Two distinct layer-specific dynamics of cortical ensembles and single neurons during learning of a motor task

Masanori Matsuzaki
National Institute for Basic Biology

Motor performance improves with repetitive training, and it has been proposed that this is mediated by functional and structural reorganization of the motor cortex. However, it is poorly understood how different cortical neuronal activities in layer 2/3 and layer 5a, including corticostriatal activity, are reorganized during learning of a motor task. We used mice performing a self-initiated lever-pull task to show that the neuronal activities that predict the lever trajectory are dynamically reorganized in layer-specific manners during long-term training. Two-photon calcium imaging in layers 2/3 and 5a of the primary motor area was conducted while mice practiced the motor task for 14 consecutive days. In layer 2/3, prediction accuracy of the lever trajectory by neuronal population activity changed during sessions. At the single-neuron level, neurons that increased the prediction accuracy were overall counterbalanced by those that decreased it, and a subset of neurons maintained high prediction ability. In layer 5a, the ensemble prediction steadily improved and one-third of neurons, including corticostriatal neurons, slowly improved their prediction ability and strongly contributed to the ensemble prediction by the late stage of learning. Our results provide a novel microcircuit model that consists of distinct intermediate layers upstream of layer 5b with the motor output activity. The balanced dynamic network in layer 2/3 may represent coordination of signals from other areas and combination of motor primitives, whereas the downstream layer 5a may constitute the evolving dynamic network that represents a well-learned movement.
