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

Alexa Riehle*[1,2,3]

[1]Institut de Neurosciences de la Timone (INT) – Aix Marseille Université, CNRS : UMR7289 – Campus Santé Timone - Bâtiment Neurosciences 27, Bd Jean Moulin - 13385 Marseille Cedex 05, France
[2]RIKEN Brain Science Institute (BSI) – 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[3]Institute of Neuroscience Medicine (INM-6) – Jülich, Germany

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 representating 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/states 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:

Requin J, Brener J, Ring C (1991) Preparation for action. In Jennings RR, Coles MGH

*Speaker

(eds) *Handbook of Cognitive Psychophysiology Central and autonomous nervous system approaches.* Wiley & Sons, New York, pp 357-448 REVIEW

Riehle A (2005) Preparation for action: one of the key functions of the motor cortex. In Riehle A, Vaadia E (eds) *Motor cortex in voluntary movements a distributed system for distributed functions.* CRC-Press, Boca Raton, FL, pp 213-240 REVIEW

Milekovic T, Trucculo W, Grün S, Riehle A, Brochier T (2015) Local field potentials in primate motor cortex encode grasp kinetic parameters. *NeuroImage 114 338-355*

Riehle A, Requin J (1993) The predictive value for performance speed of preparatory changes in neuronal activity of the monkey motor and premotor cortex. *Behav Brain Res 53 35-49*

Afshar A, Santhanam G, Yu BM, Ryu SI, Sahani M, Shenoy KV (2011) Single-trial neural correlates of arm movement preparation. *Neuron 71 555-564*

Michaels JA, Dann B, Intveld RW, Scherberger H (2015) Predicting reaction time from the neural state space of the premotor and parietal grasping network. *J Neurosci 35 11415-11432*

Brochier T, Zehl L, Hao Y, Duret M, Sprenger J, Denker M, Grün S, Riehle A (2018) Massively parallel recordings in macaque motor cortex during an instructed delayed reach-to-grasp task. *Sci Data* 5: 180055

Yu BM, Cunningham JP, Santhanam G, Ryu SI, Shenoy KV, Sahani M (2009) Gaussian-process factor analysis for low-dimensional single-trial analysis of neural population activity. *J Neurophysiol* 102: 614-635