Embracing the Enigma of Auditory Processing Disorder

By Nina Kraus, PhD, & Travis White-Schwoch

The term "auditory processing disorder" (APD) often evokes controversy, confusion, and consternation. Go to a conference or workshop on APD and you're likely to hear: How can we diagnose it? What should we call it? Is it even in the auditory system? What can we do about it? Should audiologists manage it? Does it even exist?

We think that APD is real, and that audiologists are well-equipped to play a chief role in its diagnosis and management. But the never-ending controversy suggests that the current approach to APD diagnosis and treatment isn't working. Instead of using a *test-based* or *site-of-lesion-based* framework, we want to propose a *functional* framework for evaluating APD. Our goal in this framework is to provide flexibility for the clinician's judgment in the best tests, and, eventually, to map functional listening difficulties onto treatment strategies. This framework approaches each case of APD like a puzzle. There is no one-size-fits-all approach to puzzles; rather, we need a general set of strategies and heuristics.

First, we need a working definition of APD. We consider APD to be difficulties in everyday listening that often manifest as trouble hearing in noise, following oral directions, and/or paying attention that cannot be remediated by restoring audibility.

Next, we think that a good APD assessment has to address three questions:

1. Are sounds getting in?
2. How accurately are those sounds being processed?
3. How well can an individual make meaning from those sounds?

An advantage to this framework is that it does not restrict an evaluation to a specific test battery or patient population. Tests can be selected based on a patient's age, the clinician's expertise, and the patient's presenting complaints. Another advantage of this framework is that it includes individuals with hearing loss among those who may have APD. We realize this is unconventional–typically, APD refers to patients with normal hearing thresholds. But consider, for example, an older adult who is struggling to understand speech in noisy environments. We know that auditory processing declines before presbycusis emerges. An older adult may come to the clinic and be a good candidate for amplification, but we should not assume that will be sufficient to address listening difficulties.

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Questions 1 and 3 are relatively straightforward to evaluate. Audiometry tells us if sounds are getting in, and behavioral tests tell us how well an individual makes meaning from auditory input.

Question 2 can be a bit more challenging, however. One approach is the *frequency-following response* (FFR; also known as the *auditory brainstem response to complex sounds, cABR*). The FFR is a measure of sound-evoked synchronous brain activity that shows the integrity with which sound features are processed in the brain (Kraus. *Trends Cogn Sci* 2015;19[11]:642). Many of our columns highlight how different FFR ingredients map onto different sound ingredients. The FFR is as complex as the sound that evokes it, meaning when it is elicited to a speech sound we can unpack the biological processing of any acoustic feature that conveys meaning in speech. Importantly, the FFR provides fine-grained insight into individual differences in sound processing.

How can you get started with FFRs? The good news is that they are collected very similarly to ABRs–three electrodes are placed on the scalp and an earphone is inserted into the right ear. A basic FFR protocol uses a brief /da/ sound as the stimulus and collects two runs of 3,000 trials in alternating polarities. The advantages of using this stimulus include the speed of the protocol (10 minutes of data collection once the electrodes are on), high test-retest reliability, and published norms from birth to age 72 years (Skoe. *Cereb Cortex* 2015;[6]:1415.). Free software is available to automatically analyze several response ingredients (www.brainvolts.northwestern.edu).

One of the advantages of the FFR is that a single test offers a wealth of information about an individual's strengths and weaknesses in auditory processing. Although there are many aspects of the response that can be analyzed, a simple protocol involves three domains:

(1) Response timing–how quickly is the speech sound processed? The response to the /d/ includes six stereotyped response peaks, whose latencies can be evaluated and compared to norms. These peaks correspond to processing the *onset* of sound, the perceptually-vulnerable *transition* from a "d" to an "a," and the *offset* of sound. Importantly, these peaks operate somewhat independently–just because an onset response is late does not mean a transition response will be late too. Response timing tracks with language and phonological skills, and is boosted by auditory training (Russo. *Behav Brain Res* 2005;156[1]:95; Banai. *Cereb Cortex* 2009;19[11]:2699; Anderson. *Proc Natl Acad Sci USA* 2013;110[11]:4357).

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(2) Fundamental frequency (F0)—how robust is the response to the F0? The F0 is a vital cue for real-world listening – it facilitates auditory object identification, grouping, and tracking. It also contributes to pitch perception and talker identification. Across the lifespan, the strength of F0 processing tracks listening-in-noise skills (Anderson. *Hear Res* 2010;270[1]:151; Anderson. *Hear Res* 2013;300:18). F0 processing is boosted by explicit listening-in-noise training (Song. *Cereb Cortex* 2012;[5]:1180).

(3) Response consistency—how consistent is the response across trials? The two runs of 3,000 trials are correlated, to give a number between 0 (completely inconsistent) to 1 (completely consistent). This provides a good measure of the general health of a patient's auditory processing, and is related to language and attention skills (Hornickel & Kraus. *J Neurosci* 2013;33[8]:3500). Response consistency is improved following the use of assistive listening devices such as classroom FM systems (Hornickel. *Proc Natl Acad Sci USA* 2012;109[41]:1673).

In summary, APD is complex, but this complexity should be embraced. A comprehensive, *functional* approach to its evaluation can facilitate a better understanding of an individual's profile and guide strategies for intervention. The FFR provides a fast and objective biological approach to evaluating how well sounds are processed by the brain, and along with converging evidence, can assist in evaluating an individual's strengths and weaknesses in auditory processing.