Assessing Auditory Processing Problems in the School Setting

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Recently, a consensus conference on auditory processing disorders (APDs) recommended a minimal APD test battery (Jerger & Musiek, 2000). These recommendations were made in the interest of defining a "gold standard" for APD assessment; however, they leave educational audiologists at a disadvantage since these professionals do not have ready access to certain clinical procedures. To meet the high volume of referrals for APD assessments in the school setting, it seems that another, second-tier type of test battery is needed; therefore, an alternative test battery is presented here for consideration. As a type of "silver standard" for assessment, it does not allow for a definitive APD diagnosis; however, it does provide sufficient information to identify a likely auditory processing problem. A two-dimensional model of auditory processing and an assessment matrix are described to provide an organizational framework for this alternative test battery.

Two questions consistently arise when educational audiologists talk about assessing auditory processing disorders (APD): how to manage the increasing number of referrals, and what kinds of assessments to use. Even when school programs have sufficient audiology and speech-language pathology (SLP) personnel, they typically lack the resources needed to comply with a recent report on APD assessment (Jerger & Musiek, 2000). This report recommended a minimal test battery comprised of behavioral tests, electrophysiological and electroacoustic testing, and neuroimaging studies. While certainly the clearest description of a "gold standard" for APD assessment to date, these recommendations create a dilemma for school-based personnel. Although expected to assess children experiencing listening difficulties, most school-based personnel do not have ready access to two of the three recommended procedures (i.e., electrophysiological/ electroacoustic testing and neuroimaging).

To address this "assessment dilemma," the following alternative test battery is offered for consideration. As a kind of "silver standard," this battery (comprised of behavioral tests only) **will not** provide a definitive diagnosis of a **disorder**, and therefore will not be useful to school systems requiring such a diagnosis. Some school systems, however, require only that an auditory processing **problem** be identified; for these environments, this test battery can provide the information needed to make informed programmatic decisions. This test battery can be administered by both audiologists and SLPs, thereby increasing the number of personnel available to respond to requests for assessments.

To provide an operational framework for this test battery, a two-dimensional model of auditory processing (AP) is presented. The two dimensions are then combined to create an assessment matrix, to be described in a subsequent section.

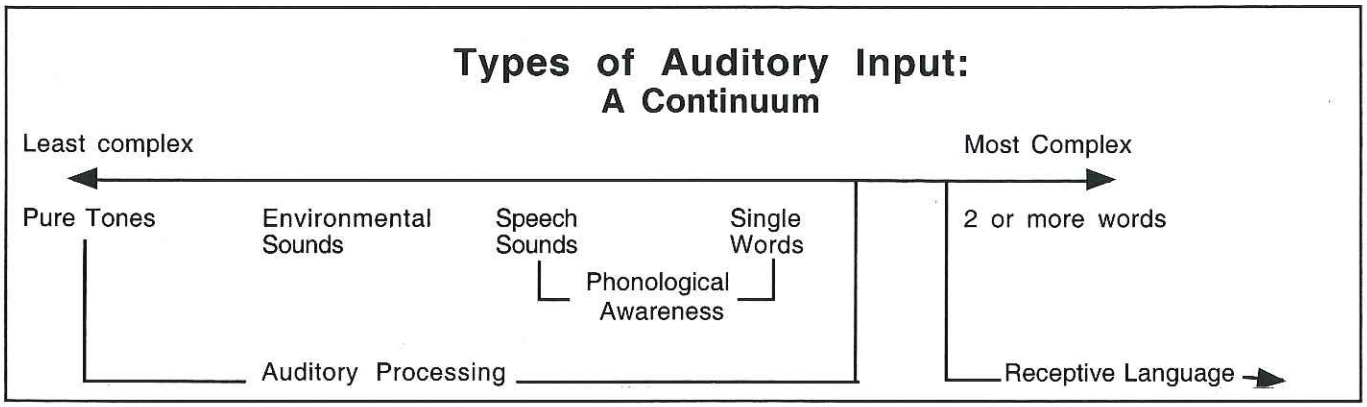
A "Horizontal" Dimension to Auditory Processing

All too often, the term "auditory processing disorder" is used to describe virtually every kind of listening difficulty, including – inaccurately – receptive language problems (e.g., following directions or remembering verbally-given homework assignments). Figure 1 makes the distinction between auditory processing skills and receptive language skills by conveying the range of auditory input along a continuum, from simple pure tones to the highest levels of receptive language analysis. Auditory processing is placed at the beginning of this continuum to represent a foundational requirement for more advanced receptive language skills. The ability to process speech sounds and single words is more specifically called "phonological awareness" (Ball & Blachman, 1991; Wagner & Torgeson, 1987). Because phonological awareness does not entail language analysis per se, it is embedded within auditory processing skills.

When two or more words are combined, the listener uses receptive language skills, which must be assessed with instruments designed for that purpose. The brackets along the continuum are meant to demarcate where AP ends and where receptive language begins, and to plan assessment accordingly.

Although not noted on Figure 1, a "gray area" does exist on this continuum straddling both sections of AP and receptive language. It involves using auditory sequential memory with two words or more, such as a set of directions. For example, if a child can readily understand, "Read page 15," or "Answer the odd-numbered questions," he or she is demonstrating a command of simple receptive language. However, frequently a child can follow one direction, but becomes confused when a set of directions is strung together ("Read page 15, answer the odd-numbered questions, place the assignment on the right hand corner of my desk, and spend the remaining time in silent reading"). When this confusion occurs, he or she is not demonstrating a problem with receptive language per se, but rather an overload or breakdown in the use of auditory sequential memory. The same concept holds for the verbatim repetition of several digits or short sentences: although two or more words are used as a stimulus, auditory sequential memory skills are being tapped, not receptive language skills.

Figure 1. Types of auditory input: A continuum



A "Vertical" Dimension to Auditory Processing

Each component of the AP continuum – pure tones, environmental sounds, speech sounds, and single words – can be evaluated at an increasingly complex cognitive level (American Speech-Language-Hearing Association, 1996a). Table 1 provides a list of different cognitive skills used to analyze auditory input. Note the quotation marks around the word "hierarchy," to caution against overgeneralization with regard to the developmental acquisition of these skills – that is, skills are not necessarily mastered in this sequential order. Temporal resolution has been placed at the end of the hierarchy because it is of relatively new interest (Pinheiro & Musiek, 1985; Tallal, Miller, & Fitch, 1993).

Table 1.

"Hierarchy" of auditory processing skills
Auditory Awareness, Localization
Auditory Discrimination
Auditory Recognition
Auditory Attention Span
Figure Ground (Discrimination in Noise)
Auditory Synthesis
Auditory Closure
Binaural Separation
Binaural Integration
Auditory Short-Term Memory
Auditory Sequential memory
Temporal Resolution

A brief review of these terms follows:

- Auditory awareness/detection and localization: is the child aware that an acoustic event occurred, and if so, can he or she indicate -- without looking -- whether it came from the left or right, in front or behind, up or down?
- Auditory discrimination: given two stimuli, can the child describe them as the same or different? That is, when presented the pair of words "pop/pop," can the child respond that these are the same words?
- Auditory recognition: without visual cues, can the child give a name to what was heard? "That was the door slamming shut; that was the principal's voice on the PA system; that was my best friend's laugh."
- Auditory attention span: can the child attend to auditory stimulation for an age-appropriate length of time? This is an auditory behavior that first catches a teacher's attention: "The rest of the class can sit and listen without problems during story time, but not Johnny."
- Auditory figure ground, or discrimination in noise: can the child attend to speech (class room instruction, peer discussion) when background noise is present?
- Auditory synthesis: can the child blend or merge discrete speech sounds together meaningfully? This skill is challenged when the teacher says, "Today we are going to make words using the 'an' family. What words do we make when we say f-an, r-an, p-an?" The child who cannot synthesize these sounds only hears /f, r, p/ placed in front of "an," and is left to wonder what they actually mean.
- Auditory closure: can the child "fill in the gap" when words are not presented in full? For example, since the teacher's voice cannot reach the child's ear at an optimal distance or loudness at all times, every phoneme of the word "airplane" might not be perceived. If the child hears only "airpla --,' will he or she be able to "close" that word or be left to ponder, "airplay? What is that?" while instruction continues onward.
- Binaural separation and auditory integration: both of these skills involve the use of binaural hearing. Can the child ignore a competing message in one ear while attending to a message in the other (auditory separation), and can the child

attend to/repeat back two different (dichotic) stimuli, presented one to each ear (binaural integraton)? In other words, is the corpus callosum transferring auditory information across hemispheres (Bellis, 1996)?
- Auditory memory and auditory sequential memory: can the child recall what was presented audition-only? Can the child recall auditory input (words, directions) in the order it was given?
- Temporal resolution: can the child do the above tasks at an age-appropriate speed? Does the auditory signal travel along the auditory pathway at the rate expected for one's age?

As mentioned earlier, these processing skills can be applied to pure tones, environmental sounds, speech sounds, and single words. The next section uses these horizontal and vertical components as axes for a matrix for behavioral assessment.

An AP Behavioral Assessment Matrix

The matrix found in Figure 2 merges the horizontal and vertical dimensions of AP to create an organizational framework to identify specific tests for specific AP problems. By no means is this an exhaustive list of all available tests; rather, it merely provides examples of tests that meet the following criteria:

1. They can be conveniently administered in the school setting, because they require at most only commonly available equipment (CD/tape player, headphones, a quiet room), and no specialized (i.e., audiologic) training.
2. They have little or no linguistic demands.
3. They have little or no memory demands.
4. They employ simple response modes (Jerger & Musiek, 2000).

If other tests are selected, they should meet the above criteria as well. The assessments included in this matrix are described below, in alphabetical order:

- Auditory Continuous Performance Test (Keith, 1994) measures auditory attention span of single words;
- Auditory Fusion Test-Revised (Screening Test) (McCroskey & Keith, 1996) measures gap detection or temporal resolution of pure tones;
- "Auditory Sequential Memory" (digit span) subtest of the Illinois Test of Psycholinguistic Abilities (ITPA) (Kirk, McCarthy, & Kirk, 1968) measures auditory sequential memory of single words (digits);
- Dichotic Digits, Double Pairs (Musiek, 1983) measures binaural separation and auditory memory of digits;
- Duration Pattern Test (Musiek, 1994) measures auditory discrimination and auditory short term memory of long and short pure tones;
- Lindamood Auditory Conceptualization (LAC) Test (Lindamood & Lindamood, 1979) measures auditory discrimination and auditory sequential memory of speech sounds;
- Pitch Pattern Sequence Test (Musiek, 1994) measures auditory discrimination and auditory short term memory of high and low pure tones;
- Subtest 1 of the SCAN-C: Test for Auditory Processing Disorders in Children, Revised (Keith, 2000) measures auditory closure of single words;
- SCAN-C, Subtest 2, measures perception of single words in background noise;
- SCAN-C, Subtest 3 measures binaural separation and auditory memory of single words;
- SCAN-C, Subtest 4 measures binaural separation of simple sentences;
- "Sound Blending" supplemental subtest of the ITPA measures auditory synthesis skills of speech sounds (as in "b-oa-t") into single words.
- "Word Discrimination" subtest of the Test of Language Development-Primary (3rd ed.) (TOLD-P:3) (Newcomer & Hammill, 1997) measures the ability to discriminate between words that are the same ("work-work") or different ("watch-wash").

It is duly noted that the subtests of the SCAN-C are screening instruments only. However, they do provide normative data for auditory skills (e.g., figure ground and binaural separation) not readily found elsewhere, especially for age 5.

Tests such as the LAC Test and the Auditory Continuous Performance Test are included in this assessment matrix because they provide additional (and academically relevant) information regarding phonological awareness delays, attention problems, etc., to help advance the overall assessment process.

An Assessment Battery for the School Setting

After reviewing the tests organized in this matrix, the following minimal test battery was developed at a university clinic with the goal of obtaining the most information possible in about one hour. Prior to an appointment, screening information is collected via two teacher questionnaires (Fisher, 1980; Smoski, Brunt, & Tannahill, 1998). At the appointment, pure tone and middle ear screenings (American Speech-Language-Hearing Association, 1996b) are administered, as well as the following tests (for age 6 and older):

1. ITPA "Auditory Sequential Memory" (digit span) subtest
2. Lindamood Test of Auditory Conceptualization
3. Auditory Fusion Test, Revised* (Screening Test)
4. Dichotic Digits, Double Pairs* (using norms from Rosenberg, 1998)
5. "Word Discrimination" subtest, TOLD-P:3
6. Duration Pattern Test* (for ages 7 and up)

In addition to the three behavioral tests recommended by Jerger & Musiek (2000) (identified above by asterisks), three other assessments were added with the following rationales:

1. Since poor performance on the Dichotic Digits Test (Double Pairs) could suggest problems with dichotic listening skills, auditory memory, or both, the digit span subtest of the ITPA provides a means either to rule out or confirm problems with auditory memory problems alone. (**Note:** the latest version of the ITPA [ITPA-3, Hammil, Mather, & Roberts, 2001] does not include an auditory memory subtest.)
2. The LAC Test provides additional information about an

Figure 2. APD behavioral assessment matrix.

	Pure Tones	Environmental Sounds	Speech Sounds	Single Words	2+ Words
Aud. Awareness, Localizing					n/a
Auditory Discrimination	Pitch Pattern *Dur. Pattrn		LindamoodAud Concept. (LAC)	TOLD-P;3, Word Discrim	n/a
Auditory Recognition					n/a
Auditory Attention Span				ACPT	n/a
Fig. Ground (Discrim/Noise)				SCAN-C #2	n/a
Auditory Synthesis				ITPA suppl "Sound Bldng"	n/a
Auditory Closure				SCAN-C #1	n/a
Binaural Separation				SCAN-C #4	n/a
Binaural Integration				*DDs, Double Pairs *SCAN-C #3	n/a
Aud. Short-Term Memory	Pitch Pattern *Dur.Pattrn			*DD, Double Pairs	n/a
Auditory Sequential Memory			LindamoodAud Concept. (LAC)		ITPA Aud. Seq. Mem (digits)
Temporal Resolution	*AFT-R				n/a

* per Jerger, J., & Musiek, F. (2000). Report of the Consensus Committee on the diagnosis of auditory processing disorders in school children. Journal of American Academy of Audiology, 11, 467-743

academically relevant skill (phonological awareness) that is not addressed in the APD consensus conference minimal test battery. The ability to discriminate speech sounds (from LAC results) can be compared to discrimination of pure tones (in the Duration Pattern Test), and sequential ordering of speech sounds (from LAC results) can be compared to sequential ordering of single words (ITPA digit recall).

3. Results from the Word Discrimination test can be used to compare discrimination problems with pure tone stimuli to results obtained with pure tone stimuli as measured by the Duration Pattern test. The Duration Pattern Test is often too long or too abstract for young children; if these scores are low but scores from the Word Discrimination test are within normal limits, a tester may decide not to put too much weight on the Duration Pattern Test.

These six tests evaluate a cross-section of auditory inputs at different processing levels. Figure 3 compresses the assessment matrix to describe specific outcomes:

1. Auditory discrimination is tested with pure tones (Duration Pattern Test), with speech sounds (LAC), and with single words (Word Discrimination Test).
2. Binaural integration is tested with single words (Dichotic Digits).
3. Auditory memory is tested with single words (Dichotic Digits).
4. Auditory sequential memory is tested with speech sounds (LAC) and words (ITPA Digit Span).
5. Temporal resolution is tested with pure tones (AFT-R).

Figure 3. auditory skills tested with a variety of auditory inputs

	Pure Tones	Speech Sounds	Single Words	2 + Words
Auditory Discrimination	✔	✔	✔	
Binaural Integration			✔	
Aud. Short-Term Memory			✔	
Auditory Sequential Memory		✔		✔
Temporal Resolution	✔			

These tests were selected to allow for reliability checks (described above). Other tests in the assessment matrix can be selected to meet the particular needs of a student or school system; the main consideration is to test multiple auditory inputs at multiple processing levels.

Conclusion

The "gold standard" of APD assessment is usually not achievable in typical school settings; therefore, an alternative minimal test battery is presented here. It can be implemented by audiologists and SLPs alike, thereby increasing the number of personnel available for AP assessment. It does not definitively confirm a diagnosis of APD but it does provide enough information to decide whether significant auditory processing problems exist, and whether services should be initiated (for instance, using a pre-set criteria of at least two scores falling two standard deviations below average).

This proposed test battery is offered as a jumping-off point for discussion: for example, yet to be considered is criteria for referral for electrophysiological assessments and/or neuroimaging. Feedback regarding both the two-dimensional AP model and the concept of a "silver standard" for AP assessment is welcomed (english@duq.edu).

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