T-17. Evidence of a memory trace in motor cortex after short-term learning

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Does learning a new task change the neural activity patterns that the brain uses to perform a previously learned task? We hypothesized that neural activity used to re-perform an original task would remain appropriate for the new task. A difficulty in addressing this hypothesis is that, in most circumstances, the causal relationship between neural activity and behavior is unknown. To overcome this, we leveraged an intracortical brain-computer interface (BCI), where the mapping between neural activity and behavior is specified by the experimenters. This experimental paradigm allows us to quantify how appropriate neural activity is for a given mapping, even when that mapping is not currently being used. Experiments utilized an “ABA” block design, where monkeys proficiently used an original mapping A in a baseline period, and then the mapping was switched to a new mapping B that had to be learned through trial and error. After several hundred trials, mapping A was reinstated in a washout period. To evaluate whether learning a new mapping leaves a memory trace in motor cortex, we quantified the extent to which neural activity patterns produced when the monkey was controlling the cursor with mapping A were appropriate for mapping B. We found evidence of a memory trace, in that neural activity during the late portion of the washout period was more appropriate for mapping B than the neural activity during the baseline period. This result held when we controlled for factors such as behavioral differences between the baseline and washout periods. Overall, our findings suggest that learning a new task brings neural activity to a novel solution for the original task that also provides a benefit for the new task. This may be a mechanism by which the brain could more rapidly learn when re-exposed to the same perturbation, a phenomenon known as “savings”.

T-18. Separation of preparatory neural states when learning multiple arm-movement dynamics

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The ability to learn new motor skills without interfering with old ones is essential for us to acquire and maintain a broad motor repertoire. Recent psychophysics studies found that when people plan for or imagine different movements associated with different curl fields, they can learn multiple skills without interference that would otherwise hurt learning (Sheahan et al. 2016 and 2019). Here we ask when learning multiple motor skills, are preparatory neural states of these skills separated to form different motor plans and subsequently reduce interference between

neural dynamics that generate distinct movements? We designed a curl force field task to investigate the neural correlate of learning multiple motor skills (here, arm-movement dynamics). We trained two rhesus macaques to learn different curl fields sequentially within the same session or over multiple sessions (block design of the task is similar to Sun et al. 2019 COSYNE abstract). We recorded neural activity in dorsal premotor and primary motor cortex using Utah-arrays, V-probes, and Neuropixels probes which gave us access to hundreds of neurons per curl field condition. We applied PCA to preparatory activity and examined the subspace spanned by the top 10 PCs that captured over 90% of the total variance. We sought response patterns most strongly present in the data and asked whether the separation of preparatory states appeared in the most prominent neural activity features. We found that after learning one curl field applied to only one reach target, preparatory neural states of reaching to all targets uniformly shifted away from the before-learning states. Preparatory states of learning different curl fields were separated by multiple uniform shifts that showed distinct geometrical relationships depending on curl field types. The uniform shifts raise the possibility that interference between neural dynamics of learning multiple motor skills is reduced by having separated preparatory neural states.

T-19. Long-range inhibition mediates decision making in the superior colliculus

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Decision making is a fundamental process of the nervous system for generating goal-directed behaviors. The midbrain superior colliculus (SC) contributes to sensorimotor decision making by integrating cortical and subcortical inputs to guide orienting movements of the eyes, head, and body towards spatial goals. The SC is topographically organized and encodes for specific regions in retinotopic space, however the underlying circuitry for how the SC selects where to orient is unknown. Multiple models of excitatory/inhibitory interactions have been proposed to describe SC function, but these are based on cellular anatomy, ex-vivo slice physiology, and in-vivo recordings in the absence of behavior, or on recordings during behavior from unknown cell types. Here, we record and manipulate the activity of GABAergic neurons in mice performing a spatial choice task to determine the functional role of inhibition during spatial choice. We trained mice to select a left or right reward port based on a binary odor mixture. Importantly, after odor delivery, mice wait for a “go tone” before orienting to the reward port, giving us access to neural activity during the decision (i.e., the “choice epoch”). We hypothesized that GABAergic neurons would shape spatial choice locally by inhibiting SC motor output neurons promoting contralateral choice, and therefore predicted that these cells would be most active before an ipsilateral choice. However, optogenetic identification (i.e., “optotagging”) and activation of channelrhodopsin-expressing GABAergic neurons revealed that GABAergic neurons are active before contralateral choices and driving their activity during the “choice epoch” biases mice to select the contralateral port. A biologically restricted attractor model recapitulated our behavioral results and supports a role for long-range inhibitory interactions between the left and right SC. Our work has revealed a neural mechanism for how the SC implements spatial choice.