Response timing and spectral encoding for speech-evoked auditory brainstem responses are highly reliable for assessing auditory function in children, providing hearing healthcare professionals a unique tool for research and clinical evaluation. Auditory brainstem function has been primarily assessed using a click stimulus since the 1970s because of the great response replicability within individuals. (Neurology 1994;44[3 Pt 1]:528.) The auditory brainstem response (ABR) collected in response to speech and other complex sounds (cABR) is gathered in the same fashion as the click-evoked ABR, except that the stimuli evoking the response are complex sounds of longer duration with temporally and spectrally dynamic acoustics. (Phys Today 2011;64[6]:40; Ear Hear 2010;31[3]:302.) This allows for an objective assessment of biological processes underlying auditory function and auditory processing deficits not revealed by responses to clicks.

The complex cues important for identifying which speech sounds were spoken (timing and harmonics) and who said them (pitch) are captured in the cABR, which, in fact, mimics the stimulus acoustics with such fidelity that the stimuli can be heard from a playback of the neural response. (Neuroreport 1995;6[17]:2363; see FastLinks.) The extent to which these pitch, timing, and harmonic cues are preserved in the response is linked to communication skills, such as reading and speech-in-noise perception, and can be altered with active experience with sound. Speech-evoked auditory brainstem responses enable objective assessment of biological processes underlying auditory representation of complex signals and of auditory processing deficits not revealed by responses to clicks.

A systematic study of the consistency of the speech-evoked brainstem response in school-age children had not previously been conducted, so we collected data twice during one year from 26 typically developing children aged 8 to 13. Response timing and spectral encoding were highly replicable over the course of that year. (Hear Res 2012;284[1-2]:52.) The consistency of response timing and spectral encoding suggests that the speech-evoked ABR is reliable for research and clinical assessment of auditory function, particularly for auditory-based communication skills. The potential utility of the speech-evoked ABR for clinical use is that it is reliable from test to retest among individuals, provides rich insight into real-world auditory processing by predicting communication skills such as speech-in-noise perception and reading, and reveals training-related changes in sensory function.

CONSISTENT ACROSS THE BOARD

We found that the speech-evoked ABR is consistent from test to retest in a manner similar to click-evoked responses. (Hear Res 2012;284[1-2]:52.) We assessed cABRs in children in response to the speech syllable /da/, and found no change over the course of one year in the timing, harmonic, or pitch representation of responses to speech in quiet or with background noise. (Figure 1). We found reasonable reliabilities for most of the timing, pitch, and harmonic measures, particularly those derived from automated processes compared with manually identified metrics that can be sensitive to the individual techniques of examiners. These effects were replicated when the data set was expanded to include children with learning impairments. (Hear Res 2012;287[1-2]:3.)

We found similar support of the stability of the cABR in young adults with normal hearing. (Clin Neurophysiol 2011;122[2]:346.) Consequently, the cABR, like the
click-evoked ABR, is consistent over time in various age groups. Analysis measures that rely on objective, automated calculations may be applicable to clinical settings because they have the highest reliabilities. Reliabilities are also good when including children with learning impairments, suggesting that cABR is a valid metric of auditory function for a variety of patients.

**MORE THAN HEARING THRESHOLDS**

cABRs are unique from click-evoked ABRs because they predict communication skills such as reading and speech-in-noise perception. Some children, such as those with reading impairments, have poorer auditory brainstem representation of timing and harmonics, important cues for distinguishing speech sounds. (Figures 2A & B; Cereb Cortex 2009;19[11]:2699; Neuron 2009;64[3]:311.) These deficits in auditory brainstem processing may contribute to documented impairments in basic auditory perception, problems identifying speech sounds, and impairments in phonological awareness in poor readers. (J Exp Child Psychol 2008;101[2]:137; J Cogn Neurosci 2011;23[2]:325.)

Children who are poor readers, for example, are more likely to show weak differentiation of three contrasting speech stimuli in their cABRs. (Proc Natl Acad Sci USA 2009;106[31]:13022.) Reading ability also correlates with response timing and representation of harmonics, with poorer reading ability associated with slower timing and weaker harmonics. (Neuroreport 2012;23[1]:6; Developmental Dyslexia: Early Precursors, Neurobehavioral Markers and Biological Substrates, Baltimore: Paul H. Brookes Publishing Co., 2012.) While good and poor readers differ on a variety of speech-evoked measures, they do not differ on click-evoked ABR measures, indicating it is only responses to the longer, more complex acoustic stimulus that reveal auditory impairments. (Audiol Neurootol 2006; 11[4]:233.)

Speech-evoked ABR measures also predict how well an individual can perceive speech in noisy backgrounds. Background noise makes the neural response slower and smaller, but those who perceive speech in noise well show less degradation. (Auditory Evoked Potentials: Basic Principles and Clinical Applications, Baltimore: Lippincott Williams & Wilkins, 2007; Hear Res 2010;270[1-2]:151.) Subcortical representation of the fundamental frequency, an important pitch cue, also predicts speech-in-noise perception in children and adults, with better pitch representation corresponding to better speech-in-noise perception. (Figure 2C; J Neurosci 2010;30[14]:4922; J Cogn Neurosci 2011;23[9]:2268.; Ear Hear 2012;32[6]:750.) Vocal pitch is a particularly resilient cue in background noise, and better neural representation of vocal pitch may help a listener track the voice in which he is interested.

**COMMUNICATION DEFICITS AND TRAINING**

Reading and speech-in-noise perception are auditory-based communication skills, and their neural profiles partially overlap. These
Auditory brainstem function can be shaped by experience, suggesting that auditory training could alleviate deficits in impaired populations. Lifelong experience with sound such as playing music and speaking multiple languages leads to a host of benefits in auditory processing skills, cognitive function, and the neural encoding of sound. (Proc Natl Acad Sci USA 2012;109[20]:7877; Nat Rev Neurosci;11:599.) Musicians, who have better speech-in-noise perception than non-musicians, have more robust cABRs in background noise. (J Neurosci 2009;29[29]:14100; Ear Hear 2009;30[6]:653.)

Improvement in speech perception with short-term training (e.g., Listening and Communication Enhancement [LACE] program) can be accompanied by strengthened cABRs in noise, even in young adults with normal hearing. (Cereb Cortex 2011;122[8]:1890; see FastLinks.) Children with reading and learning impairments can also benefit from computer-based auditory training or assistive listening devices, leading to gains in behavioral performance and improved consistency of the cABR from sound to sound. (Proc Natl Acad Sci USA in press; Behav Brain Res 2005;156[1]:95.) Children with the most abnormal responses before training are the ones who benefit the most, suggesting auditory training can alleviate their biological deficits. (Clin Neurophysiol 2003;114[4]:673; Proc Natl Acad Sci USA in press.) This line of research proposes that impairments in auditory processing can be reduced through auditory training and that the cABR provides an objective metric for tracking training outcomes.

The cABR may provide clinically valuable information for the assessment and remediation of auditory processing disorders and other auditory-based communication impairments. The observed reliabilities, particularly for clinically viable measures, recommend cABR application for these purposes and as a biological index of training-related change. Overall, the cABR can provide a biological snapshot of auditory processing that predicts auditory-based communication skills and gain with training. For more information on the auditory cortex, visit the auditory neuroscience laboratory, both at Northwestern University in Evanston, IL.

**FastLinks**

- Visit the auditory neuroscience laboratory at Northwestern University at www.brainvolts.northwestern.edu.
- Learn more about LACE at www.neurotone.com.
- **Click and Connect!** Access the links in *The Hearing Journal* by reading this issue on our website or in our new iPad app, both available at thehearingjournal.com.
- Comments about this article? Write to HJ at HJ@wolterskluwer.com.
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