Brain Imaging and Cognition (or "How I learned to think critically about the nature and use of fMRI").

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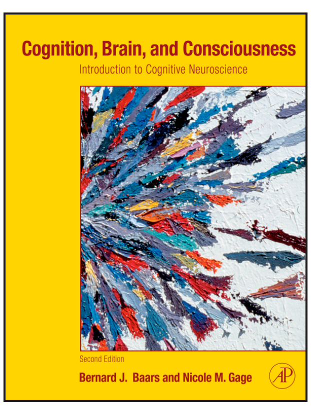
Prospectus. *In vivo* functional imaging of the brain has dramatically enhanced researchers' ability to examine the neural correlates of cognition and behavior. Functional Magnetic Resonance Imaging (or fMRI) is a particularly attractive technique. fMRI relies on the physical and magnetic properties of brain tissue (in this case, blood) which change under conditions of neural activity. This Blood Oxygen Level Dependent (BOLD) contrast is endogenous to the brain and unlike Positron Emission Tomography does not demand the injection of radioactive contrast agents. fMRI (based on BOLD) is therefore a perfectly safe technique for studying a certain type of brain responses, can and is easily applied to the study of diverse populations, and has reasonable spatial ("where in the brain") and temporal ("how quickly is something in the brain changing") resolution.

This segment of the Budapest Seminar in Cognitive Science is designed to give you a strong working introduction to fMRI and issues related to fMRI analyses. We will:

a) Examine the physical and physiological bases of fMRI. In this section, we will review the physics and technology that makes it possible to measure the fMRI signal and how this signal is correlated with electrophysiological activity in the brain;
b) Review experimental techniques and designs for fMRI. In this section, we will learn how experiments are designed for fMRI studies, and how these experiments allow us to answer questions of interest relating to brain *function.*
c) Understand how fMRI data is processed. In this section, we will learn how fMRI data are "processed" to prepare them for inference regarding brain function.
d) Understand some bases regarding data analytics. In this section, we will learn about different types of analytical techniques used to draw inferences about brain function from fMRI signals. In this section, we will discuss the challenges associated with "forward inference" ("What brain region is associated with a given task?") and "reverse inference" ("Given a pattern of brain activity, what tasks are likely to have generated it?").
e) Finally, we will conclude with some examples on the applications of fMRI with a focus on domains of human function where fMRI has particularly enhanced our understanding of the brain.

The lectures will sample material from the Suggested Text Book and additional readings. While some of the material is technical in nature, the lectures are tailored to be accessible to students with diverse and non-technical backgrounds. The effort is to make *everyone* learn to think critically about the value of a technique like fMRI.



Suggested Text Book:

Cognition, Brain, and Consciousness (CBC): Introduction to Cognitive Neuroscience (2nd Edition), 2010. Bernard J. Baars & Nicole M. Gage. Academic Press, San Diego CA.

Sept 23 (Lecture 1): A brief history of approaches to understanding brain function & Physiological Bases of fMRI. 1) CBC (Ch 1). 2) Logothetis, N.K., 2002. The neural basis of the blood-oxygen-level-dependent functional magnetic resonance imaging signal. Philos Trans R Soc Lond B Biol Sci 357, 1003-1037. 3) Logothetis, N. K., 2007. The ins and outs of fMRI signals. Nat Neurosci, *10*(10), 1230-1232.

Sept 24 (Lecture 2): Physiological Bases of fMRI contd. & Experimental Design for fMRI and Modeling Brain Interactions. 1) CBC (Ch 4: pp 113-124); Appendix: pp 555-557, 570-582). 2) Amaro, E., Jr., Barker, G.J., 2006. Study design in fMRI: Basic principles. Brain Cogn 60, 220-232. 3) Savoy, R.L., 2005. Experimental design in brain activation MRI: cautionary tales. Brain Res Bull 67, 361-367. 4) Logothetis, N. K., 2008. What we can do and what we cannot do with fMRI. Nature, *453*(7197), 869-878.

Sept 25 (Lecture 3): Experimental Design for fMRI and Modeling Brain Interactions contd. & Problems of inference in brain networks. 1) Stephan, K.E., 2004. On the role of general system theory for functional neuroimaging. J. Anat. 205, 443-470. 2) Friston, K.J., 2011. Functional and effective connectivity: a review. Brain connectivity 1, 13-36. 3) Diwadkar, V.A., 2015. Critical perspectives on causality and inference in brain networks: Allusions, illusions, solutions? Phys Life Rev 15, 141-144. 4) Silverstein, B. H. et al. (2016). Inferring the Dysconnection Syndrome in Schizophrenia: Interpretational Considerations on Methods for the Network Analyses of fMRI Data. *Front Psychiatry, 7*, 132, doi:10.3389/fpsyt.2016.00132.

Sept 26 (Lecture 4): Applications (Learning, Memory & Physiology). 1) CBC (Ch 9, pp 305-330). 2) Banyai, M. et al., 2011. Model-based dynamical analysis of functional disconnection in schizophrenia. NeuroImage 58, 870-877. 3) Jagtap P & Diwadkar, V.A., 2016. Effective connectivity of ascending and descending frontal thalamic pathways during sustained attention: Complex brain network interactions in adolescence. Hum Brain Mapp, 37, 2557-70. 4) Muzik, O., & Diwadkar, V. A., 2016. In vivo correlates of thermoregulatory defense in humans: Temporal course of sub-cortical and cortical responses assessed with fMRI. Hum Brain Mapp*, 37*(9), 3188-3202. 5) Morris, A., et al., 2018. Response Hand and Motor Set Differentially Modulate the Connectivity of Brain Pathways During Simple Uni-manual Motor Behavior. *Brain Topogr*, doi:10.1007/s10548-018-0664-5.