Integration of force and movement representation in proprioceptive area 2 of primary somatosensory cortex

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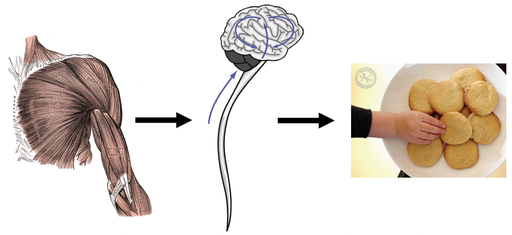
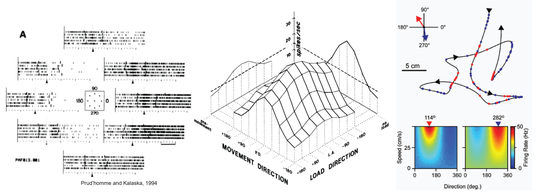
Proprioception begins with muscles, but we relate it to hand motion



Studies of area 2 assume this same relationship to hand motion.

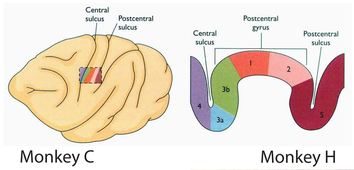


To understand what area 2 does, we need to understand how much of its neural representation comes from the periphery.

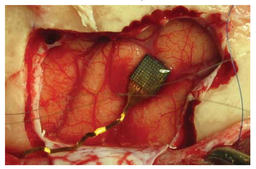
We found that using just muscle kinematics can predict many features of area 2 neural activity.

We recorded neural activity from area 2 and behavioral data from motion tracking

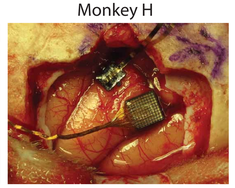
Methods

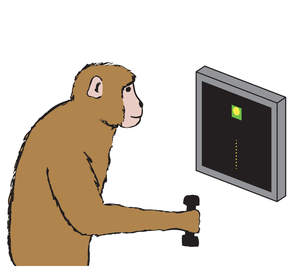


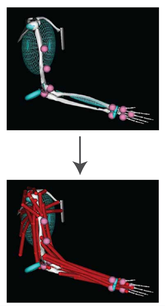
Monkey C



Monkey H



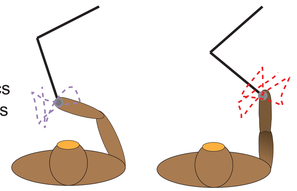


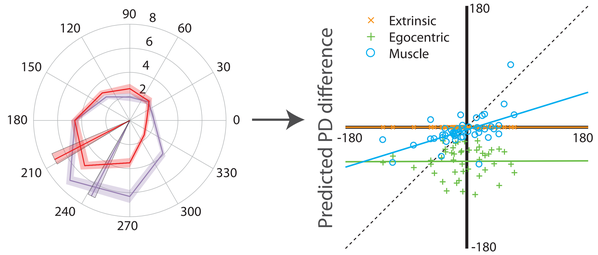


Neural tuning changes across kinematic conditions

Results

We changed the correlation between handle and joint kinematics by picking two separate workspaces with different average posture.

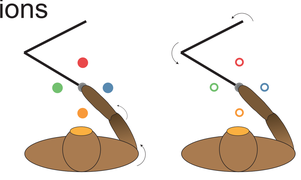


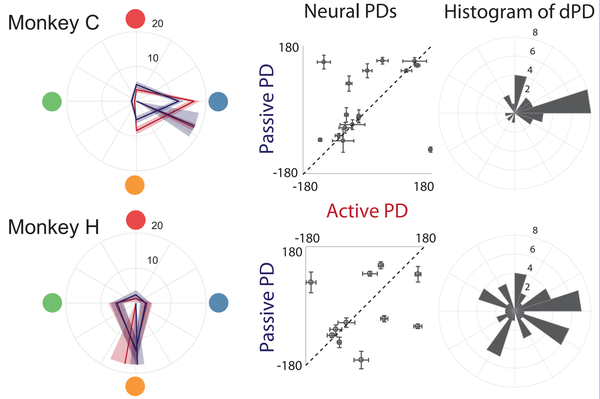


Tuning is moderately stable across dynamic conditions

Results

Two conditions:
active movement (filled)
passive perturbation (open)

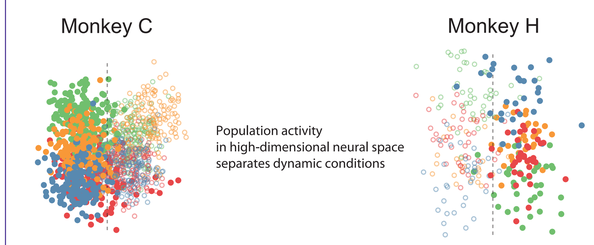




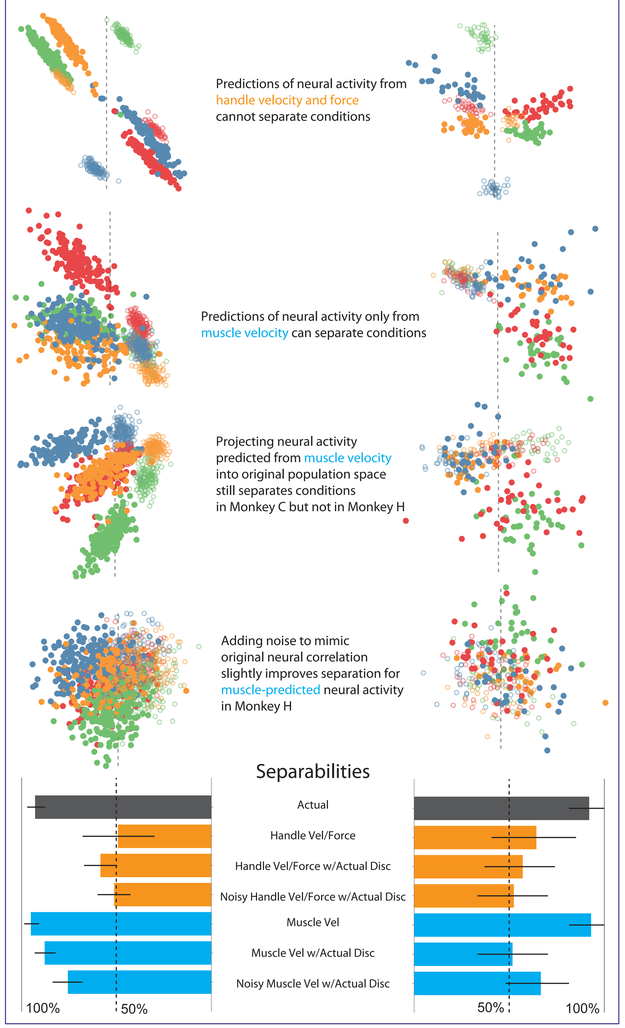
Surprisingly, cuneate nucleus does not have this stable tuning.
For more, visit Chris Versteeg's poster on Monday morning (316.07)

Muscle kinematics replicate separability in population activity

Results



We tried to replicate this separability with models of neurons

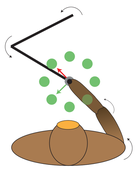


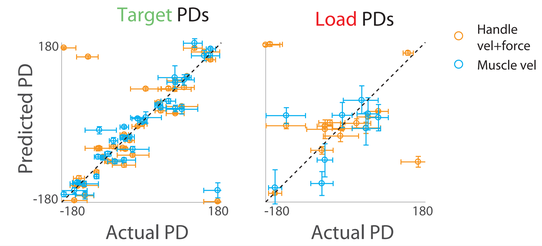
Muscle kinematics can cause apparent load tuning

Results

To dissociate movement tuning from force tuning, we had the monkey reach across the workspace while the robot imposed a constant load force

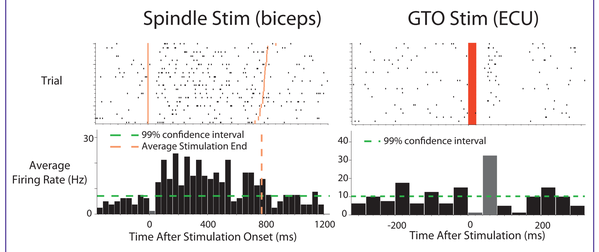
Half of the neurons tuned to load direction still looked tuned to load direction when predicted only from muscle velocity, with no information about force





Some area 2 neurons respond to muscle afferent stimulation

Results



However, very few cells responded to stimulation (9 for spindle stim and 12 for GTO stim).
Even fewer responded to stimulation of more than one muscle (1 for spindle stim and 2 for GTO stim).

Conclusions

- Early studies of area 2 assume a hand-based representation of proprioception, linearly combining information about movement and force at the hand.
- Using multiple workspaces, we've found that area 2 appears to respond to kinematics in a more muscle-like coordinate frame.
- Active and passive dynamic conditions are linearly separable in population activity. This separability can be explained by a muscle kinematics-based representation, but not a hand-based representation.
- We've found that apparent load tuning in area 2 neurons can simply arise from muscle kinematics.
- Despite this apparently large influence of the periphery on area 2, relatively few neurons responded to specific muscle afferent stimulation.

Acknowledgements

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