical patterns of neural activity, together with systematic mapping of cortical areas, guided by the myeloarchitecture visible in good quality structural images of human brain.

CONCLUSION – Considerable progress has been made recently in obtaining human ultra-high resolution fMRI, largely due to the much greater sensitivity available at MRI field strengths of 7T and greater. Parallel imaging, especially simultaneous multislice (SMS) imaging, will further increase the signal-to-noise per unit time available, and hence the feasible spatial resolution. This enables structure, function and connectivity to be correlated at submillimeter spatial scales, thinner than the cerebral cortex. For neuroscience and clinical neurology to benefit from this progress will require further well-controlled comparisons between systems-level neuroscience in human and animal brains.

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