Stochastic Synchrony: Emergence of Brain Rhythms from Noise

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Brain rhythms

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Brain rhythms: why we care

- Synchronous brain oscillations are thought to encode, route and process information in the brain.

- Synchronous activity is important for cortical development and memory formation.

- Alterations of neuronal synchronization are associated with pathologies (e.g. epilepsy, Parkinson’s disease, schizophrenia).
Precision versus Variability

• Synchronous activity requires precise entrainment: timing is everything!

• Yet, neurons display a lot of spontaneous activity and there is evidence of considerable spontaneous release

How can collective, temporal order emerge from randomness?
Neuronal Synchrony in the Olfactory System

Network circuitry creates correlations of random synaptic events

Network circuitry creates correlations of random synaptic events

Stochastic nature of synaptic interactions

Stochastic synchrony (simulations)

R.F. Galán et al. (2006) *Sensors and Actuators B.*
Stochastic synchrony
(experiments)

R.F. Galán et al. (2006) *Sensors and Actuators B.*
Input-Output response

![Graph showing input-output correlation with lines representing simulation and experiment.](image)
A deeper look into stochastic synchrony

- Single cell properties that facilitate stochastic synchronization: integrators vs. resonators
- Features of noisy currents that facilitate stochastic synchronization
Optimal time scale for stochastic synchronization

(a) mitral cell
(b) pyramidal cell
Optimal time scale for stochastic synchronization II

![Graph showing the synchrony index over time for different models]

- Integrate-and-fire model
- Hodgkin-Huxley model
- Pyramidal cells
- Mitral cells

The graph plots the synchrony index against time (τ) in milliseconds (ms) for different neural models.
Brief appendix

Other examples of a constructive role of noise in biophysical systems...
I. Molecular motors: noise-induced transport

Image modified from Wikipedia

kinesin

potential energy

microtubule
I. Molecular motors: noise-induced transport

![Image modified from Wikipedia](image_url)

- ATP
- kinesin
- microtubule
- Potential energy
II. Stochastic resonance

Conclusions

• In biophysics and neuroscience, we need to reconsider the role of noise: random processes can be active, dynamic agents rather than destructive perturbations.

• In particular, here we have shown that random, but spatially correlated synaptic barrages create collective order in the form of neuronal synchronization.