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Neuroscience 2015

Presentation Abstract

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Presentation Title: Dynamic dimensionality reduction of human motor cortical activity using recurrent neural networks

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Abstract: Several recent studies have revealed new insights relating motor cortical population activity to motor behavior using dimensionality reduction techniques (e.g. Afshar et al. 2011, Churchland et al. 2012, Kaufman et al. 2014, Sadtler et al. 2014). While these techniques often uncover structure in the population activity that is not apparent from single neuron responses, most involve smoothing neural activity in time, and often require averaging over multiple trials. Such treatments can obscure important features (e.g. fine temporal structure and trial-to-trial variability). We present an alternative approach to dimensionality reduction, called

Latent Factor Analysis of Dynamical Systems (LFADS), that uses recurrent neural networks (RNNs; e.g. Sussillo & Abbott, 2009) to characterize dynamic structure in neural population activity. In this approach, an RNN is trained to reproduce time varying, simultaneously recorded, single trial spiking activity. To constrain the RNN to find a dimensionality-reduced representation of the spiking activity, its output is forced through a low dimensional layer of hidden units (10-20 dim). Activity in this layer serves as the basis for the predicted firing rates. In summary, LFADS produces a dynamic, low-dimensional estimate of the population activity that is consistent with recorded spiking data. We applied LFADS to intracortical recordings from human primary motor cortex during movements, recorded from participant T7 in the BrainGate2 clinical trial (ClinicalTrials.gov ID: NCT00912041). We show that the network's output captures fine temporal features of the recorded spike trains and reproduces known dynamic features of motor cortical activity on multiple timescales. For example, motor cortex exhibits beta band oscillations (e.g. 15-40 Hz) in local field potentials (LFP), and phase-synchronized spiking activity, often occurring in the pre-movement period and stopping before movement onset (e.g. Donoghue et al., 1998). Although LFADS is trained to model only the spiking activity, the estimated population state successfully predicts single-trial recorded LFP activity during the pre-movement period. Furthermore, it also shows the presence of slower oscillations (1-2 Hz), consistent with structure demonstrated using trial-averaged analyses (Churchland et al., 2012). These results show that LFADS reveals dynamic features of population activity on single trials. This knowledge may lead to a better understanding of trial-to-trial variability, which is central to motor control and higher-performance Brain-Machine Interfaces (Kao et al., SfN 2013).

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