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Talk Title:
Motor cortex isolates skill-specific dynamics to implement context-specific control

Abstract:
Performing two skills, such as swinging a tennis racquet or ax, requires both differences in typical motor output and different feedback-driven adjustments. The motor cortex (M1) is involved in specifying motor output, but its role in performing computations underlying skill-specific feedback control is not well understood. Neural activity in M1 reflects the underlying dynamics necessary to create motor outputs (muscle activity) and reflects the output during context-dependent feedback-driven corrections. The major features of M1 activity don't reflect outputs *per se*, but instead may be structured to not only create the typical output, but to enable rapid sensory-guided adjustments. This extension makes a strong prediction: M1 activity should be very different when two skills require different feedback-driven responses, even if outputs are matched.
We assume a central component of skilled performance is learning a feedback control policy; i.e., a mapping from errors conveyed by the sensory inputs to corrective motor outputs. It is typically challenging to discern which aspects of neural activity reflect motor outputs and which reflect skill-specific feedback control. Here, we employed a 1D force production task with two contexts that required the same typical motor output, but opposite responses to sensory feedback, comprising different skills. We trained a monkey to match the vertical position of a cursor to a variety of scrolling dot paths. Pushing forward on a handle determined cursor height. In the positive-gain context force moved the cursor upwards, while in the negative-gain context, force moved the cursor downwards. Mirrored paths were presented across contexts so that forces were nearly identical.
Using 45 mm primate Neuropixels, we recorded thousands of neurons in the motor cortex and basal ganglia (GPi). Most neurons in M1 had complex patterns of activity that were strongly context (gain) dependent and did not directly reflect force or muscle activity, and GPi activity was strongly context-specific. Unexpectedly, identical motor outputs under the

two gain conditions were driven by very different internal patterns of neural activity in M1. We then introduced cursor jump perturbations on some trials, and using demixed PCA (dPCA), we found a high-variance dimension attributable to context, and lower-variance dimensions for visual perturbation and force output.
This empirical data suggest that context-dependent neural trajectories may allow each context to leverage different dynamics to flexibly transform the same sensory feedback into opposing outputs. Collectively, these results suggest that skills are produced by skill-specific (not output-specific) neural trajectories that allow for flexible input-output relationships produced by dynamics close to that trajectory. A prediction of this hypothesis is that motor cortex activity may leverage the vast volume of a high-dimensional neural space to store the repertoire of distinct motor skills.

Biographical information:
Eric received a bachelor of arts and a masters of engineering from Dartmouth College, and worked for two years in electrical engineering, prior to attending graduate school in neuroscience at Stanford University working with Dr. Krishna Shenoy to elucidate mechanisms underlying the neural control of movement, and to develop large-scale brain computer interface technologies. He is currently a postdoctoral scholar at Columbia University's Zuckerman Institute, working with Dr. Michael Shadlen, Dr. Mark Churchland, and Dr. Daniel Wolpert on skilled movement control.