CNeuro2025 Lecture Abstracts

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Abstract 1 – Basic Lecture:

The Bayesian Brain: From Probabilistic Inference to Neural Codes

How does the brain represent and compute with uncertainty? This lecture introduces the **Bayesian Brain Hypothesis**, which posits that perception, cognition, and action are fundamentally probabilistic processes. We begin by reviewing the foundations of **Bayesian theory** and **Probabilistic Graphical Models**, establishing a conceptual and mathematical framework for understanding how the brain might implement these computations.

We then explore two major candidate theories of neural coding under uncertainty: **Probabilistic Population Codes (PPCs)** and **Neural Sampling**. Through these models, we discuss how probability distributions might be represented and manipulated in neural circuits. Finally, we introduce **Active Inference** and the **Free Energy Principle**, offering a broader theoretical framework that unifies perception and action under the umbrella of Bayesian inference.

This lecture integrates theoretical insights with empirical findings, drawing on seminal and contemporary work from computational neuroscience and cognitive science. By the end, students will be equipped with the tools to understand and evaluate probabilistic models of brain function, setting the stage for more advanced applications in the following session.

Abstract 2 – Advanced Lecture:

Build a Bayesian Brain from Scratch: Multisensory Perception through Probabilistic Neural Codes

In this lecture, we put theory into practice by analyzing **multisensory integration** through the lens of the Bayesian brain. Using a classic **cue combination task**, we show how the brain can optimally integrate information from multiple sensory modalities by weighting cues according to their reliability—an idea naturally captured by Bayesian inference.

We compare two computational strategies for implementing this: **Probabilistic Population Codes (PPCs)** and **Sampling-based Neural Codes**. Through this comparison, we explore how different neural coding schemes give rise to different implications for behavior and neural variability. We also discuss how concepts like **posterior inference**, **marginalization**, and **belief propagation** manifest in this context.

This session provides a concrete and accessible example of how Bayesian principles and neural coding theories converge to explain complex cognitive phenomena. The lecture will give students a deeper understanding of how probabilistic computations are grounded in neural activity, while also illustrating how to construct and analyze models that bridge theory and experiment.