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NEUROSCIENCE 2012

Presentation Abstract

Program#/Poster#: 300.01/DDD45

Presentation Title: Comparing visual and motor cortex: Representational coding versus dynamical systems

Location: Hall F-J

Presentation time: Sunday, Oct 14, 2012, 1:00 PM - 2:00 PM

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Abstract: Systems neuroscience often employs models that explain neural responses in terms of represented stimulus features or movement parameters. These models can be powerful, but do not apply equally well to all circuits. E.g., the activity of a central pattern generator is best captured by its intrinsic dynamics. Here, we examine the population response in a number of cortical areas, and ask whether responses appear stimulus driven (i.e. are better described as a function of external parameters) or internally generated (i.e. are better described by a dynamical system). We analyzed datasets (44 - 218 single and/or multi-unit isolations) from visual areas V1 and MT (recorded during the presentation of visual stimuli) and from primary motor and premotor cortex (recorded during a delayed reach task). Our analyses did not fit particular representational or dynamical models, but instead asked whether basic features of the data tended to obey or violate the expectations of a dynamical system. The principal expectation is, for a k-dimensional dynamical system, the number of temporal patterns (modes) present in the data should tend to be <= k. This can be shown analytically for linear, time-varying systems. Conversely, stimulus-driven responses can display an arbitrary variety of temporal patterns, as determined by the stimuli. We therefore compared the number of temporal patterns in the data with the overall dimensionality of the system. We considered data of the form r(n,c,t), the rate of neuron n for condition c and time t. To determine the overall dimensionality, we applied PCA considering neurons as ‘variables’ and conditions and times as ‘observations’. To determine the number of temporal patterns that the system displayed, we applied PCA again considering conditions as ‘variables’ and neurons and times as ‘observations’. For each of these two applications of PCA we found the number of dimensions required to reconstruct the data to 90% precision. We then took the ratio (overall dimensionality divided by number of temporal patterns). For simulated data from stimulus-driven models, ratios were < 1. For simulated data from dynamical systems models, ratios were > 1. For the neural data from visual areas (2 datasets) the ratio lay close to the stimulus-driven prediction (ratios = 0.8, 1.1), while the population response from the motor areas (4 datasets) appeared more dynamical (ratios = 1.6, 1.8, 1.8, 2.4). These results indicate that, in visual areas the overall structure of the data is consistent with responses being largely a function of stimulus parameters. In contrast, in motor areas the structure of the data argues that responses are more strongly dominated by internal dynamics.

Disclosures: **J. Seely:** None. **M.T. Kaufman:** None. **A. Kohn:** None. **M.A. Smith:** None. **J. Movshon:** None. **N.J. Priebe:** None. **S.G. Lisberger:** None. **S.I. Ryu:** None. **K.V. Shenoy:** None. **J.P. Cunningham:** None. **M.M. Churchland:** None.

Keyword(s): MOTOR CORTEX

VISUAL CORTEX

MODELING

Support: NIH Pioneer

NIH NINDS

DARPA REPAIR

BWF

[Authors]. [Abstract Title]. Program No. XXX.XX. 2012 Neuroscience Meeting Planner. Washington, DC: Society for Neuroscience, 2012. Online.