It was more than 30 years ago that Bob Keith, Jack Willeford, and others introduced tests that could be used to assess central auditory processing in children. Several audiologists soon added these tests to their clinical services. But, at the same time, others questioned if this type of testing was an appropriate part of clinical audiology practice and, perhaps more importantly, whether these tests had the necessary sensitivity and specificity to be effective.

Today, in many respects, not much has changed. We have major audiology centers, with noted audiologists as directors, that specialize in APD testing for children, while at other major audiology centers, also with noted audiologists as directors, this type of testing is not conducted at all. Interesting.

This month on Page Ten we're bringing in someone from the "test-children-for-APD" side of the fence, **James W. "Jay" Hall III**, PhD. Dr. Hall is clinical professor and associate chair of the Department of Communicative Disorders at the University of Florida, Gainesville. Given the dichotomy of beliefs among clinical audiologists concerning APD testing with children, I thought it might be interesting to ask Jay why he is a "believer." He tells me it probably relates back to his master's degree (in speech pathology!) at Northwestern University where he studied with Doris Johnson, an expert in learning disabilities and a protégée of Helmer Myklebust. He says that after spending a year as a speech pathologist at the Methodist Hospital in Houston, he saw the light (no doubt blinking on/off every 200 msec) and converted to audiology.

During his subsequent PhD studies, Jay was further influenced by working in the audiology clinic, directed by James Jerger, where audiologists performed assessment of APD as a routine clinical service. His doctoral dissertation also was in the area of APD—comparison of amplitudes for simultaneously recorded crossed versus uncrossed acoustic reflexes in elderly adults.

With that upbringing, it's not surprising that over the past 30 years, in clinical and academic audiology positions at four different major medical centers, Dr. Hall has been a proponent of APD assessment and the go-to-guy for conducting this testing with both children and adults. And, as you're probably aware, he is internationally known for his publications and workshops on this topic. So, whether you're a believer, a doubter, or a fence sitter, you'll enjoy Jay's review of what's new in the intriguing area of APD testing and management for children.

GUS MUELLER
Page Ten Editor

Moving toward evidence-based diagnosis and management of APD in children

By James W. Hall III

Hall

1 Conducting testing for central auditory processing disorders (CAPD) seems to be more a part of mainstream audiology practice these days than it used to be. Is that true?

I don't want to start this discussion off by sounding picky, but the preferred terminology now is "auditory processing disorders" or ("APD") without the "central" or the "C". The "central" was dropped about 7 years ago because research clearly shows that deficits in auditory processing can occur anywhere in the auditory system—from the cochlear to the cortex. But you're correct; APD is becoming a household word—or acronym—nowadays.

As evidence of this, I refer you to a recent position statement on auditory processing disorders.[1] After you take a look at this you'll see lots of justification for the renewed professional and public attention to APD.

2 So, why are we hearing more about APD now than in the past?

Actually, more than 50 years have passed since the first published accounts of clinical assessment of central auditory function by three well-known Italian otolaryngologists, and the recognition of the importance of central auditory processing by Dr. Helmer Myklebust.

3 I'm not quite as old as you. You're going to have to help me out with that literature.

Okay. I was referring to the often cited classic 1954 paper by Bocca, Calearo, and Cassinari, and Myklebust's 1954 textbook *Auditory Disorders in Children: A Manual for Differential Diagnosis*.

These prophetic publications were followed 20 years later, in the 1970s, by the initial attempts of such notable audiologists as Jim Jerger, Jack Katz, Jack Williford, and Bob Keith to develop test batteries for what was then called "central auditory processing disorder."

4 If diagnostic test batteries were available back in the 70s, why are we only now witnessing the acceptance of auditory processing disorders as a clinical entity?

To give an adequate answer to that very good question would require a lengthy article, book chapter, or monograph. But, here's the bottom line multiple-part answer.

First of all, the earliest procedures used to assess central auditory processing disorders shared many fundamental limitations. For example, the tests were mostly verbal. They involved verbal test items (i.e., words or sentences) and a verbal response from the patient. Today we would describe the tests as "linguistically loaded," making it almost impossible to distinguish between auditory processing and language disorders.

Also, most of the tests were originally developed for use with adults, and then simply applied in pediatric populations without proper attention to age-related factors that might influence the outcome (developmental or cognitive status of the patient) and without sufficient normative data.

5 I'm getting the point. But weren't there other reasons why audiologists, and maybe even speech pathologists, didn't get involved clinically with auditory processing disorders?

Yes, there were. Assessment of APD in children can get pretty complicated. A variety of co-existing disorders in children undergoing APD assessment can influence APD findings, among them attention deficit hyperactivity disorder, learning disabilities, reading disorders (like dyslexia), autistic spectrum disorders and, as just mentioned, language impairment.[2]

6 I can appreciate how difficult it must be to verify that a child actually has an APD when there may also be other disorders, but at least the list is short.

But wait—there's more. A longer list of non-auditory variables can affect the outcome of an APD assessment. A report of the 2000 APD conference organized in Dallas by Jim Jerger summarized the variables, ranging from peripheral hearing sensitivity deficits to attention, fatigue, developmental age, cognitive abilities, motivation, medications, motor skills, and even visual acuity.[3] Of course, for audiologists in practice, accounting for these variables when interpreting APD findings is a considerable clinical challenge.

7 Do you have any good news? I mean, can audiologists be optimistic when it comes to the future of APD diagnosis and management?

Fortunately there's plenty of good news about the diagnosis of APD. Basic neuroscience research, especially since the beginning of the 1990s—the "decade of the brain"—generated evidence in support of the nature and anatomic origins of APD. There are many hundreds of published papers on neuro-diagnostic techniques, such as functional magnetic resonance imaging (fMRI) and cortical auditory evoked responses. The findings for normal and disordered populations reported in these papers have helped define the neuro-anatomic and neuro-physiologic underpinnings of APD.

The next time you're surfing the Internet, conduct a Medline search (www.nlm.nih.gov) with a few key words, like "auditory" and "fMRI" or "auditory processing" and "auditory evoked responses." You'll be amazed at the volume of literature on the topic.

8 Can you cite a few examples of papers that illustrate the clinical application of some of the neuroscience underpinnings of APD?

Sure. The titles of some of the fMRI papers give rather clear hints at the kind of detailed information that is accumulating on the neuro-anatomical bases of auditory processing. I'm talking about titles such as "Dissecting nonverbal auditory cortex asymmetry: An fMRI study" and "Heschl's gyrus, posterior superior temporal gyrus, and mid-ventrolateral prefrontal cortex have different roles in the detection of acoustic changes."[4,5]

9 What about investigations of and publications about auditory evoked responses and APD?

I thought you'd never ask! Naturally, I'd be happy to direct you to a comprehensive review of that literature in the *New Handbook of Auditory Evoked Responses*.[6] Seriously, we are witnessing an unprecedented growth of research exploring the use of auditory evoked responses as indices of auditory processing. It's hard to know where to begin.

Two of the most prolific authors on this topic are Nina Kraus in the U.S. and Risto Näätänen in Finland. But, around the world there many other groups of investigators publishing each year hundreds of papers on myriad connections between auditory evoked responses. The literature is particularly voluminous for the auditory late response, the P300 response, and mismatch negativity (MMN) response, and auditory processing (see Hall[6] and Hall and Johnston[7] for review).

10 I would imagine that many of the papers you just alluded to were based on experiments conducted in laboratories with complicated instrumentation not available to the average clinical audiologist.

True enough. However, the carefully performed laboratory studies are yielding findings that explain some very important and clinically relevant information about auditory processing in children and adults. For example, reports even include studies of auditory processing in infants at risk for auditory processing and reading disorders (e.g., Kujala and Näätänen[8]).

11 Not to be a pest, but wouldn't you agree that we're in for a long wait before these auditory evoked response techniques get into the hands of clinicians?

Sorry, but I just can't agree with that statement. Most cortical evoked responses can be recorded with instrumentation available to any practitioner with an ABR system. Furthermore, audiologists will soon be able to purchase auditory evoked response devices and software for clinical but remarkably sophisticated measurement of auditory processing.

For example, one manufacturer (Bio-Logic, Inc.) has incorporated into an FDA-approved clinical device software for measurement of speech-evoked auditory brainstem and cortical responses, techniques based on recent research reported by Nina Kraus and colleagues at Northwestern University (e.g., Banai, et al.[9], Banai and Kraus[10]).

12 That's certainly encouraging. Are you saying we now have the protocols and procedures, supported by scientific investigations, to confidently diagnose and manage APD?

We're making progress, with new and promising APD procedures now undergoing clinical validation, but there's still more work to do.

13 What sort of "new and improved APD procedures"?

I'll give you some examples. One of the new APD measures, the Gaps-in-Noise (GIN) test, may be a real tonic for APD assessment, so to speak. Developed by Frank Musiek[11,12] the GIN test assesses a fundamental and well-established auditory process—temporal processing via gap

detection. Briefly, during the GIN test, the patient attempts to identify 0 to 3 gaps of varying lengths (between 2 and 20 ms) and locations within a 6-second broadband noise signal.

The GIN test has some attractive clinical advantages. Remember the list of variables I cited earlier that can confound APD test administration and interpretation? Because the signal is broadband noise, performance on the GIN is less affected by peripheral hearing loss in specific frequency regions or by age. Also, detection of a gap in the noise is indicated by a simple response (e.g., pressing a button), thus minimizing a few other variables, e.g., motor abilities and cognitive status.

And, of course, the signal and response are both non-verbal and, therefore, essentially independent of language functioning. The good news for you is that you can easily do this test in your clinic with any audiometer that is connected to a CD player. It's almost as easy as pure-tone audiometry.

14 That sounds like something I need to check out! What's the second "new and promising procedure" you mentioned?

Since I'm sure you read the *JAAA* religiously, you'll recognize one of the newest clever acronyms in audiology, the LISN. The Listening in Spatialized Noise test, reported in the 2006 issue of that journal[13], creates virtually, under earphones, a three-dimensional auditory environment. The child being evaluated for APD is told to attend to a story (a continuous discourse) and indicate, using a three-alternative, forced-choice adaptive test procedure, when the story was "easy to understand," "just understandable," or "too hard to understand in the presence of the distracters," by pointing to the appropriate picture on the response card.[13(p311)]

While listening to the story, the child is exposed to "distracter sentences" under high or low cue conditions (e.g., same or different talker for the sentences versus story, presented at 0° versus +/- 90° azimuth. The LISN test will soon be ready for clinical use.

These two procedures—the GIN and LISN—may be the first of a new generation of APD tests and a totally revamped APD test battery. The GIN test could, in fact, become one of the first procedures in an international non-verbal APD test battery.

15 What do you mean by international?

By an international test battery, I mean a collection of procedures that could be used in the same way by clinicians worldwide. There's no reason why an international group of hearing scientists and audiologists couldn't collaborate in the development of a psychometrically sound test battery consisting exclusively of non-verbal procedures—with no meaningful linguistic items. Then, audiologists anywhere in the world could confidently use the test battery clinically.

Consider, for a moment, the opportunities that a well-defined international APD test protocol would create for large cross-cultural population-based investigations, and the introduction of clinical assessment and management of APD in developing countries far and near.

16 I know you're a rather peripatetic audiologist. When did you first come up with this idea of an international test battery for assessment of APD?

I guess it takes a peripatetic audiologist to know one! I began thinking about an international APD test battery a few years ago while lecturing on APD in Colombia and Brazil. I had to modify my presentations to avoid my typical references to the verbal APD procedures used in the United States.

The idea began to really sink in when I gave a workshop later in Denmark to a group of audiologists, psychologists, and physicians who were beginning to review Danish options for APD procedures. More recently, at the 2006 AAA Convention, I had a lively and thought-provoking conversation about the same concept with Melanie Ferguson, a British audiologist who presented a poster paper describing the development of a small collection of non-verbal measures of APD-assessing basic processes such as frequency discrimination and backward masking.[14]

17 We've talked only about the assessment of APD. What about APD management?

Good question. APD can have very serious consequences for communication, for academic performance, and for psychosocial functioning. Effective management of APD is very important and, of course, depends on an accurate and complete assessment and diagnosis.

18 Where does psychosocial function fit into the picture?

For years, clinical audiologists have recognized that, over time, children with APD develop low self-esteem. Also, the child with APD often becomes discouraged, frustrated, withdrawn, lonely, and sometimes even clinically depressed.

The late Dr. Carl Crandell was very interested in connections between psychosocial function and APD. One of his PhD students, Nicole Kreisman, has just completed a dissertation project examining psychosocial status of children with APD, using formal psychosocial measures such as the Social Skills Rating System (SSRS) and the Behavioral Assessment System for Children-Second Edition (BASC-2). Dr. Kreisman found clear evidence of psychosocial problems in children with APD in comparison with an age-matched control group.[15]

19 That's very interesting. But what can we do for a child with a diagnosis of APD?

The answer to your question could very easily be another Page Ten article. Carrying on the work initiated by my friend and colleague Carl Crandell, I'm investigating the benefits of various types of FM technology in the laboratory and classroom setting.

The use of an FM system is invariably beneficial for some children with APD. We're developing criteria to determine which children are the best candidates for management with FM systems, and examining the differential benefits of specific types of devices. Early studies confirmed that personal FM devices offered, for children with APD, significantly greater benefits in signal-to-noise ratio than classroom or desktop style devices.[16] And, ongoing formal study of new personal FM technology, the Phonak EduLink device, in the laboratory and school settings has shown remarkable benefits for children with APD.[17]

20 I'm glad to hear we have more than anecdotal find-

ings in support of the benefits of FM technology for children with APD. Would you please conclude with a brief mention of some other management options available for children with APD?

I'll try to be brief, but it won't be easy because the past few years have brought us multiple exciting treatment options for APD. Computer-based programs, such as Earobics, can play an important role in the remediation of auditory skills that are necessary for communication and for the phonemic processing that is essential for reading success.

Frank Musiek has developed the DIID (Dichotic Intensity Increment Difference) technique for management of APD. Formal investigations of the outcomes of children undergoing treatment with the DIID technique are under way at the University of Connecticut and the University of Florida.

Let *me* ask *you* a question: Why not have another Page Ten article soon on APD management?

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