Acquisition and Performance of Delayed-response Tasks: a Neural Network Model

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Abstract:
We study the time evolution of a neural network model as it learns the three stages of a visual delayed-matching-to-sample (DMS) task: identification of the sample, retention during delay, and matching of sample and target, ignoring distractors. We introduce a neurobiologically plausible, uncommitted architecture, comprising an ‘executive’ subnetwork gating connections to and from a ‘working’ layer. The network learns DMS by reinforcement: reward-dependent synaptic plasticity generates task-dependent behaviour. During learning, working layer cells exhibit stimulus specialization and increased tuning of their firing. The emergence of top-down activity is observed, reproducing aspects of prefrontal cortex control on activity in the visual areas of inferior temporal cortex. We observe a lability of neural systems during learning, with a tendency to encode spurious associations. Executive areas are instrumental during learning to prevent such associations; they are also fundamental for the ‘mature’ network to keep passing DMS. In the mature model, the working layer functions as a short-term memory. The mature system is remarkably robust against cell damage and its performance degrades gracefully as damage increases. The model underlines that executive systems, which regulate the flow of information between working memory and sensory areas, are required for passing tests such as DMS. At the behavioural level, the model makes testable predictions about the errors expected from subjects learning the DMS.

Keywords: computer simulation, executive control, Hebb rule, reinforcement learning, cognitive tasks, electrophysiological data