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Adaptation in the anuran auditory system contributes to nonlinear response properties of peripheral and midlevel neurons

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Background

Male frogs use species-specific acoustic signals to communicate their reproductive and defensive potential to other frogs. The peripheral receiver of frogs is composed of two end organs, the amphibian papilla (AP) and basilar papilla (BP), which respond to different frequency ranges. The auditory nerve fibers (ANF) of the BP all tend to be tuned to the same high frequency. The fibers of the AP display a continuum of best frequencies from the low to mid-frequency range of the frog's hearing. The response properties of the ANF from the AP are similar in many ways to those of mammals however there are a few interesting differences. Both show adaptation to ongoing signals but only frog ANF display a trend of increasing speed of adaptation with increasing best frequency. Another frequency-dependent form of adaptation in frogs is revealed when signals other than best frequency are used. Signals higher than best frequency produce a more phasic response whereas lower signals produce a more tonic response [1]. As the information ascends the frog auditory pathway there is a gradual transition from a time-based to a rate-based code of waveform periodicity. The regularity observed in the intervals between discharges in ANF is replaced by band-pass tuning at the torus semicircularis (TS), the homologue of the mammalian inferior colliculus and the site of convergence of multiple parallel brainstem pathways [2].

Model

To examine how nonlinear properties in the anuran periphery influence responses in the brainstem and midbrain, we have created a 3-layer convergent network of leaky-integrate and fire neurons in Matlab (Mathworks Inc). Our model aims to determine the functional significance of frequency-dependent adaptation on masking, two-tone suppression (TTS) and frequency tuning. The peripheral tuning of the ANF is established with a bank of gamma tone filters centered at the best frequency of the fibers. Adaptation is implemented with a changing firing threshold in combination with a non-linear frequency function. Many ANF converge on a few medullary neurons that in turn project to a single TS cell.

Simulations reveal that the model accurately reflects the physiology at each layer and the inclusion of frequency-dependent adaptation accounts for the asymmetrical TTS seen in frog ANF without the need for additional nonlinear mechanisms.

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