Title: Multi-region 'Network of Networks' Recurrent Neural Network Models of Adaptive and Maladaptive Learning

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Abstract Text:

Based on imaging in over 10,000 neurons across more than 15 regions imaged simultaneously in larval zebrafish during a novel behavioral challenge paradigm, we built and analyzed a recurrent neural network model constrained by the data from the outset. The model focused on activity in the habenula and raphe, identifying a significant and specific change in intra-habenular connectivity as a result of the behavioral challenge paradigm. We are extending this work to a whole-brain level multi-region recurrent neural network model and its accompanying theory of brain-wide control of adaptive to maladaptive state transitions. We consider the complex multi-dimensional interactions in the whole brain and relate them causally to behavior of the intact organism. We therefore present a new, more robust, scalable class of circuit models – multi-region neural network models, with support from a BRAIN Initiative/NIH Theories, Models, and Methods grant (1R01EB028166-01). These models are constrained by experimental data at two levels simultaneously: (a) large-scale neural dynamics – cellular resolution activity imaged from all 15 larval zebrafish brain regions – and (b) the behavior of the organism – tail movements tracked real-time in a range of behavioral states. We develop an innovative method for analyzing and visualizing essential features extracted from multi-region network models fit directly to these data, and derive from them the measurable signatures of brain-wide fluctuations that are causally predictive of transitions between behavioral states of the fish. Our findings demonstrate that theories and mechanistic models constructed in tight conjunction with data, as in this test case, will have far reaching applications for other studies using a range of collection methods and across nervous systems, even those sampled with differing levels of granularity.