Classification technique to detect activation patterns in pain fMRI data

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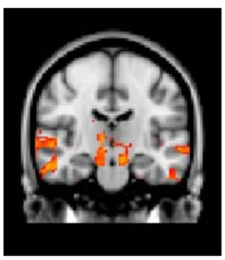
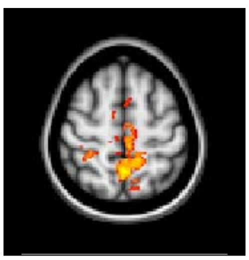
Introduction: Studies of pain fMRI have shed some light into the understanding of the roles of central nervous systems in pain processing and pain perception. Potentially they can be used to evaluate pain conditions in an objective way to assess drug efficacies that lead to new pain treatments. Conventionally, neuroscientists used GLM (General Linear Model) analysis to observe brain activation regions under different pain stimuli. While it is known that GLM fails to take advantage of the spatial relationship of fMRI data at different voxel locations., to achieve a better understanding about the little-had-been-known pain processing and perception in the central neural system, we apply SVM (Support Vector Machine) classification for fMRI data to find brain activation patterns for a passive leg-raising stimuli.

Methods: A 3T Siemens Allegra scanner with a single channel quadrature coil was used to image subjects in two groups including lumbar radiculopathy patients and controls. We used a block design with 20s-off and 20s-on stimuli. The stimuli was raising the right leg of the patients to induce pain in the lower back. A series of T2*-weighted fMRI volumes were acquired at a voxel size of 3.8x3.8x4mm. In addition, a high resolution T1-weighted brain volume of each subject was also acquired by a MPRAGE sequence. All subjects signed an IRB-approved consent form.
The data was preprocessed which included slice timing correction and motion correction. Binary classifications were applied to distinguish data extracted from the active blocks and ones from the resting blocks. Input data of classifications are extracted from a region of 3x3x3 voxels of each volume and with assigned labels of +1 or -1 (corresponding to 'active' and 'resting' blocks). Data from the brain regions that lead to high classific ation rate shows that the regions where the data are extracted from involved differently (i.e. 'activated') during the course of the two different cognitive processing - in our case, it is the pain-feeling associated with passive leg-raising and the non-pain resting state. Hence, when we repeat the whole classification process at all location in the brain i.e. moving the region of extracting 3x3x3 input data around the whole brain and at each time we recorded the classification rate output at the center of the extracted region. we get a classification map which tells us which regions in the brain are activated. These outputs are then non-linearly registered into Talairach space and thresholded to report. After testing with different type of classification kernels and methods, our results here are reported with linear-kernel SVM*light* classification tools written by Thorsten.

Results and Discussion:

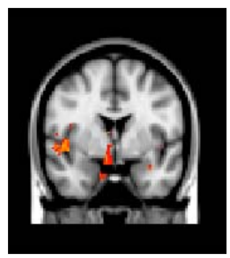


Thalamus activity for Pain

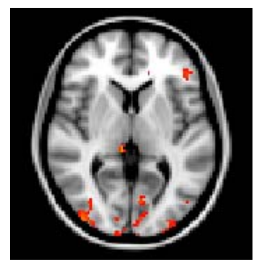


Motor activity

Thalamus activity



Insular activity for pain



No Thalamus activity for no pain

In fMRI analyses with the traditional general linear model , the 4D acquired fMRI data are treated as a bunch of 1-D time series signal at different voxel locations. In this way, the relationship of data collected at voxels in the same functional regions (such as voxels in the near neighborhood) are discarded and hence the methods become less sensitive in decoding cognitive states. While currently, we have little understanding of pain processing and perception, there's a need to use higher sensitive decoding methods. In the current study, we use a "spot light" approach (Haynes et al.) based on classification method in machine learning to decode cognitive states in pain processes.
In this study, we are able to see the effectiveness of SVM classification in decoding activation patterns when subjects felt pain for legraise compared to non painful legraise. In the group of patients, we found activations not only at the motor regions but also at the insula and the thalamus – those are considered as pain regions. In contrast, for the group of healthy controlled subjects, we did see activation at the motor regions but no activation was found in the pain regions. The difference in brain activation patterns between the two groups is expected and it agrees with the literatures in back pain fMRI study using GLM analysis.
Moreover, classification analyses with its higher sensitivity in decoding different activation conditions than the GLM, promises to give us a better understanding of pain processing in the central nervous system.

References

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