Changes in inhibition explain cortical variability and its role in sensory representations
C. Stringer*, M. Pachitariu*, K.J. Hildebrandt, P. Bartho, K.D. Harris, J.F. Linden, P. Latham,
N. Lesica, M Sahani

The firing rate of a neuron in the mammalian cortex fluctuates in a way that depends strongly on
the activity of its neighbors. The nature of this relationship varies across behavioral states,
and affects the reliability of the neuron’s sensory representation. We found that the rich range of
statistical structures in multi-neuron recordings could be reproduced by different operating
regimes of a single deterministic network model of spiking neurons.

We fit the parameters of the spiking network model to the statistics of spontaneous and driven
activity from 47 different electrophysiology datasets of 20-100 neurons recorded in the
sensory and motor cortices of rats, gerbils and monkeys, using novel computational
techniques. First, we used graphics processing units to simulate networks of 512 spiking
neurons at 10000x real-time speed. Second, we used Bayesian optimization algorithms to
find parameters which best reproduced a collection of summary statistics for each dataset:
autocorrelation function, mean and variance of spike counts, and stimulus response.

The model successfully fit both the diversity of autocorrelation timescales and the magnitude
of the correlations present in the neuronal activity. To investigate the coding behavior of the
fitted networks, we drove them with external inputs. We consistently observed that noise
correlations within the same population were smaller for stimuli evoking high firing rate
responses than for stimuli evoking lower firing rate responses. This prediction was verified in
recordings from both awake and anesthetized auditory cortex.

Further, the lowest noise correlations of stimulus responses were present in simulations with
the largest inhibitory-to-excitatory firing rate ratios. The high inhibitory activity abolished
correlated fluctuations and enhanced coding properties. We investigated this relationship in
recordings from auditory cortex driven with auditory stimuli, where high levels of fast-spiking
inhibition did indeed correlate with large decreases in noise correlations. To confirm the role of
fast-spiking inhibition in stabilizing neural activity, we continuously activated PV-positive
neurons virally transfected with stable step-function opsin (SSFO) in auditory cortex, and
found that stimulus-independent coordinated population variability decreased.

Our modelling work suggests that networks with a common architecture can generate widely
different multi-neuron patterns depending on their precise parameters. These results provide
a computational tool for relating the statistical structure of multi-neuron recordings to neural
network connectivity and mechanisms.