cABR: A Framework for Intervention in Listening Disorders

By Nina Kraus, PhD, & Travis White-Schwoch

Auditory training works, but how do we make choices about the best course of training to ameliorate listening difficulties? This month's column offers a practical guide to how complex auditory brainstem response (cABR) can direct targeted auditory training on an individual basis.

cABR: A NEURAL SNAPSHOT

A cABR evaluation is performed similarly to a conventional ABR, except that responses are elicited to complex sounds such as speech, rather than to clicks or tones. By using a speech sound, a single cABR offers a rich biological tapestry of insights into the integrity of biological sound processing.[1] Several of these outcome measures exist, but here we focus on three: neural timing, pitch processing, and neural stability (see Table).

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- Neural timing is the most conventional ABR metric. The timing (also known as latency) of characteristic cABR peaks is identified. Unlike a click-ABR, however, the timing of several response peaks across a phoneme or syllable is considered. Fine timing details are crucial to distinguish speech sounds such as /b/ and /d/. Slower response timing is associated with language disorders—particularly phonological processing and literacy challenges—and also with auditory aging.[2,3]
- Pitch processing reflects the strength with which the fundamental frequency (F_0) of speech is encoded. "Locking on" to an F_0 facilitates speech understanding by directing attention to a single talker, which is vital to understand speech in noisy settings. Listeners with stronger pitch processing perform better on tests such as the Quick Speech-in-Noise Test and the Hearing in Noise Test.[4]
- Neural stability is an overall measure of the health of biological sound processing, examining how consistently the brain processes and responds to sound. Poor stability is associated with learning disabilities such as developmental dyslexia;[5,6] in addition, older adults have less stable responses.[7]


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**, right, is a data analyst in the Auditory Neuroscience Laboratory (brainvolts.northwestern.edu), where he focuses on translational questions in speech, language, and hearing.

cABR GUIDES INTERVENTION

Now that we understand three outcome measures from a cABR, we turn to the question of auditory training. The diversity of both training strategies and of listening difficulties makes it difficult to determine the best route for an individual patient. Our view is that identifying a cABR bottleneck can identify a weakness in neural processing. Addressing this weakness could improve communication skills, such as hearing in noise.

One strategy for auditory training uses computer technology to direct attention to fine-grained acoustic building blocks of speech. For example, Fast ForWord and Brain Fitness train the perception of subtle, fast-changing sounds, and Earobics emphasizes careful listening and phonological processing. Research has shown that these training programs improve neural timing, speech perception in noise, and language and cognitive skills in both children and older adults.[8,9] Converging evidence from animal models supports this conclusion.[10,11] This suggests that a neural timing bottleneck may indicate training that directs attention to the subtle details of sound by enhancing sound processing in the brain, which will facilitate better communication.

Another strategy for auditory training employs more complex linguistic tasks in difficult listening environments. For example, Listening and Communication Enhancement (LACE) exercises sentence perception in complex listening situations, such as when there is background noise, a competing talker, or rapid speech. Research has shown that LACE training can improve pitch processing and speech perception in noise.[12] Newer programs such as ReadMyQuips may confer similar gains. This suggests that a pitch processing bottleneck may benefit from training that emphasizes sentence perception in adverse listening conditions.

A third strategy for auditory training is to improve access to sound to facilitate active listening. For example, assistive listening devices can be effective to help children focus on a teacher's voice in the classroom. Research has shown that using a classroom FM system for one year improves response consistency and literacy skills in children with developmental dyslexia,[13] likely by teaching children to direct attention to meaningful sound. Although controversial, low-gain hearing aids and personal sound amplification devices may confer

Table. cABR offers a framework for intervention. Identifying bottlenecks in biological sound processing, such as neural timing, pitch processing, and/or neural stability, can inform strategies for auditory training. Although there are many off-the-shelf training strategies, this framework can also help tailor custom one-on-one regimens for an individual, in addition to the design of new programs.

cABR Measures	What It Measures	Strategy for Intervention
Neural timing	How quickly the brain processes sound	Direct attention to fine-grained sound features, such as the subtle contrasts between two consonants
Pitch processing	How well the brain processes the pitch (F_0) of sounds	Training higher-order linguistic cues such as words and sentences in challenging listening conditions
Neural stability	How consistently the brain responds to sounds across trials	Improve access to sound in everyday settings to teach a listener what is important to pay attention to in a complex soundscape

similar gains by clueing listeners in on what sounds in the environment they should pay attention to, and to connect those sounds to meaning. This suggests that a neural stability bottleneck may benefit from training that facilitates access and directs attention to sound in everyday settings. This cognitive engagement can refine automatic sound processing in the brain, facilitating better communication.

PUTTING IT ALL TOGETHER

Together, research over the past decade has not only established the potential for auditory training, but also demonstrated how electrophysiology can guide tailored interventions to address listening difficulties. cABR also has the potential to assess treatment outcomes in an individual, which is important because brain changes may precede behavioral changes.[14]

Finally, we highlight an important theme from each of these success stories of auditory training: cognition. The cognitive–sensorimotor–reward framework for auditory learning argues that effective interventions need to integrate sensory processing with cognitive functions (such as attention and memory) and reward cues (such as built-in feedback and reinforcement).[1] These factors are essential to optimize learning and should be considered when evaluating any strategy for auditory training.

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