Lateral Inhibition Enhances the Detectability of a Pure Tone in the Presence of Background Noise

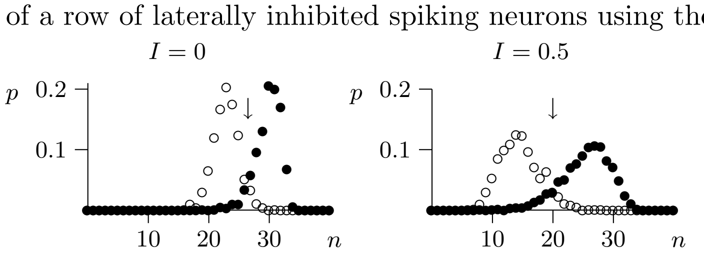
Jan-Moritz Peter Franosch and J. Leo van Hemmen

Physik Department der TU München, D-85747 Garching, Germany

It is well-known from vision that edges are enhanced by lateral inhibition. But what does "enhanced" mean? Not only that edges are amplified and noise is attenuated but also that an edge can be detected in the presence of background noise more easily with than without inhibition. Here we examine a simple model with tonotopically organized spiking neurons in the auditory system. We use a detector that only considers the firing rate of neurons. This detector shall discriminate between a stimulus with only background noise and a stimulus with an additional pure tone. Our simulations show that the detector performs much better with lateral inhibition between the neurons than without.

Haft [1] has shown that a linear retinal filter which preprocesses information effectively is characterized by an excitatory center and an inhibitory boundary. Here "effectively" means that after this special preprocessing an *ideal* detector can reconstruct the retinal picture thoroughly. It is not possible to exactly reconstruct the picture, however, because the detector has not enough data to do so (there are many more photoreceptors than ganglion cells in the retina). One may also say that the data the visual system has to process is reduced as much as possible while the information the visual system gets about its environment is not reduced so much.

An ideal detector may be, and in general is, very complicated. We therefore assume that lateral inhibition *is* already the detector, viz., a detector for edges or lines. Lines in the visual system correspond to pure tones in the auditory system. A natural task for the auditory system is to detect pure tones in the presence of background noise. (Most natural stimuli are not pure tones, but they contain tonal parts that have to be identified.) The simplest and, at least at the moment, most plausible detector is one that only considers the firing rate of a neuron in a row of tonotopically organized auditory neurons. Such a detector can be implemented on a neuronal basis very easily. It only has to fire if e.g. in the last 100 milliseconds more than a critical number of input spikes have arrived. If there is only background noise (open circles; see below), an input neuron's firing rate tends to be lower than if there is an additional pure tone (full circles) at or near the best frequency of the input neuron. The critical number of incoming spikes above which the detector votes for "there is a pure tone" is always optimally adjusted, i.e., the error rate of the detector is minimized. This minimal error rate, however, is even lower when additional inhibition between the neurons is switched on. We illustrate this in a simulation of a row of laterally inhibited spiking neurons using the spike response model [2]:



The probability p that an input neuron of a detector fires exactly n times during 100 ms is shown for both with (full circles) and without (open circles) an additional pure tone. More inhibition I leads to less overlap between the two probability distributions and, thus, less errors. ↓ indicates the discrimination criterion.

[1] M. Haft and J. L. van Hemmen, Theory and implementation of infomax filters for the retina, Network: Comput. Neural Syst. **9** (1998) 39–71

[2] W. Gerstner and J. L. van Hemmen (1994), in: *Models of Neural Networks II.* E. Domany, J. L. van Hemmen, K. Schulten, Eds. (Springer, Berlin)