Pattern Analysis & Machine Intelligence

Towards Recognizing Deep Grammatical Information during Silent Reading from fMRI

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"This paper is eligible for the student paper award"

Individuals were scanned while reading text the size of words in silent reading. The intention of the experiment was to see if information related to linguistic characteristics of the word can be deduced from fMRI data via machine learning techniques.

Three experiments were performed corresponding to different degrees of grammatical complexity that presumably is performed during silent reading: (1) words and pseudo-words were presented to subjects; (2) words with diacritical marking and words without diacritical markings were presented to subjects; (3) words with complex Hebrew roots and words with simple Hebrew roots were presented to subjects.

The working hypothesis was that the more complex the needed grammatical processing needed, the more difficult it should be to perform the classification at the level of temporal and spatial resolution given by an fMRI signal. Each voxel was independently normalized by using the number of standard deviations from the mean of the voxel over an entire run of the experiment by each subject. A de-convolution techniques was used to separate the affect of different input on the signals. The 100 most active voxels were selected. We then applied neural network methodology to tell these classes apart using classification techniques, using a fully connected three level feed-forward network appropriate for, in each case, a binary classification task with 50 hidden level neurons.

Experiments were performed both within subject and cross-subject. In each case, we used a leave-one-out cross-validation technique.

In the results reported in this paper we discovered that: (1) words versus pseudo-words can be told apart during silent reading even across different subjects at the level of 80% accuracy in a very robust manner. (2) The diacritical/non-diacritical experiment was unable to separate at reliably greater than chance even within a single subject. (3) The complex Hebrew roots/simple Hebrew roots was unable to separate at reliably greater than chance even within a single subject.

These results are consistent with more standard methods run using General Linear Model (GLM) based software. Accordingly, at this time, we are able to classify our most shallow grammatical task (word versus pseudo-word) and were unable to classify the other "deeper" tasks

at more than chance levels. At this time our interim conclusions are that, it is possible that either the more refined information for questions 2 and 3 are not available at the resolution of fMRI readings or alternatively some deeper extraction methods are necessary.

In the future we intend to investigate this question further in two directions: (1) we intend to implement "deep networks" in an attempt to extract automatically the appropriate feature for these classification tasks (2) more primitively, it is possible that a different selection technique for the voxels should be used (3) Since question (1) was successful, it may be pertinent to do a more careful study of the chosen voxels to see how it is related to the specific task.