IT neurons firing rate prediction in primates

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I Introduction

Deciphering the mechanisms behind visual perception in primates is fundamental to our understanding of cognitive brain functions. The inferior temporal (IT) cortex plays a crucial role in object recognition and is a focal point for studies on visual processing. This project leverages a dataset obtained from behavioral experiments where non-human primates were shown various images, and the resultant neural activity was captured using multielectrode arrays. The primary goal is to develop a highly accurate computational model that mimics the visual pathway processing in the brain. To accomplish this goal, we are presenting 4 different models and compare their performances.

II Methods

A. Linear regression, data driven

Following this approach, we used as input the images and as output the activation of the 168 IT neurons. We first performed PCA and extracted the first 1000 principal components of the input stimuli. Then, we tuned the regularization parameter (alpha) of the ridge regression model using cross-fold validation. Finally, we fitted our tuned linear regression model using the pcs as input and the neurons activation as output.

B. Linear regression, task driven

For this method we uploaded a residual neural network (ResNet-50), pre-trained with a task driven approach. We gave as input to the network the images stimuli and extract the corresponding activations of the six ResNet50 layer blocks. Then, we computed the first 1000 pcs of the activations for each layer and we used them to predict the neural activity using a tuned ridge regression model. Finally we compared the performances of the models using the activations of the 6 different layers.

C. Shallow neural network

For this data driven approach, we developed a shallow convolutional neural network that takes as input the images stimuli and returns as output the neural activity. The CNN is composed by one convolutional layer, one max-pooling layer and a fully connected, ReLU activated layer, with dropout (rate = 0.2), mean squared error loss and Adam optimizer.

D. Residual Neural network

Our deep neural network, designed for predicting firing rates, is built on top of the pre-trained ResNet50 architecture: We have cutoff the ResNet architecture at the layer with the best explained variance, and inserted a Maxpool layer and three fully connected layers, each activated by a ReLU function and incorporating dropout. Additionally, we conducted extensive hyperparameter tuning, focusing on the learning rate of our Adam optimizer, along with the dropout rates and neuron counts in the fully connected layers.

E. Model evaluations

Each models have been evaluated comparing the predictions and the ground-truth in the validation dataset. To assess the performance of the models we calculated the explained variance and the pearson correlation across the 168 neurons between the predictions and the ground-truth.

III Results

A. Best layer for the task driven approach

Before comparing the 4 different models, we first identified the ResNet50 layer whose activations produce the most accurate prediction: layer 3 (Fig. 1).

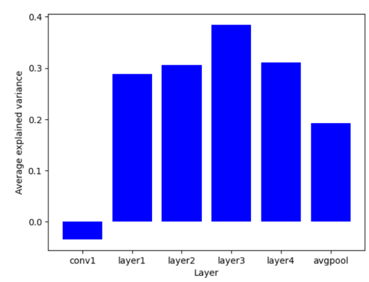

Fig. 1. Explained variance of ResNet50 layers activation

B. Models evaluations

Using our evaluations we found that the best model, among the ones proposed, for predicting IT neurons is Residual Network (Table 1).

TABLE I
EVALUATION OF THE MODELS

Model	Explained variance	Correlation
linear regression (data driven)	0.09236	0.28452
linear regression (task driven)	0.38595	0.61031
shallow CNN	0.01139	0.37534
Residual network	0.42560	0.64141

IV Conclusions

In summary, our study highlights that Residual Network models can predict IT neuron firing rates in primates, achieving the highest correlation and explained variance among the tested models, while leaving room for further imporvements to the layers added on top of the model.