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Neural population dynamics for hierarchical inference in mice performing the International Brain Lab task

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Abstract:
We study the neural basis of probabilistic binary decision making in mice performing the International Brain Lab task, which combines perception of noisy stimuli with tracking a slowly shifting bias in the probability that one of the two possible actions is correct. Performing well at this task requires performing hierarchical inference over disparate timescales separated over 1-2 orders of magnitude. We generate hypotheses for how the brain might solve the task by training a continuous-time recurrent

neural network. The model makes four key predictions we seek to test: First, the encoding of two key latent variables, stimulus side and bias side, is non-orthogonal, enabling interaction between the latent variables in a way that subserves hierarchical inference. Second, within-trial sensory evidence moves the neural state in the appropriate direction along both dimensions, albeit with different amplitudes that is related to the difference in timescales between the latent variables. Third, feedback from the previous trial, which in principle should enable more accurate inference of the bias, should have no effect on the integration of information. Fourth, that movement in the two-dimensional plane should display two kinds of dynamical behavior: within trials, sensory evidence drives the neural state to one of two discrete fixed points to infer one latent variable, whereas between trials, the neural state relaxes to a line attractor to infer the other latent variable. We test these predictions by first analyzing behavior from 342 sessions, quantifying performance metrics and showing a wide distribution of performance across mice. Next, we perform preliminary analyses of brain-wide Neuropixels recordings from 3 high-performing mice, and find they match these four predictions, with both model and mice exhibiting similar sub-optimalities relative to optimal Bayesian agents. Our findings shed light on the neural mechanisms involved in hierarchical probabilistic inference.

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