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Neural dynamics of probabilistic information processing in humans and recurrent neural networks

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In nature, sensory inputs are often highly structured, and statistical regularities of these signals can be extracted to form expectation about future sensorimotor associations, thereby optimizing behavior. One of the fundamental questions in neuroscience concerns theneural computations that underlie these probabilistic sensorimotor processing. Through a recurrent neural network (RNN) model and human psychophysics and electroencephalography (EEG), the present study investigates circuit mechanisms for processing probabilistic structures of sensory signals to guide behavior. We first constructed and trained a biophysically constrained RNN model to perform a series of probabilistic decision-making tasks similar to paradigms designed for humans. Specifically, the training environment was probabilistic such that one stimulus was more probable than the others. We show that both humans and the RNN model successfully extract information about stimulus probability and integrate this knowledge into their decisions and task strategy in a new environment. Specifically, performance of both humans and the RNN model varied with the degree to which the stimulus probability of the new environment matched the formed expectation. In both cases, this expectation effect was more prominent when the strength of sensory evidence was low, suggesting that like humans, our RNNs placed more emphasis on prior expectation (top-down signals) when the available sensory information (bottom-up signals) was limited, thereby optimizing task performance. Finally, by dissecting the trained RNN model, we demonstrate how competitive inhibition and recurrent excitation form the basis for neural circuitry optimized to perform probabilistic information processing.

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