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Sound encoding in auditory pathway, implications for cochlear implants

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We model lower parts of auditory pathway as a neural circuit consisting of neurons of several nuclei at lower stages of the pathway. We focus on neurons of lateral and medial superior olive, first binaural neurons from periphery in mammals [1]. Our aim is to estimate computational load of neurons. We introduce coding complexity of neuron as a set of four properties: 1) Input capacity, 2) output capacity (both measured as channel capacities in bits/s), 3) complexity of the neural operation (measured in number of steps with given input data) and 4) neuron memory (in bits).

By the term of "feasible coding complexity," we understand to mean a set of algorithms computed by single neurons that are performed with spikes under biologically feasible constraints of processing time, neuronal inner memory and input/output conditions. The level of detail in our model is chosen for studies of algorithms with plausible firing frequencies, spike duration and single neuron coding complexity. In previous work, we proposed neural algorithm for first binaural neurons in auditory pathway [2,3]. We used this algorithm as an example for our calculations. The algorithm is a probabilistic algorithm of binaural sound azimuth location [3] using one delay, instead of the Jeffress delay line [4] with series of delays. We observed that in our model, the succession of individual processing stages can be shuffled to simplify the implementation of the whole neural circuit and to maintain identical coding complexity at the same time. Based on this observation, we give quantitative measures (of coding complexity) of our algorithm. Using our algorithm, we reproduce some of the experimental findings in binaural neurons, corresponding to several neural response types. The experimental counterpart to our work discussing the origin of the delay used for determining azimuth, coincidence detection and other neural processing steps can be found in [5]. We study two types of neuronal responses in detail, excitatory and excitatory-inhibitory. Our algorithm can also use as input spike trains generated by cochlear implant (CI) [6] encoding strategies instead of spike trains from normal auditory processing at the organ of Corti. We compare outputs of our algorithm for several encoding strategies used by the nucleus type CI. We discuss some consequences of our findings for the binaural CI stimulation.

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