This Week in The Journal

Neural Synchrony and Understanding Speech in Noise

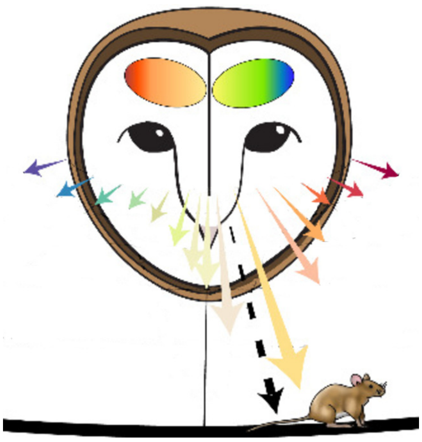
Kelly C. Harris, Jayne B. Ahlstrom, James W. Dias, Lilyana B. Kerouac, Carolyn M. McClaskey, et al.

(see pages 10293–10304)

Difficulty understanding conversation is a common complaint in older people. Sometimes hearing loss stems from loss of cochlear hair cells, as indicated by elevated thresholds for detecting pure tone stimuli. But many people with normal auditory thresholds have trouble comprehending speech in the presence of background noise. This impairment may result from loss or dysfunction of auditory nerve fibers. Indeed, aging in mice and humans is associated with the loss of synapses between auditory nerve fibers and hair cells and subsequent degeneration of nerve fibers. (Liberman and Kujawa, 2017, Hear Res 349:138). But Harris et al. suggest that it is loss of synchrony in auditory neurons, rather than loss of nerve fibers per se, that leads to deficits in speech perception in older adults.

Comparing auditory perception in young and older adults, the authors found that younger people were better able to detect small frequency modulations and to decipher condensed speech. The ability to understand speech in noise did not differ between age groups, however. Structurally, the density of the auditory nerve was greater in younger than in older people. And physiologically, the amplitude and width of the sound-evoked compound action potential in the auditory nerve increased with sound level in young people, and this effect was diminished in older people. In addition, neural synchrony in the auditory nerve increased with sound level in young people, but not in older people. Importantly, by using linear regression models, the authors determined that increased neural synchrony was associated with increased auditory nerve density and increased ability to decipher compressed speech and speech in noise, regardless of age. In contrast, differences in compound action potential waveform did not explain differences in nerve density or auditory perception.

The shape of the compound action potential is determined by the number and type of axons recruited by sound stimuli. Therefore, these results suggest that fewer nerve fibers are recruited with increasing sound volume in older than in younger adults, but this does not significantly affect speech comprehension. Instead, neural synchrony, which decreases with age, plays an important role in understanding speech.



An illustration of population vector coding in owl optic tectum. Each neuron is represented by a vector pointing toward its preferred direction (colored arrows). Because more neurons represent frontal than lateral space, the resultant vector is pulled frontally (dashed arrow), leading to underestimation of sound location.

Sound Localization in Owls

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(see pages 10305–10315)

Animals use differences in the time of arrival of sounds at each ear—the interaural time difference (ITD)—to localize sound sources. In barn owls, ITD information is transmitted to the optic tectum, which drives movements that orient the head toward the sound. Neurons in the optic tectum respond most strongly to sounds with a particular ITD, and they are organized topographically. Therefore, orientation behavior could theoretically be driven solely by the most active neurons. Owls' behavior is inconsistent with this hypothesis, however. Although owls accurately orient toward sounds arising in front of them, they consistently undershoot turns toward lateral sounds. This frontal bias increases with noise. To explain these observations, Fischer and Peña (2011, Nat Neurosci 14:1061) proposed that owls localize sounds by combining information from all optic tectum neurons, regardless of activity level. They conceptualized neurons as vectors pointing in the direction indicated by the preferred ITD with magnitudes proportional to neuronal spike rate, and they proposed that orientation is driven by a population vector created by summing the individual vectors.

A computational model based on this strategy reproduced owl orientation behavior, including the increase in frontal bias with increasing noise, if three conditions were met. First, a stimulus with a given ITD must activate a sufficiently broad population, producing weak activity in neurons preferring different ITDs. Second, more neurons had to be tuned to small (frontal) ITDs than to large (lateral) ITDs to pull the population vector toward frontal ITDs. And third, adding noise had to increase the spread of activation across the population, activating more (or more strongly activating) neurons tuned to small ITDs.

That frontal ITDs are represented by a relatively large population of optic tectum neurons has long been known, but the extent to which activity spreads across the population remained unclear. To assess this, Ferger et al. recorded auditory responses simultaneously from neurons with different preferred ITDs. Stimuli with a given ITD indeed activated neurons tuned to different ITDs. Moreover, the spread of activity increased with increasing noise. Most importantly, when single-trial population response profiles were plugged into the previously generated computational model, the model accurately estimated frontal ITDs and underestimated lateral ITDs. This supports the hypothesis that owls use a population-vector approach to localize sounds.

This Week in The Journal was written by Teresa Esch, Ph.D.

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