Statistical Learning in the Brain

June 12 – July 21, 2023

Abstract

The "Statistical Learning in the Brain" program was motivated by the need to lay theoretical foundations and develop experimental approaches for studying statistical learning in the brain. Progress toward those goals had been hampered by the isolation of communities working on statistical learning from theoretical, cognitive, and neurobiological perspectives. We felt that synthesizing those perspectives would lead to an appropriate theoretical framework. Theories would need to consider the limit of a very large number of interacting variables, as common in statistical physics, while also taking into account the computational complexity of learning algorithms, as well as worst case analysis.

The program made significant progress on multiple themes. First, consensus emerged on formal criteria for distinguishing statistical learning from other forms of learning in the brain. Second, participants presented theoretical frameworks for formalizing statistical learning mathematically: dynamical systems and statistical physics (including maximal entropy methods and neural manifolds), branches of machine learning (including reinforcement, Bayesian, and deep learning), and control theory (including data-driven control). Formal connections emerged between these seemingly distinct frameworks. Third, participants started working out the relation of formal mathematical constructs to concepts developed in psychology and cognitive science related to statistical learning. Fourth, the relevance for statistical learning of many fundamental neurobiological phenomena across species from insects to humans was spelled out, often for the first time: neural circuit organization and dynamics, representational drift, eye movements, stimulus-specific adaptation, and synaptic and intrinsic forms of plasticity. This allowed us to identify experimental strategies that we believe will be useful for future studies of statistical learning in the brain.

In addition to other collaborative work arising from the program, participants agreed to contribute papers summarizing their discussions to a special issue of *Current Opinion in Neurobiology*.