**The brain re-sequences motor cortex output not by re-sequencing output-specific cortex activity, but by controlling general motor cortex dynamics**

The brain produces behavior through the collective action of motor cortex (M1) neurons which drive downstream structures to generate a particular sequence of outputs. The set of outputs that are ordered to produced one behavior, such as straight movements, can be reordered to generated a second behavior, such as curved movements. How does the brain re-sequence outputs to produce different behaviors? One possiblity is that the same M1 neural activity patterns that produce particular outputs are simply re-used in a new sequence, as expected if M1 activity is tuned to instantaneous output. However, recent work has shown that M1 possesses strong recurrent connectivity which can result in neural dynamics: rules that govern how neural activity patterns transition in time based on past activity patterns and inputs. These rules imply M1 neural activity patterns cannot be arbitrarily re-sequenced, since activity patterns have a dependence on past activity. To precisely answer how M1 neural activity produces re-sequenced out, we trained two rhesus macaques to control a brain-machine interface (BMI). The BMI exactly defines how population M1 activity produces output velocity commands to a two-dimensional neuroprosthetic cursor. Animals performed two BMI tasks; a center-out task and obstacle task which elicited straight and curved neuroprosthetic cursor behaviors relying upon the same repertoire of output velocity commands but demanding different sequences.

We found that M1 activity generating an output command in a curved behavior during the obstacle-avoidance task deviated from the activity used to generate the same output command in a straight behavior during the center-out task, showing that activity is not simply re-sequenced when output is re-sequenced. Instead, we found that modifications to neural activity patterns used in the re-sequenced behavior could be predicted by neural dynamics common to both tasks. These neural activity modifications were also predictive of future neural activity and future output in the re-sequenced task, suggesting the use of neural dynamics for behavioral control. A model of motor cortex feedback control shows that these experiementally-observed general neural dynamics can be used to help execute BMI control, reducing the input motor cortex needs.

Thus, we find critical evidence for the hypothesis that the brain re-sequences M1 output by controlling motor cortex dynamics rather than re-sequencing output-specific M1 activity.  These results shed light on the neural control of flexible behavior and have implications for future BMI design.