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Neuroscience 2015

Presentation Abstract

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Authors: ***G. F. ELSAYED**[1], M. T. KAUFMAN[3], S. I. RYU[4], K. V. SHENOY[4], M. M. CHURCHLAND[1], J. P. CUNNINGHAM[2];
[1]Neurosci., [2]Statistics, Columbia Univ. In the City of New York, New York, NY; [3]Cold Spring Harbor Lab., Cold Spring Harbor, NY; [4]Stanford Univ., Stanford, CA

Abstract: Many hypotheses consider the role that population dynamics play in the computational structure of various neural systems. One common question is whether there exist consistent population dynamics across different experimental conditions. To illustrate this, consider the joint neural responses of N neurons to each experimental condition, which can be viewed as a point moving over time forming a trajectory through N-dimensional neural space. In neural spaces, dynamics are modeled as a single flow field that governs the evolution of many neural trajectories. Here, we test for the existence of consistent dynamics, defined as a single fixed dynamical rule that governs the evolution of neural trajectories for all conditions. In particular, we are interested in the basic question: do neural data show any dynamical consistency beyond what would be expected by non-dynamical 'null' data? The main difficulty in addressing this question is that the notion of null data is ill-defined. For example, white noise is a null dataset that may make any collection of neural data look dynamically consistent in comparison, due to the surface features of real data such as temporal smoothness, across-condition smoothness, and pairwise neural correlations. Thus, the central challenge is to create null data with similar surface features to the real data. Here, we demonstrate procedures to create surrogate (null) data that preserve the surface features of the real neural data. To generate these surrogate datasets, we use ideas from permutation tests, which assume exchangeability of conditions under null hypotheses, to disrupt any dynamical consistency across neurons in real data. More importantly, via permutation techniques and matrix optimization methods, we enforce exchangeability of the surface features. If a dataset truly follows dynamical systems rules, it should be distinguishable from these surrogate datasets even though both share the same surface features. These permutation tests provide a conservative statistical test for dynamical structures and give guidance as to the number of neurons, conditions and time points needed to provide statistical power to these tests. As a first application, we test for the dynamical consistency of data from the motor cortex. The results show significant dynamical structure in the motor cortical population responses ($R2 = 0.6, p < 0.001$), providing statistical support to recent hypotheses [Churchland & Cunningham et al., 12].

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