MR-Encephalography (MREG): ultra-high temporal resolution functional MRI

Functional magnetic resonance imaging (fMRI) is generally performed using a 2D echo-planar imaging (EPI) trajectory, which allows whole-brain acquisition at a temporal resolution of 2-3 seconds to track hemodynamic changes related to neuronal activity. While the hemodynamic response function (HRF) is temporally sluggish, subtle fluctuations in HRF shape across time may reveal information about underlying neuronal processes. The accurate identification of such small fluctuations requires a higher temporal resolution that is not achievable by standard methods. A higher temporal resolution would also allow the non-aliased sampling of physiological noise, mainly cardio-respiratory artifacts, which strongly contaminate the fMRI signal and cannot be effectively removed. Finally, a higher temporal resolution would allow a better integration of electroencephalography (EEG) and fMRI for the investigation of neurovascular coupling. While EEG can directly measure neuronal electrical activity with a high temporal resolution, it suffers from poor spatial resolution. In contrast, fMRI offers a much better spatial resolution, but standard methods are limited by poor temporal resolution. Faster fMRI acquisition methods could thus facilitate the integration between the two modalities.

We present a method for fMRI acquisition with high temporal resolution. The data are acquired using an efficient 3D trajectory consisting of concentric shells in k-space. Using a low number of shells, the readout time is 65 ms. To compensate for the high k-space undersampling, the data are acquired using a 32-channel head coil, allowing image reconstruction by parallel imaging techniques. Specifically, the forward problem is represented by a non-uniform Fourier transform of the image data weighted by the coil sensitivities. The inverse problem is then solved by a conjugate gradient method with Tikhonov regularization. The resulting reconstructed images only show a slight reduction in spatial resolution compared to the fully sampled case, but with a dramatic increase in temporal resolution.