III-70. Inter-area interactions encode real-time adaptive biasing of performance during motor skill learning

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Enhanced neural interactions between higher-order and primary motor areas have been observed during various types of motor learning, but the behavioral function of such interactions remains poorly understood. An intriguing possibility is that increased top-down interactions during learning reflect the development of signals that bias performance in real-time (i.e., by controlling moment-by-moment adaptive variation in motor output) in order to implement more adaptive behavioral variants. Here, we tested this possibility in adult songbirds during vocal learning, by measuring moment-by-moment interactions between a primary motor area (RA) - which controls the production of song acoustic features - and a higher order nucleus (LMAN) - which contributes to the learning of song modifications. We quantified LMAN-RA interactions by measuring the cross-covariance between LMAN and RA spiking activity. The cross-covariance function exhibited an LMAN-leading peak, consistent with a top-down influence of LMAN on RA. The strength of LMAN-RA cross-covariance increased during learning. This increase was specific to behavioral features targeted for learning, including both its precise timing (sub-second) and sequential context. Moreover, analysis of interleaved song renditions revealed a moment-by-moment correlation between the strength of enhanced LMAN-RA cross-covariance and the expression of adaptive pitch changes. These results indicate that enhanced interactions between higher-order (LMAN) and primary motor (RA) circuitry reflect a real-time, top-down motor bias that implements adaptive modifications of song during performance.

III-71. Neural state space geometry in human motor cortex underlying speaking different phonemes

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Neurological disorders such as stroke and amyotrophic lateral sclerosis impair speech in millions worldwide. For afflicted individuals, restoring speech through a brain-computer interface (BCI) is a promising therapeutic approach that could substantially improve quality of life. To access high-quality neural signals, speech BCIs have often used invasive electrocorticography (ECoG) measurements from distributed populations across the cortex (Mugler et al. 2014, Anumanchipalli et al. 2019, Angrick et al. 2019). In this work, we explored a complementary speech decoding approach: accessing higher spatial resolution neural activity using two 96-microelectrode arrays in "hand knob" area of human motor cortex. Using a linear decoder, we achieved 29% classification accuracy (chance = 6%) across 39 English phonemes and 73% accuracy for the best phoneme, comparable with ECoG-based performance on a similar corpus (Mugler et al. 2014). Performance did not saturate with increasing dataset size or channel count, indicating room for further improvement. Classification errors reflected latent phonetic structure, with higher confusion within phonetic groups. We analyzed the structure of phonetic representations at the neural population level. Our analyses reveal a distributed representation, with condition-invariant changes in activity during speech preparation and initiation, followed by divergence by phoneme group and individual

phoneme. Our results 1) suggest that multi-unit activity from nontraditional speech areas is a viable neural signal for speech decoding efforts, carrying implications for the design of future BCI systems, and 2) highlight the strength of natural speech as a lens for studying neural population dynamics during a complex motor behavior.

III-72. Real-time discovery of effective dynamics from streaming noisy neural observations

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New technologies for recording the activity of large neural populations during complex behavior provide exciting opportunities for investigating the neural computations that underlie perception, cognition, and decision-making. State-space models, that combine an intuitive dynamical system and a probabilistic observation model, provide an interpretable view of complex time series, and inferring such models can provide insights into neural dynamics, neural computation, and development of neural prosthetics and treatment through feedback control. It yet brings the challenge of learning both latent neural state and the underlying dynamical system because neither is known for neural systems a priori. While offline batch analyses, such as expectation maximization (EM) and variational autoencoders, are promising, their offline nature slow down the scientific cycle of experiment, data analysis, hypothesis generation, and further experiments. This highlights the need for new tools to analyze and manipulate neural activity and animal behavior in real time. We developed a novel streaming variational Monte Carlo (SVMC) framework for simultaneously inferring nonlinear latent dynamics and latent states that is applicable to a wide range of state-space models. Modeling unknown dynamics with sparse Gaussian processes allows for Bayesian inference on the dynamical system and efficient computation. Unlike previous approaches, our framework can incorporate non-trivial observational distributions. Constant time and space complexity makes our approach amenable to online learning scenarios and suitable for real-time applications. The aim of this work is to automate analysis and experimental design through feedback stimulation. It can potentially be used in the experiments to perturb neural activity in ways that testably affect behavior, and to track and modify behavior using stimuli designed to influence learning.

III-73. Counterintuitive effects of excitatory and inhibitory perturbations in spiking networks

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Perturbation studies, in which neural activity in an area of interest is selectively manipulated, have become widespread in experimental neuroscience research. However, the interpretation of such experiments may not always be straightforward – e.g., the stimulation or suppression of a neural population may lead to indirect effects such as compensation from other areas. Here we present a theory of neural circuit responses to perturbations, and use it to explain robustness and sensitivity to different types of excitatory and inhibitory perturbations on neural populations. Using this theory, as well as accompanying spiking network simulations, we find that perturbation responses can change dramatically depending upon the amount and type of feedback in recurrent networks, and are also modulated by the proportion of perturbed neurons and the relationship between their receptive fields. On one extreme, networks with weak feedback, including strictly feedforward networks, exhibit biases in response to both excitatory and inhibitory perturbations, provided the perturbations are sufficiently large. On the other