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Presentation Abstract

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Authors: ***B. PETRESKA**[1], B. M. YU[2,6,7], J. P. CUNNINGHAM[8], G. SANTHANAM[2], S. I. RYU[2,9], K. V. SHENOY[2,3,4,5], M. SAHANI[1];
[1]Gatsby Computat. Neurosci. Unit, UCL, London, United Kingdom; [2]Dept. of Electrical Engin., [3]Dept. of Bioengineering, [4]Dept. of Neurobio., [5]Neurosciences Program, Stanford Univ., Stanford, CA; [6]Dept. of Electrical & Computer Engin., [7]Dept. of Biomed. Engin., Carnegie Mellon Univ., Pittsburgh, PA; [8]Dept. of Engin., Univ. of Cambridge, Cambridge, United Kingdom; [9]Palo Alto Med. Fndn., Palo Alto, CA

Abstract: Recurrently-connected cortical networks compute by a dynamical process. The dynamical rules underlying these computations are likely to be nonlinear, and the system may evolve along paths that vary from trial to trial even as experimental conditions are held constant. How, then, can the properties of the dynamical system and the evolution of the corresponding dynamical state be identified? Simultaneous array-based recordings of the activity of many neurons embedded within a cortical neuronal network may provide the essential data. Our approach assumes that the computationally-relevant dynamics are described by a relatively compact set of order parameters or latent variables, and that these may be identified by statistical approaches from such array measurements.
Here we attempt to characterise these non-linear dynamics using a Hidden Switching Linear Dynamical System (HSLDS) model, an entirely unsupervised method that can be applied effectively to single-trial and multi-neuron data. The model finds multiple different linear dynamical rules for the evolution of dynamical state. At each point in time, it selects between these rules to chart the trajectory followed by this state. The multiple potential rules may thus reflect both

local linear approximations to nonlinear dynamics, as well as input-driven changes in the dynamics of the local network.
We applied the HSLDS model to a population of hundreds of neurons recorded in the monkey premotor and motor cortices during several delayed-reach tasks. The HSLDS captured shared variability in the neuronal population more effectively than either Gaussian Process Factor Analysis (GPFA) and a single Linear Dynamical System (LDS), showing that it provides a successful model of population neural activity. Intriguingly, many switches between linear dynamical rules correlate reliably with trial-by-trial behavioural events. The temporal lags found are consistent with causality: a change in the filtered neural state is estimated to occur at 120ms ± 40ms following the target onset and the first change following the go-cue onset occurs around 150ms ± 40ms before movement can be observed. Thus, the HSLDS models do appear to successfully capture behaviourally-related changes in the neural dynamics of single-trial and multi-neuron recordings.

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