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Non-Deterministic Computation Cortical Neuron Signaling Network using Thermodynamic Process

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DESCRIPTION

Probabilistic coding is used by neuronal populations in the cerebral cortex to effectively and efficiently encode the state of the surrounding environment. The outcomes of cortical neuron signalling are modelled as a thermodynamic process of non-deterministic computation in a new way because they are inherently probabilistic. The trial Hamiltonian is compared to a reference Hamiltonian in order to maximize free energy and minimize net temperature-entropy using a mean field approach. Throughout the computation, thermodynamic quantities are always conserved; Information production requires the use of free energy, which is released during information compression when correlations between the encoding system and its environment are discovered. Any increase in free energy is accompanied by a local decrease in membrane potential because of the connection between the Gibbs free energy equation and the Nernst equation. Consequently, this thermodynamic computation procedure alters the probability of each neuron firing an action potential. Through an energy-efficient computational process that involves optimally redistributing a Hamiltonian over some time evolution, this model demonstrates that noisy cortical neurons can achieve non-deterministic signalling outcomes. With net entropy production far too low to maintain the assumptions of a classical system, calculations demonstrate that this model of non-deterministic computation is consistent with the human brain's energy efficiency.

A cortical neural network must choose an optimal system state in the current context from a large probability distribution in order to compute the most likely state of the environment. With the help of random-connection models, factor analysis of spike variance over time, or Bayesian statistics, this inherently probabilistic computation has previously been modelled. The steady state firing patterns of individual neurons can be roughly approximated using the Hodgkin-Huxley equations. However, a cell's likelihood of reaching the action potential threshold is significantly influenced by channel leak and spontaneous subthreshold fluctuations in membrane potential. In point of fact, the classical limit that emerges from intrinsically stochastic processes is the relationship that the Hodgkin-Huxley equations provide between membrane voltage, ion conductances, and channel activation. Particularly noteworthy is the fact that cortical neurons actively maintain a coordinated "upstate," allowing electrical noise to control the outcomes of signalling. The mechanistic basis for achieving inherently probabilistic signalling outcomes across a cortical neural network is not well understood, despite the extensive literature on the statistical randomness of neuronal population coding and inter-spike variability. Cortical neural networks have been used to model probabilistic coding using mean field theory. The selection of a system state from a probability distribution can be accomplished through the exploration of the solution space made possible by this approach. The network reaches a fixed state at the mean field limit, where the excitatory and inhibitory contributions are balanced, and preventing fluctuations.

Friston's free energy principle is supported by this neural computation model, which provides a thermodynamic basis for the reduction of "surprise" during predictive processing. While earlier endeavours utilized factual techniques to demonstrate the innately probabilistic examples of cortical brain network movement, the current model conveniently shows how energy-effective nondeterministic calculation may be accomplished by keeping thermodynamic regulations.

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CONFLICT OF INTEREST

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