A Computational Model of Rapid Task-Related Plasticity of Auditory Cortical Neurons

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It has been recently shown that receptive field properties of neurons in A1 can be rapidly and adaptively reshaped during task performance in accord with specific task demands and salient sensory cues [1]. This change may be characterized as modulation of auditory cortical receptive fields that is behaviorally driven by attentive focus on salient acoustic features necessary for task performance. Such modulatory changes selectively enhance overall cortical responsiveness to the target sound and thus increase the likelihood of detecting the attended foreground target against the acoustic background. Distinctive changes in cortical tuning characterize different auditory tasks, reflected in the spectrotemporal receptive field (STRF) of neurons [1,2]. The auditory tasks include detection of a tone in a noise background [1], discrimination of two tones with different frequencies [2] and discrimination of a temporal change in the repetition rate of a click train [3,4]. Our data suggests that there is an attention-triggered neural plasticity algorithm in A1 that can swiftly change STRF shape by transforming receptive fields to enhance stimulus discrimination in a task-dependent fashion [4].

In this study, we used a mathematical model to calculate the changes in the STRFs needed for the optimal discrimination between any two classes of sounds. The neurons are modeled as filters that change their spectro-temporal tuning properties in order to extract the discriminatory features of two sound groups. The changes are optimal in the sense they maximize the quadratic distance between the responses of the neurons to two classes of sounds over the time course of the stimuli. In addition, we describe how this optimization can be achieved under any set of arbitrary constraints on the spectro-temporal properties of neurons reflecting the biological limitations and finite resources that set boundary constraints on the extent of neural plasticity, (e.g. limited synaptic input to a neuron or finite temporal integration). We tested the predictive power of the model in several spectral and temporal tasks. In the conditions tested, the predictions of the model matched the existing experimental data from behavioral physiology, consistent with the suggestion that A1 neurons change their tuning in an optimal way. In addition, we use the model to predict optimal receptive field changes for other more complex classes of sound that can further motivate experimental research to test and extend the model.

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References

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