cABR Can Predict Auditory-Based Communication Skills

By Jane Hornickel, PhD & Nina Kraus, PhD

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.

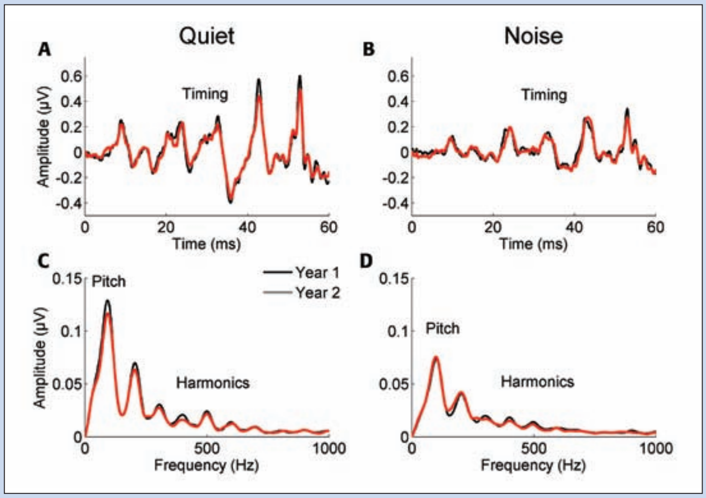

Figure 1. *Speech-evoked auditory brainstem responses (cABRs) show no change over one year in typically developing children aged 8 to 13. Responses to speech syllables presented in quiet (A, C) or with background noise (B, D) are stable from one year to the next (black vs. red lines). The response stability can be observed in cABR measures of timing (A, B), pitch, and harmonics (C, D). A similar level of test-retest stability is seen in children with learning impairments, suggesting the speech-evoked ABR is replicable during one year for typical and impaired populations. (*Hear Res *2012;284[1-2]:52;* Hear Res *2012;287[1-2]:3.)*

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 U S A* 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

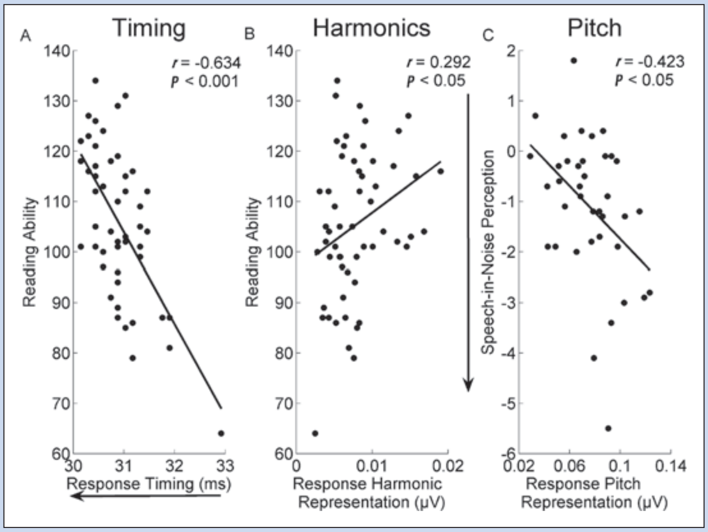

Figure 2. *Speech-evoked auditory brainstem metrics predict reading and speech-in-noise perception. Reading skills relate to auditory brainstem representation of speech timing and harmonics (A, B), with poor readers having slower response timing (A) and weaker representation of response harmonics (B). Timing and harmonic cues in the formant transition are important for distinguishing speech sounds, suggesting that these neural deficits may contribute to phonological awareness deficits in poor readers. Auditory brainstem representation of pitch relates to speech-in-noise perception, with those perceiving speech in background noise poorly having weaker representation of vocal pitch (C). Vocal pitch is a resilient cue that can be used to identify and track a voice in background noise, suggesting that those perceiving speech in noise poorly have impairments in representing this cue. The arrows in A and C refer to the direction of better performance. (*Ear Hear *2011;32[6]:750;* Hear Res *2010;270[1- 2]: 151;* Cereb Cortex *2009;19[11]:2699;* J Cogn Neurosci *2011; 23[9]:2268.)*

skills relate to the brain's ability to differentiate speech sounds neurally, and are linked to neural timing in response to the most acoustically dynamic portion of the syllable. (*Proc Natl Acad Sci U S A* 2009;106[31]:13022; *Behav Brain Res* 2011;216[2]:597.) Reading and speech-in-noise perception, however, have distinct neural signatures. Reading ability relates to cABR encoding of response timing and harmonics, and speech-in-noise perception tracks closely with pitch encoding. (*Cereb Cortex* 2009:19[11]:2699; *Hear Res* 2010;270[1-2]:151.)

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 U S A* 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 U S A* 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 U S A* 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.

Dr. Hornickel (left) is a post-doctoral fellow in communication sciences and disorders, and a member of the auditory neuroscience laboratory, and **Dr. Kraus** (right) is a Hugh Knowles Professor in communication sciences and disorders, neurobiology and physiology, and otolaryngology, and heads 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.
- See a demo of brainstem responses to complex sounds at http://bit.ly/ABRdemo.
- Learn more about LACE at www.neurotone.com.
- Visit *HJ*'s Student Blog at http://bit.ly/HJStudentBlog.
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