Listening in on the Listening Brain

By Nina Kraus, PhD, and Travis White-Schwoch

The evoked potentials taught in audiology programs tend to be rather coarse. Consider the auditory brainstem response (ABR): All you can do is evaluate its timing and, perhaps, amplitude. We're taught to infer some additional metrics from an ABR by using a more complicated protocol, with multiple rates and intensities, and to be sure those measures are valuable. But, fundamentally, the ABR allows us to infer whether or not sound gets into the brain.

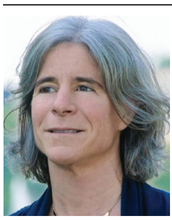
The textbooks teach later evoked potentials, such as the middle latency response (MLR) and late latency response (LLR), sometimes called the cortical auditory evoked response. These, too, boil down to timing and amplitude. While scientists have developed clever protocols to probe listening skills, particularly with the cortical response, at the end of the day, these potentials still ask a question with a binary outcome: Either the brain detects a sound, or it doesn't.

What we really want to know is *how well sound is processed in the brain.* And because sound is a rich and dynamic signal, that is never simply on or off, we need a probe of neural function that reflects this richness. That probe is the frequency-following response (FFR), which reflects synchronized neural activity in response to sound.

In previous Hearing Matters articles in *The Hearing Journal,* we've shared insights from research using the FFR. Here, we highlight how far our understanding of the FFR has come in the past decade. In particular, a fully developed suite of analyses can now be derived from a single FFR that goes far beyond latency and amplitude.

Krizman and Kraus recently reviewed these strategies (*Hear Res.* 2019 Oct;382:107779.). One of the key points they made is that the FFR is as rich as the neural sound processing it measures. And this sound processing in the brain is as rich as sound itself. Think of the many ways we can describe a sound: A sonorous narration. A glimmering trumpet solo. A gravely rasp.

Real-world sounds, such as speech and music, comprise several ingredients, with each sound a unique combination of pitch, timing, and timbre. The FFR can be decomposed into multiple measures that reflect how well each of these ingredients is processed. One notable and remarkably consistent finding in the FFR literature is that each group of listeners has a unique fine-tuning of these sound ingredients in the brain. Consider children with dyslexia v. children with autism spectrum disorder (ASD).



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

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Children with dyslexia tend to struggle to understand the fine-grained features of sound ("Did he say 'bad' or 'dad'?"). Such features are conveyed by the timbre of speech, which are the harmonic cues that clue a listener into what phoneme a speaker said. The FFRs of children with reading disorders show sluggish and imprecise processing of these harmonics. In fact, their FFRs to /b/ and /d/ are indistinguishable, showing that their brains do not encode these crucial speech cues.

In contrast, many children with ASD struggle to understand prosody and emotion in speech. If children with dyslexia struggle to understand "What I said," children with ASD struggle to discern "How I said it." Intonation is conveyed by altering the pitch of our voice. ASD children's FFRs show strong timbral processing, but poor pitch processing—particularly for changing pitch contours across a sound. For example, their brains do not accurately process the rising pitch contour of a question or the falling pitch contour of a strong statement.

Interestingly, both children with dyslexia and ASD tend to exhibit inconsistent responses to sound, which manifest in FFRs variable across trials. This suggests that there is some overlap in how well the brain processes sound in general, but that different clinical populations exhibit distinct sound processing bottlenecks. This crucial subtlety is hidden in ABRs, MLRs, and LLRs.

Understanding the signature patterns of FFR disruption exhibited by each clinical population is important because the FFR can be used to evaluate auditory function. The FFR requires no patient input and, as in the Krizman and Kraus review, a wealth of automated methods are available to quantify each of the sound ingredients reflected in the FFR. Thus, it is a completely objective measure. Having a better understanding of which aspects of sound processing are strengths and weaknesses for each clinical population can assist in developing customized therapies. HJ