How the coupling strength of horizontal cells effects the retinal processing of spatio-temporal light stimuli - Model and experiments

Funding acknowledgement:
694829 - Microtechnology and integrated microsystems to investigate neuronal networks across scales (EC)
173728 - Visual processing in foveated retinæ in the presence of self-motion (SNF)
167989 - Position Dependence of Retinal Computation (SNF)

How the coupling strength of horizontal cells effects the retinal processing of spatio-temporal light stimuli - Model and experiments

*A. BUCCI[1], R. DIGGELMANN[1], M. ŽNIDARIČ[1], B. ROSKA[2], R. DA SILVEIRA[3], A. HIERLEMANN[1], F. FRANKE[1];
[1]D-BSSE, ETH Zürich, Basel, Switzerland; [2]IOB, Basel, Switzerland; [3]ENS, Paris, France

In the retina, photoreceptors (PRs) convert an input of light into electrical signals that eventually result in an output of spikes in ~30 types of retinal ganglion cells (RGCs). Natural images falling on the retina contain strong spatial correlations; therefore, PR activity is highly redundant. Lateral processing pools this redundant electrical activity in order to generate RGC spiking activity. The synapse between PRs, bipolar cells and horizontal cells (HCs) is the first location in the visual processing hierarchy where lateral processing occurs. Bipolar cells pool their input from multiple PRs and pass on the signal via parallel pathways to the RGCs. HCs (i) receive excitatory input from PRs, (ii) are strongly laterally coupled by gap junctions, and (iii) feed spatially averaged inhibitory signals back to the PRs. In this work, we combined theoretical and experimental approaches to investigate how HCs participate in the retinal processing of light stimuli that are not spatially uniform. We developed a model consisting of coupled differential equations, which describe the dynamics of interactions between PRs and HCs. In the model, PRs independently detect light levels, but are laterally connected to each other via HCs. The lateral connections between HCs are weighted by a coupling strength parameter that controls the lateral spread of electrical activity. We analyzed how the spiking activity of different model RGCs are affected by (i) removing HC feedback to the PRs and (ii) varying the coupling strength between HCs. Experimentally, we measured how HC feedback to the PRs shapes the spiking activity of RGCs by specifically and reversibly perturbing the activity of HCs. To do so, we used chemogenetics in ex-vivo experiments with mouse retinae. We monitored changes in the light-induced spiking activity of the very same RGCs before, during and after the perturbation by means of high-density microelectrode arrays. With our model, we elucidated the effect of lateral connectivity of HCs on neighboring PRs that are not directly excited, but still participate in visual processing. Ultimately, combining the approaches will help us to better understand the function of HCs in the presence of stimuli that are not spatially uniform.

Grant Support

Swiss National Science Foundation Sinergia Project CRSII5_173728

Swiss National Science Foundation Ambizione grant PZ00P3_167989 [F.F.]

ERC Advanced Grant 694829 “neuroX-scales”