Following stage II retinal waves during development with a biophysical model

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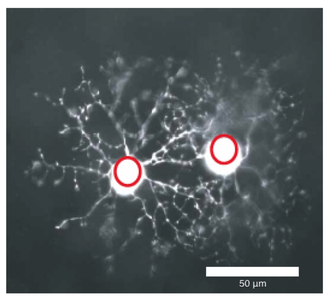
Abstract

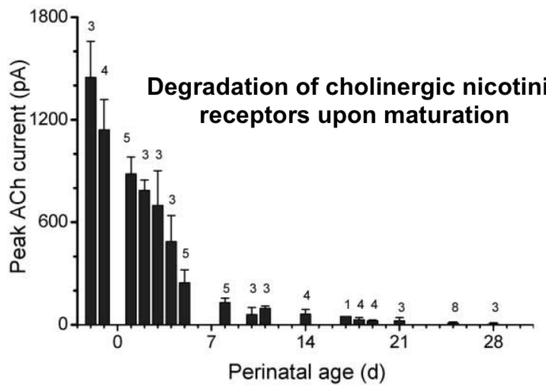
Retinal waves are bursts of activity occurring spontaneously in the developing retina of vertebrate species, contributing to the shaping of the visual system organization and disappear short after birth. Waves during development are a transient process which evolves dynamically exhibiting different features. Based on our previous modelling work [1,2], we now propose a classification of stage II retinal waves patterns as a function of acetylcholine coupling strength and a possible mechanism for waves generation. Our model predicts that spatiotemporal patterns evolve upon maturation or pharmacological manipulation and that waves emerge from a complete homogeneous state without the need of the variability of a neural population.

Context & Motivation

SACs dynamically change their synaptic coupling upon maturation



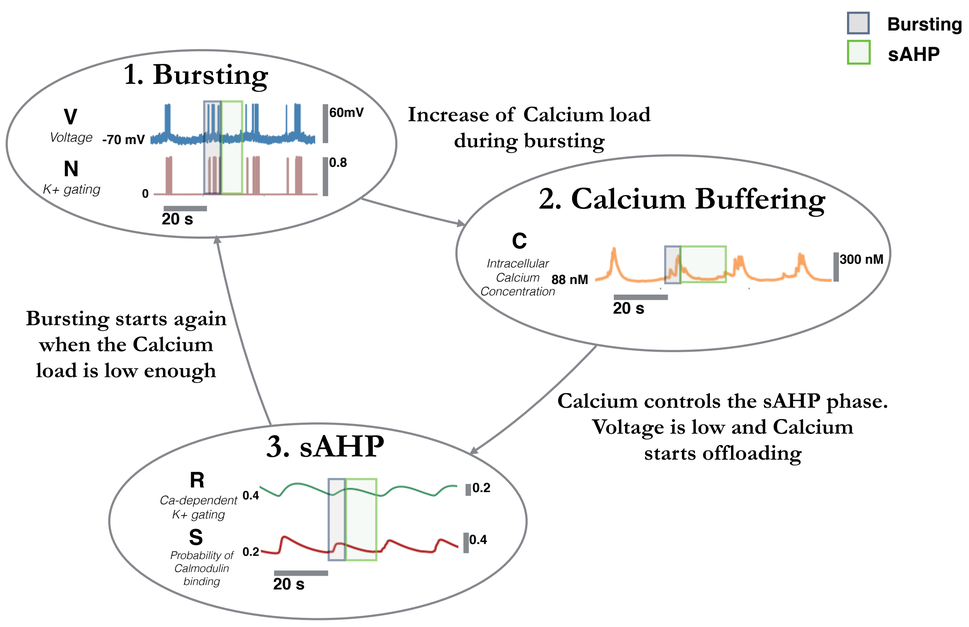
Coupled cholinergic SACs [3]



Cholinergic current evolution upon maturation [4]

A biophysical model for retinal waves

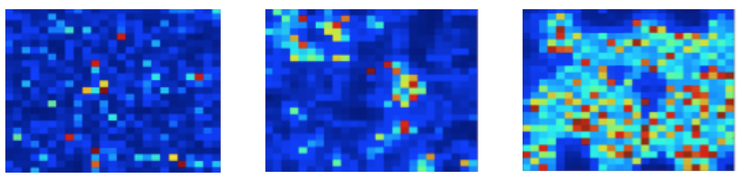
Spontaneous Bursting Mechanism of SACs



Our biophysical model reproduces experimental observations for individual and coupled SACs dynamics [3,4], where no previous computational model [5] has been able to do so before.

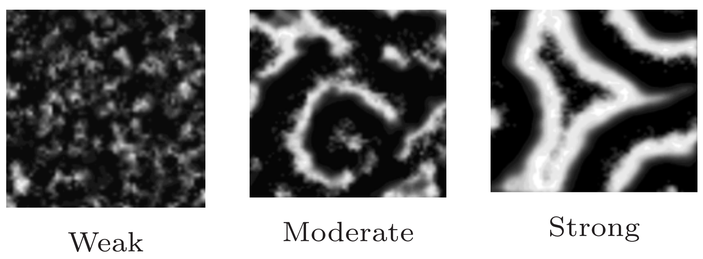
Network Simulations

Simulated Retinal Waves (Voltage)



Weak Moderate Strong

Simulated Calcium Waves

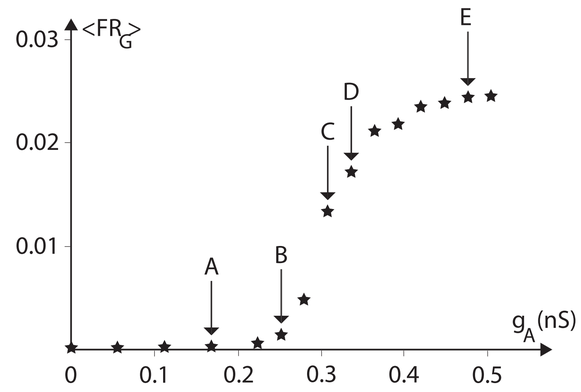


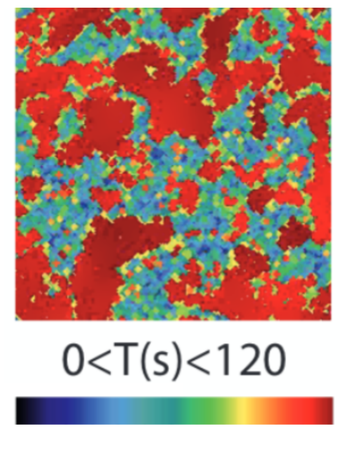
Weak Moderate Strong

- Simulated Calcium waves of 4096 neurons on a square lattice. Black and white colours correspond to low and high activity respectively. **Weak coupling:** localised bumps of activity. **Strong coupling:** complete synchrony standing waves. **Moderate coupling:** propagating patterns.

Following Retinal Waves Evolution

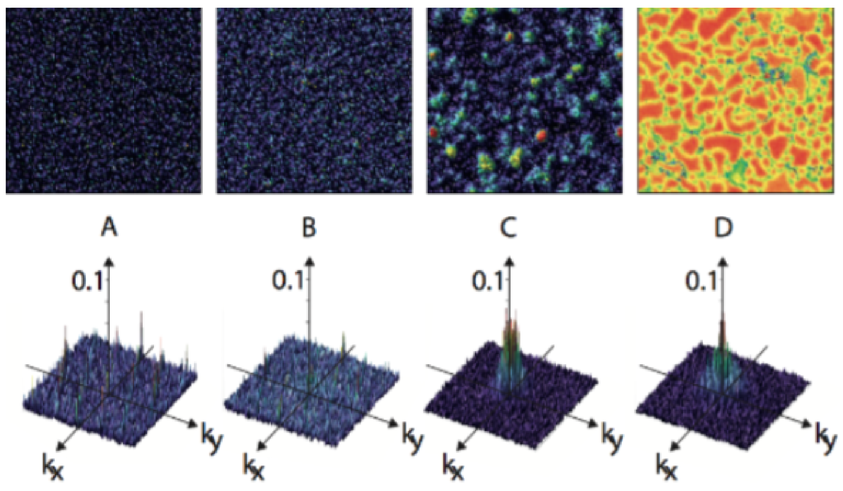
Average Population Bursting Rate





- The average population bursting rate exhibits a **sharp transition** upon increasing the cholinergic coupling
- Network simulations show patterns where waves do emerge (red) and where they do not (blue). A heat map of the average bursting period T, in seconds, of the network illustrates this observation.
- Domaines are formed where the propagation of waves is restrained, as observed experimentally in [7]. In contrast to what is shown in [7], our model describes these domains without the need to add two neural population species.
- Different types of spatiotemporal patterns are observed corresponding to each value of cholinergic coupling strength

Evolution of the spatiotemporal patterns



Evolution of the spatiotemporal patterns when increasing the cholinergic conductance (from left to right) starting from a completely homogeneous state where all cells are identical.

Conclusions and Perspectives

- Spatio-temporal patterns emerge out of a complete homogeneous state showing that variability in neurons is not the underlying drive of pattern formation.
- The role of variability in neural populations can be addressed from a computational aspect more easily.
- Biophysical parameters (e.g. conductances) could vary upon maturation or pharmacological manipulations, affecting the characterstics of emerging waves.
- A computational model able to follow the transitions of neural networks properties could help us gain a lot of insight in understanding the underlying mechanisms that drive them.

Acknowledgements

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