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

Citation for published version:
Kudryashova, N, Perich, MG, Miller, LE & Hennig, MH 2023, 'Ctrl-TNDM: Decoding feedback-driven movement corrections from motor cortex neurons', Computational and Systems Neuroscience (Cosyne) 2023, Montréal, Canada, 9/03/23 - 12/03/23.

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Other version

General rights
Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and/or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.
Ctrl-TNDM: Decoding feedback-driven movement corrections from motor cortex neurons

Nina Kudryashova, Matthew Perich, Lee Miller, Matthias Hennig
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

Chewie / Mihili [2]
Baseline (BL)
Adaptation (AD)
Washout (WO)

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

Instructed
- mov. onset
- peak
- stop
- target average
- single-trial

Uninstructed
- density
- time, ms
- target direction
- Temporal variability
- Spatial variability

Problem: a classic variance explained $R^2$ is insensitive to uninstructed variability

Example: knowing the correct task instruction allows to score $R^2_{\text{pos}} = 97\%$, $R^2_{\text{col}} = 84\%$

Solution: quantify the uninstructed variance explained $R^2_{\text{uninstructed}}$.

$$R^2_{\text{uninstructed}} = \left(1 - \frac{\sum (y_{\text{pos}} - y)^2}{\sum (y_{\text{pos}} - \mu)^2}\right)$$

where $y$, $\mu$, $\sigma$ correspond to the trial number, time bin, behavioral component and target direction;

* we also treat the behavior (e.g. velocity) as a 2D vector, and include temporal variability

Hand velocity in adaptation trials exhibits 4–5 Hz oscillations

Hypothesis: oscillations arise from a closed-loop feedback control

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

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

Example model with 4 factors:

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, 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