

Synchronized excitation and inhibition during spontaneous and sensory evoked response in the rat barrel cortex

Michael Okun and Ilan Lampl

Weizmann Institute of Science

The firing of a cortical neuron is shaped by the fine balance and timing of excitatory and inhibitory inputs [8, 6, 5]. Yet, the instantaneous correlation between excitation and inhibition during spontaneous or evoked response remained unknown. In fact, due to the lack of such data some studies even assume that these two inputs are uncorrelated (or independent), e.g., see [7, 4]. The scarcity of experimental data is explained by the fact that extracellular recordings are not able to directly address this question, while the intracellular recordings can only present an average picture, by calculating the synaptic conductance from the averaged data obtained at different voltages [1, 8].

In this work we demonstrate a new approach which allows to present adequate real-time picture of the correlation between excitatory and inhibitory inputs to cortical cells. It is based on simultaneous intracellular recording from pairs of nearby neurons that receive similar synaptic inputs. We have performed a series of such recordings in the barrel cortex of halothane anesthetized rats (the spontaneous activity in this preparation is similar to the activity observed in awake animals [3, 2]). To find the extent of correlation between inhibition and excitation during spontaneous activity, the cells' membrane potential was recorded when both cells were hyperpolarized (activity dominated by EPSCs), depolarized (activity dominated by IPSCs) and when one cell was depolarized and the other hyperpolarized (in both possible combinations). A marked correlation between the cells' membrane potentials was observed in the first two cases. In addition, high (negative) correlation was observed between the hyperpolarized membrane potential of one cell and the depolarized membrane potential of the other. Together these observations imply that spontaneous EPSCs and IPSCs of individual cells are also highly correlated. The observed high correlation is due to two main factors. First, there exists a high temporal correlation between the EPSPs and IPSPs. In addition, the amplitudes of the excitatory and inhibitory events are also strongly correlated. In some pairs we also examined the correlation between excitation and inhibition in single trials during whisker stimulation. A strong correlation between the excitatory and inhibitory sensory evoked inputs of the cells was found, though for trials with small evoked EPSPs almost no inhibition was observed. Our results indicate that a strong coupling exists in the cortex between excitation and inhibition during both spontaneous activity and evoked responses. They also suggest that inhibitory inputs are evoked only when strong excitation is measured. These findings demonstrate the strength of our experimental approach in revealing the instantaneous excitatory-inhibitory dynamics of cortical activity.

References

- [1] Borg-Graham LJ et al., (1998) *Nature* 393(6683):369-73.
- [2] Crochet S and Petersen CC, (2006) *Nat. Neurosci.* 9(5):608-10.
- [3] DeWeese MR and Zador AM, (2006) *J Neurosci.* 26(47):12206-18.
- [4] Fellous JM et al., (2003) *Neuroscience* 122(3):811-29.
- [5] Shadlen MN and Newsome WT, (1998) *J Neurosci.* 18(10):3870-96.
- [6] Shu Y et al., (2003) *Nature* 423(6937):288-93.
- [7] Song S et al., (2000) *Nat. Neurosci.* 3(9):919-26.
- [8] Wehr M and Zador AM, (2003) *Nature* 426(6965):442-6