Difficulty Hearing in Noise? Listen to the Brain

By Nina Kraus, PhD, and Travis White-Schwoch

Why do certain patients with normal audiograms struggle to understand speech in noise? It's a profile that goes by many names–auditory processing disorder, hidden hearing loss, and more–and to which volumes of research have been dedicated. Despite these efforts, a parsimonious explanation for this phenomenon is still lacking.

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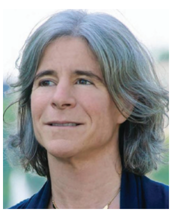
"Hidden hearing loss" refers to a relatively new hypothesis based on evidence that following acute noise exposure, hair cell function recovers. But the synapse between the ear and the brain do not. Thus, even if the cochlea is functioning normally, certain signals are not effectively transmitted to the brain. This elegant explanation is based on compelling physiological evidence in animal models. Still, there has yet to be a clear demonstration that the animals with this profile struggle to process signals in noise. This hypothesis has also been challenging to test in humans, given the unreliability of proxies for hidden hearing loss (such as Wave I of the auditory brainstem response or ABR) and the difficulty quantifying lifetime noise exposure.

Nevertheless, the hidden hearing loss hypothesis makes a strong prediction: If you test adults with normal hearing thresholds but have difficulty hearing in noise, you should see evidence that the initial ear-to-brain connections have deteriorated. Smith and colleagues tested this prediction in a study of 194 adults with normal audiograms.[2] They measured ABR Wave I, a putative measure of hidden hearing loss, along with questionnaires on lifetime noise exposure and hearing difficulties. They also tested subjects on the QuickSIN to gauge their ability to understand speech in noise. They found no evidence that Wave I amplitudes differed between subjects who reported a significant noise exposure and those who did not. Additionally, they found no evidence of correlations between speech-in-noise and Wave I amplitudes.



Dr. Kraus, left, is a professor of auditory neuroscience at Northwestern University, investigating the neurobiology underlying speech and music perception and learning-associated brain plasticity. **Mr. White-Schwoch** is a data analyst in the Auditory Neuroscience Laboratory (www.brainvolts.northwestern.edu), where he focuses on translational questions in speech, language, and hearing.

They also tested a competing hypothesis for why listeners have difficulty hearing in noise: poor high-frequency hearing.[3] This hypothesis contends that hair cell damage beyond the range measured by a standard audiogram compromises speech understanding in difficulty listening conditions. Indeed, extended high-frequency hearing thresholds (>8 kHz) show much more inter-individual variability than those in the range of a convention audiogram. Additionally, there is evidence that very high-frequency speech cues provide important redundancies to speech in noisy environments. While Smith and colleagues showed that listeners with noise exposure had slightly poorer high-frequency hearing thresholds (5 vs. 10 dB nHL at 12.5 and 14 kHz), they found no relationship to speech-in-noise performance.

It should be noted that the listeners in the study by Smith, et al., were not a clinical population. Perhaps listeners whose hearing difficulties are substantial enough to draw them to an audiology clinic would exhibit evidence in favor of one or both hypotheses. Still, Smith, et al.'s conclusions are in line with several other large-scale studies of hearing-in-noise abilities that suggest ruling out peripheral factors (e.g., *Hear Res.* 2018 364:142-151; *Int J Audiol.* 2018 S3-S32 [published online ahead of print, doi:10.1080/14992027.2018.1534010]).

This evidence suggests that neither hidden hearing loss nor high-frequency hearing loss compromise hearing-in-noise abilities in a typical population. What factors, then, underlie hearing-in-noise difficulties?

The answer may be in the central nervous system, both in terms of the precision of auditory encoding and in general cognitive abilities.[4] For example, listeners with better hearing-in-noise abilities have more robust encoding of key speech features such as the pitch, timing, and harmonics. Training to improve hearing in noise also boosts these aspects of auditory encoding.[5] There is also the view from cognitive hearing science.[3,6] That is, cognitive abilities such as working memory and attention are strongly linked to the ability to hear in noise—as they are to the neural processing of sound.

An intact auditory periphery is necessary to hear in noise; after all, it's necessary to hear. But it may not be enough. Fundamental aspects of the neural processing of sound, along with cognitive abilities, likely underlie speech-in-noise perception. Therefore, these should be key considerations in clinical evaluations and rehabilitation strategies.

References for this article can be found online at http://www.thehearingjournal.com.