Dimensionality reduction or how does motor cortex make sense of the multitude of incoming information

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Abstract

Movement preparation is based on central processes responsible for the maximally efficient organization of motor performance [1]. A strong argument in favor of such an efficiency hypothesis is that providing prior information about individual movement parameters significantly shortens reaction time (RT), but not movement time (MT) [2]. During movement preparation, individual parameters are selectively reflected in motor cortical activity [2,3]. However, averaging across trials does not account for the variability of the behavioral outcome (e.g. significant trial-by-trial correlation between RT and cortical activity recorded long before the movement [4-6]). While individual neurons have their intrinsic variability (membrane potentials, ion channels, timing of rate modulation, spike timing ....), groups of neurons may reflect a network state at any given point in time representing individual movement parameters. To explore if such neural states and neural trajectories, obtained from many simultaneously recorded single neurons in monkey motor cortex during a delayed reach-to-grasp task [7], reflect the encoding of individual parameters, we extracted smooth, low-dimensional trajectories/statess from noisy, high-dimensional signals [8], both in single trials and across trials. We did such dimensionality reduction based on Gaussian-process factor analysis (GPFA) [8] and related the obtained states and trajectories to population spiking activity, the behavioral output in terms of reaction and reach movement times, and object displacement.

We found a clear separation of neural trajectories for the parameters grip and force as soon as information about them is provided, even long before the movement. The processing speed in a network varies clearly as a function of behavior, being an indicator for the evolution and modification of such network states in time. For instance, neural states related to different behavioral events reveal a different evolution in internal or state time from trial to trial. Neural states in single trials during movement preparation before GO predict the behavioral output, indicated by the velocity profile of the movement. Finally, a "kink" in a neural trajectory may be an expression of an input to the network, either externally triggered by a visual signal or internally triggered by somatosensory input related to the movement (e.g. receptor input from muscles or articulations).

References:


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