COMMUNICATION SUBSPACES BETWEEN FRONTAL CORTEX AND MIDBRAIN

Using Steinmetz dataset
Connected Lizards:
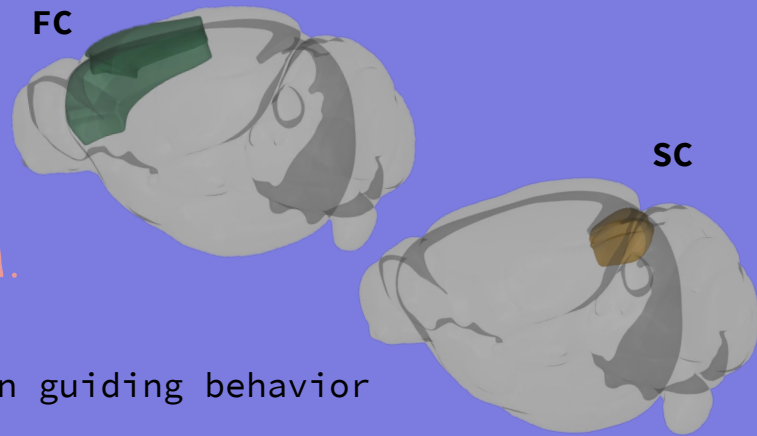**Xin Wei Chia, Jean Simonnet, Maria Kesa**
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NeuroMatch Academy, 2020

FC

SC

*WHAT IS A COMMUNICATION SUBSPACE?
-- IT'S THE DIMENSIONS ALONG WHICH ACTIVITY IN THE
SOURCE AREA BEST PREDICTS THE ACTIVITY IN THE TARGET AREA.

Top-down modulation of sensory information
Selection of the relevant environmental information guiding behavior

Frontal cortex (FC) → superior colliculus (SC) anatomical pathway
(e.g. Fei Hu et al. 2019, Neuron)

What kind of information is communicated from prefrontal cortex to superior colliculus?
Can we find a communication subspace and is it modulated by behavior or context?

Steinmetz dataset → neuropixel recordings / visual discrimination task
Richards_2017-10-31 → animal with simultaneous recordings in FC and SC

Neuronal activity → PCA projection of binned (20ms) trial averaged spike trains
Behavior → Face motion energy

METHODS

We used dimensionality reduction to identify neural activity subspaces and how they are related to behavior.

Main Tools:
PCA-- we use dominant correlations to identify low-dimensional patterns in neural data.
Ridge regression-- to find mappings between neural subspaces in different circuits (Step 1) and mappings between neural data and behavior (Step 3).

Step 1
Ridge Regression

Predicted

$$\begin{bmatrix} \textbf{Midbrain Activity} \end{bmatrix} = \begin{bmatrix} \textbf{Frontal Activity} \end{bmatrix} \ \textbf{X} \ \boxed{\textbf{Coefficients}}$$

Predictor

(Bin times x PCs)   (Bin times x PCs)   (PCs x PCs)

Step 2
$$\hat{Y} \textbf{ (Predicted activity)} = \textbf{Coefficients} \ \textbf{X} \ \textbf{Test PCA components}$$

Selection of predictive dimensions using explained variance of $\hat{Y}$
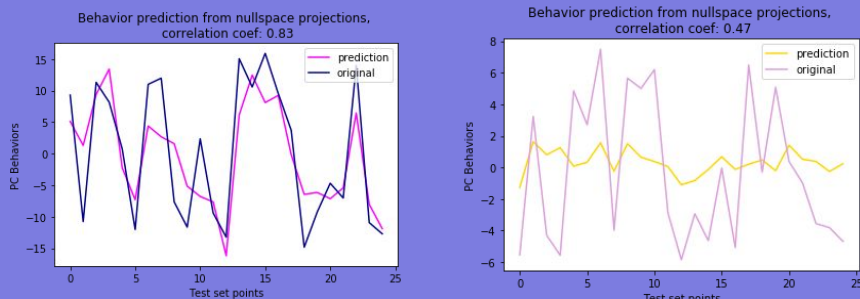
Step 3
Regress activity to behaviour

$$\begin{bmatrix} \textbf{Predicted Behaviour} \end{bmatrix} = \begin{bmatrix} \textbf{Predictive Frontal Activity} \end{bmatrix} \ \textbf{X} \ \boxed{\textbf{Behaviour Coefficients}}$$

(Bins x PCs)   (Bins x PCs)   (PCs x PCs)

Results

- 2 PC's in the SC predicted by FC PC's with correlation > 0.9 on test set
- The dimensions explaining most of the variance in the SC PC's predict behavior

Prediction of midbrain activity, correlation coef: 0.92

Prediction of behavior, correlation coef: 0.98
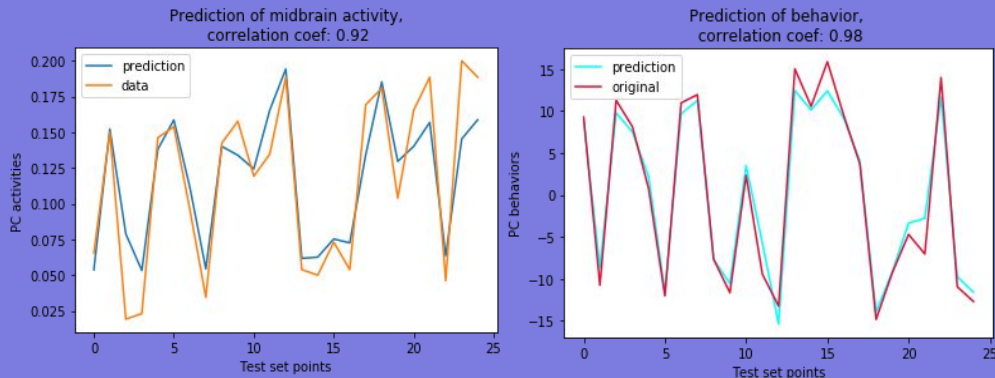
- Null space
  Private dimension that predicts well behavior
  Other dimensions do not predict behavior well

Behavior prediction from nullspace projections, correlation coef: 0.83

Behavior prediction from nullspace projections, correlation coef: 0.47

Future work

- Validation of the subspace function: are the subspaces the same for different contexts?

- Preprocessing and selection of the data
- K-fold cross-validation for the regression hyperparameters

LIMITS

- Behavior as a **confounder**
- The **chicken/egg situation** : FC receives indirect SC information via cortical and subcortical areas

DISCUSSION

- Identification of a communication subspace between PC and SC
  Communication channel for top-down control of sensory-motor processing?

REFERENCES

Fei Hu, Tsukasa Kamigaki, Zhe Zhang, Siyu Zhang, Usan Dan, Yang Dan, "Prefrontal Corticotectal Neurons Enhance Visual Processing through the Superior Colliculus and Pulvinar Thalamus", Neuron, 2019

Kaufman et al,"Cortical activity in the null space: permitting preparation without movement", Nature Neuroscience, 2014

Steinmetz et al, "Distributed coding of choice, action and engagement across the mouse brain", Nature, 2019

Semedo et al, "Cortical areas interact through a communication subspace", Neuron, 2019

MIT Linear Algebra lectures
https://ocw.mit.edu/courses/mathematics/18-06-linear-algebra-spring-2010/video-lectures/

Thank you!

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