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Syntax Processing Properties of Generic Cortical Circuits

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Higher cognitive functioning is assumed to be largely representational and compositional in nature. At various processing stages, from perceptual to motor, discrete structural elements with intricate temporal dependencies are combined into increasingly complex constructs. In order to address these issues and to attempt to map these complex processes to the underlying neuronal infrastructure, we adopt ideas and formalisms developed by theoretical linguistics to study the nature of rule-like or compositional behavior. The Artificial Grammar Learning (AGL) paradigm has a long tradition as a means to study the nature of syntactic processing and implicit sequence learning. With mere exposure and without performance feedback, human beings implicitly acquire knowledge about the structural regularities implemented by complex rule systems.

In this work, we investigate to which extent generic cortical microcircuits can support formally explicit symbolic computations, instantiated by formal grammars and implementing various types of local and non-adjacent dependencies between the sequence elements, thus requiring varying degrees of computational complexity and online processing memory to be adequately learned. We use concrete implementations of input-driven recurrent networks composed of noisy, spiking neurons, built according to the reservoir computing framework and dynamically shaped by a variety of synaptic and intrinsic plasticity mechanisms operating concomitantly [1]. We show that, when shaped by plasticity, these models are capable of acquiring the structure of simple (regular) grammars. Additionally, when asked to judge string legality (in a manner similar to human subjects), the networks perform at a qualitatively comparable level.

1. Zheng P, Dimitrakakis C, Triesch J. Network self-organization explains the statistics and dynamics of synaptic connection strengths in cortex. PLoS Computational Biology 2013, 9(1): e1002848.