Challenging the neural-fluctuation model for pitch using harmonic complexes in background noise

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Abstract

The ability of listeners to discriminate fundamental frequency (F0) of complex tones in background noise is a challenge for many models of pitch perception, especially those based on rate-place cues, or average rate as a function of characteristic frequency (CF). Pitch models based on temporal fine structure (TFS) of neural responses are expected to perform better in background noise but to fail as component frequencies increase above the range of strong phase-locking, as well as at low signal-to-noise ratios (SNRs). Here, we explore a model for pitch perception based on neural fluctuations (NFs), the slow fluctuations in the rate functions of auditory-nerve (AN) fibers. The NF model addresses some of the limitations of rate-place and TFS models. In this study, we challenge the NF model with additive background noise. The amplitudes of slow fluctuations in the responses of AN fibers to complex tones vary depending upon the proximity of the neuron's CF to component tones. The profile of AN fluctuation amplitudes along the tonotopic axis thus provides a neural representation of the stimulus spectrum. The AN fluctuation profile is ultimately mapped into a rate profile at the level of the midbrain (inferior colliculus) because nearly all midbrain neurons are sensitive to the amplitude of neural fluctuations on their inputs. This sensitivity is demonstrated by amplitude-modulation transfer functions, which illustrate the bands of modulation frequencies over which a neuron's responses to a carrier are enhanced or suppressed. Some neurons exhibit both enhancement and suppression over different modulation frequency ranges. Representations of harmonic stimuli in average rates of midbrain neurons have been shown to be robust in background noise and across a wide range of sound levels. Here, we modeled midbrain responses to harmonic complexes and background noises matched to stimuli used in perceptual studies. Discrimination thresholds were estimated using a decision variable based on a harmonic template applied to the average-rate response profile of the model midbrain. Preliminary tests show that a simple version of the NF model, based on only one population of midbrain neurons, comes close to predicting human F0-discrimination thresholds in background noise. We hypothesize that extension of the model to combine information across multiple types of midbrain neurons will be necessary to explain the impressive ability of listeners in this task. Comparisons to models based on rate-place and TFS cues will be presented.

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