第210回 創薬科学セミナー

Reusable Modular Architecture for Flexible Cognitive Operations in the Mouse Cortex

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場所：創薬科学研究館 4階 セミナー室

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Complex behaviors are thought to be built by combining simpler cognitive components. Theoretical modeling has shown that artificial neural networks can perform a variety of tasks by flexibly combining small functional modules of neurons, each specialized for a specific computation, to construct complex behavior. However, empirical evidence for such reusable modular networks in the brain has been limited. Here, we show that mice performing a delayed match-to-sample with delayed report (DMS-dr) task reuse neuronal subspaces that are specialized for stimulus processing and memory maintenance across different epochs and contexts. These subspaces were selectively reused to represent new information inputs and different types of memories, respectively, and clustering analyses revealed that each subspace was supported by a functionally distinct cluster of neurons in medial prefrontal cortex (mPFC).

To further examine how these modular computations are deployed across different behavioral contexts, we compared neural dynamics during active task engagement and passive stimulus exposure. This analysis revealed that contextual differences selectively modulated the memory-maintenance subspace while leaving the stimulus subspace largely unchanged. Consistent with this, data-constrained recurrent neural networks that captured the observed neural dynamics showed that contextual input specifically alters the attractor dynamics supporting memory representations. Gradual shifts in these attractor dynamics predicted behavioral performance, suggesting that internal states tune the accessibility of memory-related computations without disrupting the underlying modular organization.

By bridging theoretical predictions with empirical evidence, our findings demonstrate that the brain flexibly combines and reuses computational components, while dynamically tuning their deployment according to internal state and task context to support complex cognitive behavior.

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