

## Hearing with Our Brains

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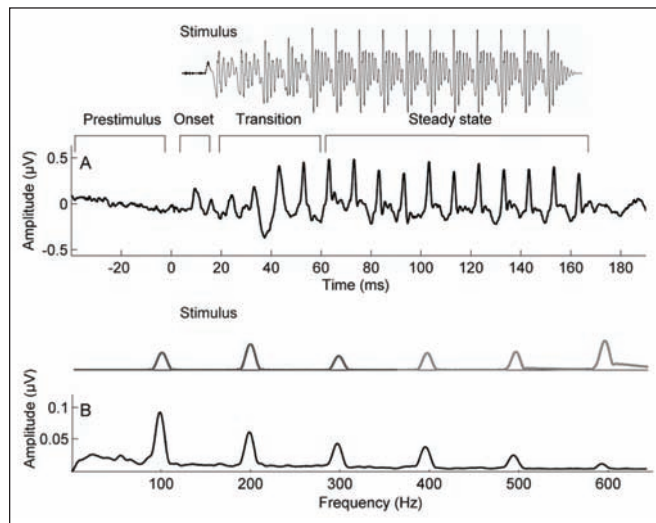
Scientists, clinicians, and others interested in helping individuals with hearing loss have become increasingly aware in recent years of cognition's role in our ability to hear, especially in background noise. The phrase "we hear with our brains, not with our ears" can be an important counseling tool when working with those with hearing loss.

Evidence from auditory neuroscience research confirmed behavioral findings of suprathreshold deficits in speech processing in the absence of peripheral hearing loss deficits. (*Ear Hear* 2011;32[6]:750; *PNAS* 2011;108[37]:15516; *J Speech Hear Res* 1993; 36[6]:1276; *Int J Audiol* 2003;42:11.) We need to approach our patients with the knowledge that the audiogram, while necessary and useful, provides information only about the early stages of auditory input. Other factors along the auditory pathway may influence the ability to communicate successfully in noise and to profit from traditional approaches to remediation that emphasize increased audibility.

We developed analysis techniques for objective evaluation of suprathreshold processing at the Auditory Neuroscience Laboratory at Northwestern University in Evanston, IL, using the auditory brainstem response to complex sounds (cABR). (*Physics Today* 2011;64[6]:45.) The term cABR can be confusing to clinicians because we are accustomed to a time scale of up to 20 ms for the brainstem response. This time scale, however, refers to the response to transient elements such as the click stimulus or the onset of a speech syllable. The brainstem, likely the inferior colliculus, is also capable of generating the frequency following response, with responses that last up to several hundred ms and phase locking up to 2,000 Hz.

The cABR has advantages for assessing the auditory system's ability to process speech in noise because of the brainstem's temporal and spectral precision. (*J Neurosci* 2007;27[23]:6091.) The cABR, in fact, is visually and acoustically similar to the evoking sound, allowing for evaluation of the auditory system's representation of pitch, timing, and timbre. The figure shows that the periodicity of the stimulus (speech syllable [da]) is reflected in the response with peaks occurring every 10 ms. The fundamental frequency (100 Hz) and its integer harmonics are also faithfully represented in the response.

You may wonder why we are so interested in the brainstem if we "hear with our brains." The brainstem is called the reptilian brain, reflecting its evolutionary place of emergence. The extensive network of afferent pathways through the brain are matched or exceeded by efferent projections, hinting at the important role of brainstem sensory learning and top-down response modulation. The critical role of the inferior colliculus of the brainstem for auditory learning has been demonstrated in animal models. (*Nat Neurosci*



**Figure.** The periodicity of the stimulus (speech syllable [da]), the fundamental frequency (100 Hz), and its integer harmonics are reflected in the response with peaks occurring every 10 ms.

2010;13[2]:253.) Although recording brainstem responses can be done in a passive participant, the cABR itself can be considered a snapshot in time of auditory processing, reflecting sensory input, cognitive function, and the ways in which sound has been used throughout life.

We will highlight methods in future columns for evaluating the robustness of neural responses, such as phase analysis, which are more objective and less time-consuming than the traditional method of marking peak latencies. We will explore the brainstem use and cortical measures for clinical impairments, such as difficulty hearing in background noise, central auditory processing disorder, and language-based learning impairments. Like the traditional ABR, the cABR is meaningful in individuals, making it an effective instrument for documenting training-induced enhancements or deterioration resulting from disease. We will discuss its use for documentation of aural rehabilitation outcomes, and our next column will consider its application for evaluating the efficacy of different hearing aid algorithms during hearing aid fitting. [\[1\]](#)



**Dr. Kraus** (left) is a professor of auditory neuroscience, investigating the neurobiology underlying speech and music perception and learning-associated brain plasticity, at Northwestern University in Evanston, IL. **Dr. Anderson** was a clinical audiologist for 26 years before entering the doctoral program at Northwestern University in 2007. She will join the faculty at the University of Maryland in January, where she plans to continue her research on the effects of hearing loss and aging on neural processing in older adults. Read more about the work being done at Northwestern University at [www.brainvolts.northwestern.edu](http://www.brainvolts.northwestern.edu).