

fMRI group analysis with Spatial Bayesian Variable Selection

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Introduction: In recent times, Bayesian approaches have been increasingly popular in fMRI data analysis. One obvious appeal of the Bayesian approach is its interpretability. Instead of performing a hypothesis based inference at each voxel with an artificial threshold for declaration of activation, in the Bayesian approach we simply estimate the posterior probability of a voxel being active based on a suitable prior. In fact, with the Bayesian approach the arbitrary thresholding process may actually be eliminated. More importantly, the Bayesian approach permits us to use a framework that can incorporate anatomical information or other expert knowledge into the model with appropriate priors. In a classical framework this can be achieved only with segmentation or a region of interest (ROI) based approach, which is too restrictive. One popular Bayesian approach that does not suffer from the problems of the classical approach is the spatial Bayesian variable selection (SBVS) framework introduced by Smith et al. [1]. However, the method as introduced by Smith et. al. is only applicable to a single subject analysis and hence is of limited interest. In this paper we build upon their model for a single subject and extend it to data from a hierarchical experiment (e.g., group data) which allows inferences to be generalized to a larger population. Furthermore, through this model we can account for anatomical heterogeneity across subjects. To our knowledge, this is the only model that can handle such feature.

Methods: The general framework is built upon a Bayesian hierarchical linear model which is synonymous with group data analysis and allows inferences to be extended to a larger population. The inclusion of external information is done through an Ising prior. The Ising prior unites voxels at the highest level of the hierarchical model, induces smoothing of the activation surface which eliminates the need to smooth the functional data, and allows us to make direct inferences on a voxel's activation status. An additional feature of our model specification is the introduction of a thresholding mechanism directly into the model [2], so that the voxel activation is favored if the regression parameter exceeds a prespecified threshold.

Description of Data: In this experiment, 10 Alzheimer subjects performed a learning task with pairs of unrelated word in a blocked design; the encoding (learn) block was interleaved with a retrieval (recall) and baseline fixation block. Within a learning block, each subject were presented seven word pairs each lasting for 2.5 sec. Subjects were instructed to learn these words. During retrieval, subjects are instructed to recall the 2nd word by pressing one of two assigned buttons (indexed for YES - I remember and NO - I do not remember). Our interest for the analysis is the effect of the learning task relative to the baseline fixation. For the SBVS model, the data was analyzed under two cases for the model prior distribution. The first model, we do not include anatomical information into the analysis. The second model accounts for uncertainty in anatomical structure by assigning our prior belief a voxel is active a prior distribution. Activation maps are also compared with SPM.

Results: Activation maps for the model are provided in Figure 1. Regions in the SPM activation map with large test statistics appear in the SBVS maps with large posterior probability of being active. Between SBVS model, our uncertainty about a subjects anatomical structure increased the region of activation.

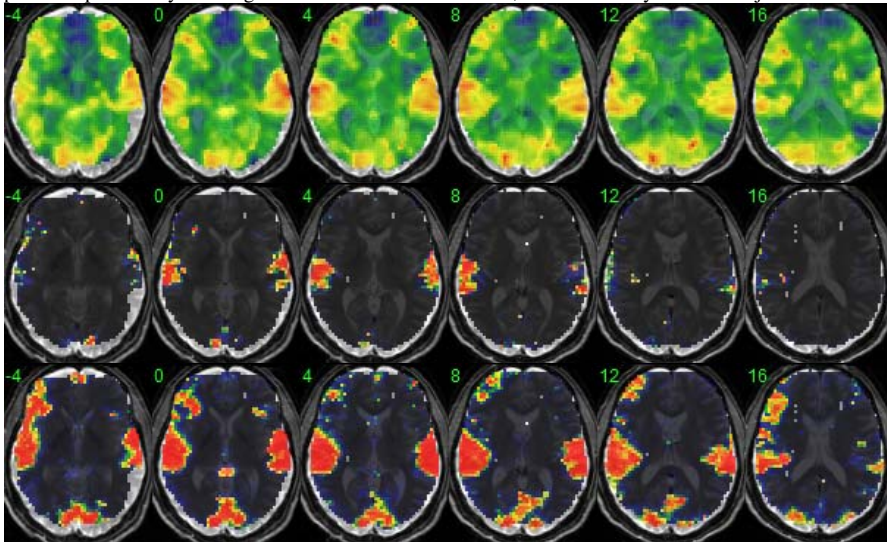


Figure 1. Activation maps from the 10 Alzheimer subjects. The first row corresponds to SPM, and the second and third to SBVS. The second row does not include anatomical information in our belief a voxel is active, while the third row our belief is assigned a prior distribution which accounts for the uncertainty in anatomical composition across subjects.

Conclusion: We have shown that the SBVS framework extended to group data is a viable alternative to the traditional hierarchical model. This approach should be favored since it seamlessly provides the fMRI researcher features—direct modeling of activation probabilities, anatomical information and expert opinion—that aren't available through the standard approach. Furthermore, activation maps provide sharp contrast between regions with large and small posterior probabilities of activation; this does not necessitate thresholding of the map to infer activation.

References:

1. Smith et al (2003), Assessing brain activity through spatial Bayesian variable selection, *Neuroimage*, 20: 802-815.
2. Mcevoy and Nandy, ISMRM proceedings 2008.