Dynamic imaging of brain function: relating imaging signals to underlying physiology

Anna Devor, Andrew K Dunn, Mark L Andermann, Istvan Ulbert, Suresh N Narayanan, Stephanie R Jones, Gaute T Einevoll, James M Bower, David A Boas, Anders M Dale

Neuronal activity changes are coupled to changes in blood flow, blood volume, and blood oxygenation, collectively referred to as the hemodynamic response. Coupling between the hemodynamic response and brain electrical activity is of a great importance for interpreting fMRI. We address this question by employing simultaneous optical and electrophysiological recordings from rat cerebral and cerebellar cortex using multiple stimulus conditions.

During reflectance imaging of intrinsic signals, the illuminating light was filtered at 6 wavelengths (560-610 nm) using a rotating filter wheel. The raw optical data was corrected for wavelength-dependent path length differences. These multiwavelength maps were used to calculate oxyhemoglobin (HbO) and deoxyhemoglobin (Hbr) concentration changes in the response to stimulation. During laser speckle-contrast imaging the cortex was illuminated with a diode laser (785 nm), and the raw speckle images were converted to blood flow maps. Using both spectral and speckle data, we calculated oxygen consumption (CMRO2) maps.

Electrophysiological recordings were performed using either single metal electrodes or laminar multi-electrodes. In the cerebrum, the electrode was placed in the center of the barrel as determined by the optical activation. In the cerebellum, the signal was mapped along crus IIA. The signals were filtered at 0.1-500 Hz to record population field and at 150-5000 Hz to record multi-unit activity.

We demonstrate a non-linear relationship between the hemodynamic signal and the underlying electrical activity. Earliest hemodynamic response gives better localization of the neuronal activity. During the positive phase of Hbr, blood volume gives the best and blood flow the poorest localization.