PROJECT: Modeling adaptive Bayesian priors and designing experiments to test the models (Philip Sabes, instructor)

The goals of this project are to gain experience using rate-based adaptive networks to model behavioral and neural function and to think about how to compare various versions of the model and/or how to test the models experimentally. Students should pick the elements of the project that appeal to them most. These include building one or more network implementations of adaptive Bayesian priors and using the network(s) as a model of a real neural system in order to devise physiological experiments that test the hypotheses behind the models.

1. **Build and adaptive Bayesian prior.** Verstynen and Sabes (2011) describe a neural network implementation of adaptive Bayesian priors. Specifically, Hebbian learning in the lateral connections of the network creates changes in the network dynamics that mimic adaptive Bayesian estimation. There are many other ways that this network could have been implemented, and a few are outlined here:

   a. Verstynen and Sabes (2011) use the line-attractor model published by Deneve, Latham and Pouget (Nature Neuroscience, 2011), which was shown to approximate maximum-likelihood estimation. To achieve adaptive Bayesian estimation, Hebbian learning was added in the lateral weights using Oja’s rule. Wu and Amari (Neural Computation, 2005) develop a very similar model using a different normalization scheme. Their scheme could also be used in the experimental context of Verstynen and Sabes (2011).

   b. Learning could occur at the inputs to the network, not in the lateral connections.

   c. An alternative network for Maximum Likelihood estimation is introduced in Ma et al. (Nature Neuroscience, 2006). Here, no dynamics are needed. Could this model capture the data in Verstynen and Sabes (2011), with learning on the input weights?

   d. Ma et al. (2006) suggest that Bayesian integration can be accomplished with a separate input that represents the prior information. Implementing this option would require designing that input and determining how it learns. In the simplest case, you could use a population code like that used for the sensory input, and the adaptive prior could be implemented with something like Equation 6 in Verstynen and Sabes (2011). More interesting adaptive networks could also be considered.

   One approach to this project would be to implement at least two of these and compare them based on their intrinsic abilities (e.g., ability to mimic adaptive Bayesian estimation) or based on their ability to capture the experimental data.

2. **Design a physiological experiment to test the model(s).** An alternative (or additional) approach to this project would be to treat the models as real neural systems and design behavioral/physiological experiments to test the basic underlying hypotheses (that the networks reflect adaptive Bayesian estimation) or to compare two or more implementations. What physiological measures (at the cell or population level) provide evidence of this form of learning? What level of detail between the models can be compared experimentally?