Reading Out Visual Information from Populations of Neurons in ITC and PFC

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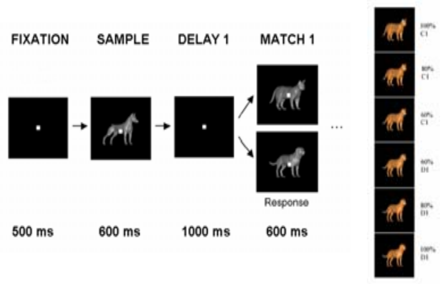
Overview

In this work we use Linear Support Vector Machines (SVMs) to decode visual information from neurons in Inferior Temporal (ITC) and Prefrontal Cortex (PFC). The decoding accuracy for different classification tasks provides insights about the dynamics and nature of the information being represented by these two brain areas.

The Experiment



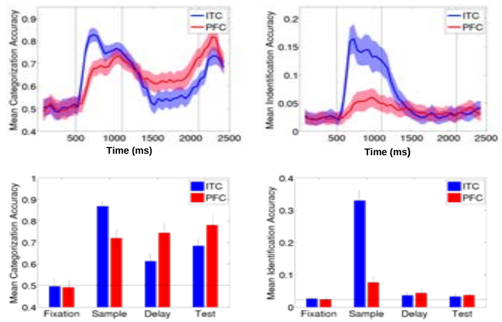
443 ITC, 525 PFC neurons were recording from two rhesus macaque monkeys as they engaged in a delayed match to category task. 42 different images were shown during the sample period that were created from morphs of 3 prototype dog and 3 prototype cat images. Results from single neuron analyses were reported by Freedman et al., J. Neuroscience 2003.

The 'Read Out' Analysis

Linear SVMs were trained on the firing rates of 256 randomly chosen neurons from either ITC or PFC (only neurons that were shown 5 repetitions of each stimulus were used).

We decoded **Category Information** – was the sample stimulus a cat or a dog (chance ½), and **Identity Information** – which cat or dog stimulus was shown (chance 1/42). Mean accuracy on 5-fold cross-validation (averaged over 100 repetitions of random neuron/trial choice) is the main statistic we report.

Initial Results



Using 150ms Bins

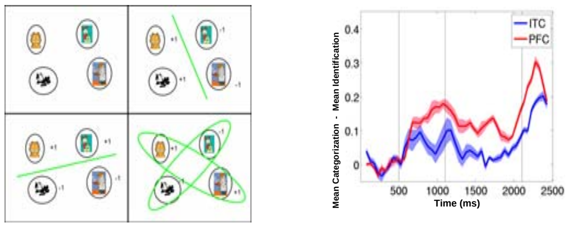
Using Task Related Time Periods

Categorization

Identification

Initial results show that there seems to be much more stimulus identity information in ITC during the sample period than in PFC. It also seems that PFC has more category information in the delay and test periods and that ITC might have more category information during the sample period.

Separating Category and Identity Information

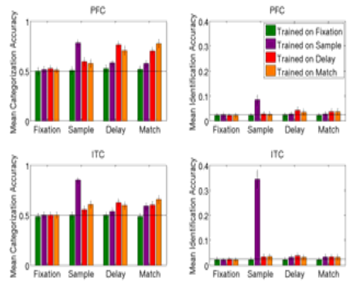


If a set of neurons contains stimulus identity information, a SVM can easily decode category information.

To separate category from identity information, we trained a SVM on images from 2 dog vs. 2 cat prototypes (D1,D2 vs. C1 C2), and subtracted the results from the averaged of mixed class decoding accuracy ((D1, C1 vs. D2, C2) + (D1, C2 vs. D2, C1))/2.

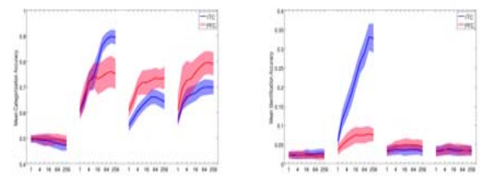
Results from this analysis suggest that PFC might be representing information in a more 'category-based' format starting in the Sample period.

Dynamics of Information Representation



By training the classifier on one time period and testing on data from either the same or a different time period, we see that the best results are almost always obtained when training and testing are done on the same time interval. This suggests that different sets of neurons hold the category/identity information at different time periods.

Sparse and Distributed Representations



Here we do feature selection on the training data, and then train and test the classifier using the best 2^i neurons (for i = {0,.., 8}). In several periods, such as during the delay period for PFC, we see that the best 4 neurons do about as well as using all 256 neurons, which suggests a sparse representation. In other time periods, such as during the sample period for ITC, we see that performance continues to increase, suggesting a much more distributed representation.

Conclusions

- Using statistical classifiers on populations of neural data is a powerful way to decode the content and dynamics of information in different brain regions.

Our analyses indicate that:
- PFC contains more category information during most time periods, while ITC contains more identity information when a stimulus is visible.
- The neurons that contain particular information change through the course of a task.
- The sparse vs. distributed nature of representations varies from PFC and ITC at different points in time.

References

Freedman, D. J., Riesenhuber, M., Poggio, T., and Miller E. K. (2003). J. Neurosci. 23(12):5235-5246
Hung, C. P., Kreiman, G., Poggio, T., Dicarlo, J.J. (2005). Science 310, 863-866