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Treating Voxels as Words: Word-to-Vector Methods for fMRI Meta-Analyses

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Abstract : With the increasing popularity of fMRI as an experimental method, psychology and neuroscience can greatly benefit from advanced techniques for summarizing and synthesizing large amounts of data from brain imaging studies. One promising avenue is automated meta-analyses, in which natural language processing methods are used to identify the brain regions consistently associated with certain semantic concepts (e.g. “social”, “reward’) across large corpora of studies. This study builds on this approach by demonstrating how, in fMRI meta-analyses, individual voxels can be treated as vectors in a semantic space and evaluated for their “proximity” to terms of interest. In this technique, a low-dimensional semantic space is built from brain imaging study texts, allowing words in each text to be represented as vectors (where words that frequently appear together are near each other in the semantic space). Consequently, each voxel in a brain mask can be represented as a normalized vector sum of all of the words in the studies that showed activation in that voxel. The entire brain mask can then be visualized in terms of each voxel’s proximity to a given term of interest (e.g., “vision”, “decision making”) or collection of terms (e.g., “theory of mind”, “social”, “agent”), as measured by the cosine similarity between the voxel’s vector and the term vector (or the average of multiple term vectors). Analysis can also proceed in the opposite direction, allowing word cloud visualizations of the nearest semantic neighbors for a given brain region. This approach allows for continuous, fine-grained metrics of voxel-term associations, and relies on state-of-the-art “open vocabulary” methods that go beyond mere word-counts. An analysis of over 11,000 neuroimaging studies from an existing meta-analytic fMRI database demonstrates that this technique can be used to recover known neural bases for multiple psychological functions, suggesting this method’s utility for efficient, high-level meta-analyses of localized brain function. While automated text analytic methods are no replacement for deliberate, manual meta-analyses, they seem to show promise for the efficient aggregation of large bodies of scientific knowledge, at least on a relatively general level.

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