Predicting Active Cognitive Processes from Task-Based Contrast Images

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**Overview**

Many neuroimaging studies report results that claim to show

There is an incomplete understanding of how brain activation and cognitive processes map onto one another. An underlying assumption in neuroimaging is that there is a bidirectional causal link between a specific process and its associated neural activity. In other words, performing a task that requires “attention” should activate an attentional network, while observing activity in the attentional network implies that attention was being used. This directionality is impossible to observe in small-scale neuroimaging studies due to a lack of power and an incomplete set of stimuli -> activation mappings. Instead, we propose here to use datasets of brain activation maps from dozens of studies to build a large collection of task-based contrast maps. Following on the design of Schwartz et al. 2013 we will use these maps to calculate the forward inference for task-related functions, for example the activation that occurs when “attention” is employed. By selecting contrasts from multiple studies with overlapping terms we can ensure that these forward inference maps do not reflect study-specific activations but are function-specific. In addition, we can calculate the reverse inference maps to determine what functions are active given a previously unseen brain activation map. This approach will allow us to disentangle functions that are overlapping in their neural processing from functions that are dissociable, while giving insight into brain organization that has a direction connection to behavior.

**Goals**

The main goal is to predict, from an activation map the active cognitive processes—in some sense a description of the task being performed when the activation map was recorded. There are several smaller stepping stones to achieving this goal:

1. Forward inference maps for the terms in the task dataset(s). (I.e. when a term is seen, what activation do we expect)
2. Reverse inference maps for the terms in the task dataset(s). (I.e. what activation map predicts the presence of the term)
3. Leave-one-study out prediction of a studies terms. (i.e. given an unseen set of study data, but where every process has overlap with another study, return a description of the study’s task)
4. Prediction from a single subject brain map.

**Datasets**

We plan on using task fMRI data from the Open fMRI project (currently 31 studies, many different tasks) and the Human Connectome Project (500 subjects, resting state, tasks: working memory, recognition memory, gambling, motor, language, social cognition, relational processing, emotion). An initial design could train and test on different datasets, or on subsets of both datasets for maximum term coverage.

**Labeling**

The contrasts in the task data will need to be labeled to identify what processes are active at a given moment. We plan to do task labeling by hand, possibly following the outline provided by CogPO (<http://www.wiki.cogpo.org/index.php?title=Main_Page>).

**Forward Inference**

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-others* contrasts the GLM formulation estimates each term’s effect while partialing out the effects of the other terms. It is crucial that terms do not overlap perfectly across studies or contrasts to ensure that they are not collinear and can be estimated separately.

**Reverse Inference**

We plan to follow a similar procedure to that outlined in Schwartz et al. 2013 (*2.3 Reverse inference*, pg. 3).

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