Predicting Active Cognitive Processes from Task-Based Contrast Images

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Conceptual Overview

Much of the current research in neuroscience relies on the assumption that cognitive processes are different and therefore dissociable. This assumptions rests on our intuitive knowledge—largely coming from introspection. On the other hand, individual studies rarely collect brain imaging data that spans a large set of cognitive processes. This leads to a fallacy: given activation in a single study (for example, the amygdala when emotions are probed), many authors would attribute to the amygdala a role in emotional processing. But forward inference can only show that an area is activated by a probe, not that activation in a region predicts that a specific cognitive process is in use. Leveraging meta-analytic tools is one way to resolve this and as an example we can look to Neurosynth (neurosynth.org). In general reverse inference maps, i.e. the probability of a specific region’s activation predicting a specific process (attention/memory/etc) are sparse compared to the forward inference maps (activation predicted from a term), suggesting that there is considerable overlap between the activation predicted by a term’s appearance in a study. This discrepancy suggests our use of distinct cognitive processes derived from experience may in fact be a mistake. In contrast, basing our knowledge of cognitive processes on dissociable activations in the brain can help us understand what processes share overlap and what processes are distinct.

One approach to this question is to investigate the processes involved in specific experimental tasks. This has the significant advantage that two public databases already exist that have collected task-based fMRI for a multitude of tasks in a large population, OpenfMRI (OpenfMRI.org) and the Human Connectome Project Task fMRI (humanconnectome.org). The goal would be to use the brain activation maps to build a bidirectional mapping between cognitive functions and activation. Again, the goal is to predict from new brain images the cognitive processes that are involved. For task fMRI this would allow us to identify the processes that are currently active in a brain as a task proceeds.

Labeling

Forward Inference based on (Schwartz, Thirion, & Varoquaux, 2013). The process we plan to use is to generate a linear regression model (GLM) for each voxel in the subject activation maps, under the assumption that the response in each voxel, x, is derived from a linear combination of the effects of the task labels on that voxel:

As Schwartz et al. point out, by using *term-versus-rest* contrasts the GLM formulation estimates each term’s effect while partialing out the effects of the other terms.

Schwartz, Y., Thirion, B., & Varoquaux, G. (2013). Mapping paradigm ontologies to and from the brain. In *Advances in Neural Information Processing Systems* (pp. 1673–1681). Retrieved from http://papers.nips.cc/paper/5168-mapping-paradigm-ontologies-to-and-from-the-brain