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Ctrl-TNDM: Decoding feedback-driven movement corrections from motor cortex neurons

Nina Kudryashaova¹,², Matthew Perich², Lee Miller³,⁴, Matthias Hennig¹
1. University of Edinburgh, UK; 2. Université de Montréal, Canada; 3. Northwestern Univ., USA; 4. Shirley Ryan AbilityLab, USA; *email: nkudryas@ed.ac.uk

Motivation:
- Manifold hypothesis [1]: a low number of latent dynamical factors explain a large fraction of neural variability.
- Do these factors contain information about movement corrections during the trial?

Approach:
- Disentangle sources of variability in behavioral data: instructed vs. uninstructed
- Find latent dynamics in neural recordings from PMd/M1 of monkeys engaged in a center-out reaching task with perturbations that explains the uninstructed behavior.

A center-out reaching task, force field perturbation

Classical $R^2$ quantifies the total behavioral variability, which is dominated by the task instruction

Hypothesis: oscillations arise from a closed-loop feedback control

Ctrl-TNDM: controlled targeted neural dynamical model is an extended LFADS [3] model with a controller that has an additional sequence-to-sequence behavior decoder (as in [4]) from inferred latent factors

Hand velocity in adaptation trials exhibits ~4–5 Hz oscillations

Oscillating factors explain a small portion of neuronal variability, mostly during movement and in AD trials

Ctrl-TNDM discovers oscillating factors, which oscillate more in AD

Ctrl-TNDM captures neural activity related to hand velocity oscillations during movement, while predictions for the movement initiation phase remain similar to LFADS

Conclusion
Movement corrections during adaptation to the force field can be decoded from PMd/M1 neuronal activity. Yet, only a small portion of neuronal variability corresponds to movement corrections. Thus, unsupervised models (LFADS) discard this uninstructed variability, modeling it as noise. A weak supervision with behavioral output (velocity) enables detection of neuronal latent dynamics that corresponds to movement corrections.

References