

## LETTER TO THE EDITOR

### *Neuronal Interspike Time Histograms for a Random Input Model*

Dear Sir:

It is currently accepted that the randomness of the interspike intervals of neurons may originate from either variability in the synaptic input or the spike production process or both. In a recent article (Levine and Shefner, 1977) an interesting model for retinal ganglion cells of goldfish was proposed and analyzed, in which the input was fixed and all the variability arose from the spike production process. The experimental histograms of intervals were found to be well fitted to "hyperbolic normal" densities or linear combinations thereof.

I wish to comment on the results obtained when the randomness is contained only in the synaptic inputs. The neuron under consideration has a trigger zone with depolarization  $V(t)$ . The model employed is a slight modification of the "leaky integrator" model, in that excitatory and inhibitory postsynaptic potential amplitudes depend on how close the membrane potential is to the corresponding reversal potentials. Let  $s$  be the time constant of decay: the model is summarized by the stochastic differential equation

$$dV(t) = -(V(t)/s)dt + g_E(V_E - V(t))dP(f_E;t) + g_I(V_I - V(t))dP(f_I;t),$$

with  $V(0) = 0$ . Excitatory and inhibitory inputs occur according to events in the independent Poisson processes denoted  $P(f_E;t)$  and  $P(f_I;t)$  where  $f_E$  and  $f_I$  are the corresponding mean rates. The reversal potentials are  $V_E$  and  $V_I$  and  $g_E, g_I$  are constants. The quantity of interest is the random variable  $T$ , which is the time at which  $V(t)$  first reaches or exceeds the threshold  $\theta$ .

The density of  $T$  is very difficult to find analytically for this model, though sometimes expressions can be found for the first few moments (Tuckwell, 1976). Hence computer simulations were performed for various amounts of excitatory and inhibitory inputs. Results are shown in Fig. 1 for two cases, where histograms of interspike intervals are plotted with time on a logarithmic scale. The parameters were  $s = 5.8$  ms, a typical value for central nervous system

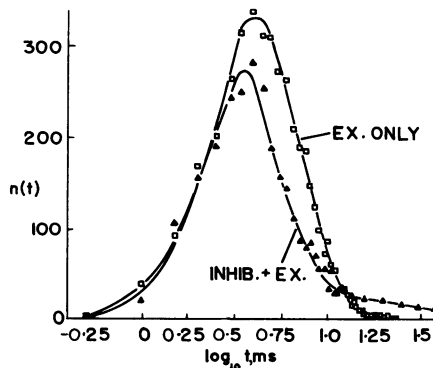


FIGURE 1 Histograms, with time plotted logarithmically, of interspike intervals obtained with the model neuron described above. The squares are for excitation only, triangles for excitation with inhibition.

(CNS) neurons,  $\theta = 12$  mV,  $V_E = 100$  mV,  $V_I = -10$  mV,  $g_E = 0.02$ ,  $g_I = 0.2$ . For both runs shown  $f_E = 8/s = 1,379$  s<sup>-1</sup> and for the run with inhibition,  $f_I = 4/s$ . A total of 4,000 simulated action potentials was obtained in each case.

The mean values of  $T$  were 5.83 ms and 14.6 ms. These correspond to fairly high firing rates but are not outside the physiological ranges of some CNS neurons. Lower firing rates lead to large amounts of computer time if reasonable sample sizes are to be obtained. The hand-drawn curves in the figure are unimodal, they have similar initial slopes, their modes are close (about 4 ms), and the medians differ by only 1.2 ms. It is apparent that the curve for excitation only resembles a normal curve, which implies that  $\log T$  is approximately normally distributed. For the run with inhibition,  $\log T$  is almost normal except for a pronounced tail (not shown in its entirety) at large  $T$ .

These histograms are plotted in the same fashion as those of Burns and Webb (1976) for experimentally determined spike trains of cerebral cortical neurons in spontaneous activity. Their histograms fell into two classes: one in which  $\log T$  was approximately normal and another in which  $\log T$  was nearly normal except for a preponderance of long intervals. The cells in the latter class were more slowly firing. A concrete conclusion cannot be drawn from the similarity of these two sets of results but the possibility is raised that the two classes of experimental histograms reflect the relative strengths of the excitatory and inhibitory synaptic inputs.

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HENRY C. TUCKWELL  
Department of Mathematics  
University of British Columbia  
Vancouver, British Columbia  
Canada