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Session PSTR039 - Computational Modeling of Decision-Making and Learning

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PSTR039.02 / AA5 - Task-dependence of network-to-network variability in learning, performance, and dynamics of heterogeneous recurrent networks

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Abstract
Artificial recurrent networks (ARNs) are endowed with the ability to efficaciously process time-dependent information through feedback connections. Although ARNs have been useful in studying neural dynamics and representation of complex cognitive tasks, their composition and training protocols lack several features of brain networks. Chief among the several lacunae in ARN units is the absence of pronounced heterogeneities that biological neurons manifest. Here, we implemented a systematic framework to analyze task-dependence of the impact of neural heterogeneities on recurrent networks. We initialized multiple ARNs (200 units) with six levels of intrinsic heterogeneity in time constants (H0-H5), with H0 representing homogeneous networks and H5 being the highest heterogeneity level. We trained these ARNs using a reward-modulated Hebbian learning algorithm to perform six different cognitive tasks - Go, DlyGo, Anti, DlyAnti, MSDM, and DlyMSDM - one at a time. We compared the number of training trials required for convergence, task performance, and task-execution dynamics of the trained networks across levels of heterogeneities and hyperparameters. We found network-to-network variability in the impact of intrinsic heterogeneity on each metric. Importantly, network-to-network variability was pronounced in networks trained on complex tasks (memory tasks such as DlyGo), compared to those trained on simpler tasks (memoryless tasks such as Go). Finally, we tested these trained networks by introducing several post-training heterogeneities (in a graded fashion from P0 to P5) by altering the time constants, recurrent synaptic weights, initial activity, trial duration, activity perturbation, and the task performed. Of all the post-training heterogeneities tested, we found synaptic jitter to be the most detrimental. We found the robustness of these networks to depend critically on network initialization, intrinsic heterogeneity level, and task complexity. Overall, our analyses caution against strong generalizations on the impact of heterogeneities on training, performance, and resilience of ARNs, given the strong dependence of such impact on several factors including level of heterogeneities, form and extent of perturbations, network hyperparameters, and the specific task being executed. These observations strongly advocate a complex system framework to study the impact of neural heterogeneities on circuit function. In particular, we emphasise the need to focus on the global structure and interactions among different forms of heterogeneities in a system, rather than focusing on any one form of neural-circuit heterogeneity.