HST.723J/9.285J - Neural Coding and Perception of Sound

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Dai (2000)

The question asked by this paper is: which harmonics contribute most to the overall pitch of a complex tone? This question is addressed by asking people to judge which of a pair of complex tones had the higher pitch. The trick is that both complexes have the same nominal fundamental frequency (and hence the same nominal pitch), but the frequencies of the individual harmonics are randomized in each complex. The idea is that the most dominant harmonics will have the most influence on the overall pitch and hence will influence judgments most. By correlating listeners judgments with the actual component frequencies on a trial-by-trail basis, it is possible to derive the perceptual "weights" listeners give each harmonic.

Darwin et al. (1995)

This paper serves as a reminder that not all pitch phenomena can be explained by simple transformations of auditory nerve activity. Normally, a little mistuning of one component within a harmonic complex will result in a slight pitch shift of the whole complex. This experiment shows that this does not occur if the mistuned component is perceptually segregated from the rest of the complex. The results show that some level of perceptual organization is taking place before a pitch estimate is made. Think about how one might incorporate these findings within a model of pitch perception.

Shamma and Klein (2000)

- This paper proposes a model for the formation of harmonic templates for the pitch of complex tones with resolved harmonics. Unlike previous models, harmonic templates are formed automatically even if the stimulus set presented to the auditory system contains no harmonic (periodic) tones. Once formed (either in development or over the course of evolution) the templates can be used to identify the pitch of both harmonic and inharmonic sounds.
- The model includes both a peripheral component (frequency tuning, hair-cell rectification and lowpass filtering) and a central component (lateral inhibitory network, cross-frequency coincidence array). Which of these components are essential to the function of the model and which ones are just embellishments?
- The paper also proposes a model for the pitch of complex tones with unresolved harmonics. Is it as convincing as the model for resolved harmonics?
- The central coincidence network cross-correlates temporal discharge patterns from every CF with those for every other CF. How could such a network be implemented in neural circuitry that would be consistent with known neuroanatomy?

Winter et al. (2001)

- This paper investigates the neural coding of iterated ripple noise (IRN, a.k.a. regular interval noise) in single-unit responses in the ventral cochlear nucleus (VCN) of the guinea pig. IRN is a convenient stimulus for studies of pitch because pitch strength can be varied parametrically by changing the number of "iterations," i.e. the number of times the noise waveform is added to a delayed version of itself. Moreover, because it lacks an exact periodicity, IRN precludes analyses with questionable neural plausibility such as period histograms. Here, responses to IRN are analyzed with first-order and all-order interspike interval distributions. The all-order interval distribution has been shown to provide a robust representation of pitch in the auditory nerve (Cariani and Delgutte, 1996).
- The main finding is that there is a larger number of intervals at the pseudoperiod of IRN stimuli, which evoke a strong pitch, than in response to broadband noise, which evokes no pitch. The degree to which this "interval enhancement" occurs is tuned with respect to the pseudoperiod, i.e. VCN neurons have a preferred period for IRN. This period tuning is seen in both first-order and all-order interval distributions, but is more prominent for first-order distributions. Moreover, for onset-chopper (OC) and sustained chopper neurons (CS), the preferred period for IRN correlates with the cell's "intrinsic periodicity" defined by the peak in the interspike interval distribution for broadband noise. These results suggest that OC and CS units may perform a form of periodicity detection relevant for pitch processing.
- While these results are interesting, they raise a number of questions: What are the neural mechanisms for computing the proposed interval enhancement metric? Is the observed periodicity tuning sufficiently fine to account for fine pitch discrimination? How robust is the preferred period of VCN units with respect to variations in stimulus level and spectral envelope? How does the range of periods represented in the VCN compare with the periods that evoke a pitch percept in the guinea pig?

Krumbholtz et al. (2003)

This MEG study uses a novel approach to identify auditory cortical areas involved in processing pitch. Most studies of neuromagnetic (and neuroelectric) responses examine activity evoked by the onset of sound. This study examines activity evoked when an on-going sound without pitch (random noise) changes to a sound with pitch (a “regular interval” (RI) sound). The RI sound was created from random noise by repeatedly delaying and adding the noise back onto itself. The pitch of the resulting stimulus corresponds to the inverse of the delay, while the pitch strength corresponds to the number of delay and add repetitions. The change from noise to RI sound produced a distinct neuromagnetic response that may reflect the activity of auditory cortical neurons involved in the detection and extraction of pitch. This interpretation is supported by the fact that the amplitude and latency of the evoked neuromagnetic signal varied with the pitch and pitch strength of the RI sound.

Penagos et al. (2004)

This paper examines the representation of pitch salience (i.e., pitch strength) in the human auditory cortex using fMRI. Subjects listened to harnonic tone complexes high- and low-pass filtered into stimuli comprising unresolved harmonics (producing a weak pitch) or resolved harmonics (strong pitch). Importantly, the study also included control stimulus conditions so that activation dependencies on physical stimulus differences could be dissociated from those related to perceptual differences in pitch salience. Contrasting fMRI activation between stimulus conditions revealed a cortical region sensitive to pitch salience that overlapped anterior Heschl's gyrus. This result is one of several implicating anterior non-primary auditory cortex in pitch processing.