Motor cortical and striatal activity during goal-directed reaching

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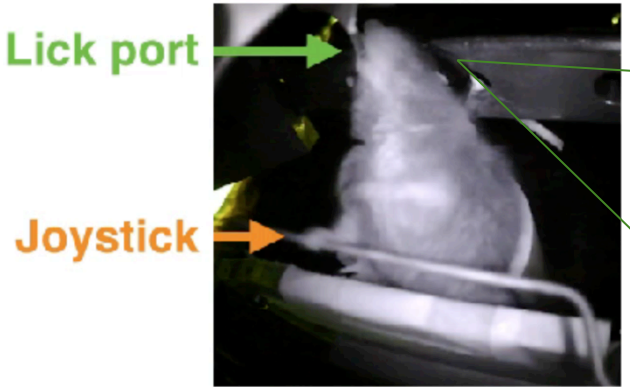
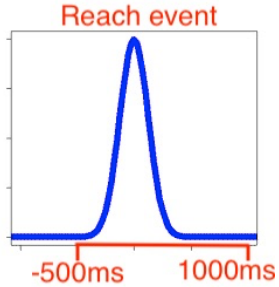
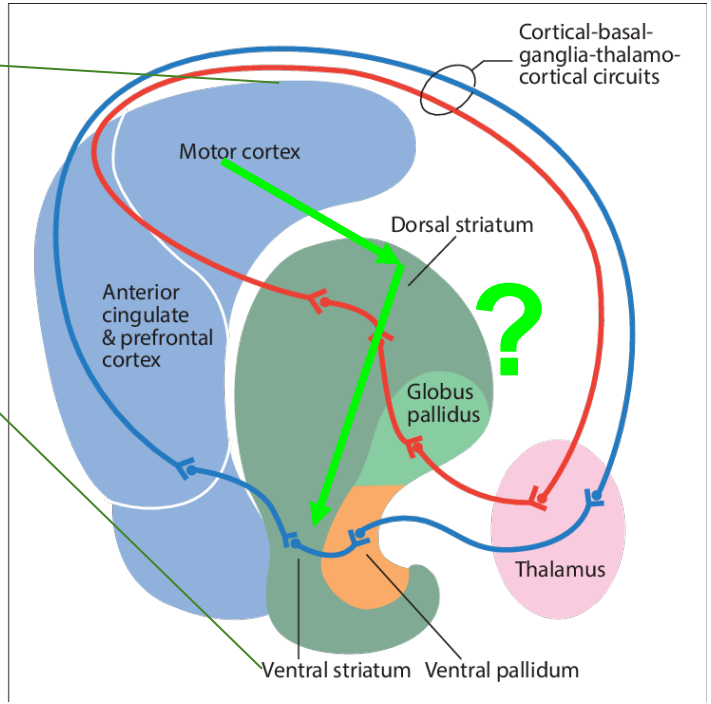
How does neural activity in motor cortex and striatum coordinate to create goal-directed reaching?

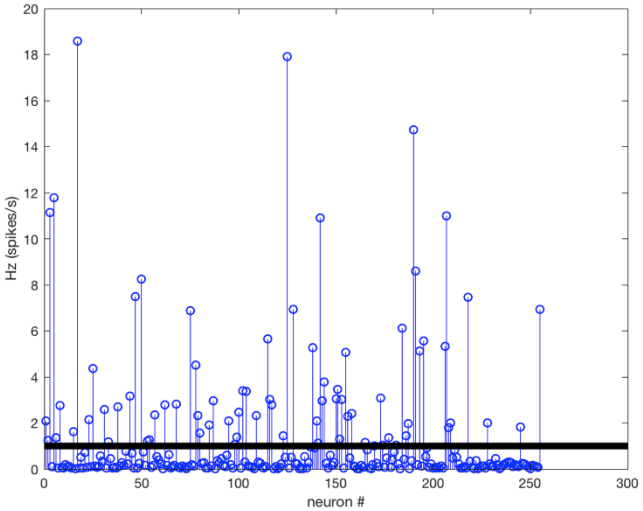




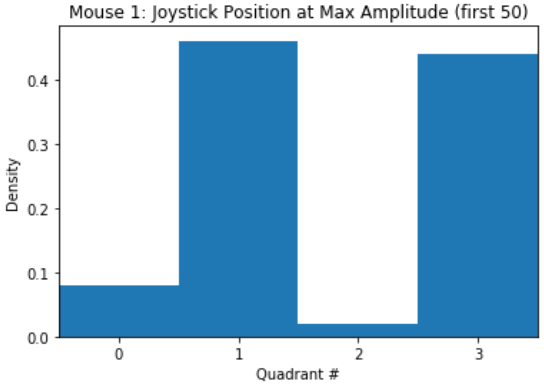


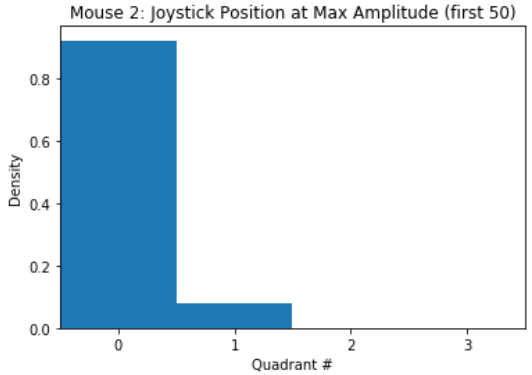
Data Overview and Processing

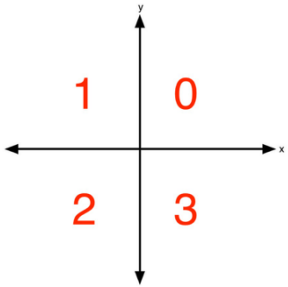
1. Mouse1: 163 reaches, Mouse2: 170 reaches
2. Considered neurons with >1 Hz Firing rate during analysis period:
    a. Mouse1: 2 motor, 49 dorsal striatum, 22 ventral striatum
    b. Mouse 2: 46 motor, 69 dorsal striatum, 66 ventral striatum

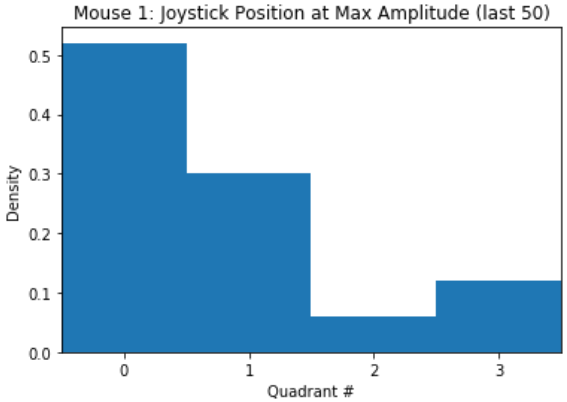


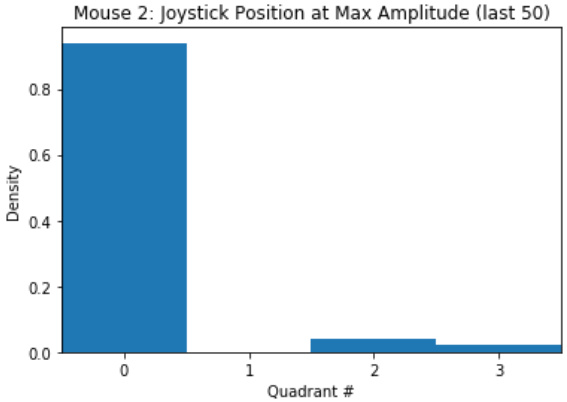
Mouse1 explores different directions while Mouse2 tends to reach into the same direction



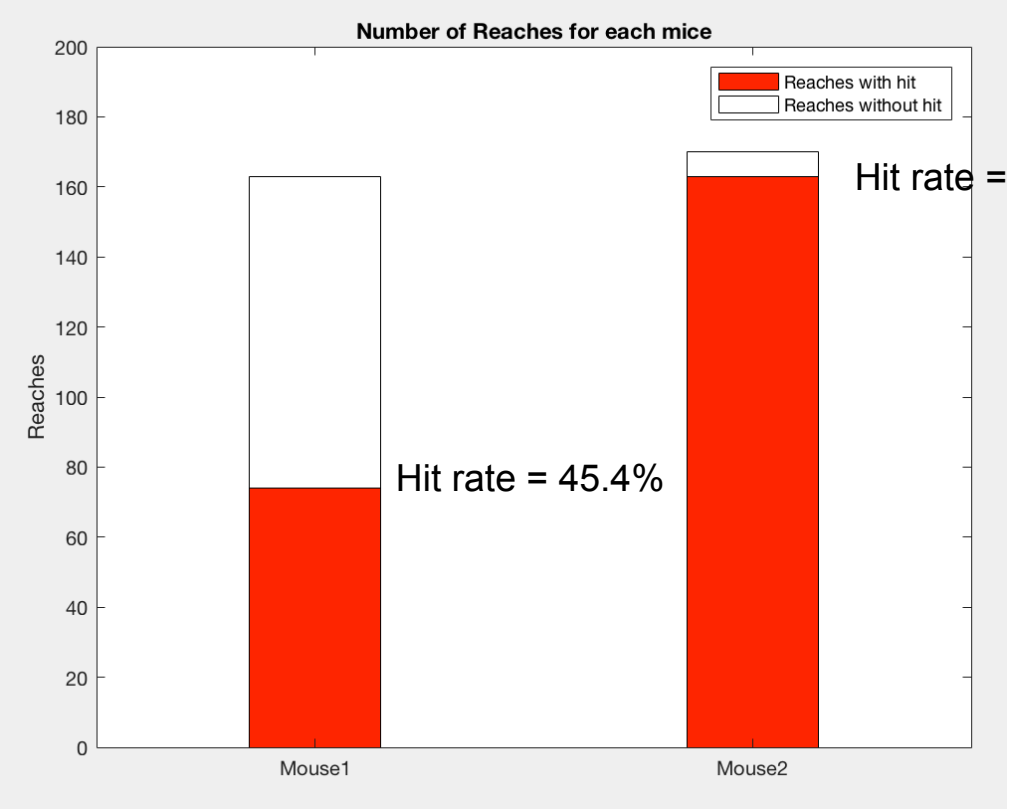




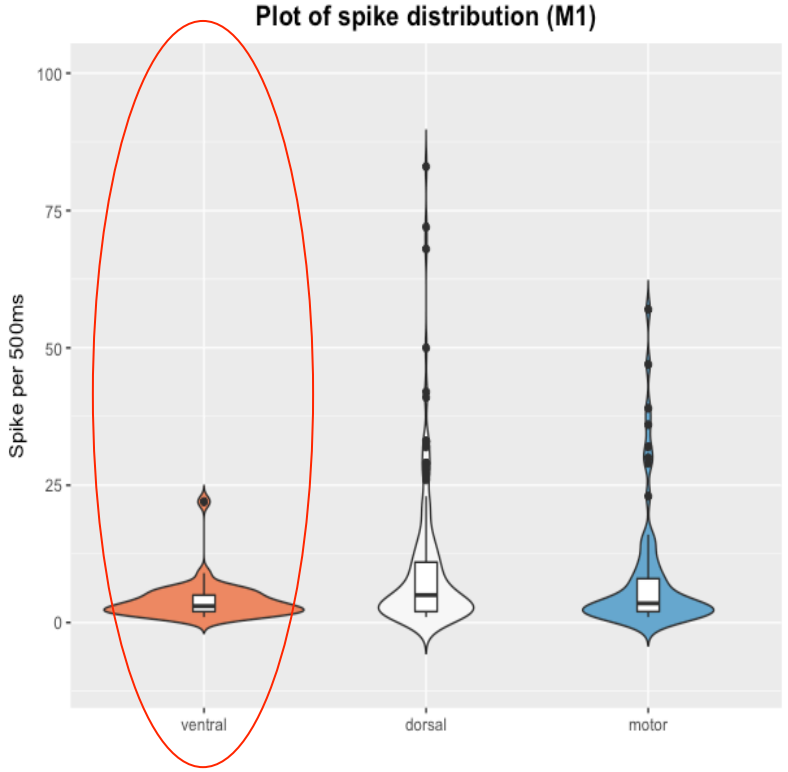


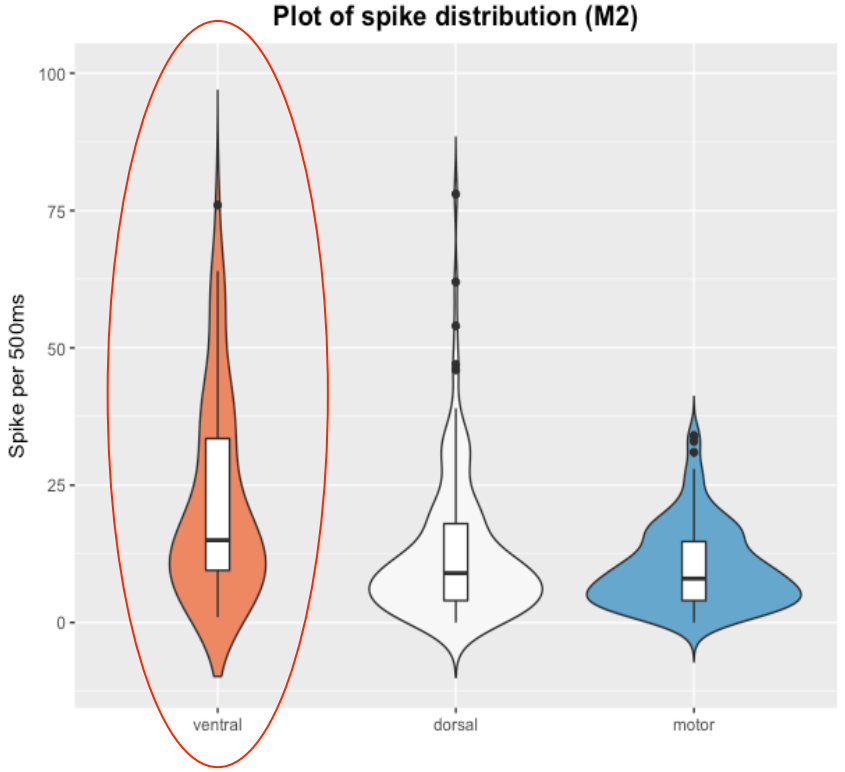


Mouse2 has a higher success rate than Mouse1

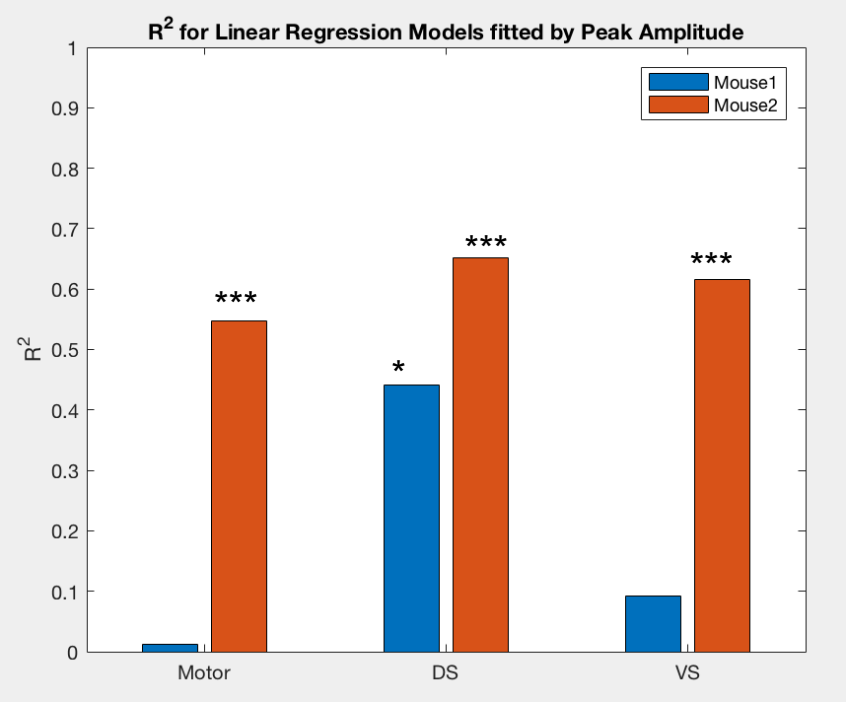


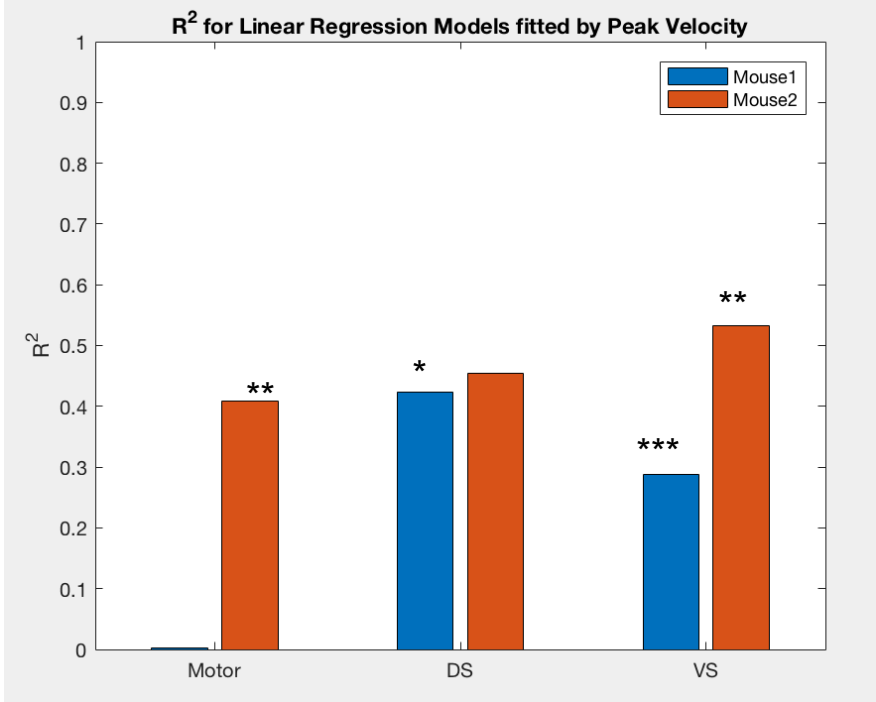
The distribution of action potential firings per neuron varies depending upon neuron type for each mouse





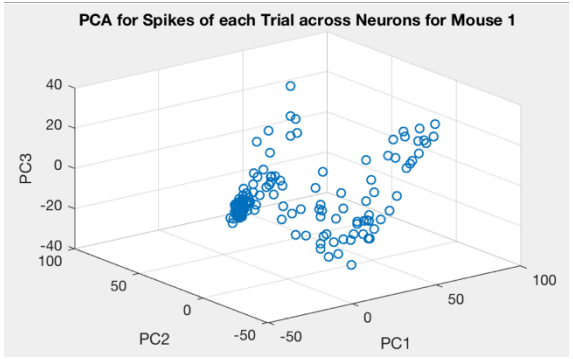
Linear Models for Predicting Peak Amplitude & Velocity

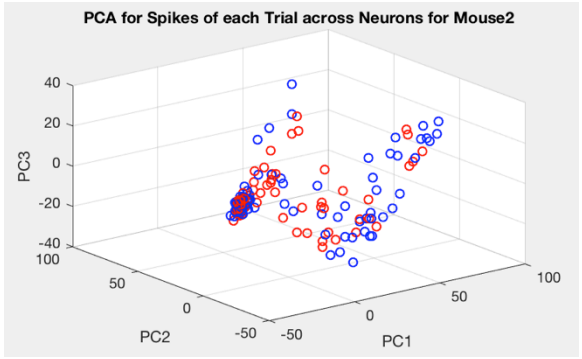


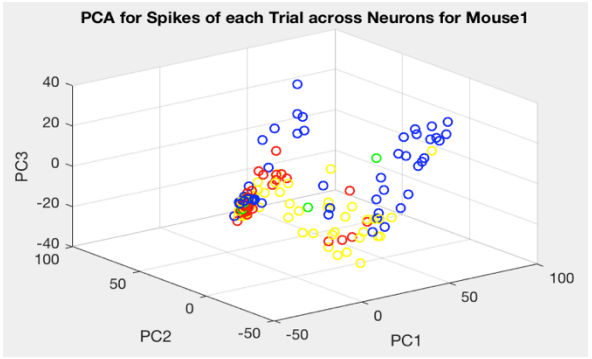


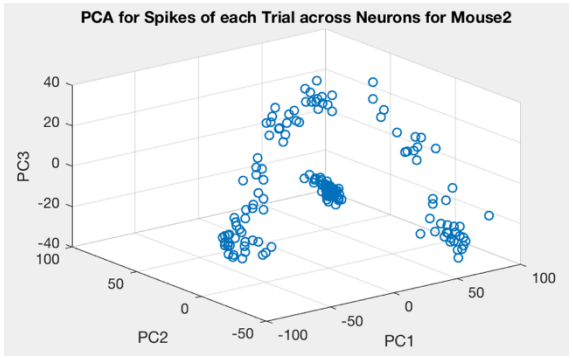
Ventral striatum better predicts behavior in mouse 2 than mouse 1

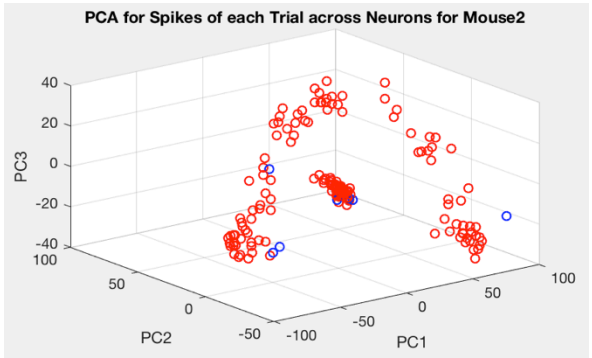
PCA for Spikes per neuron across Trials

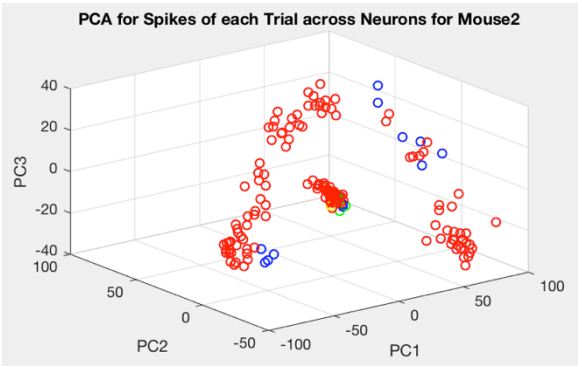










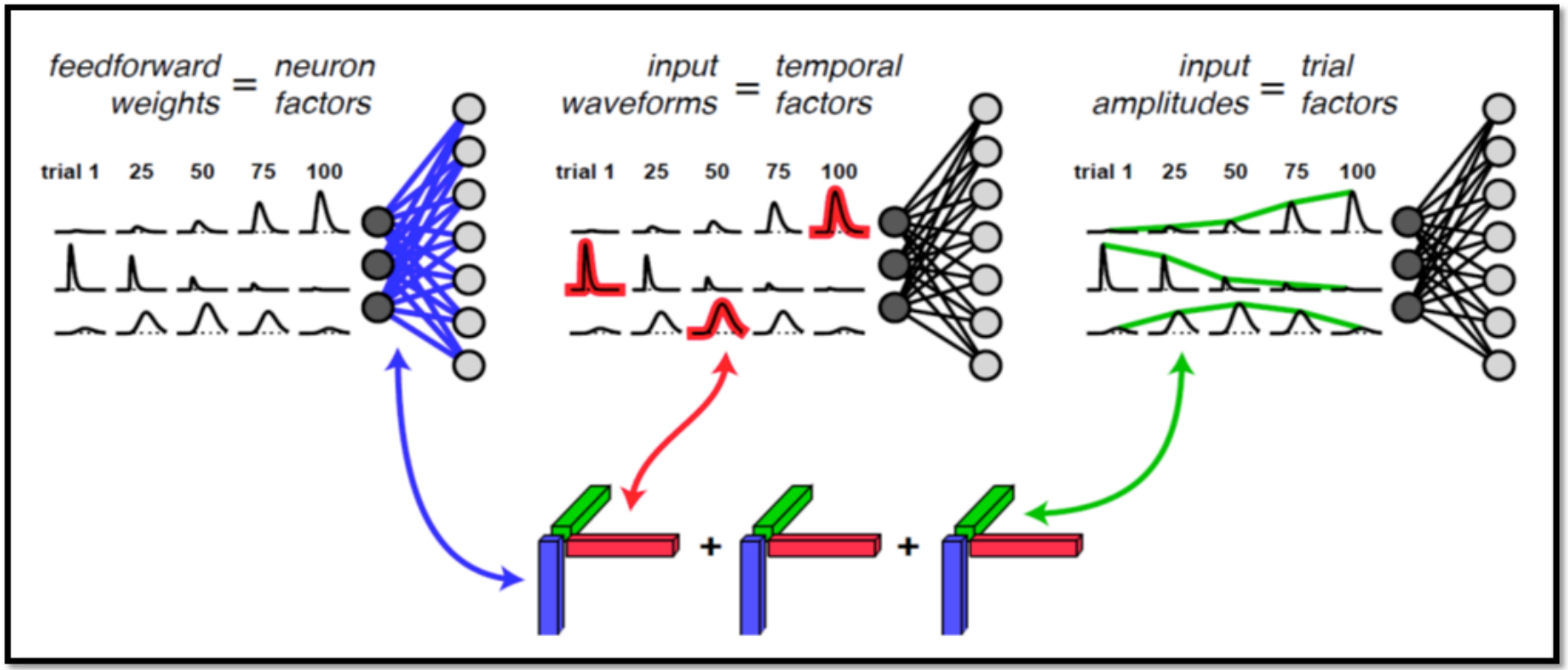


No Label

Rewards

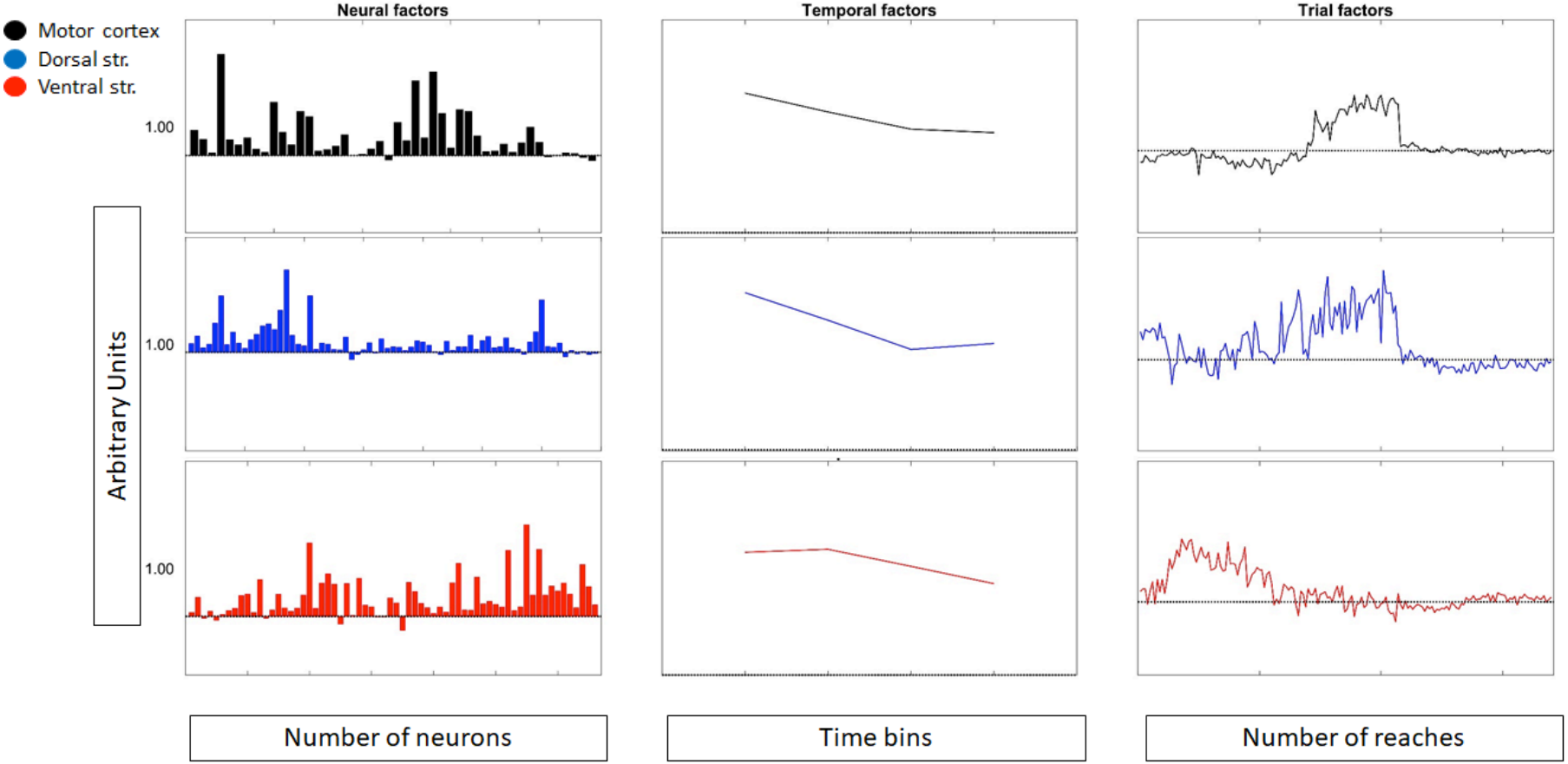
Direction

Activity decomposition (neurons x time x trials)

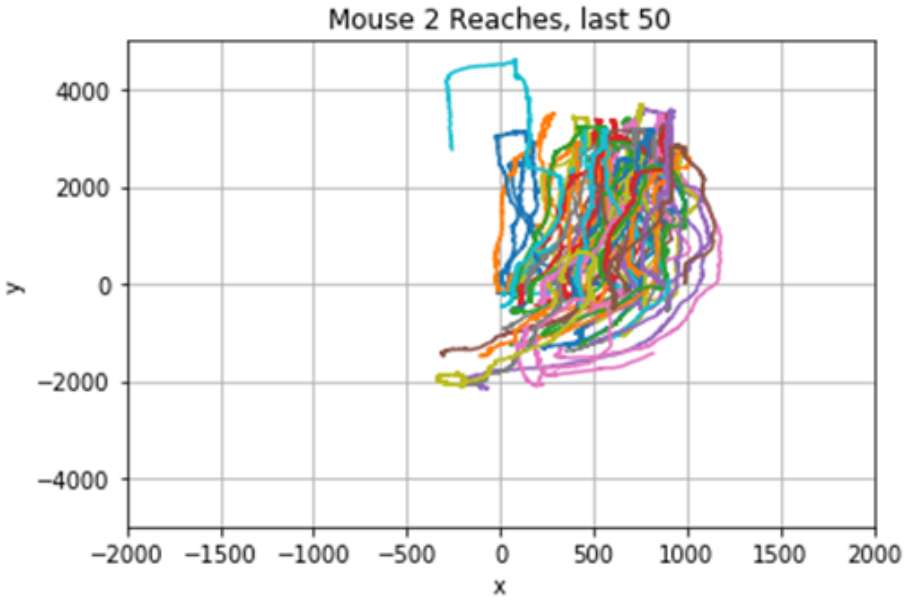


Canonical Polyadic Decomposition(Kolda and Bader 2009)

First factor(trial) predicts transition from goal directed to habitual behavior



Mouse 2 reaches become more stereotyped with trials



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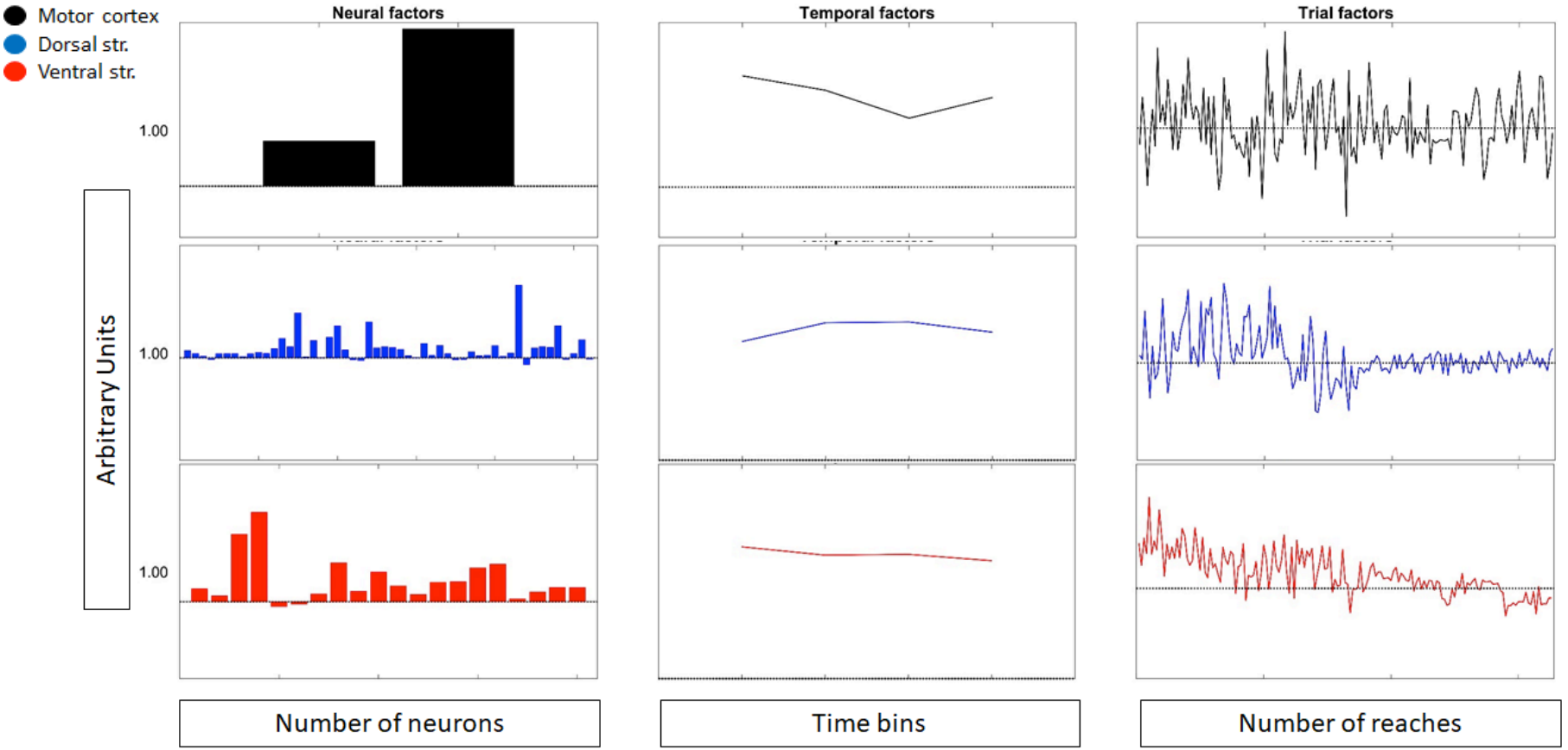
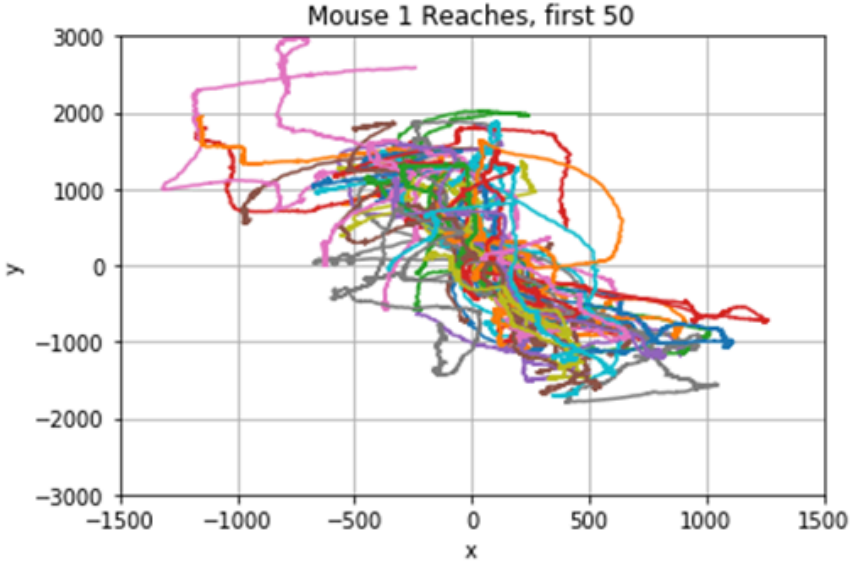
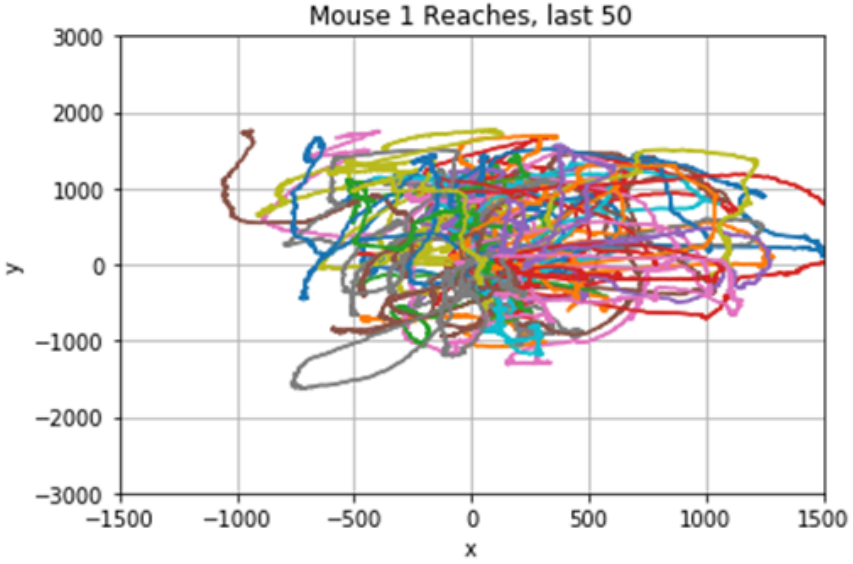
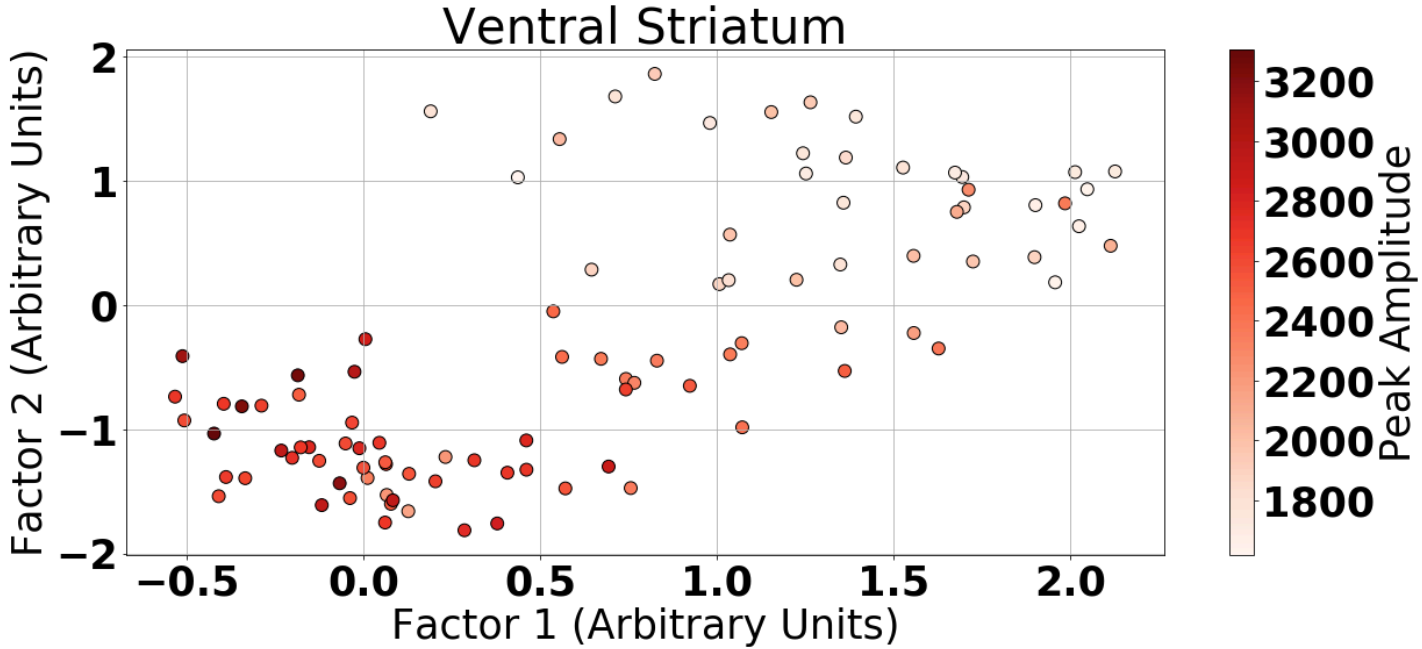


Mouse 1 reaches are variable throughout the session





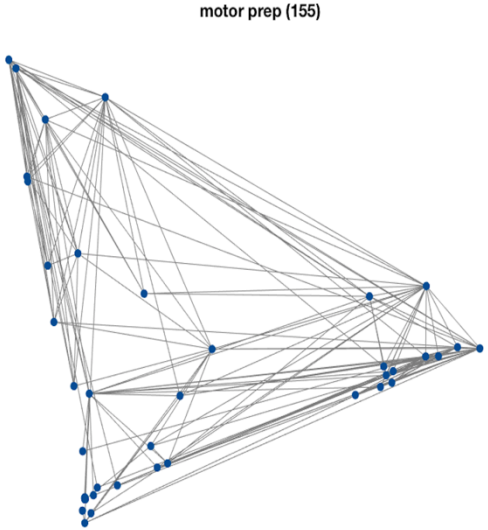
Condition-Invariant Factor Space Predicts Task Performance for Each Brain Area

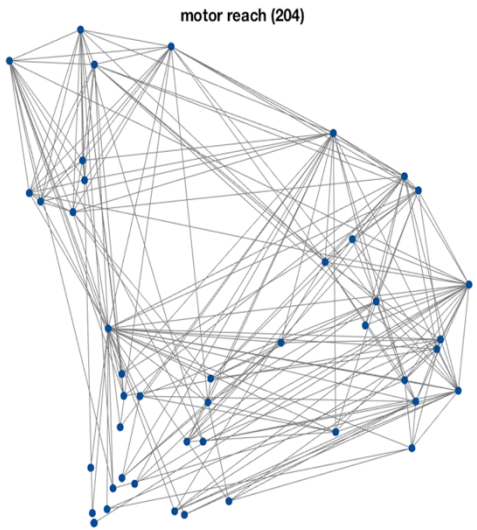


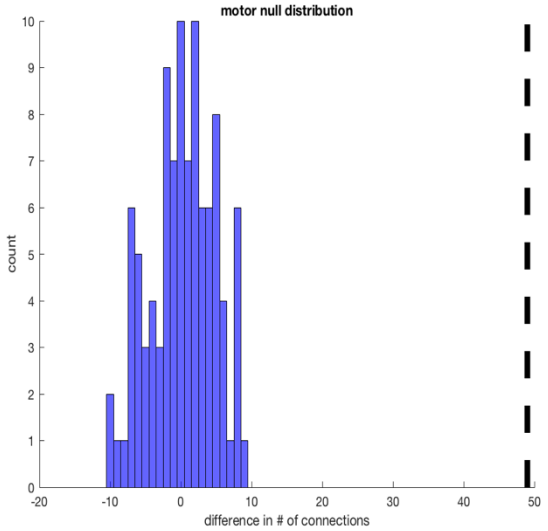
How are neurons interacting during goal-directed movements?

- How are neurons within a brain area interacting?
  - Method: graphical lasso to generate conditional independence graphs between neurons
- How are neurons between brain areas interacting?
  - Method: probabilistic CCA to assess correlation and dimensionality of interactions between areas
- Is there a difference in interactions during preparation (500 to 0 ms before reach initiation) and actual reach?

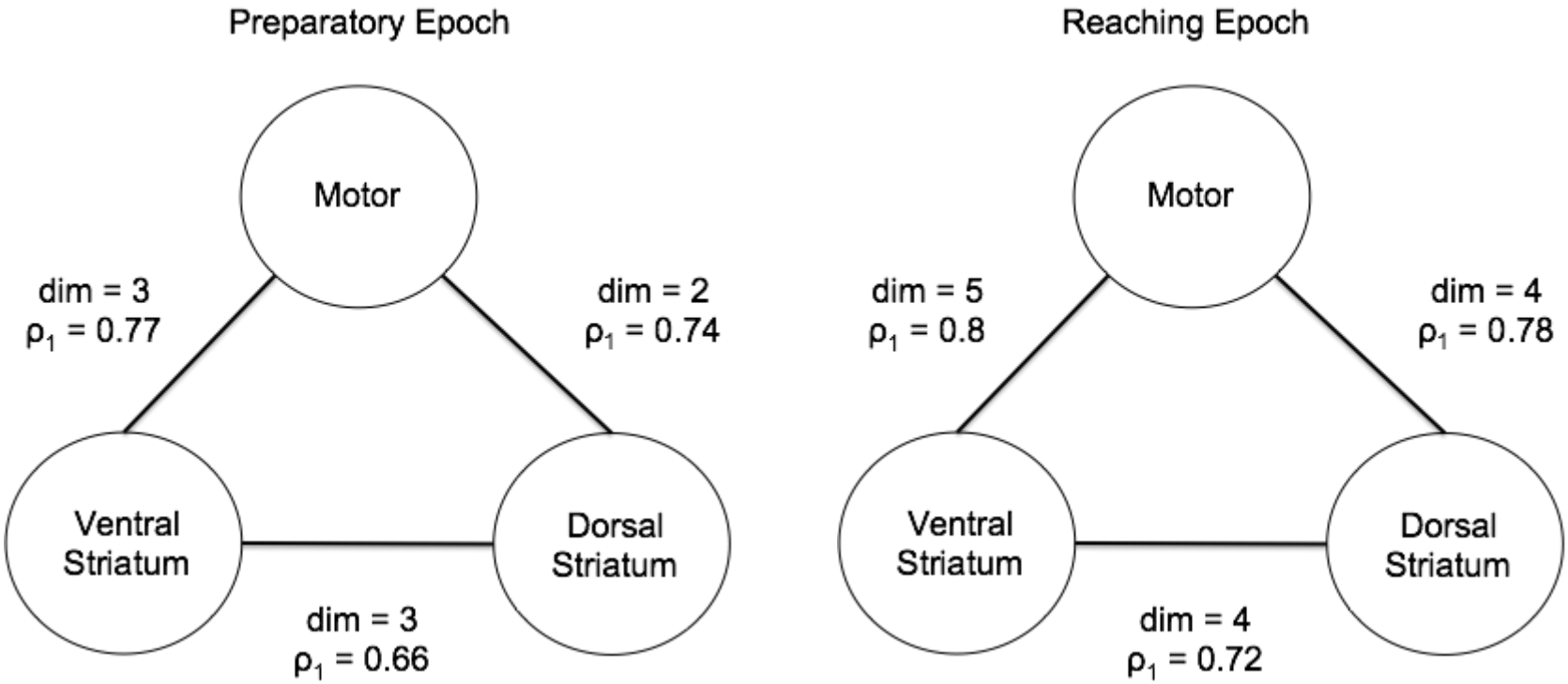
Within-area interactions (glasso) are more prominent during reaching than during preparation







Between-area interactions are higher-dimensional, and stronger during preparation and reaching epochs



Conclusions

- Mouse 2 had comparatively more activity in ventral relative to dorsal and motor neurons
- Mouse 2 had a better reward rate and performed more habitual reaches
- Low-dimensional activity across trials predicts change from goal-directed behavior for mouse 2, but not mouse 1
- Interactions both within a brain area and between brain areas increase during reaching epochs (versus preparatory epochs)

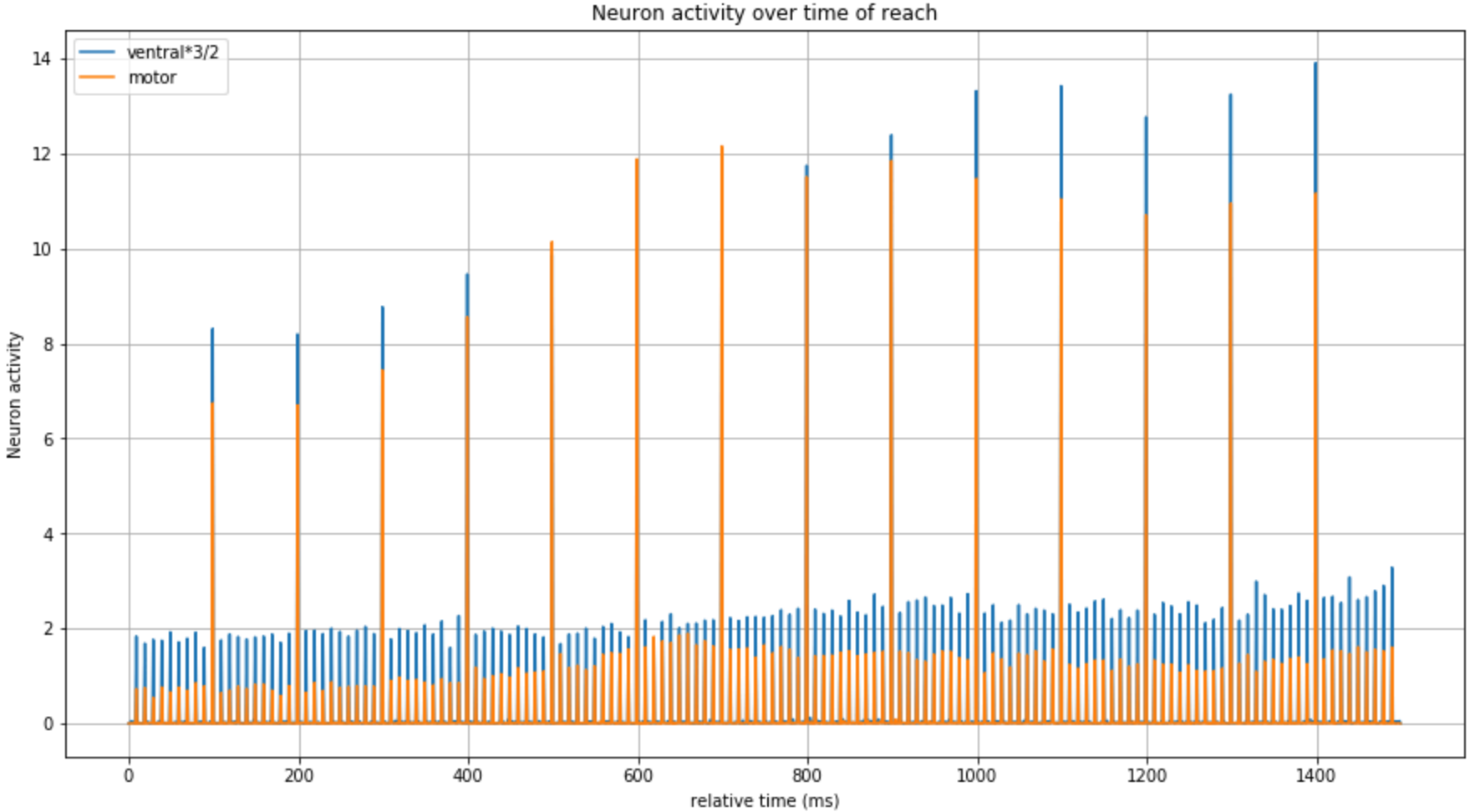
Future Directions

- Repeat experiments and analyses with multiple replicates to have higher statistical confidence.
- Potential for brain-machine interface: can predict moment-to-moment joystick position and/or joystick velocity based on neural activity
    - Simpler models: regression, Kalman filtering
    - Complex model: deep recurrent neural network

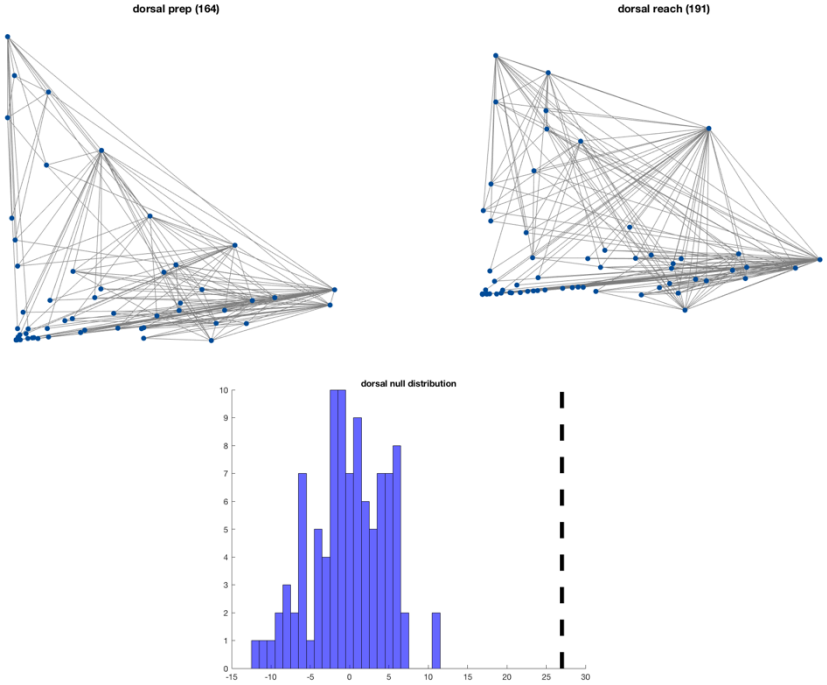
Supplemental material

Questions:

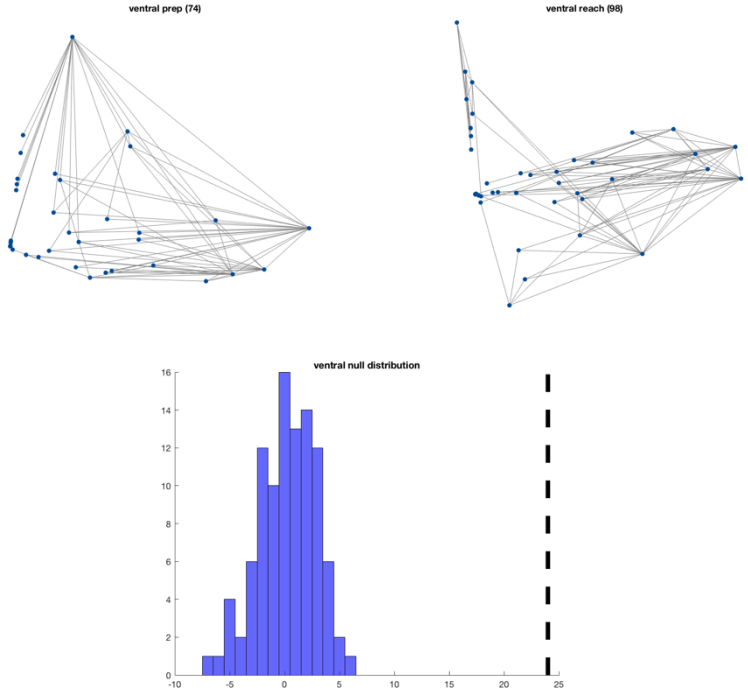
1. Data background/visualization
2. Decoding movement direction from neural activity
3. Relationship between velocity and neural activity
4. Neural activity on a low dimensional manifold
5. How do neurons interact throughout the reach
    a. Clustering of neurons into functional groups during different parts of the trial
    b. Interactions between neurons in different parts of the trial


Neuron activity over time of reach
ventral*3/2
motor
Neuron activity
relative time (ms)
0
2
4
6
8
10
12
14
0
200
400
600
800
1000
1200
1400

Within area interactions are more prominent during reaching than during preparation (dorsal striatum)



Within area interactions are more prominent during reaching than during preparation (ventral striatum)



Condition-Invariant Factor Space Predicts Task Performance for Each Brain Area (Supplemental Plots)