Spiking neuron model of motor control with adaptation to visuomotor rotation

Natarajan Vaidyanathan, Chris Eliasmith | {nvaidyan, celiasmith } @uwaterloo.ca
Centre for Theoretical Neuroscience, University of Waterloo | http://ctn.uwaterloo.ca/

Abstract

- To study how the brain compensates for uncertainties and unexpected changes in the sensory environment, we here consider one of the well studied behaviors of **adaptation to Visuomotor Rotation**

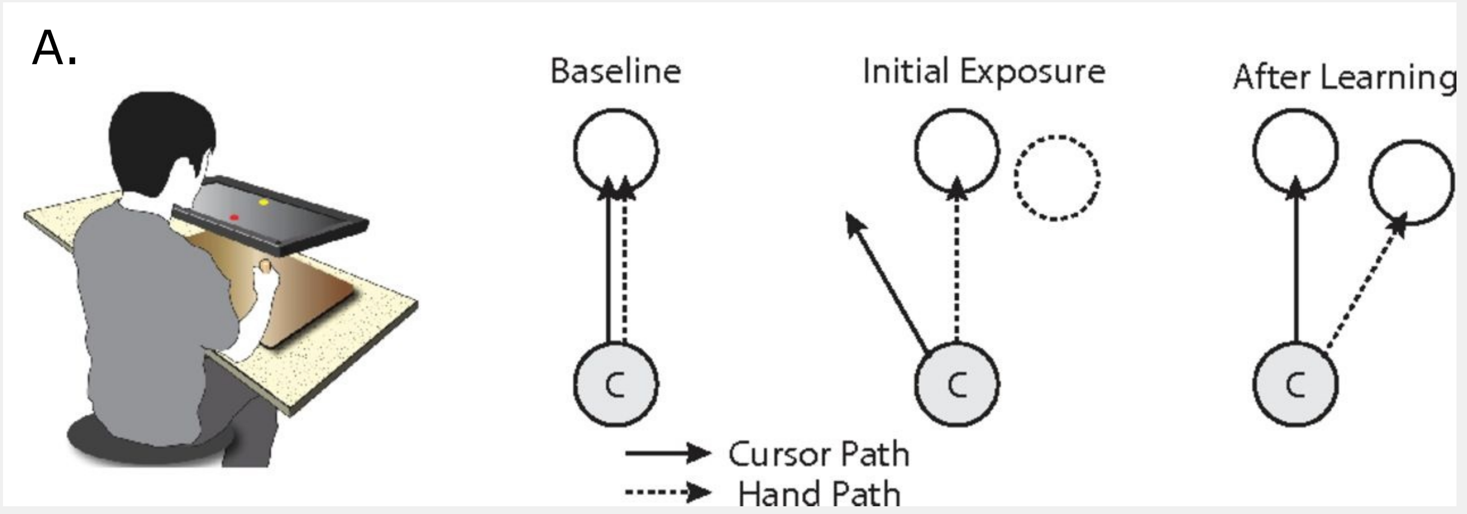
- He we extend a previous model, the **Recurrent Error-driven Adaptive Control Hierarchy (REACH)**, that accounts for dynamic and kinematic adaptation, to also capture visuomotor adaptations.

- We propose this spiking neuron model to capture both neural activities and the higher order behaviors that they give rise to

- The model is built using the **Neural Engineering Framework**

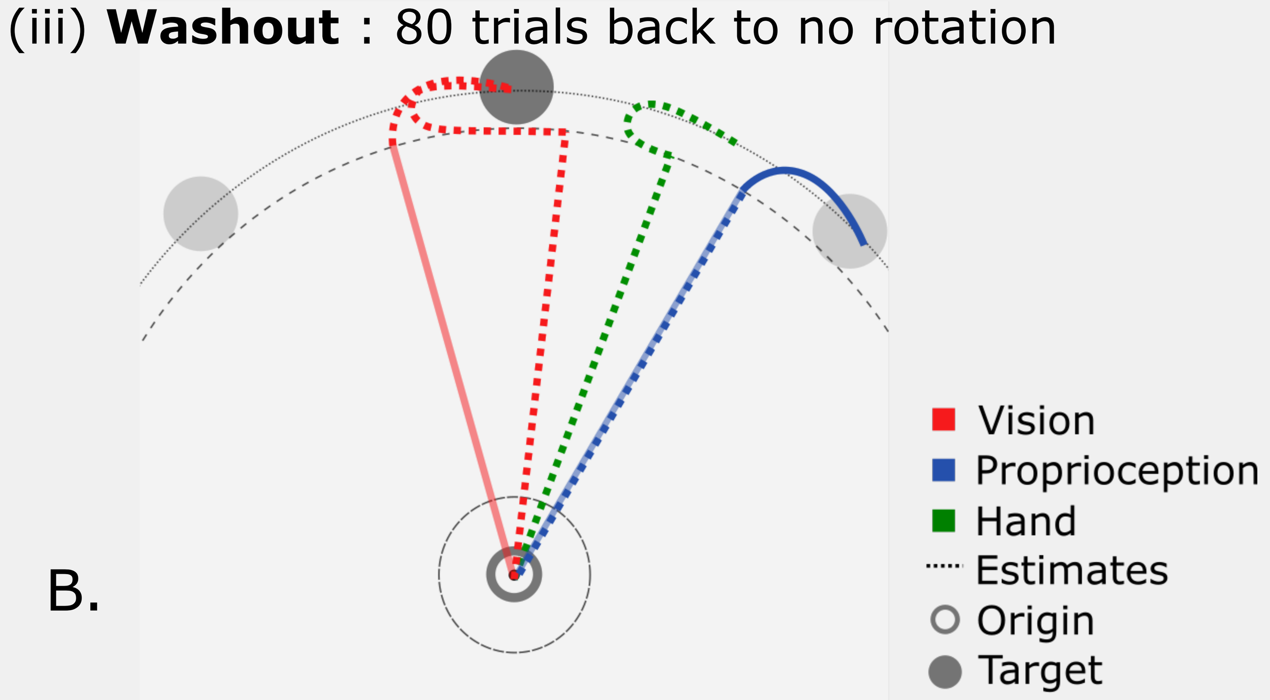
- The learning is achieved using the PES or the prescribed error sensitivity rule $\Delta\omega ij = -\kappa \cdot Eai$

Task

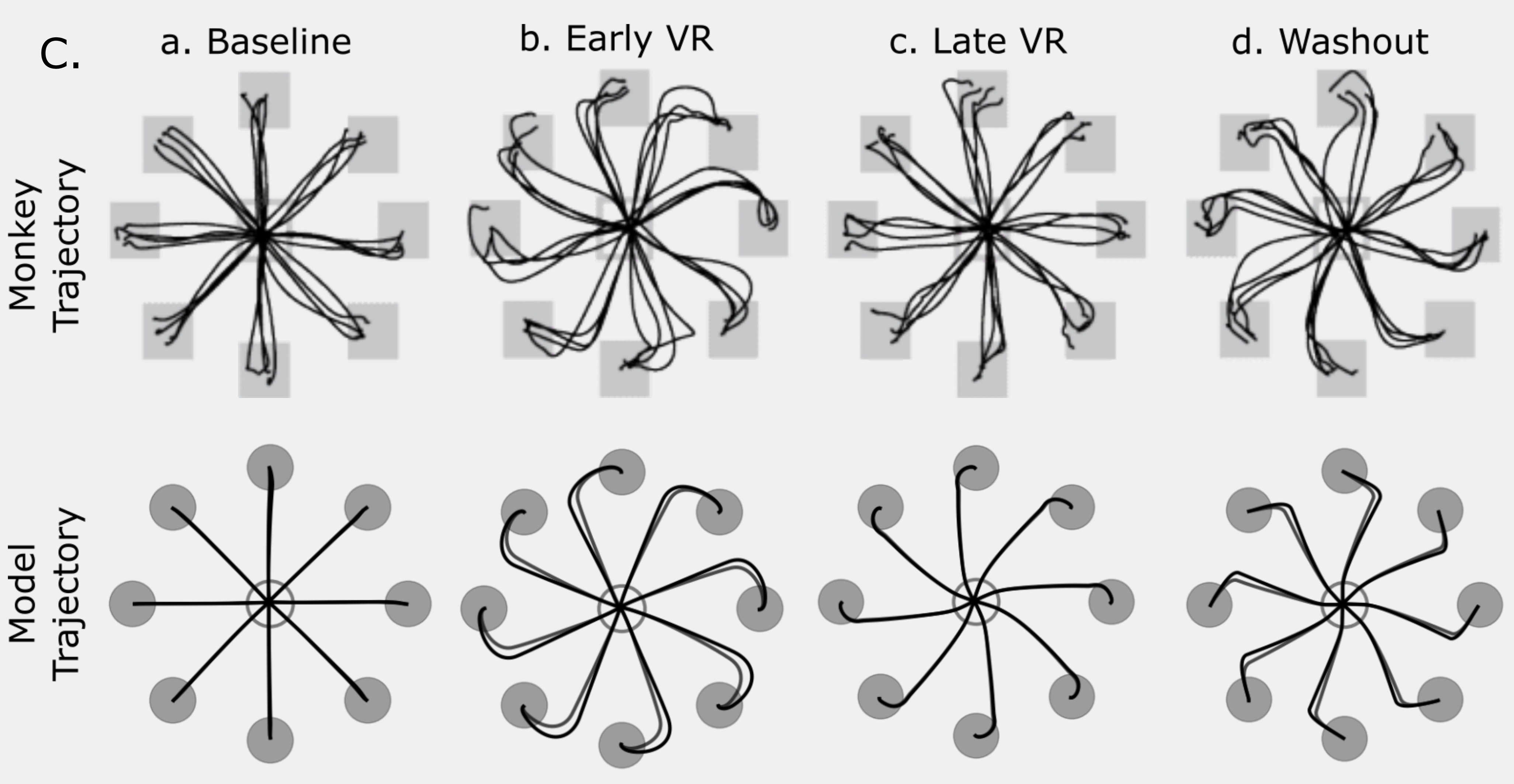


Reaching task where the view of the hand is blocked and the subject is provided with a cursor representing the hand location. In a ***visuomotor rotation*** task, the displayed cursor is rotated with repsect to the origin.

(i) **Baseline** : 16 trials without rotation
(ii) **Rotation** : 80 trials 45° CCW rotation
(iii) **Washout** : 80 trials back to no rotation

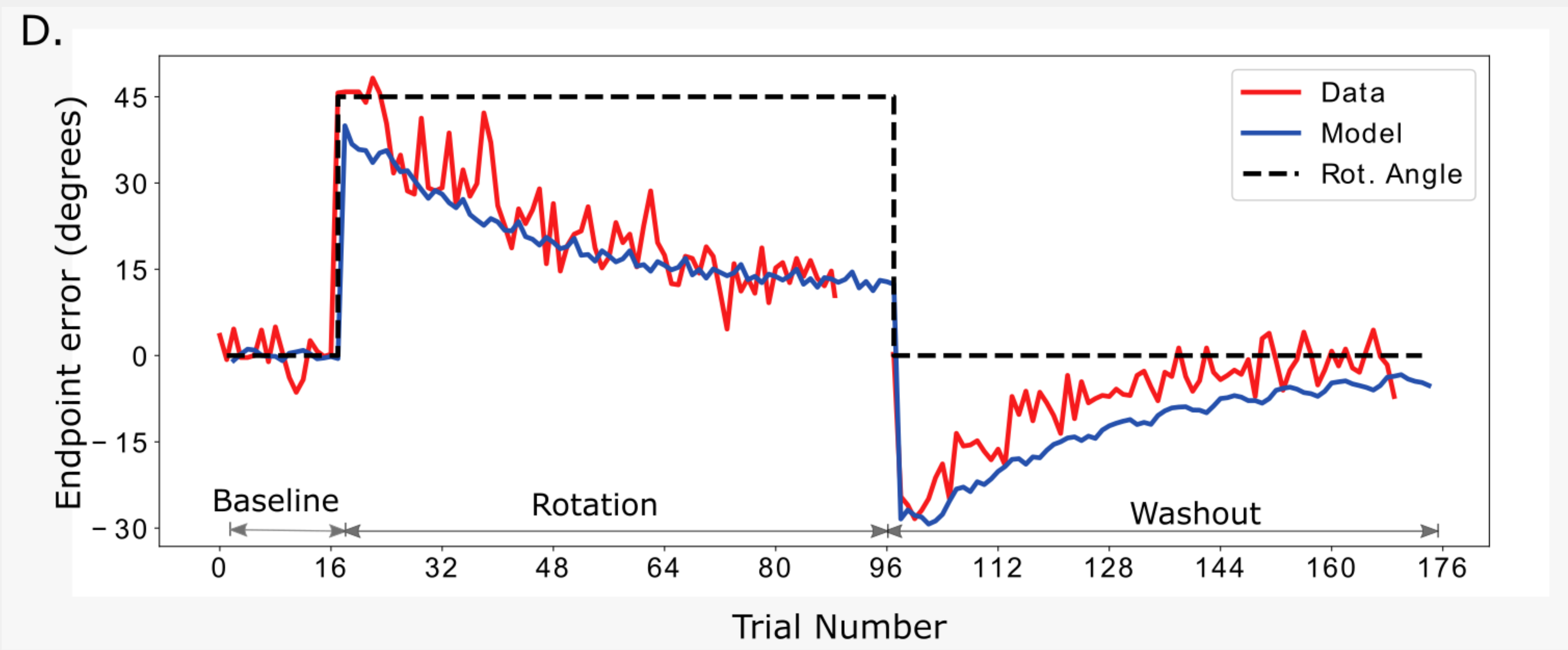


Results



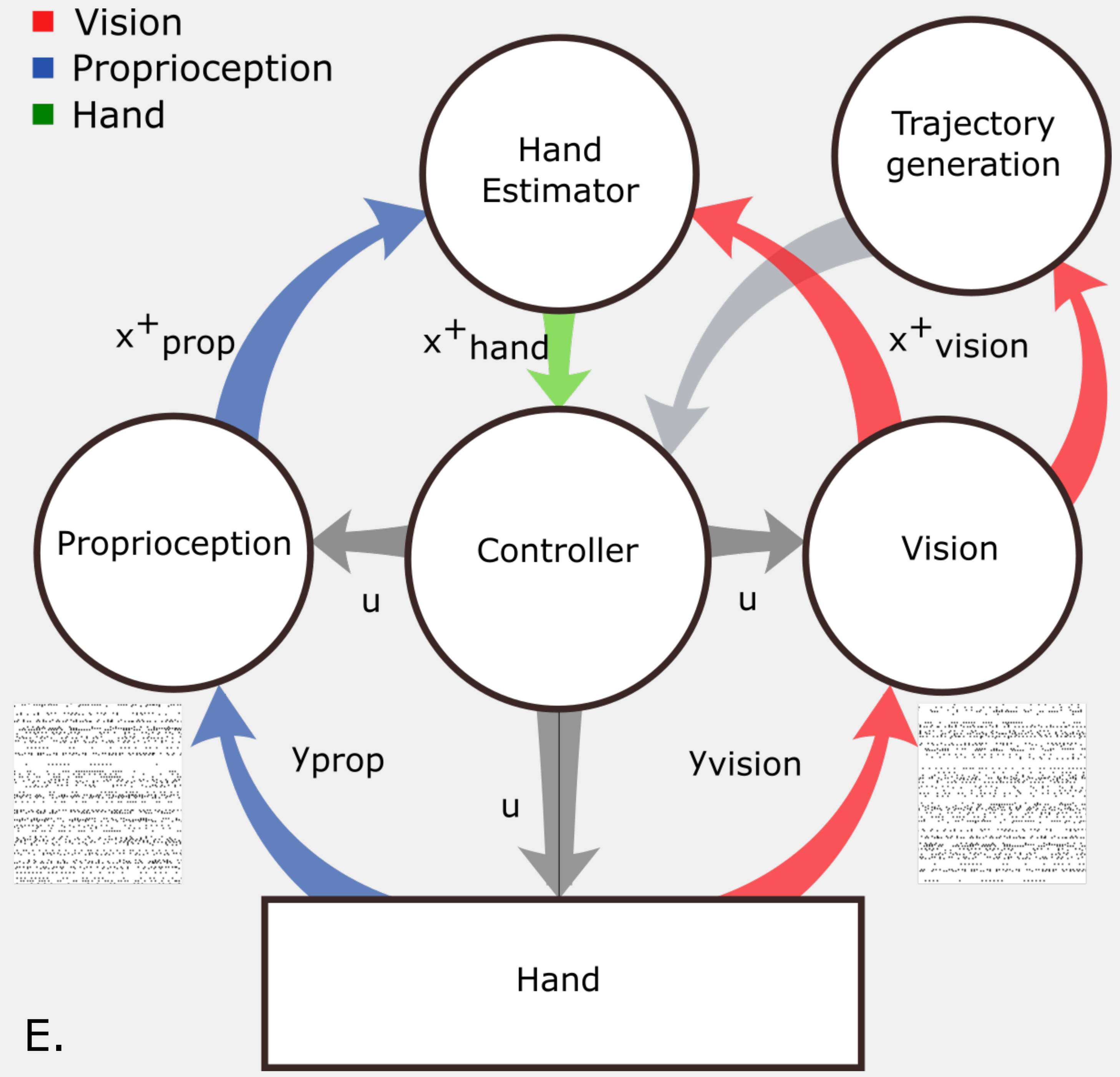
Trajectory comparison of experiment (top) vs model (bottom) during visuomotor rotation in: (a) the initial baseline trials without any rotation (b) early adaptation with onset of rotation at 30° CCW direction (30° for top panel) (c) later stage of adaptation to rotation (d) washout trials when the rotation is returned to 0°

Time course of adaptation



Time course of directional error at threshold of the model's reaches (blue) compared against experimental data (red) (reproduced from the graphs from *Mazzoni and Krakauer, 2006*). The black line shows the angle of rotation of the cursor with respect to the hand location.

Model



From the two noisy observation of the hand, vision and proprioception and the efference copy from the controller two estimates are obtained using the **Kalman filters**. These are further fused together to know the estimate of the hand position and velocity. A combined movement vector is learnt from the hand heading direction and correction realized from the end point error. The model consists of 28500 neurons describing anatomically organized structures including M1, pMd and cerebellum

References

[1] Eliasmith and Anderson. Neural Engineering, MIT Press 2003
[2] Mazzoni P, Krakauer JW. J Neurosci 2006
[3] DeWolf T, et al, Proceedings of the Royal Society , 2016
[4] L. Miller. et al. Neuron 2018
[5] Krakauer, John W. Progress in motor control , 2009.
[6] Henriques et al. Journal of neurophysiology 2010
[7] Bekolay et al. Annual Meeting of the Cognitive Science Society, 2013