

Importance of Timing for Understanding Speech. Focus on “Perceptual Consequences of Disrupted Auditory Nerve Activity”

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Patients with auditory neuropathy can hear but they cannot understand. Their difficulties have been traced to timing-related deficits, revealing the importance of the neural encoding of timing cues for understanding speech. The absence of brain stem evoked responses indicates that firing of neurons in the early stages of the auditory pathway is abnormally asynchronous in these patients. Understanding speech reflects a higher brain function that is uniquely human. Knowledge concerning the mechanisms that underlie the recognition of speech can be applied not only to treating disorders but also to improving electronic devices for hearing impaired listeners and for the automated detection of speech. Despite its importance, the neuronal mechanisms that support the understanding of speech are not well understood. There is a gap between what is known about understanding speech in humans and what is known about signaling in auditory pathways that has been elucidated in animals that do not generally understand speech. A paper published in this issue of the *Journal of Neurophysiology* by Fan-Gang Zeng and his colleagues (p. 3050–3063) takes an important step in closing this gap. These investigators have identified a group of patients that have great difficulty understanding speech and have traced their deficits to abnormal functioning of the auditory nerve (Zeng et al. 2005). Their findings suggest that timing and synchronicity in firing of neurons in brain stem auditory pathways is important for understanding speech.

Patients with auditory neuropathy have difficulty understanding speech although their cochlear and cognitive functions have minimal deficits. Zeng and his colleagues show that these patients have difficulty with timing-related perception but not intensity-related perception. They have difficulties with discriminating pitch at low frequencies, temporal integration, detecting gaps, detecting modulation in amplitude, perceiving sounds in the context of sounds that precede or follow, detecting signals in noise, detecting beating when sounds to the two ears differ slightly in frequency, and using interaural time differences for localizing sounds. The deficits in patients with auditory neuropathy differ diametrically from the more common deficits that arise from damage to the cochlea and lead to disruption of intensity-related perception: hearing soft sounds, discriminating pitch at high frequencies, and using interaural intensity differences and spectral cues to localize sounds. Unlike the intensity-related deficits, those in patients with auditory neuropathy are not helped by hearing aids.

Auditory neuropathy was first diagnosed in an 11-yr-old girl (Starr et al. 1991). Although her hearing loss was moderate across all frequencies, she found speech to sound “weird, like spacemen” and had to learn to lip-read. She had difficulty

distinguishing vowels but could easily distinguish consonants with energy at high frequencies. The absence of brain stem-evoked potentials in the presence of normal cochlear microphonic and cognitive potentials suggested that synchrony and the timing or synchronicity of firing of neurons in the brain stem was disrupted. In 1999, these investigators presented a more comprehensive report on 10 patients with auditory neuropathy (Zeng et al. 1999). The presence of cochlear microphonic potentials and otoacoustic emissions indicated that cochlear function was relatively normal, yet these patients had great difficulty in recognizing words and were unable to detect brief gaps in noise. The present paper describes detailed psychophysical tests on 21 patients that document a clear and consistent pattern of deficits that are related to timing and synchronicity. Zeng and his colleagues point out that the deficits in patients with auditory neuropathy could result from either abnormal timing of firing (resulting from demyelination or abnormal synaptic function) or loss of auditory nerve fibers or both. Indeed, pathological examination of the inner ears in one afflicted patient whose problems were traced to a mutation in a myelin protein showed nearly normal hair cells but a >90% loss of spiral ganglion cells; some remaining auditory nerve fibers revealed incomplete remyelination (Starr et al. 2003).

It was discovered long ago that acoustic information is encoded in the timing of auditory nerve fibers (Galambos and Davis 1943; Kiang et al. 1965; Rose et al. 1967). Precision in the timing of signaling by auditory nerve fibers is not only preserved but sharpened in their targets in the ventral cochlear nucleus and along several of the auditory pathways through the brain stem up to, but not including, the inferior colliculus. Over the last three decades, the role of timing of firing for localizing sounds in the horizontal plane has been beautifully elucidated. The pathways from auditory nerve fibers to bushy cells in the ventral cochlear nucleus to the principal cells of the medial superior olive make interaural comparisons for computing the angle of incidence of a sound source onto the head (Carr and Konishi 1990; Joris et al. 1998; Young and Rubel 1983). In mammals, the sharply timed contralateral inhibition from the medial nucleus of the trapezoid body to the lateral superior olive is matched in latency to excitation from the ipsilateral ear in a circuit that makes comparisons in interaural intensity (Joris 1996; Tollin and Yin 2002). Octopus cells and their targets in the ventral nucleus of the lateral lemniscus detect and convey synchronous firing among auditory nerve fibers with exquisite precision, but their role is not understood (Covey and Casseday 1991; Oertel et al. 2000). The study by Zeng et al. suggests that the timing of firing along some or all of these pathways play a role in the perception of speech.

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