What are you looking at? Classifying neural activity of the fusiform face area.

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Problem and Motivation

Since the advent of functional magnetic resonance imaging (fMRI) in the early 1990s, advances in functional brain mapping have continuously necessitated the development of analysis methods for neural imaging data. Traditional fMRI analyses have been primarily univariately based, focusing on localizing neural activity given specific tasks. Multivariate approaches, on the other hand, can allow the analysis of information available in patterns of neural activity.

The motivation for this study stems from current neuroscience literature of abnormal processing of emotional brain areas in the autism, including the fusiform face area (FFA), a brain region known for its role in visual processing and face recognition (Schultz 2005). Motivated by these studies to seek to establish a baseline for future work toward the direction of autistic diagnosis through brain imaging methods, we investigated the ability to discriminate the representational content of the FFA in neurotypicals (normal, healthy individuals).

We thus collected a repository of fMRI data from neurotypical subjects viewing images of either faces, objects, or scrambled objects, determined the location of the FFA in each subject, and analyzed the activity of this region for pattern specific information. This becomes a brain image classification problem. Can we predict a viewed image type based on the neural activity of the fusiform face area?

Background and Related Work

In current ongoing studies at the Caltech Emotion and Social Cognition Laboratory, we have seen that emotional areas such as the FFA and amygdala deviate from normal processing. Neurotypicals depend mainly on facial information from others' eyes in making social judgments during normal conversation (Spezio et al. 2007), and such facial information from the eyes elicit significantly weaker responses from the FFA in autism than is normal. The FFA is also a cortical region of particular interest that has been documented for its role in face recognition and categorical processing (Kanwisher et al. 1997). While such observations have been determined by traditional univariate analyses of brain imaging data, we sought to analyze for representational information of the FFA through classification methods.

Cognitive neuroscience studies often focus at the interface between neural anatomy and function, seeking to determine the neural correlates of specific mental processes. Over the past couple decades, fMRI methods have become central to these efforts. A typical fMRI scan produces a three-dimensional image of the brain every 0.5 seconds with a spatial resolution of 3mm. The activity of each 3x3x3 mm voxel can be analyzed in relation to the experimental conditions. However, traditional univariate fMRI analyses focusing on the activation of individual voxels do not make use of information available in patterns of activation across voxels. This has led to multivariate approaches to fMRI data analysis methods, which allows honing the focus from determining the involvement of brain areas in specific processes toward determining representational content in patterns of neural activity (Kriegeskorte and Bandettini 2007; Mur et al. 2009; Norman et al. 2006; Pereira et al. 2009). We brought these perspectives to the analyses of neural activation of the FFA.

Approach and Uniqueness

In order to analyze for representational content in different activity patterns of the fusiform face area (FFA), we applied multivariate analyses to fMRI data in an attempt to classify this activity. The specific location of the FFA varies slightly from person to person. In FFA functional localizer tasks, participants view images of different types (e.g. faces, objects, scrambled objects). The location of the FFA is then determined by comparing cortical activation between these image types, revealing the areas that are most highly face-selective. However, this does not give much information beyond the fact of where the FFA is located and the specific tasks in which it is involved. We therefore localized the FFA and then applied multivariate techniques using support vector machines (SVMs) to analyze for information found in activation patterns across voxels of the FFA. If we can classify better than chance for the image type (face, object, or scrambled object) given the neural activity, then this indicates that there is meaningful information within the neural response patterns of the FFA about the image types. Aside from asking what tasks the FFA is involved with, we ask if we can decode mental activity to predict neural response based on image type, or, conversely, if we can discern image type based on neural activity.

Data collection and experimental design

10 neurotypical subjects participated in our experiment. fMRI data was collected using a Siemens 3.0-T Trio MRI scanner and gradient-echo T2*-weighted echo-planar images with blood oxygenation level-dependent (BOLD) contrast using an interleaved, ascending image sequence.

The FFA is a face selective area in the fusiform gyrus, but its exact location varies from individual to individual. In order to locate the FFA, participants were given n-back block-design tasks. Participants watched series of images of either faces, objects, or scrambled objects flash in quick succession while trying to determine when an image was flashed twice in a row. Each subject participated in three fMRI scanning sessions, with two trials of each of the three image types within each session, for a total of 18 complete trials.

Figure 1. Experimental stimuli: images of faces, objects, and scrambled objects

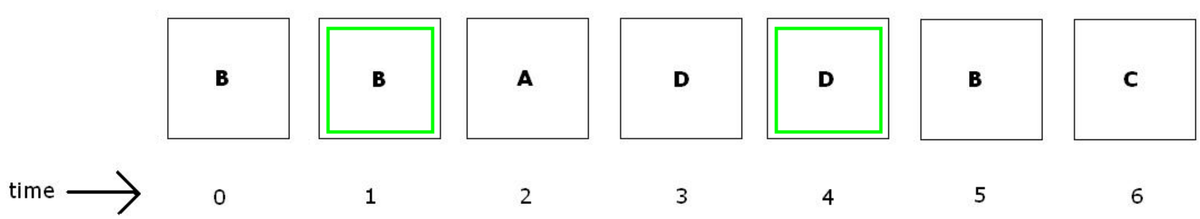


Figure 2. One-back task schematic. In this trial example, participants watch images flash on a screen and would press a button on timesteps 1 and 4, where the image is the same as the previous image.

Data preprocessing and ROI analyses

Traditional fMRI data preprocessing techniques were carried out using the SPM5 toolbox in MATLAB. Voxel masks of the brain determining the FFA region of interest were found through univariate analyses of activations during the one-back tasks, based on the knowledge that the FFA in neurotypicals respond more strongly to images of faces (Figure 3). A total of 1,299 voxels for the FFA were determined.

Classification

The classification system was implemented using R and was based on SVM algorithms as originally developed by Vladimir Vapnik. Classifications were based on vector representations of given trials, where each vector contained information from the functionally determined FFA voxels of interest, along with the subject id, the experimental session, and the image condition of the trial (face, object, or scrambled object).

The neural activity information from scrambled objects images was used in two ways. In the first approach, the scrambled objects images were treated as an image type of its own so that the system was made to classify among three image types. In the second approach, neural activity elicited from viewing scrambled objects was treated as a baseline representation of normal FFA neural activity. In this second approach, the signal for each voxel from the scrambled object trials were subtracted from each corresponding voxel for the faces and objects trials. The system was then trained to classified between the baseline removed representations of neural activity during faces and objects trials.

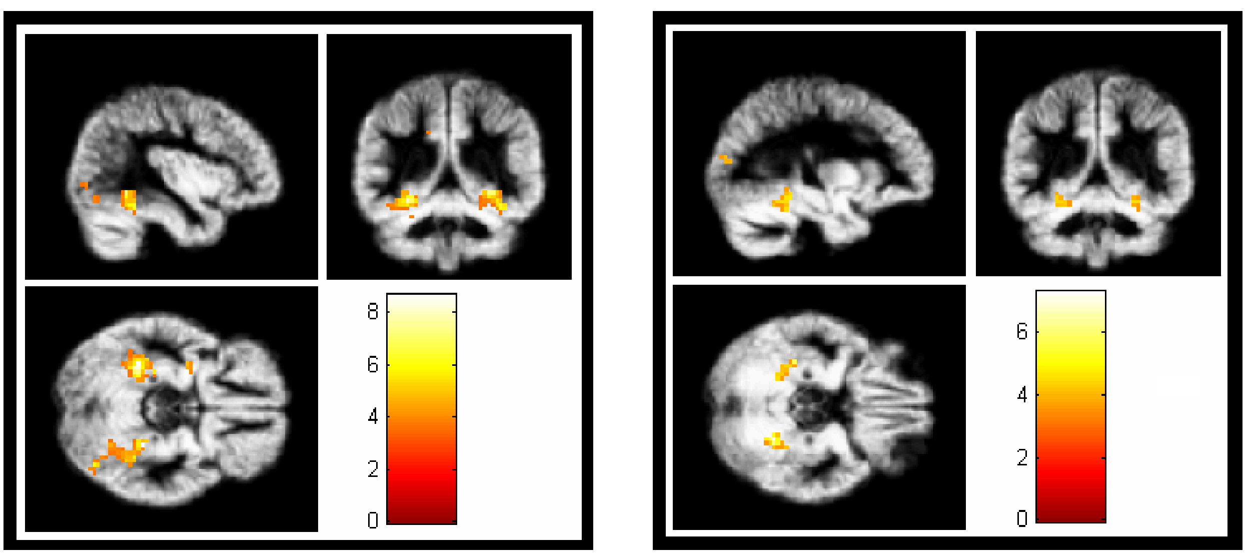
The most significant voxels were found by summing the area under the receiver operating characteristic (ROC) curve between each class comparison. This area under the ROC curve (AUC) is always between 0.5 (two classes statistically identical) and 1.0 (perfectly separable classes). The AUC cutoff value was experimentally set at 0.6, and only the information from 406 voxels with AUC values above this was included in classification. As per usual SVM protocol, we found hyperparameters for our classification system by tuning on a training set of vectors containing information from the significant voxels and the given image type for each trial. The SVM model was made with the same set of training data.

The classification system was evaluated across subjects by forming subgroups of subjects to include in a training group and finding classification rates on the remaining subjects. In our final evaluations, different 3-subject groups for training and 7-subject groups for prediction were formed, yielding 120 distinct groups.

Results and Contribution

The cross-validation rates on trials from subjects included in the training set is very high, essentially 100%, but lower across subjects classification rates suggest large variations between subjects and the need to increase participant numbers in training for classification. For across subjects classification, we are currently classifying at a rate of 45-50% given three image types (faces, objects, scrambled objects), and 65-70% between only object and face images with baseline activity removed. The classification rate at random chance should be 33% given three image types and 50% given two image types.

From the methodological standpoint, these results exemplify the ability to evaluate neural activity patterns in a specific area of interest using a multivariate classification approach across voxels, accessing information of representational content contained within the fMRI data. This is also consistent with current computational and neural systems models of how information is encoded in the brain, in patterns of activation across areas as opposed to single voxels. Further studies based on these results may lead toward neurometrics based diagnoses of disorders such as autism, in which abnormal activation have been found in the FFA and related areas.



A: faces - scrambled objects

B: faces - objects

Figure 3. Functional FFA localization: areas selective for facial information.
A shows areas which respond more significantly to images of faces than to images of scrambled objects. *B* similarly shows the areas which are more responsive to faces than objects.

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