An application of multi-voxel pattern analysis to investigating patient groups: face classification in the autism fusiform face area

Marc N. Coutanche[1], Sharon L. Thompson-Schill[1] and Robert T. Schultz[2]

[1]Department of Psychology and Center for Cognitive Neuroscience, University of Pennsylvania

[2]Center for Autism Research, Children's Hospital of Philadelphia

INTRODUCTION

- Multi-voxel pattern analysis (MVPA), a technique sensitive to information encoded within distributed patterns of activity, is increasingly being used to investigate the neural basis for behavior and cognition in typical populations. Despite this success, it has minimally been applied to patient groups.
- Individuals with an autism spectrum disorder (ASD) show performance differences in a variety of face processing domains, including processing facial identity (Wolf et al., 2008) and expressions (Ashwin et al., 2006).
- fMRI investigations into ASD face processing have repeatedly found lower levels of activation in an area of the fusiform gyrus when ASD participants view faces, compared to controls (e.g. Schultz et al., 2000). This functional region of the ventral temporal (VT) cortex, termed the fusiform face area (FFA), is typically active during face processing (Kanwisher et al., 1997).
- All previous studies of FFA activation in this group have used traditional fMRI analysis techniques, where statistical tests are run on each voxel individually, or on an averaged region of responses. This ignores information that may be present in the pattern of voxel responses.
- This study applied MVPA to data from a face processing experiment in ASD and control participants to examine if the pattern of FFA activity reveals face information in this group.
- It was hypothesized that face information would be present within the ASD FFA, despite lower overall activation levels.

METHODS

Participants: Data from 8 ASD (males, ages 9.3 - 19.9, mean = 12.7) and 8 control participants (males, ages 9.4 - 14.8, mean = 11.7) were analyzed from a larger sample of participants in an fMRI face processing study. Groups were not significantly different in age (p = 0.51) or IQ (p = 0.07). Although an IQ difference approached significance, behavioral performance on face tasks in the scanner was not significantly different between groups. ASD participants met criteria for autism or Asperger's syndrome and were recruited through the Yale University Child Study Center.

Tasks: 4 runs of data were analyzed here, each with a different task / stimulus-type combination (figure 1). Faces and house stimuli were presented in alternating blocks. Runs included a common subordinate level house discrimination task (same vs. different) to act as a baseline, allowing between run comparisons. Block duration was 20 seconds, with a 12 second inter-block interval. Block order was counterbalanced across participants and varied between runs.

Scanning and preprocessing: Functional T2*-weighted images were acquired on a Siemens Trio 3T scanner (40 axial slices parallel to AC-PC plane, in-plane voxels = 3.5 mm^2, slice thickness = 3.5 mm, TR = 2320, TE = 25, flip angle = 60°. Five functional runs of 144 volumes were collected (four analyzed here). Functional data were motion-corrected and aligned to the last volume. Linear trends and low frequency information were removed. Data were coregistered with 3D anatomical data in standardized Talairach space for later analyses in coordinate-defined masks.

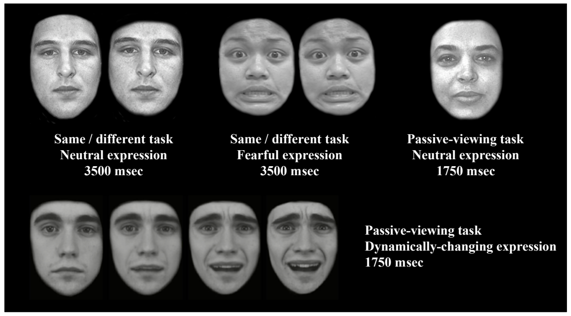

Figure 1: Face stimuli and tasks, with associated presentation times.

Regions: Regions of interest in the VT and the fusiform gyrus (FG) were defined anatomically. The FFA was defined using functional loci reported in prior studies of face-selective activation. Due to the inherent difficulties in localizing the FFA in a group that does not show robust FFA activity, three overlapping spheres (5 mm radius each) were placed at average FFA coordinates reported in controls in previous publications (+40x, -55y, -10z; +38x, -58y, -10z; +36x, -50y, -10z; figure 2).

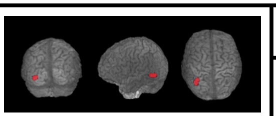

Figure 2: Three overlapping spheres placed at previously reported FFA coordinates.

Classification analyses: A ridge regression classifier was applied to classify activity patterns for faces from houses. A cross-validation framework was implemented using the Princeton MVPA toolbox (Detre et al.,2006), ensuring testing only occurred on data points unseen during training. The particular ridge regression penalty parameter was chosen for each classification using an embedded cross-validation procedure with a custom script that systematically tested a broad, and then more targeted, range of parameter values on training data, before selecting the best value for use on the final testing data. Total performance was assessed as the percentage of correct classifier guesses, averaged across iterations. Above-chance significance was assessed using permutation testing, where labels were permuted across blocks.

RESULTS

A traditional activation-based analysis confirmed that this ASD sample shows the reported reduction in FFA activity (figure 3).

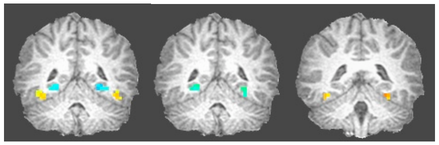

Figure 3: Left and middle: t-maps with a corrected threshold of *p* =0.05 (voxelwise p < 0.005; cluster size >=6 voxels), centered at y=-45. Face activation is shown in orange/yellow. House activation is blue/green. Right: Group t-map with a corrected threshold of p = 0.05. Orange / yellow indicates significantly greater activation in controls. Right and left are reversed by convention.

Despite ASD participants having reduced activation to faces, and no voxels reaching significance for face responses in the ASD group, MVPA revealed above-chance classification performance for VT, FG and coordinate-defined FFA in all ASD participants. Furthermore, classification accuracies were not significantly different between groups (figure 4).

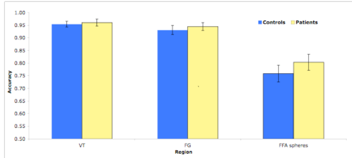

Figure 4: Classification results for both groups

In contrast to these areas, classification accuracies were not significantly different from chance in a control region in the ITG, in the majority of participants.

To compare face vs. house classification performance for faces with different expressions, classifiers were trained and tested on neutral and fearful faces separately. Significantly higher face classification accuracies were found for fearful faces than neutral faces in controls (t (7) = 2.39, *p* = 0.048). ASD participants did not show this enhancement (t (7) = -0.53, *p* = 0.610; figure 5).

RESULTS (continued)

Classification accuracy within the coordinate-defined FFA correlated significantly with a standard measure of face recognition ability in ASD participants (r = .71, p = 0.047) but not in control participants (r = .12, p = 0.78; figure 6).

Classification accuracy in the coordinate-defined FFA also correlated significantly with severity of social deficits in ASD participants, as measured through the ADOS, a standardized clinical diagnostic observation schedule (r = -.72, p = 0.046, figure 7).

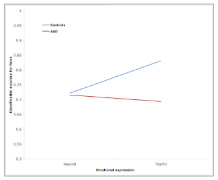

Figure 5: Classification accuracy for same / different face trials with different expressions

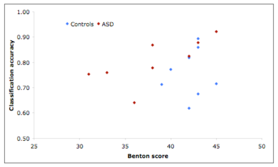

Figure 6: Classification accuracy against face recognition ability

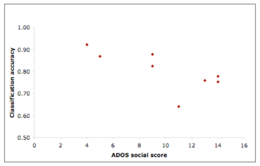

Figure 7: Classification accuracy against social deficits in the ASD group

A searchlight analysis across the VT area revealed similar locations for the most accurate regions in each group. The top searchlights in controls included some with a majority of face-responsive voxels and others with a majority of house-responsive voxels. In contrast, ASD participants showed only searchlights with a majority of house-responsive voxels (figure 8).

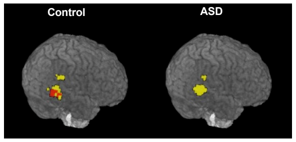

Figure 8: 50 most accurate searchlights in representative participants (central voxels). Brain anatomies are transparent. Red signifies searchlights with more voxels responding to faces than houses. Yellow indicates more voxels responding to houses.

DISCUSSION

Using MVPA, this study suggests there is sufficient information within the pattern of activity in the autism FFA to classify faces from non-faces at levels not significantly different from controls. A high level of classification performance was found despite no face-responsive voxels reaching significance in a traditional analysis of the ASD group. This finding of high performance in both groups is particularly compelling given the established sensitivity of MVPA.

Further, classification performance in the patient group was strongly correlated with a standard (out of scanner) face recognition measure and a central clinical symptom (severity of social deficit). This suggests MVPA is a technique sensitive to individual variation in the amount of information encoded within the autism FFA region. Both groups showed similar locations of the best classification performance within the VT region, although the compositions of the top searchlights differed.

These findings validate and argue for the use of MVPA in investigating activity patterns in patient groups. They also show the potential for relating classification performance to meaningful clinically-relevant measures.

REFERENCES

Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). *Social Neuroscience*, *1*(3-4), 349-363.

Detre, G. J., Polyn, S.M., Moore, C.D., Natu, V.S., Singer, B.D., Cohen, J.D., Haxby, J.V. & Norman, K.A. (2006). *Human Brain Mapping 2006.*

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). *The Journal of Neuroscience. 17*(11), 4302-4311.

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., et al. (2000). *Archives of General Psychiatry*, *57*(4), 331-340.

Wolf, J. M., Tanaka, J. W., Klaiman, C., Cockburn, J., Herlihy, L., Brown, C., et al (2008). Autism Research, 1(6), 329-340.

ACKNOWLEDGEMENTS

This study was funded by the National Institute of Mental Health (R01MH073084). Further support came from the National Institutes of Health (R01MH070850).

CONTACT

Marc Coutanche: coumarc@psych.upenn.edu

Lab website: http://www.psych.upenn.edu/stslab/