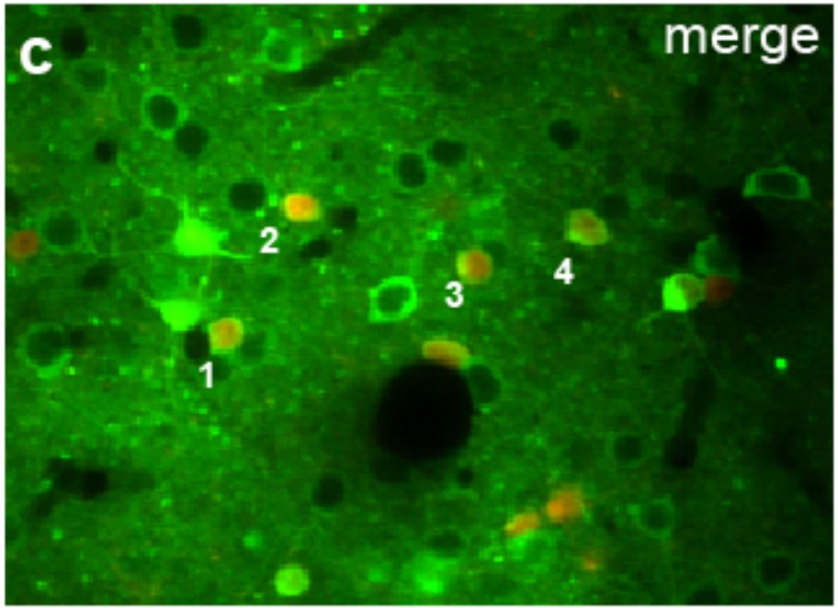
Understanding neurons in motor cortex:
From decoding behavior to dimensionality reduction



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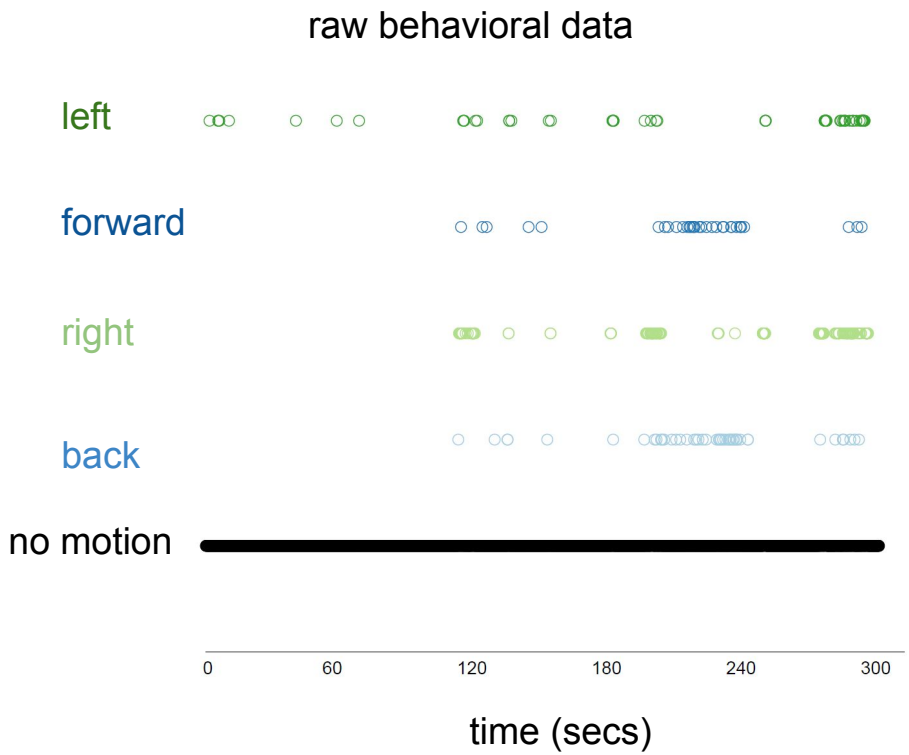
Questions

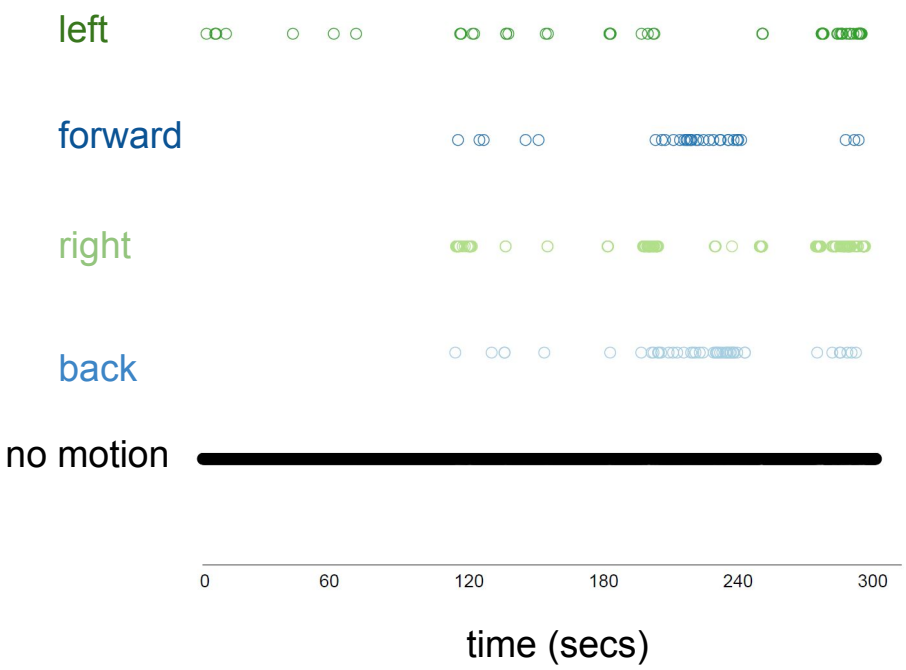
- Can we decode behavior from calcium signals of neurons?
- How complex is the neural activity, across the population?
- Are there distinct subgroups of neurons?
- Can we predict the spatial locations of neurons, given the neural activity?

Given:

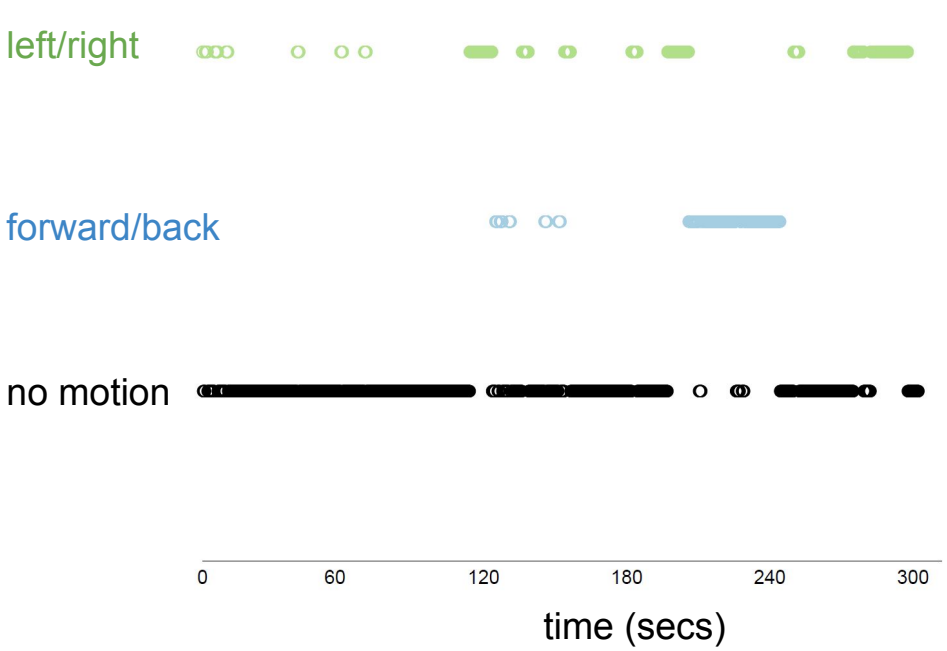

raw behavioral data
left
forward
right
back
no motion
0
60
120
180
240
300
time (secs)

Given:

raw behavioral data

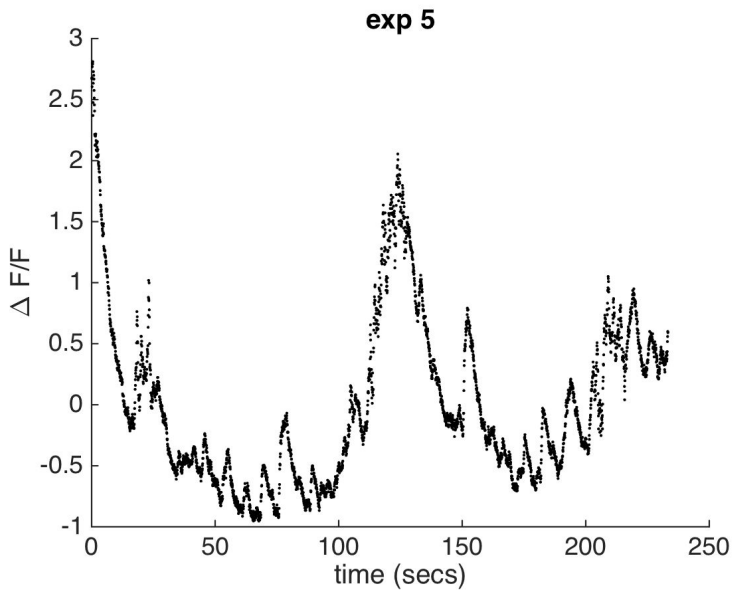


smoothed behavioral data

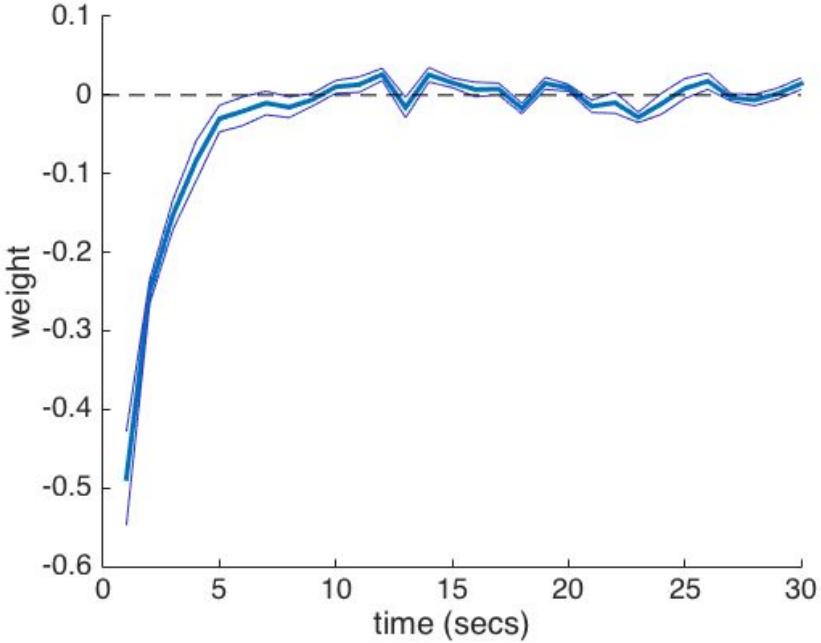


Given:

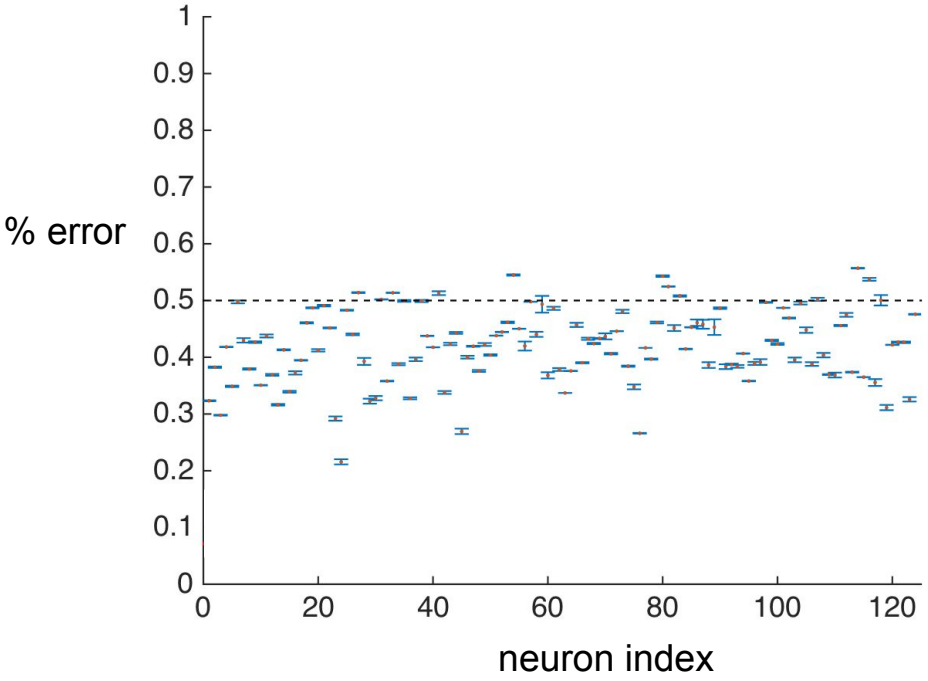
calcium signal for one neuron

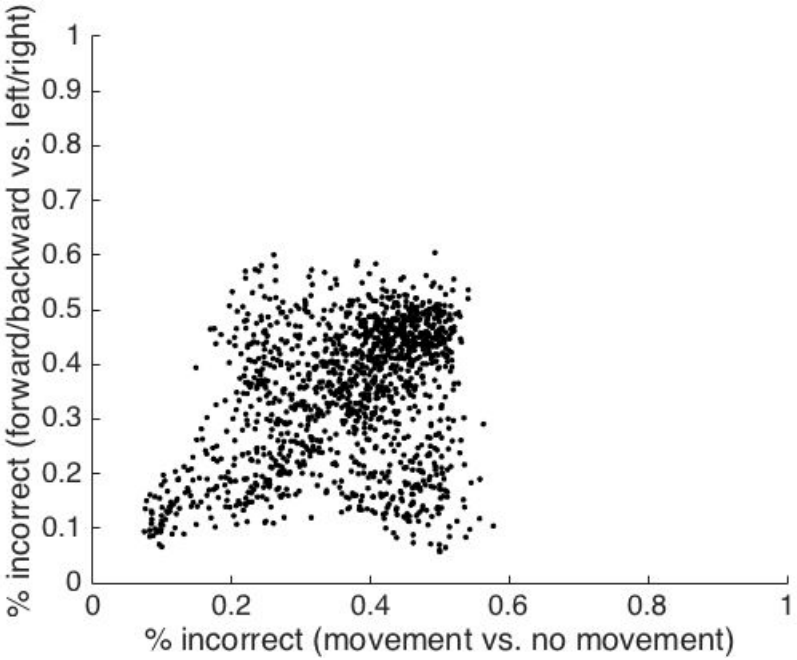


Autoregressive weights (averaged)

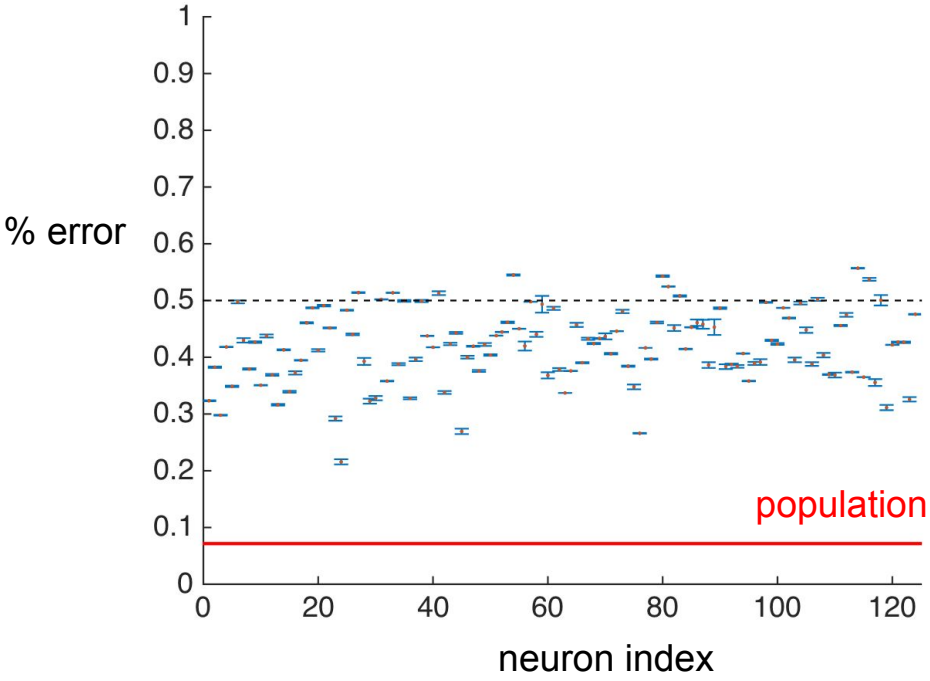


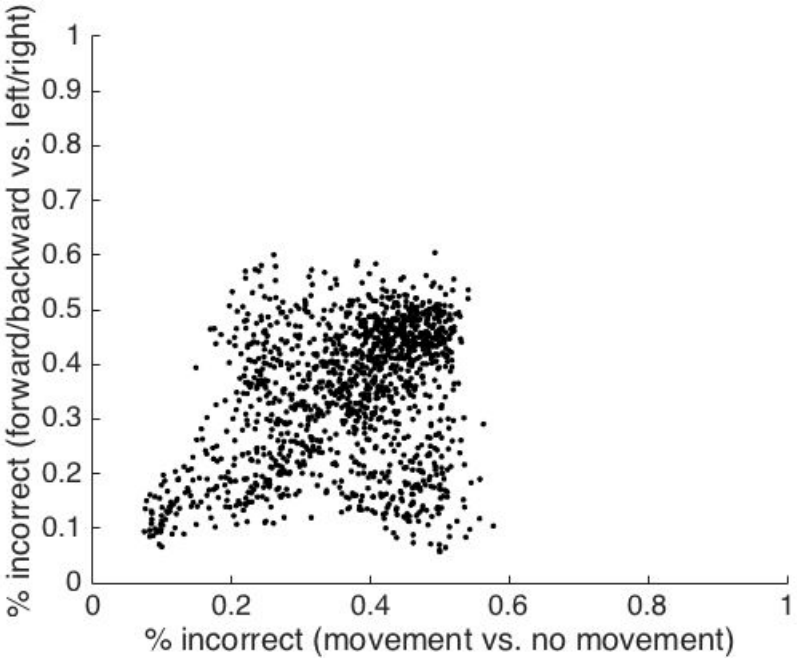
Decoding behavior across population > single neurons



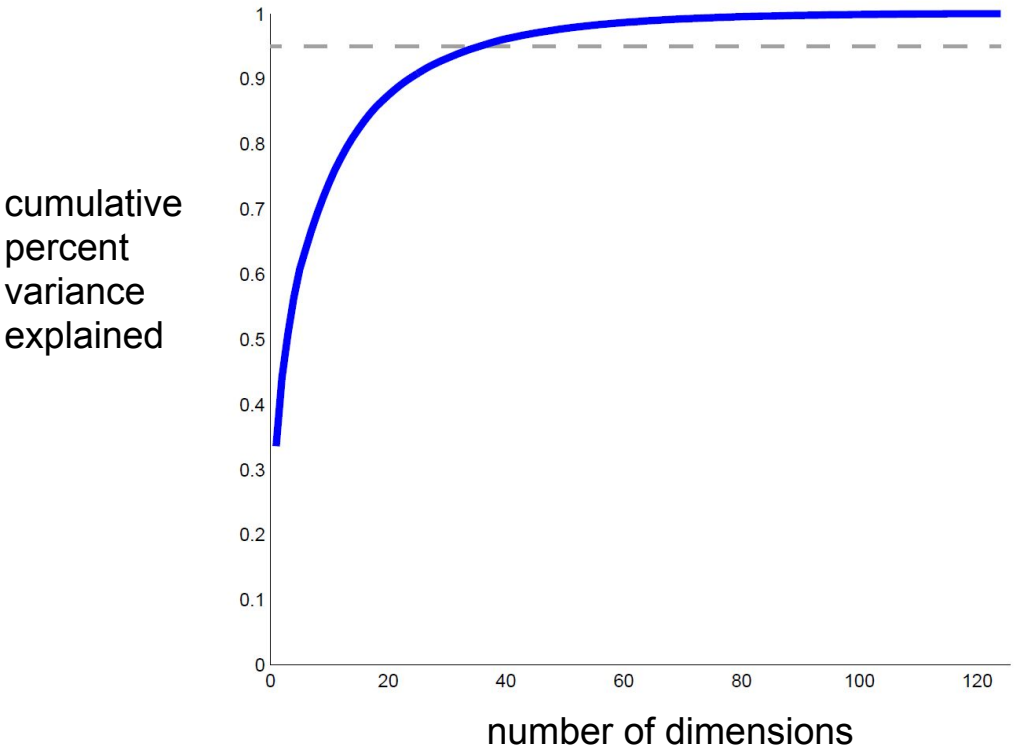


Decoding behavior across population > single neurons



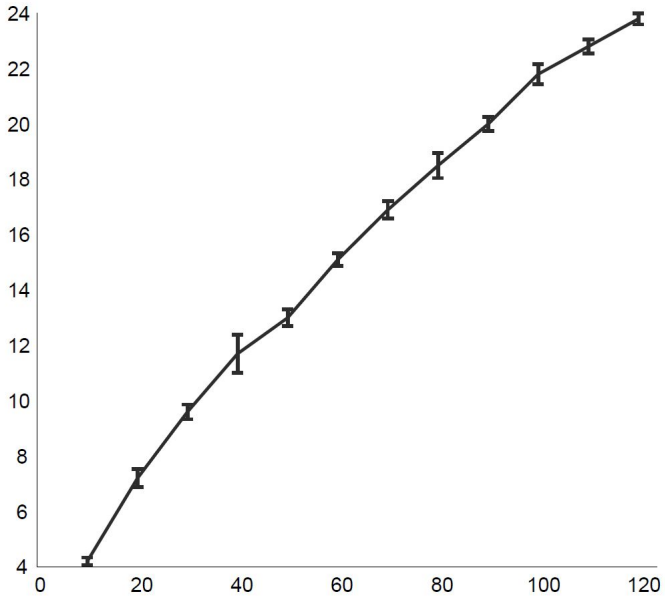


How complex is the population activity?

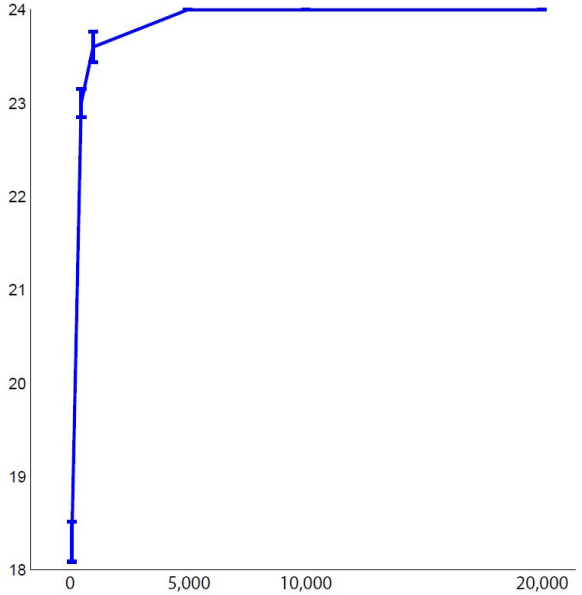


Ideal: Record from more neurons; more time not necessary

number of dimensions



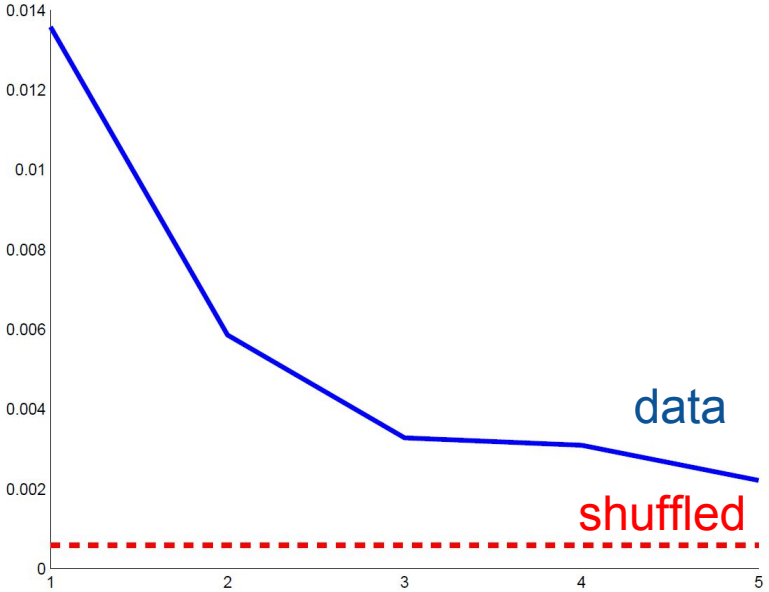
number of neurons



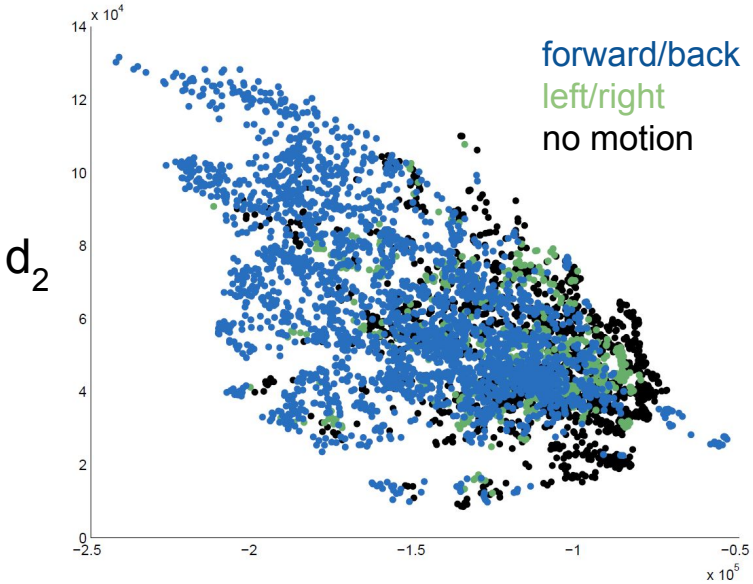
number of samples

Dimensionality of data = 25. How many dimensions capture motor-related activity?

distance covariance



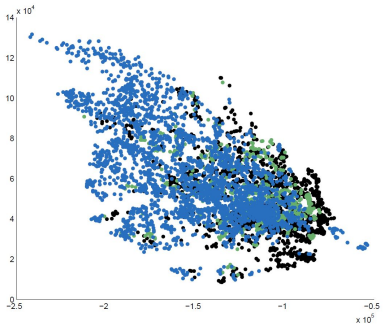
number of dimensions

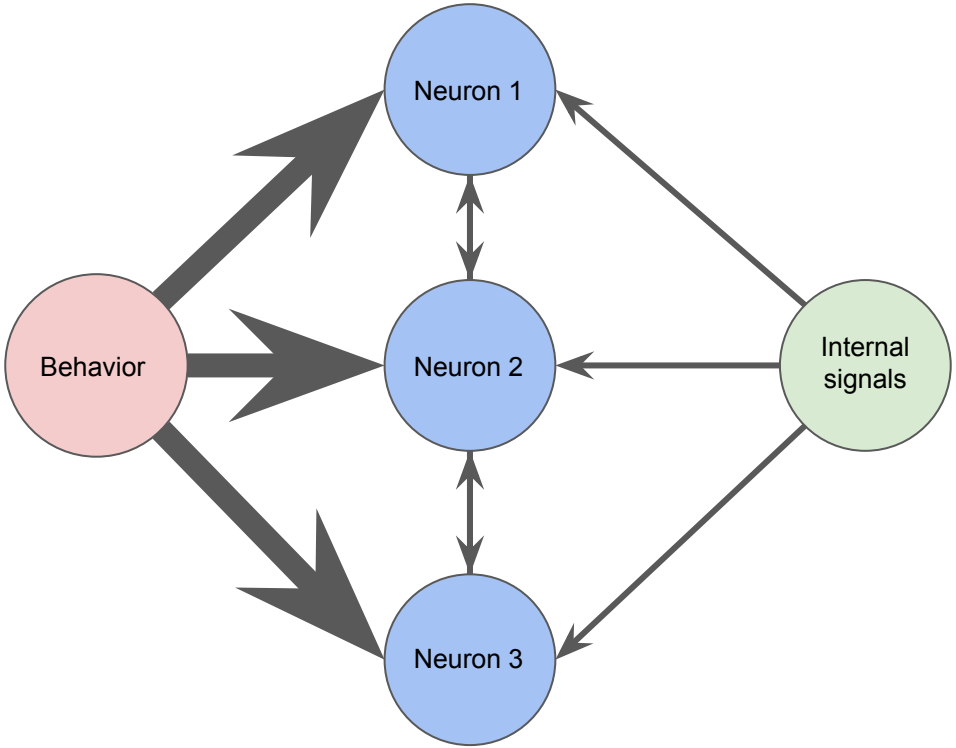


d_2

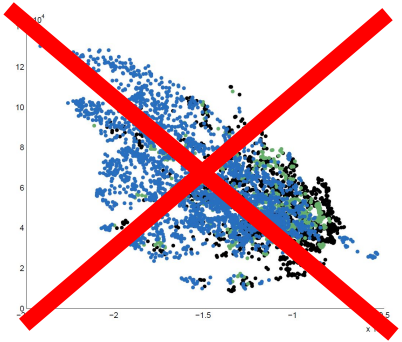
d_1

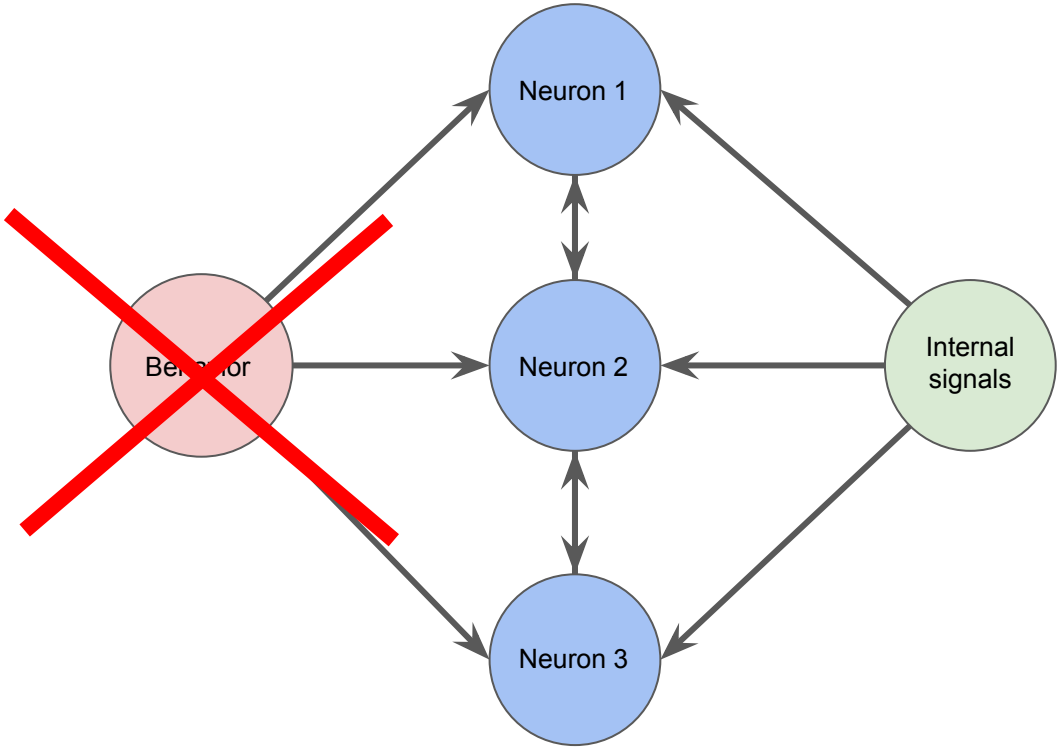
Behavior-related co-fluctuations may dominate neuronal interactions



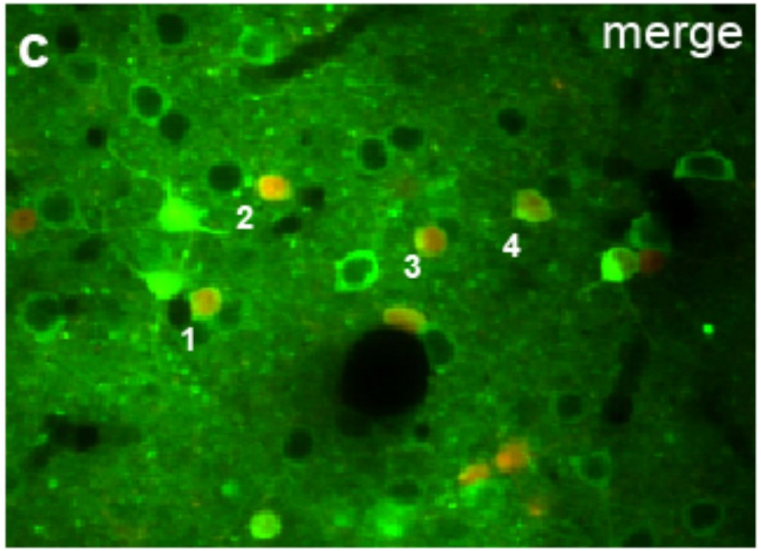


Underlying co-fluctuations, unrelated to behavior, may give information about underlying network topography





Can we use calcium signals to identify subgroups of neurons?



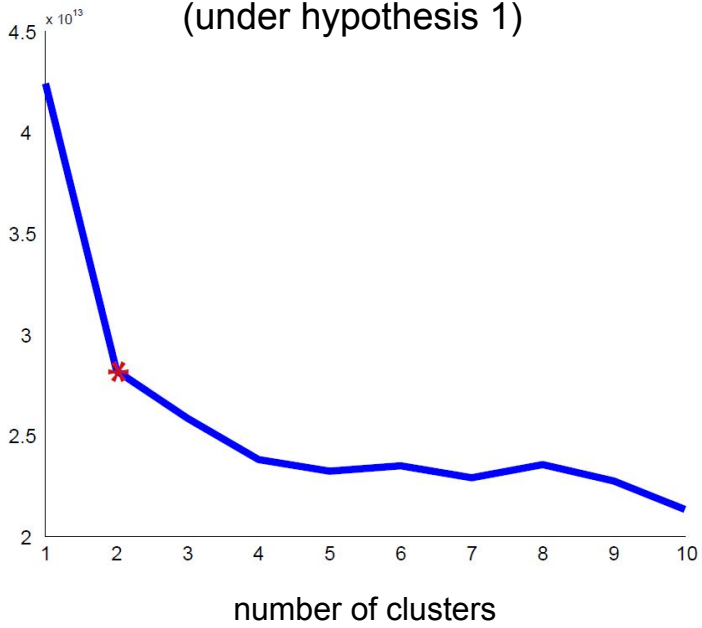
Hypothesis 1: Nearby cells will have similar behavioral responses (functional clustering).

Hypothesis 2: Nearby cells will have similar responses to “internal signals,” after removing behavioral signal.

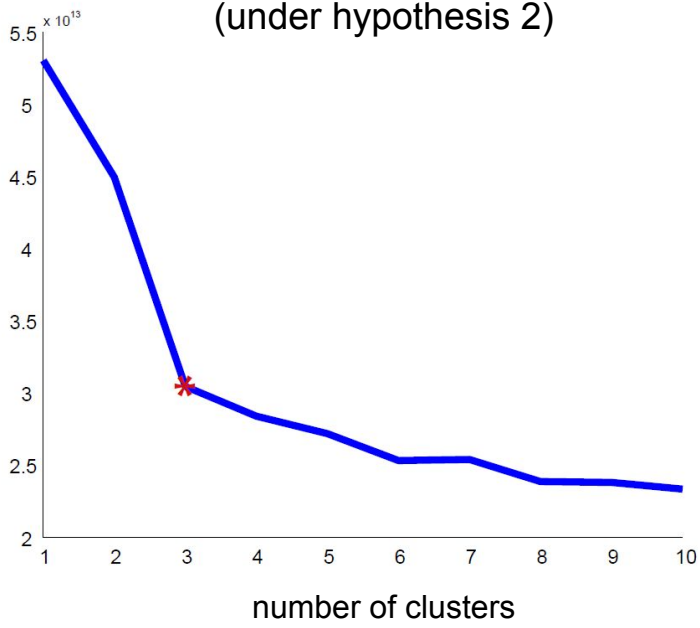
Different number of subgroups

Cross-validated mean-squared-error

Full signal
(under hypothesis 1)

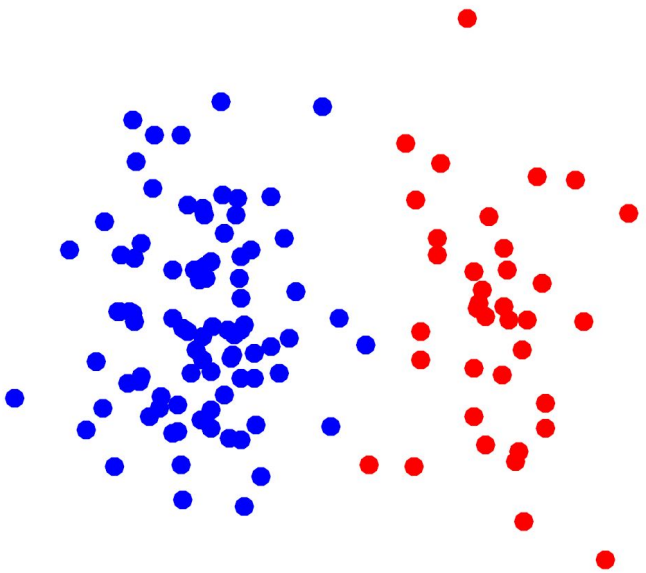


Residual/Internal signal
(under hypothesis 2)

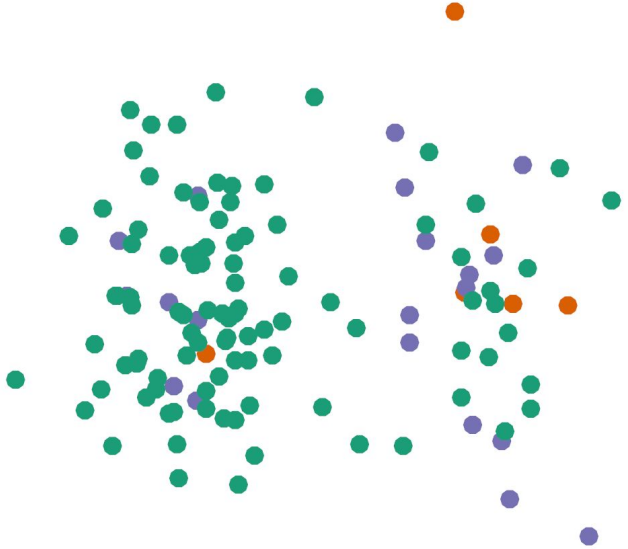


Different subgroups of neurons under hypotheses

Full signal
(under hypothesis 1)



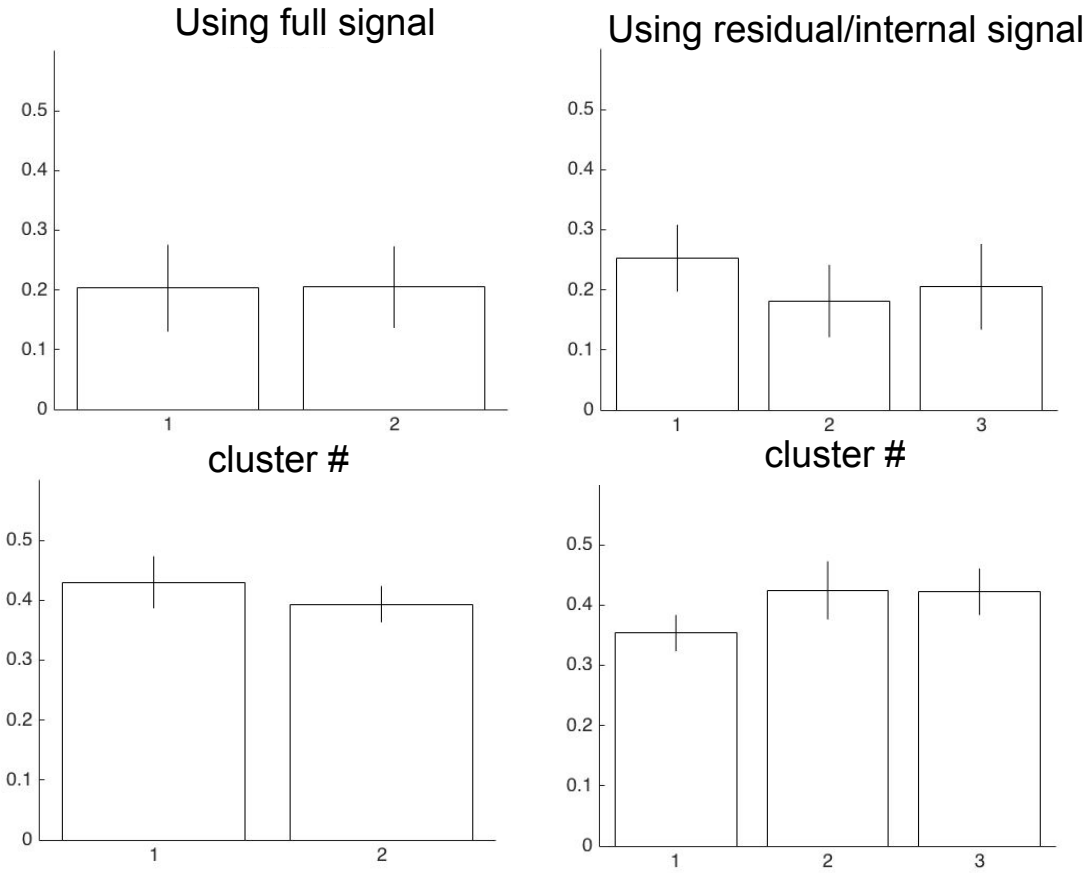
Residual/internal signal
(under hypothesis 2)



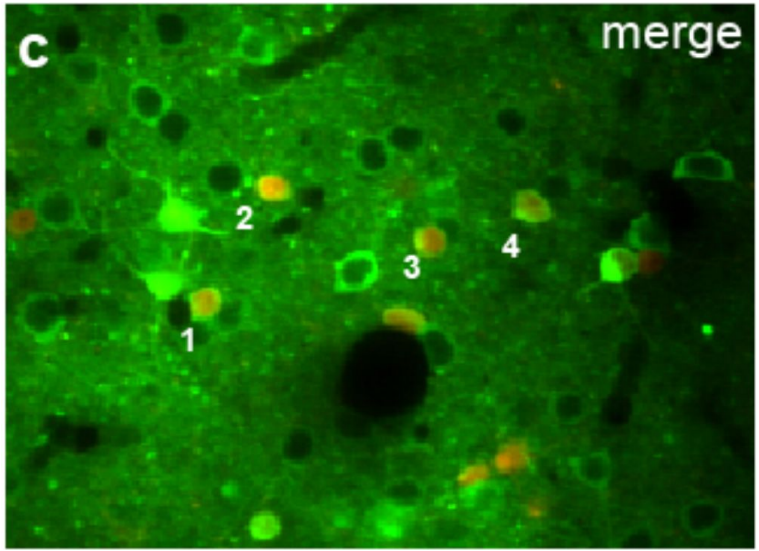
Subgroups of neurons carry similar amount of information

Forward/backward vs. left/right

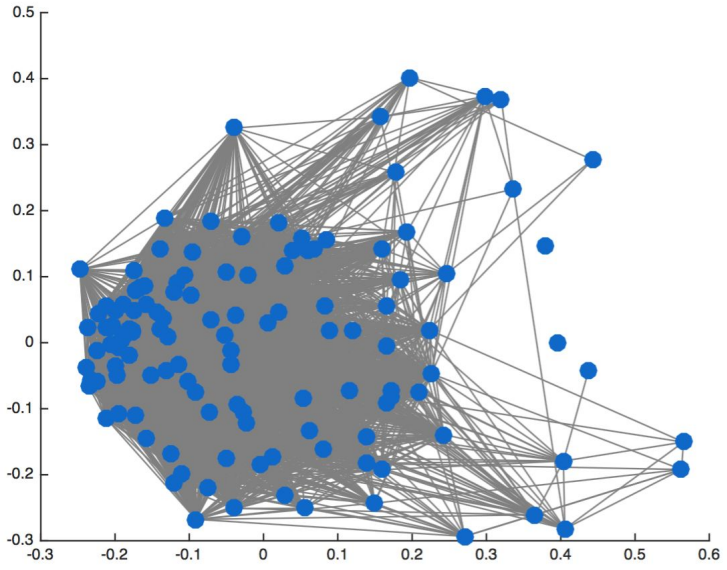
Movement vs. no movement



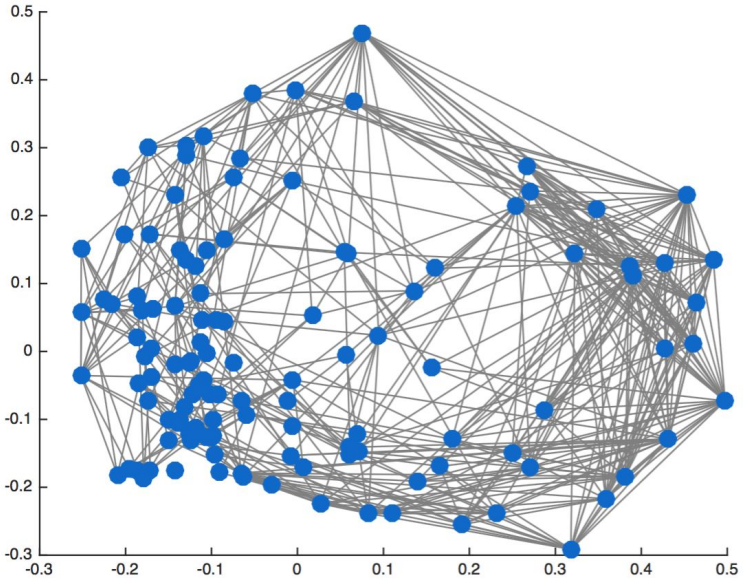
Hypotheses predict different neuron locations



Hypotheses predict different neuron locations



Hypothesis 1: Network connected based on response similarity (“functional clustering”)



Hypothesis 2: Network connected based on residual correlations (without behavioral signal)

Future directions

- Given positions of recorded cells in cortex:
  - Compare our network hypotheses to determine relationship between responses and actual connectivity.
  - Develop decoder that utilizes position information (as a prior)
- Given movement speed:
  - Compare population encoding of speed vs. direction of movement

Conclusions

- Individual neurons do not reliably decode behavior, but full population does.
- Dimensionality results indicate need to record from more neurons, but not necessarily increase recording time
- Analyzing similarities of neural activity may offer insights into local cortical connectivity.
- Results suggest two hypotheses (functional connectivity + internal input) are distinct