Comments

Comment by Divenyi:

The importance of clear burst onsets for the discrimination of brief unfilled intervals has been known for some time (Divenyi and Danner 1977). It is reassuring to see that the clarity of these monaural cues maintains its importance, at least as the cat's inferior colliculus is concerned, when binaural bursts are cross-correlated for the purpose of localization.

Divenyi, P. L., and Danner, W. F. (1977) Discrimination of time intervals marked by brief acoustic pulses of various intensities and spectra. Perception and Psychophysics, 21, 125-142.

Reply:

Certainly the sensitivity to temporal envelope seems important for understanding the neural responses in the cat inferior colliculus, including those of low-frequency, ITD-sensitive neurons. The brief stimuli you used in your experiments would be expected to produce strong responses in many IC neurons. However, because your experiments differ from those we discussed in the nature of the task (signal detection vs. length discrimination), the type of stimuli (200-ms chirp trains vs. brief sounds), and the mode of presentation (monaural vs. binaural), further work is needed to draw convincing parallels.

Comment by Kollmeier:

Many aspects of binaural speech reception under spatial conditions are compatible with a two-sensor adaptive beamformer (e.g. Peissig and Kollmeier 1997; v. Hövel 1984). How much does your model deviate from the comparatively simple assumption of a delay-and-sum beamformer (with appropriate delay and gain) and an optimum detector matched to your signal condition?

Peissig, J. and B. Kollmeier (1997) Directivity of binaural noise reduction in spatial multiple noise-source arrangements for normal and impaired listeners. J. Acoust. Soc. A. 101, 1660-1670.
v. Hövel, H. (1984) Zur Bedeutung der Übertragungseigenschaften des Außenohres sowie des binauralen Hörsystems bei gestörter Sprachübertragung. Ing. Dissertation, RWTH Aachen.

Reply:

The beamformer and optimal detector is analogous in some respects to our neural model. The cross-correlation is mathematically similar to the delay-and-sum beamformer if the decision variable of the beamformer is based on energy (Colburn and Durlach 1978). The modulation sensitivity in our model could be thought of as a matched filter for the modulation in the signal, assuming that the neuron's best modulation frequency matches the signal's modulation rate. Such envelope processing does appear to improve the detection of signals in noise as one would expect from a matched filter system. On the other hand, an obvious difference is that the beamformer and matched filter are linear systems while auditory processing shows several nonlinearities. For example, the binaural cross-corrrelation is a nonlinear operation. Furthermore, in general, envelope processing is non-linear. In particular, our envelope processor depends on the auditory system's non-linearities to create energy at 40-Hz that can be processed to change the overall rate, and the modulation filter implementation that we used was non-linear. It is also worth noting that neurons in the IC are broadly tuned to modulation frequency and that the neural population shows a fairly narrow range of best modulation frequencies (Krishna and Semple 2000). Therefore, it may not be appropriate to assume that there is a complete bank of modulation filters matched to a wide range of envelope frequencies.

Overall, as an analogy, the beamformer followed by a matched filter may provide insight into binaural signal detection; however, differences in the linear system and the actual neural implementation may create real differences in the predictions of the two systems.

Colburn, H. S. and Durlach, N. I. (1978) Models of binaural interaction. In: E. C. Carterette and M. P. Friedman (Eds.), *Handbook of Perception, Volume IV.* Academic Press, New York, pp 467-518.

Krishna, B. S. and Semple, M. N. (2000) Auditory temporal processing: responses to sinusoidally amplitude-modulated tones in the inferior colliculus. J. Neurophysiol. 84, 255-73.