

# This Week in The Journal

## Temporal Coding after Hearing Loss

Kenneth S. Henry, Sushrut Kale, and Michael G. Heinz

(see pages 2227–2237)

The basilar membrane in the cochlea vibrates in response to incoming sounds. Low-frequency sounds cause more displacement of the apical portion of the basilar membrane, while high-frequency sounds cause more displacement of the basal portion. Thus, auditory-nerve fibers innervating different portions of the basilar membrane are activated by a narrow range of frequencies, giving rise to tonotopic coding. The frequency a fiber is most sensitive to is called its characteristic frequency.

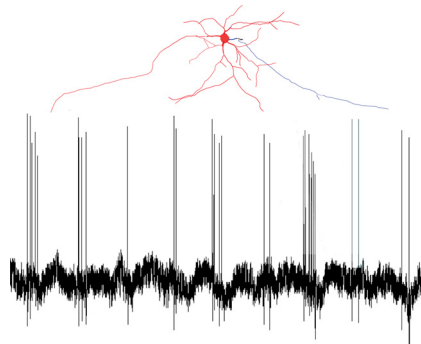
Natural sounds are composed of numerous frequencies that interact on the basilar membrane to produce complex vibration patterns over time. These vibrations can be separated into a rapidly varying component, called the temporal fine structure (TFS), and a slowly varying component, called the envelope. The firing rate of auditory-nerve fibers fluctuates with the envelope of complex sounds and with TFS frequencies up to 3–5 kHz.

Envelope cues make an important contribution to speech comprehension, but TFS is thought to enhance comprehension, particularly in noisy environments. The ability to comprehend speech in the presence of background noise is impaired in people with mild to moderate hearing loss, and this deficit has been hypothesized to stem from impaired TFS processing. Studies in animals have provided limited support for this hypothesis, however. This may be because these studies typically use narrowband stimuli unrepresentative of human speech. Henry et al. therefore used broadband Gaussian noise to investigate the effects of noise-induced cochlear damage on envelope and TFS coding in chinchillas.

As shown previously, noise-overexposed auditory-nerve fibers respond to a broader range of frequencies than normal fibers. As a result, unlike normal fibers that encoded TFS and/or envelope

within a narrow frequency range centered on their characteristic frequency, noise-damaged fibers locked onto TFS frequencies far below their characteristic frequency with abnormally high amplitude. Thus, tonotopic coding was distorted. Furthermore, the upper limit of tonotopic TFS coding was substantially reduced for broadband sounds. Effects on envelope coding were evident only with the most severe damage.

These results clearly demonstrate that TFS coding is distorted by noise-induced hearing loss, and thus help to explain the difficulties people with noise-induced hearing loss have in comprehending speech in noisy environments, where TFS cues are most important.



Head-direction cells are found in rat parasubiculum. Reconstructed dendrites (red) and an axon (blue) of a cell are shown above electrophysiological traces recorded juxtacellularly while the rat explored an environment. See Tang et al. for details.

## Anatomy and Physiology of Parasubiculum

Qiusong Tang, Andrea Burgalossi, Christian Laut Ebbesen, Juan Ignacio Sanguinetti-Scheck, Helene Schmidt, et al.

(see pages 2289–2301)

The hippocampus and parahippocampal structures are essential for spatial navigation and episodic memory. Studies in rodents have revealed that neurons in these regions respond to different types of environmental cues. For example, place cells respond when a rat is in a specific location in an environment, head-direction cells

fire when a rat is facing a particular direction, grid cells fire at periodic spatial intervals, and border cells fire at the boundaries of an environment. Most studies of spatially responsive cells have been conducted in the hippocampus proper and in the entorhinal cortex, which provides input to the hippocampus. But neurons with spatial responses have also been found in other areas, including the parasubiculum, which provides most of the input to the medial entorhinal cortex. Relatively little is known about the circuitry and function of the parasubiculum, however.

In their study, Tang et al. used several histological markers to show that the parasubiculum is longer than previously thought and unusually thin—only about as wide as one dendritic arbor. It is a three-layered structure, and in the most superficial two layers, neurons are grouped into large patches. These patches are interconnected by long axons that extend the entire length of the parasubiculum (~5 mm).

The parasubiculum receives inputs from the presubiculum, subiculum, and anterior thalamus. It also receives relatively dense projections from GABAergic medial septum neurons, which are thought to drive theta rhythms. Indeed, spiking of most parasubicular neurons was strongly locked to the theta rhythm. Moreover, parasubiculum neurons tended to fire at an earlier phase of the theta rhythm than neurons in the medial entorhinal cortex to which they project. Finally, electrophysiological recordings in freely behaving rats showed that the parasubiculum contains numerous head-direction cells, as well as grid and border cells.

These results suggest that the parasubiculum shapes the firing patterns of grid cells in the entorhinal cortex. In particular, the authors propose that the parasubiculum helps entrain grid cells to the theta rhythm and anchors grid cells to environmental borders. The groundwork provided by this study will allow further investigation into how the parahippocampal network enables spatial navigation.

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