

produces a saccade (GO process) and the other that prevents the GO process from finishing (STOP process; Logan & Cowan, 1984, Psych Rev). An interactive race model was formulated to explore how the STOP process can prevent GO from finishing through lateral inhibition, motivated by the finding that firing rates in presaccadic movement cells in the saccadic generator network, including the frontal eye field (FEF), superior colliculus (SC), basal ganglia, etc., which may instantiate the GO process, decline markedly when saccades are successfully inhibited (Boucher et al. 2007, Psych Rev). However, the interactive race model did not take into account the full temporal dynamics of fixation cells in the network, which may instantiate the STOP process. We incorporated this aspect of physiological data in revised interactive race models and tested several reformulations to examine core assumptions of the original model. We found that models that assumed an external inhibitory control (e.g., blocking input to the GO unit, boosting input to the STOP unit, or strengthening the inhibitory connection from the STOP unit to the GO unit) after the presentation of a countermanding signal fit the behavioral data better than models that did not. The former models also exhibited the activation functions of the GO and STOP units that resembled the activities of the movement and fixation cells. We conclude that the source of inhibitory control exists outside of the site (i.e., FEF, SC) of saccadic countermanding.

## II-67. Dimensionality in motor cortex: differences between models and experiment

Jeffrey Seely<sup>1</sup>  
 Matthew T Kaufman<sup>2</sup>  
 John Cunningham<sup>3</sup>  
 Stephen Ryu<sup>2</sup>  
 Krishna Shenoy<sup>2</sup>  
 Mark Churchland<sup>1</sup>

JSSEELY@GMAIL.COM  
 MATT235@STANFORD.EDU  
 JPC74@CAM.AC.UK  
 SEOULMAN@STANFORD.EDU  
 SHENOY@STANFORD.EDU  
 MC3502@COLUMBIA.EDU

<sup>1</sup>Columbia University

<sup>2</sup>Stanford University

<sup>3</sup>University of Cambridge

During movement, neurons in motor cortex exhibit complex, time-varying response patterns. Yet while it has been difficult to determine what movement variables are represented by these responses, it is relatively easier to ask how many variables are encoded. This can be done by assessing dimensionality using principal component analysis (PCA). We analyzed multi-electrode recordings from two monkeys performing a reaching task involving several different arm movements (e.g. right versus left, curved versus straight). We first assessed dimensionality across neurons—i.e., given the responses of  $k$  neurons, is the response of the  $k+1$ th neuron a linear combination of the first  $k$ ? We then assessed dimensionality across movements—i.e. given the population responses for  $k$  movements, is the population response for the  $k+1$ th movement a linear combination of the first  $k$ ? We first examined simulated data from a traditional model, where each neuron is tuned to reach end-point (during planning) and velocity (during movement). These simulated data had firing rates / noise properties matched to the real data. For both simulated data sets, the across-neuron and across-movement dimensionalities were low and nearly equal. This is expected; the model neurons represent a modest number of movement parameters. However, the results from the experimental data differed strikingly from those of the model. The experimental data shows high dimensionality across neurons, yet remarkably low dimensionality across movements. This asymmetry across dimensionality measures is dramatic in the data, yet absent in the traditional model. Thus, the data differ in both quantitative and qualitative ways from the predictions of a traditional model. Nevertheless, this result is compatible with what is expected of many classes of dynamical systems. For example, a high-dimensional dynamical system could show such an effect if its initial states (one per movement) lay on a low-dimensional manifold.