Comments

Comment by Moore:

You showed that your model could account qualitatively for the pitch-shift effect described by De Boer and others. Recently, Geoff Moore and I showed that, when the stimuli are bandpass filtered to eliminate differences in excitation pattern of the test and matching sounds, the pitch shift occurred only for low and intermediate harmonic numbers and not for high harmonic numbers (around the sixteenth). Can your model capture this effect ?

Reply:

Based on your comment, we have investigated the predicted pitch based on the maximum interval enhancement of different Chop-S populations with chopping rates between 170 and 250 Hz in response to harmonics 14 to 30 of a fundamental frequency of 200 Hz as a function of the inharmonic frequency shift applied to each harmonic. Unlike the simulation results with low harmonics, these high, spectrally unresolved harmonics do not produce a systematic and monotonic change in the predicted pitch with changing degree of inharmonic shift. The predicted pitches are weak and they are always near 200 Hz. Thus, the current model is able to produce qualitatively correct predictions for the results by Moore and Moore (2003).

Moore, G. A. and Moore, B. C. (2003) Perception of the low pitch of frequency-shifted complexes. J. Acoust. Soc. Am. 113, 977-985.

Comment by Young:

The proposal that chopper neurons serve as periodicity detectors in pitch processing is interesting. The important physiologial property of choppers for this purpose is their regularity of discharge, which makes them selective for stimulus periodicities near the cell's preferred interval for discharge. A problem with this suggestion is that a chopper's preferred interval is 1/discharge rate. Choppers' discharge rates are strong functions of stimulus level and stimulus spectrum, so that for a complex stimulus like a vowel, the "preferred interval" of a chopper will vary as a function of the stimulus spectrum near the unit's BF. This effect is quite strong for complex stimuli, even though the chopper may seem to be saturated when studied with a tone (see May *et al*. 1998). Given this situation, how would the periodicity sensitivity of a chopper be decoded in terms of the pitch of the stimulus?

May, B. J., Prell, G. S., and Sachs, M. B. (1998) Vowel representations in the ventral cochlear nucleus of the cat: effects of level, background noise, and behavioral state. J. Neurophysiol. 79, 1755-1767.

Reply:

It is correct to point out that the temporal representation of the fundamental frequency of a harmonic in terms of its 1st-order, inter-spike interval characteristics is sensitive to changes in the unit's firing rate. Thus, the finding by May *et al.* (1998) does represent an interesting challenge for the current suggestion that temporal response characteristics of Chop-S units play an important role in pitch perception.

First, however, it must be pointed out that the suggested role in pitch perception applies to relatively low pitches with fundamental frequencies below about 500 Hz. The role of Chop-S units in the encoding of spectral envelope features applies to formants that are typically located at frequencies of 1 kHz and above. Thus, the encoding of the low harmonics numbers (which are the most important for pitch perception), is not likely to be affected by the unit's sensitivity to spectral envelope features. For higher harmonic numbers, however, it must be assumed that there will be interference between a Chop-S unit's rate-response changes in response to changes in the spectral envelope and the unit's sensitivity to the fundamental frequency of these high harmonics. Such interference, however, is also observed perceptually: It is difficult for listeners to estimate the low pitch of higher-order harmonics independently of spectral envelope and overall sound level. One example is the study by Walliser (1969) where it was shown that the pitch of a 300-Hz harmonic complex octave-band filtered around 4000 Hz depends significantly on sound pressure level. Another example is the occurrence of edge pitches.

An extensive study of Chop-S units with iterated rippled noise, where the spectral envelope is flat, has shown that (for these 'non-vowel' sounds) Chop-S units reach their rate saturation at relatively low sound pressure levels and they preserve their sensitivity to periodic sounds in rate saturation (Wiegrebe and Winter 2001).

May, B. J., Prell, G. S., and Sachs, M. B. (1998) Vowel representations in the ventral cochlear nucleus of the cat: effects of level, background noise, and behavioral state. J. Neurophysiol. 79, 1755-1767.

Walliser, K. (1969) Zusammenhänge zwischen dem Schallreiz und der Periodentonhöhe. Acustica 21, 319-329.

Wiegrebe, L. and Winter, I. M. (2001) Temporal representation of iterated rippled noise as a function of delay and sound level in the ventral cochlear nucleus. J. Neurophysiol. 85, 1206-1219.