

Recurrent Artificial Neural Networks (RNNs) are popular models for neural function in motor control. A common approach to build such models is to train RNNs to reproduce the input-output mapping likely performed by biological networks. However, this approach suffers from the problem that the internal dynamics of the resulting networks are typically highly under-constrained: even though the networks correctly reproduce the desired input-output behavior, the neural dynamics are not under control and usually deviate strongly from the ones of real neurons. Here, we show that it is possible to accomplish the dual goal of both reproducing the target input-output behavior and constraining the internal dynamics to be similar to the ones of real neurons. As a test-bed, we simulated an 8-target reaching task; we assumed that a network of 200 primary motor cortex (M1) neurons generates the necessary activity to perform such tasks - in response to 8 different inputs - and that this activity drives the contraction of 10 different arm muscles. We further assumed to have access to only a sample of M1 neurons (30%) and relevant muscles (40%). In particular, we first generated multiphasic EMG-like activity by drawing samples from a Gaussian process. Secondly, we generated ground truth M1-like activity by training a stability-optimized circuit (SOC) network [2] to reproduce the EMG activity through gain modulation [1]. Finally, we trained two RNN models with the full-FORCE method [3] to reproduce the subset of observed EMG activity; critically, while one of the networks (FF) was free to reach such a goal through the generation of arbitrary dynamics, the other (FFH) was constrained to do so by generating, through its recurrent dynamics, activity patterns resembling those of the observed SOC neurons. To assess the similarity between the activity patterns of FF, FFH and SOC neurons, we applied canonical correlation analysis (CCA) on the latent factors extracted through PCA [4]. This analysis revealed that while both the FF and FFH network were able to reproduce the EMG activities accurately, the FFH network, that is the one with constrained internal dynamics, showed greater similarity in the neural response space with the SOC network. Such similarity is noteworthy since the sample used to constrain the internal dynamics was small. Our results suggest that this approach might facilitate the design of neural network models that bridge multiple hierarchical levels in motor control, at the same time including details of available single-cell data.

### **Funding**

BMBF FKZ 01GQ1704, DFG GZ: KA 1258/15-1; CogIMon H2020 ICT-644727, HFSP RGP0036/2016, KONSENS BW Stiftung NEU007/1

### **References**

1. Stroud, J. P., Porter, M. A., Hennequin, G., & Vogels, T. P. (2018). Motor primitives in space and time via targeted gain modulation in cortical networks. *Nature neuroscience*, 21(12), 1774.
2. Hennequin, G., Vogels, T. P., & Gerstner, W. (2014). Article Optimal Control of Transient Dynamics in Balanced Networks Supports Generation of Complex Movements. *Neuron*, 82(6), 1394–1406.
- 3 DePasquale, B., Cueva, C. J., Rajan, K., & Abbott, L. F. (2018). full-FORCE: A target-based method for training recurrent networks. *PloS one*, 13(2), e0191527.
- 4 Sussillo, D., Churchland, M. M., Kaufman, M. T., & Shenoy, K. V. (2015). A neural network that finds a naturalistic solution for the production of muscle activity. *Nature Neuroscience*, 18(7), 1025–1033