Synchronization as a mechanism for attentional modulation. 722.11

Jorge V. Jose[1,2], Paul Tiesinga[2], Jean-Marc Fellous[2], Emilio Salinas[2,3], Terrence Sejnowski[2]

(1) Physics department and CIRCS, Northeastern University, Boston, MA

(2) Sloan-Swartz Center for Theoretical Neurobiology, Computational Neurobiology Lab, Howard Hughes Medical Institute; The Salk Institute, La Jolla, CA

(3) Wake Forest University Medical School, Winston-Salem, NC

Introduction

Neuronal responses can often be written as a product of two stimulus features: firing rate=f(x)g(y). For instance, contrast (y) modulates the gain of the orientation tuning curve (x) (McAdams & Maunsell, 1999). Attention may modulate neuronal response properties in a similar way. When attention is shifted to the receptive field of a neuron, the firing of the neuronmaybecome more synchronized with other similar units, as observed in somatosensory cortex (Steinmetz et al (2000)) or with the local field potential at gamma frequencies as reported for extrastriate cortex (Fries et al (2001)). Here we explore the hypothesis that synchrony modulates the gain of neuronal responses.

Methods

Model neurons had Hodgkin-Huxley type sodium and potassium currents and a leak current (Wang & Buzsaki (1996)). Synaptic inputs were modeled as exponentially decaying conductance pulses. Decay time was ($GABA_A$) 10 ms and (AMPA) 2 ms. Model implementation was as in Tiesinga & Jose (2000). Experimental recordings from rat prefrontal cortex neurons were performedasinFellousetal(2001).

References

Fellous, J.-M., et al (2001) J. Neurophys., 85:1782-1787

Fries, P., et al (2001) Science 291:1560-1563.

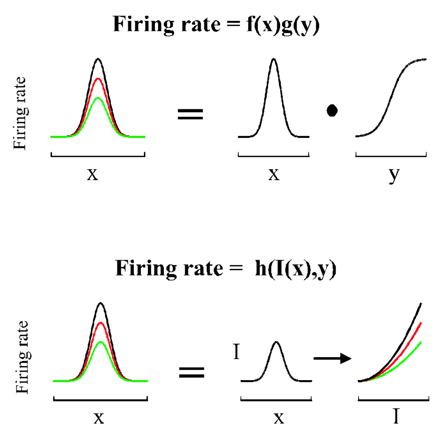
McAdams, C., & Maunsell, J. (1999) J Neurosci. 19:431-441.

Steinmetz, P., et al (2000) Nature 404:187-190.

Tiesinga, P., & Jose, J. (2000) Network 11:1-23.

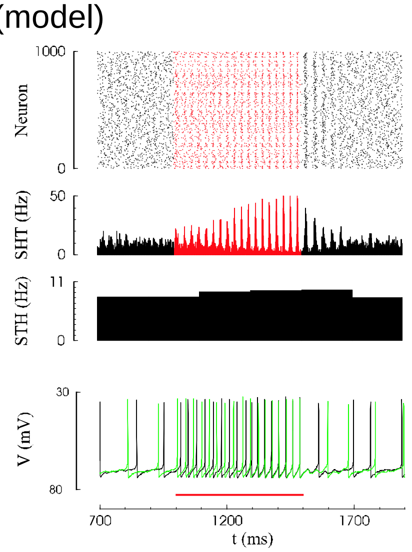
Wang, X. & Buzsaki, G. (1996) J. Neurosci. 16:6402 -6413

1



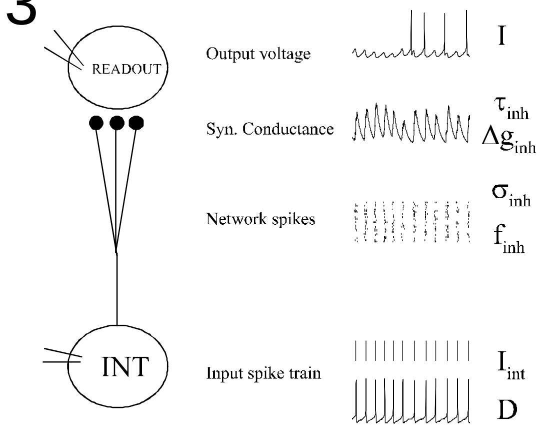
Single neuronmechanism for gainmodulation.

2 (model)



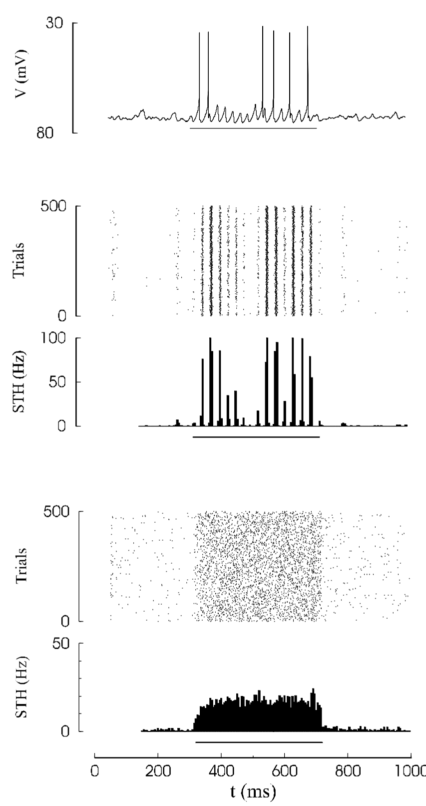
Uniform depolarization increased synchrony of interneuron network without changing the mean firing rate.

3



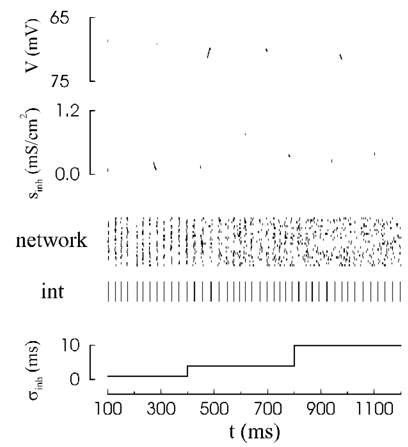
Synchrony of inhibitory input was characterized in terms of jitter σ_{inh}. Small jitter means high synchrony.

4 (model)



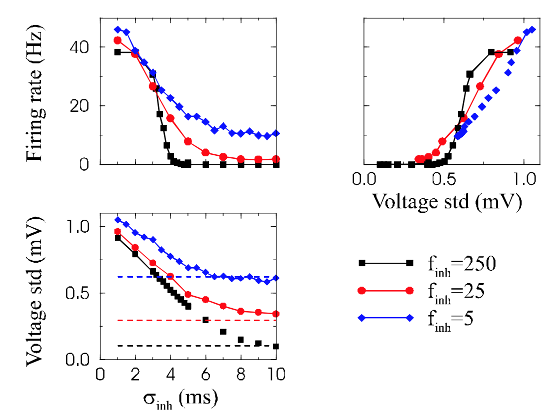
Transient increase in inhibitory input synchrony increased the firing rate of the readout neuron. The resulting discharge could be reliable or unreliable.

5 (model)



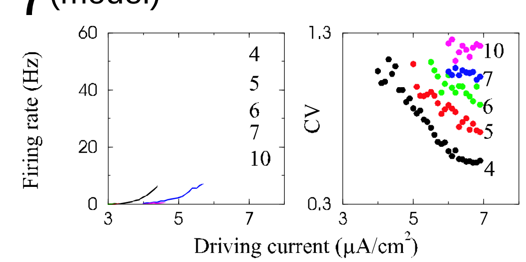
Voltage fluctuations decreased when synchronywasreduced.

6 (model)



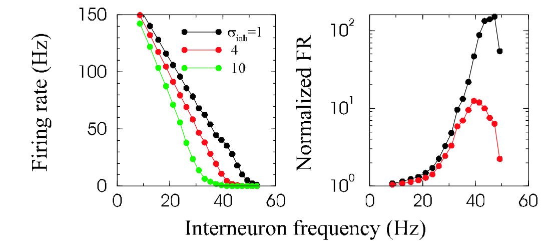
Variance of the voltage fluctuations determined the firing rate of the readout neuron.

7 (model)



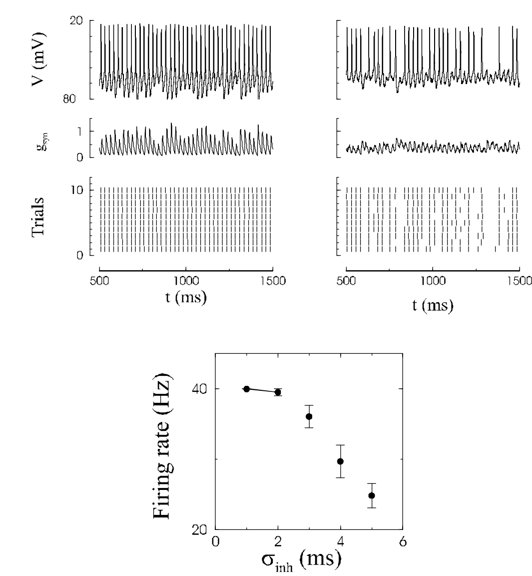
Gain of firing rate versus injected current curve increased with synchrony (σ_{inh} as labeled in graph).

8 (model)



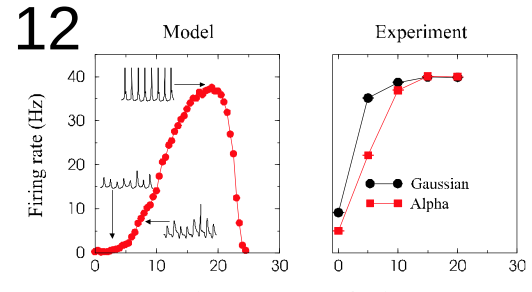
The increase of firing rate with synchrony depended on the interneuron network frequency.

9 (experiment)



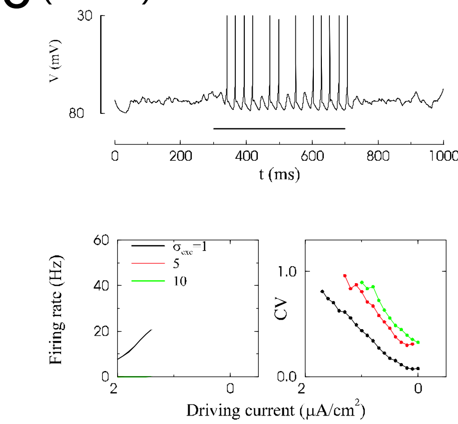
In experiment firing rate also increased with synchrony.

12



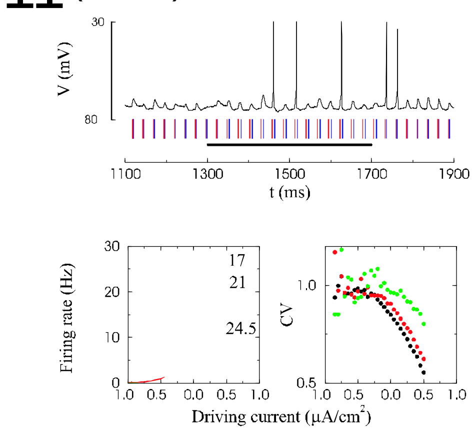
Firing rate of cortical neuron depended on relative timing between excitation and inhibition.

10 (model)



Synchrony of excitatory synaptic inputs also increased firing rate and gain of readout neuron.

11 (model)



Firing rate and gain of readout neuron depended on relative timing between excitation and inhibition.

Summary

- Firing rate and gain increased with the variance of voltage fluctuations.
- Voltage fluctuations increased with the synchrony of excitatory or inhibitory synaptic inputs.
- Voltage fluctuations also increased when excitation preceded inhibition.
- Modulation of synchrony or relative timing of excitation and inhibition with stimulus features or attention is a mechanism for gain modulation.
- Results were supported by recordings from cortical neurons in vitro.

Supported by the Sloan-Swartz Center for Theoretical Neurobiology and the Howard Hughes Medical Institute.