LEARNING AND ADAPTATION IN BRAIN MACHINE INTERFACES

SPENCER BRADLEY TORENE

Boston University School of Medicine, 2017

Major Professor: Jason T. Ritt, Ph.D., Assistant Professor of Biomedical Engineering

ABSTRACT

Balancing subject learning and decoder adaptation is central to increasing brain machine interface (**BMI**) performance. We addressed these complementary aspects in two studies: (1) a learning study, in which mice modulated “beta” band activity to control a 1D auditory cursor, and (2) an adaptive decoding study, in which a simple recurrent artificial neural network (**RNN**) decoded intended saccade targets of monkeys.

In the learning study, three mice successfully increased beta band power following trial initiations, and specifically increased beta burst durations from 157 ms to 182 ms, likely contributing to performance. Though the task did not explicitly require specific movements, all three mice appeared to modulate beta activity via active motor control and had consistent vibrissal motor cortex multiunit activity and local field potential relationships with contralateral whisker pad electromyograms. The increased burst durations may therefore by a direct result of increased motor activity. These findings suggest that only a subset of beta rhythm phenomenology can be volitionally modulated (e.g. the tonic “hold” beta), therefore limiting the possible set of successful beta neuromodulation strategies.

In the adaptive decoding study, RNNs decoded delay period activity in oculomotor and working memory regions while monkeys performed a delayed saccade task. Adaptive decoding sessions began with brain-controlled trials using pre-trained RNN models, in contrast to static decoding sessions in which 300-500 initial eye-controlled training trials were performed. Closed loop RNN decoding performance was lower than predicted by offline simulations. More consistent delay period activity and saccade paths across trials were associated with higher decoding performance. Despite the advantage of consistency, one monkey's delay period activity patterns changed over the first week of adaptive decoding, and the other monkey's saccades were more erratic during adaptive decoding than during static decoding sessions. It is possible that the altered session paradigm eliminating eye-controlled training trials led to either frustration or exploratory learning, causing the neural and behavioral changes.

Considering neural control and decoder adaptation of BMIs in these studies, future work should improve the "two-learner" subject-decoder system by better modeling the interaction between underlying states (and possibly their modulation), and the neural signatures representing desired outcomes.