Cortical Encoding and Decoding of Whisk-To-Touch Behavior

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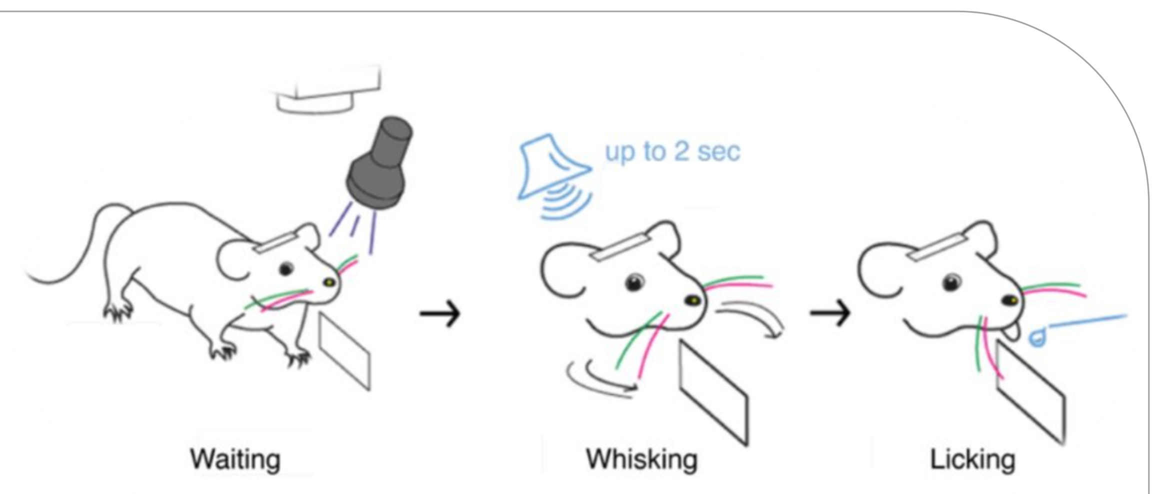
Summary

Activity in multiple brain circuits is necessary for planning, initiating and executing movements. In this study, we developed a pipeline for analyzing whether motor cortical or POm thalamic activity was related to the execution of whisking or licking behaviors. Mice were trained to perform a go-cue triggered whisking to touch behaviour using a single whisker, the C2 whisker to touch a sensor. Our analysis characterized 1) temporal differences in event-locked decoding power between regions and at different depths 2) action encoding kernels for individual units and 3) the non-linearity of the neural manifold for different regions. We found that decoding power in both Pom and MCx was often very high for touch, whisking, and licking movement moments. In MCx, decoding power was highest in deep layers of cortex.

For encoding, only two units, one in POm and one in MCX, exhibited statistically significant reduction in variance when applying movement kernels. Finally, the analysis of linearity, shows a greater advantage gained from nonlinear dimensionality reduction in POm as opposed to MCX. This analysis pipeline hints at the role of MCx and Pom in movement execution and behavior

Experimental Setup

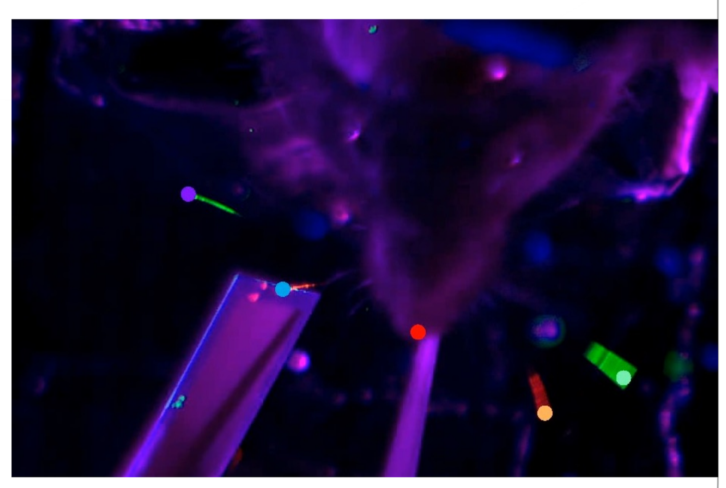
- Trained head fixed mouse to respond to cue by whisking to touch
- Whisking to touch in two seconds -> reward
- Cameras record whiskers, jaw, and tongue



Recording Sites

Record from Motor Cortex (MCx) and posterior medial nucleus of the thalamus (POm) with silicon probes

- MCX because it could encode motor responses
  - Entered at 18 angle, from surface to 1mm deep
- POm because it projects to M1 and may be a waystation for M1 output (Mo & Sherman 2018)



Data Pre-processing

1. E-phys data clustered with Kilosort and manually curated with Phy
2. Extracted movement initiation times, whisker angles, lick onset and jaw position using DLC.

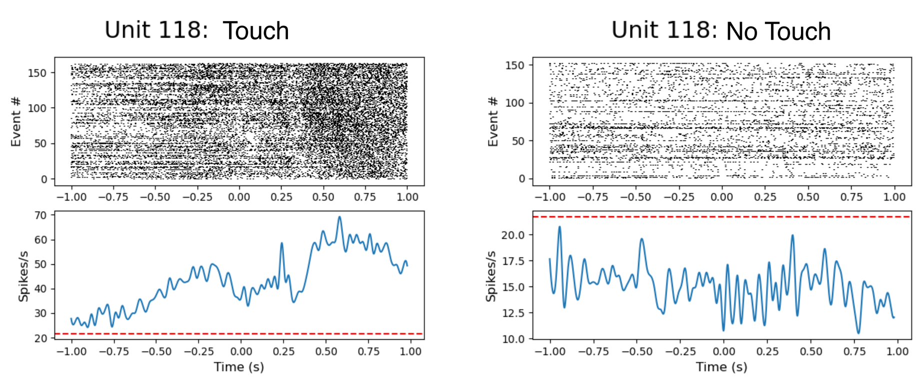
Decoding Behavior with MCx and POm Thalamus Spikes

Goals

- Identify units with significant decoding power
- Characterize whether neurons decoding power is relevant to whisking, licking, and whisker touch.

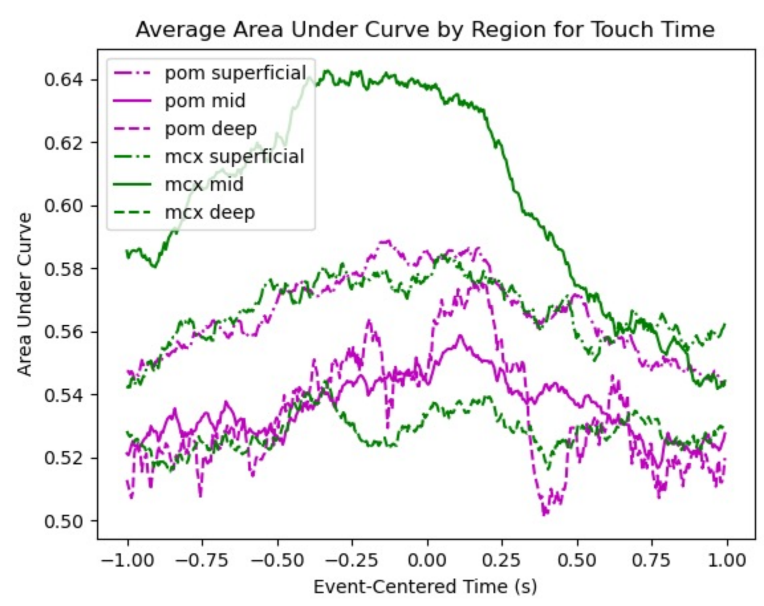
Methods

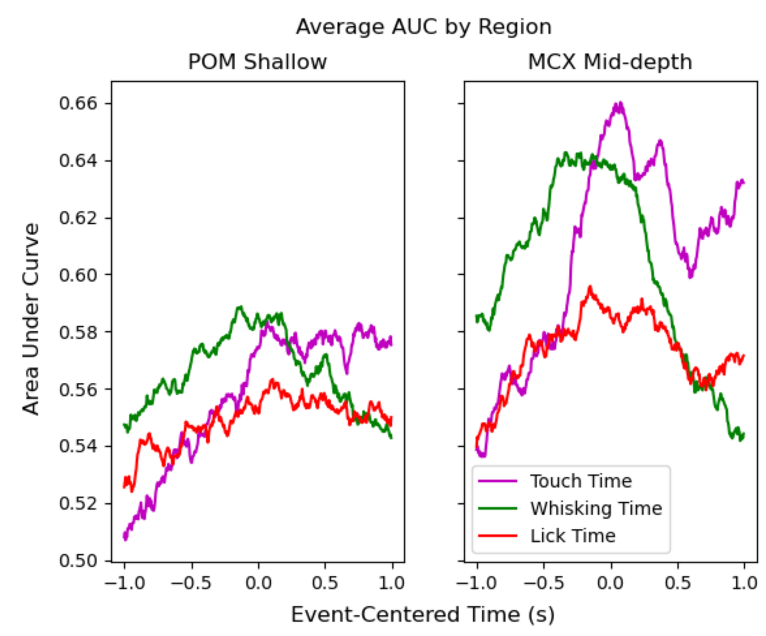
- A rolling 150 ms window locked to each event was used to predict actions (Currie et al 2022).

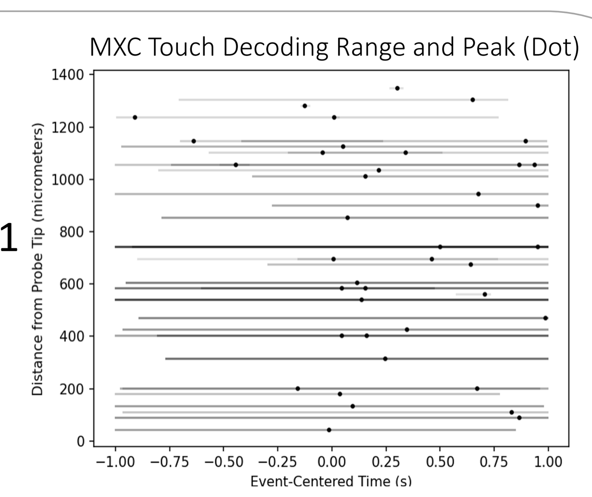


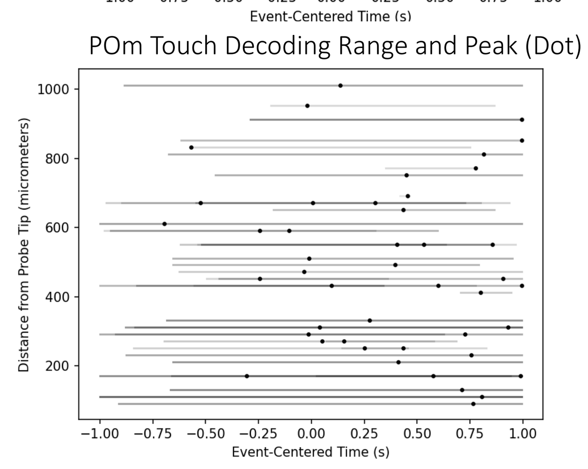
Results

1. Peak decoding in motor cortex was in L5.
2. Units with high decoding power were found in motor cortex.
3. Peak decoding time was earlier for whisking than for whisker touch in both POM and M1









Neural Encoding of Behavior

Goal

- Determine whether variance in firing rate can be explained by behavior

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Out[108]:
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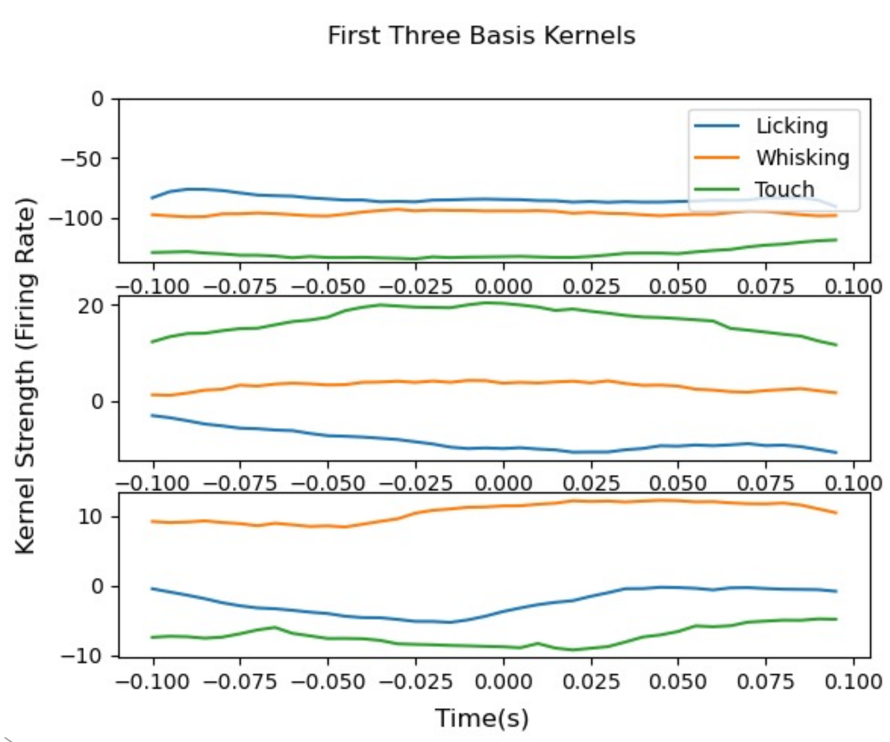
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

Methods

1. Bin / smooth spike times
2. Create a matrix of event times aligned to spiking
3. Perform reduced rank regression to get basis kernels (Steinmetz et al 2019).
4. Use regression to find linear combination of basis kernels for individual units

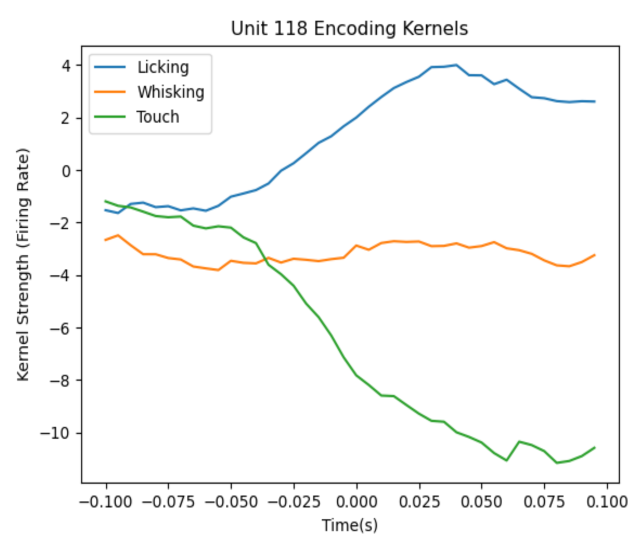
Results

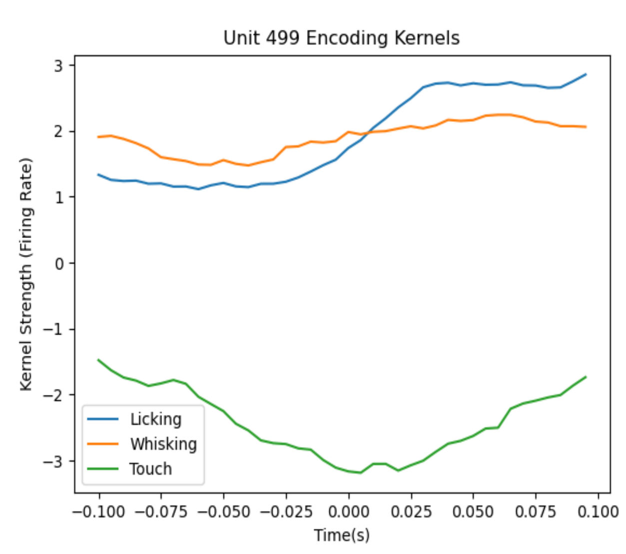
- Generated basis kernels for specific behaviors



Few Units Had Significant Kernels

- In a single session, spiking of very few MCx and POM units explained 2% of the variance
- Example units in MCX (left) and POm (right)





Linearity of Neural Manifold

Goals

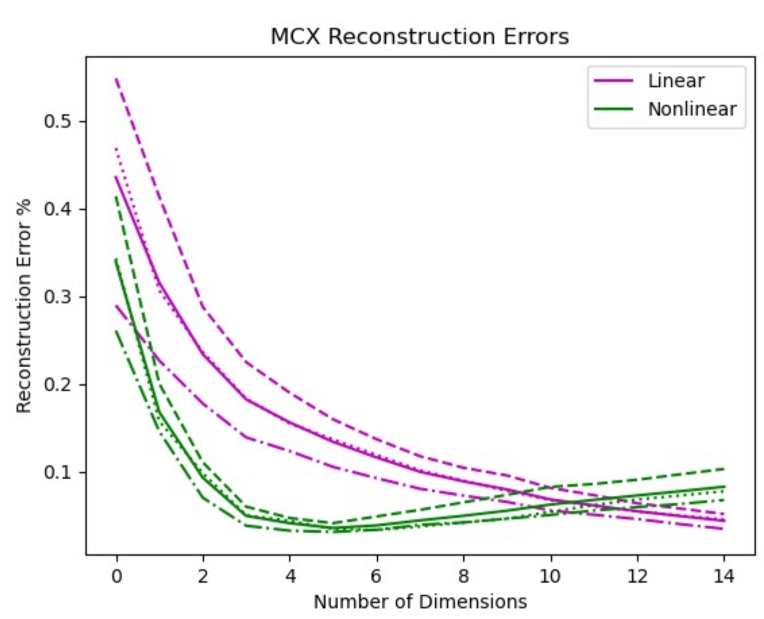
- Examine whether neural manifolds from underlying behavior were linear for both MCx and POm.
- Examine whether individual behaviors had distinct manifolds.

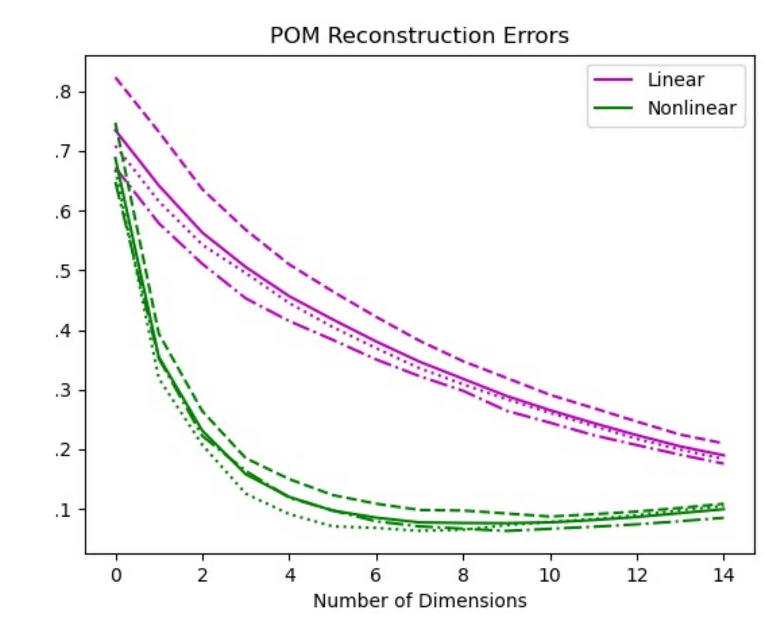
Methods

- Apply dimensionality reduction to neural activity (Fortunato et al 2023).
- Measure reconstruction errors across dimensions.

Results

1. Gap between linear (green) and nonlinear reconstruction errors greater in POm
2. Very little difference between nonlinearity of different behaviors (dashed vs dot lines)





References

1) Currie, Stephen P., et al. "Movement-specific signaling is differentially distributed across motor cortex layer 5 projection neuron classes." Cell Reports, vol. 39, no. 6, 2022, p. 110801, https://doi.org/10.1016/j.celrep.2022.110801.
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