Bridging the gap between physiology and functional magnetic resonance imaging*

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Functional magnetic resonance imaging (fMRI) provides data from multiple areas of the brain enabling studies of large-scale activation patterns. Interestingly, fMRI can show physiologically and computationally meaningful results, such as tuning functions for visual field position [1, 2] and spatial frequency [3]. Moreover, information from cortical activation patterns enable decoding visual objects [4] or imagined concepts [5], indicating that macroscopic patterns contain information about sensory stimuli. In addition, interaction between fMRI responses suggests implementation of efficient sensory coding principles at macroscopic scale [6].

Unfortunately, neural populations included in single fMRI voxels are very large, single fMRI voxel covering always thousands of neurons. Moreover, the fMRI signals reflect blood flow response to neural activation, and thus are indirect measures of neural activation. With more invasive methods, we are able to study single neurons and local networks in animal brain, but simultaneous recordings from multiple areas in awake animals are difficult. How could we bridge the gap between single neurons and voxels, and enable physiologically motivated, theory-based studies of neural systems?

Earlier work have shown that although both action potentials and synaptic activity are reflected in fMRI signals, the signals are more directly linked to the relative quantity of synaptic activity [7]. Recently, simultaneous measurements of electrophysiology and fMRI signals have suggested that a fixed transfer function could account for the nonlinearity in the neurovascular coupling [8]. Moreover, the role of astrocytes in neurovascular coupling has been better understood [9]. These data are important steps towards linking neural and fMRI data, enabling use of computational models to predict fMRI signals. Particularly, mesoscopic models, where a large group of neurons act as single model units, allows implementation of physiologically relevant parameters into a model while having reasonable computation time. These mesoscopic models could be a start for direct comparison of model predictions and fMRI data.

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Referenses

1. Dumoulin, S.O. and B.A. Wandell. Population receptive field estimates in human visual cortex. Neuroimage, 2008. 39(2): p. 647-60.

2. Nurminen, L., M. Kilpelainen, P. Laurinen, and S. Vanni. Area summation in human visual system: psychophysics, fMRI, and modeling. J Neurophysiol, 2009. 102(5): p. 2900-9.

3. Henriksson, L., L. Nurminen, A. Hyvarinen, and S. Vanni. Spatial frequency tuning in human retinotopic visual areas. J Vis, 2008. 8(10): p. 5 1-13.

4. Kay, K.N., T. Naselaris, R.J. Prenger, and J.L. Gallant. Identifying natural images from human brain activity. Nature, 2008. 452(7185): p. 352-5.

5. Mitchell, T.M., S.V. Shinkareva, A. Carlson, K.M. Chang, V.L. Malave, R.A. Mason, and M.A. Just. Predicting human brain activity associated with the meanings of nouns. Science, 2008. 320(5880): p. 1191-5.

6. Vanni, S. and T. Rosenstrom. Local non-linear interactions in the visual cortex may reflect global decorrelation. J Comput Neurosci, 2011. 30(1): p. 109-24.

7. Logothetis, N.K., J. Pauls, M. Augath, T. Trinath, and A. Oeltermann. Neurophysiological investigation of the basis of the fMRI signal. Nature, 2001. 412(6843): p. 150-7.

8. Magri, C., N.K. Logothetis, and S. Panzeri. Investigating static nonlinearities in neurovascular coupling. Magn Reson Imaging, 2011.

9. Koehler, R.C., R.J. Roman, and D.R. Harder. Astrocytes and the regulation of cerebral blood flow. Trends Neurosci, 2009. 32(3): p. 160-9.