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Automated regional behavioral analysis for human brain images

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Behavioral categories of functional imaging experiments along with standardized brain coordinates of associated activations were used to develop a method to automate regional behavioral analysis of human brain images. Behavioral and coordinate data were taken from the BrainMap database (http://www.brainmap.org/), which documents over 20 years of published functional brain imaging studies. A brain region of interest (ROI) for behavioral analysis can be defined in functional images, anatomical images or brain atlases, if images are spatially normalized to MNI or Talairach standards. Results of behavioral analysis are presented for each of BrainMap's 51 behavioral sub-domains spanning five behavioral domains (Action, Cognition, Emotion, Interoception, and Perception). For each behavioral sub-domain the fraction of coordinates falling within the ROI was computed and compared with the fraction expected if coordinates for the behavior were not clustered, i.e., uniformly distributed. When the difference between these fractions is large behavioral association is indicated. A z-score ≥ 3.0 was used to designate statistically significant behavioral association. The left-right symmetry of ~100K activation foci was evaluated by hemisphere, lobe, and by behavioral sub-domain. Results highlighted the classic left-side dominance for language while asymmetry for most sub-domains (~75%) was not statistically significant. Use scenarios were presented for anatomical ROIs from the Harvard-Oxford cortical (HOC) brain atlas, functional ROIs from statistical parametric maps in a TMS-PET study, a task-based fMRI study, and ROIs from the ten "major representative" functional networks in a previously published resting state fMRI study. Statistically significant behavioral findings for these use scenarios were consistent with published behaviors for associated anatomical and functional regions.

Keywords: BrainMap, Mango, behavior analysis, region of interest, brain atlas, TMS-PET, fMRI, ICA

INTRODUCTION

Relating findings from functional imaging studies to prior research is an important step in expanding our understanding of brain and behavior. Relevant publications are often found using keyword searches in databases such as Pub Med followed by *ad hoc* filtering, but interpretation can vary between researchers. Neuroimaging databases providing access to metadata from functional human brain research can help make more concise interpretations of behavior (Neurosynth—http://neurosynth.org/, Brede—http://neuro.imm.dtu.dk/services/jerne/brede/, PubBrain—http://www.pubbrain.org/, and BrainMap—http://www.brainmap.org/). However, finding relevant information in such databases can be difficult, the information is generally not presented in a manner that facilitates concise interpretation, and issues can arise regarding reverse inference (Poldrack, 2006, 2011). To address these problems we developed software to automate regional behavioral analysis of the human brain using data from the BrainMap database (http://www.brainmap.org/). The approach uses 3-D images formulated as spatial probability distributions of activation foci classified according to BrainMap's behavioral sub-domains. With over 20 years of development BrainMap has evolved into an extensive resource cataloging functional metadata from more than 2100 peer-reviewed papers, and over 10,000 experiments characterized using 83 paradigm classes. BrainMap categorizes functional imaging experiments using five major behavioral domains (action, cognition, emotion, interoception, and perception) with 51 sub-domains (Fox et al., 2005; **Table 1**). Each experiment is assigned one or more behavioral classifications along with a set of x-y-z coordinates for reported activations, and these data provide the basic structure for forming behavioral probability distributions as 3-D images. Region of interest (ROI) analysis is applied to these spatial probability images to assess behaviors. Findings can be charted as a "behavior profile" or viewed as z-score significance ranked behavior listing (**Figure 1**) to facilitate interpretation. The variety of experiments, imaging systems, processing methods, and paradigm classes in the BrainMap database provide breadth and depth for behavioral analyses.