by Sharon Cameron
and Harvey Dillon

Essays in Audiology

Auditory Processing Disorder - from Screening to Diagnosis and Management - A Step-by-Step Guide

"My child's teacher told me that my son can't hear properly in class. He is starting to fall behind in reading and spelling. The school counsellor said that I should have him assessed for auditory processing disorder. How do you assess an auditory processing disorder, and if he has APD, can you do anything to help him?"

The following article discusses the options available to audiologists in dealing with referrals from parents, school counsellors, and other professionals, for screening, diagnostic assessment, and management, of children with suspected auditory processing disorder (APD).

In line with Bamiou, Musiek & Luxon (2001); Bellis (2003); Friel-Patti (1999); Jerger & Musiek (2000); Richard (2001); and Wilson, Heine & Harvey (2004), a multi-disciplinary screening process is recommended to eliminate the influence of supra-modal factors such as IQ, attention, language disorders and memory on a reported listening and learning dysfunction. It is desirable that diagnostic testing for APD is not undertaken until a comprehensive report from an educational psychologist, and also, preferably, a speech pathologist, has been completed. Review of these reports enables the audiologist to make an informed decision as to whether supra-modal factors are contributing to the child's listening and learning deficits. If such reporting is not available, it is very difficulty to interpret central auditory test results with any degree of reliability. Often, the child will have already had the necessary educational psychology and speech pathology tests performed, and it is therefore only necessary to review the reports and make an assessment as to whether further audiological testing is required, or whether the child should be treated for any supra-modal deficits uncovered by the psychology and speech pathology evaluations.

Steps 1 to 3 below discuss the screening process. The recommended diagnostic test battery is outlined in Step 4, and the appropriate management options arising from the diagnostic assessment is discussed in Steps 5 and 6.

Step 1: Rule out peripheral auditory involvement

Peripheral hearing loss can contribute to listening and learning difficulties. In all likelihood, a portion of the listening and learning difficulties experienced by children with peripheral hearing loss may be attributed to defective processing of auditory information beyond the periphery. Whilst not denying the possible interaction of peripheral hearing loss on central processing, a proportion of children experience listening and learning problems associated with the defective processing of auditory information, in spite of normal auditory thresholds (Jerger & Musiek, 2000). Children with such a profile are defined as having an auditory processing disorder (APD). In line with this definition of APD, the first step that the audiologist should take as part of the APD screening process is to rule out peripheral hearing loss as a possible contributing factor to listening and learning difficulties. Testing should include pure-tone audiometry, speech discrimination testing, and immittance audiometry. In addition to conducting a routine audiological assessment, Bellis (2003) notes that the audiologist should be alert for signs that would indicate the need for special tests of auditory function such as otoacoustic emissions and electrophysiology.

Step 2: Rule out attention, memory and IQ-related disorders

APD is defined as a deficit in the auditory pathways of the brain that results in the inability to listen to, or comprehend, auditory information accurately, even though normal intelligence is documented (Richard, 2001). Further, Jerger and Musiek (2002) stress that in order to maintain a clear focus on the accurate diagnosis of APD, it is necessary to view it as a discrete entity, apart from other childhood problems such as attention deficit/hyperactivity disorder (ADD/ADHD) specific language impairment (SLI) and dyslexia.

As noted by Wilson et al. (2004), children with a supra-modal deficit may perform poorly on tests of auditory processing, not because they have auditory-specific perceptual problems, but because the test in question is sensitive to other processing demands – such as attention, memory, cognition and motor skills - which are necessary to perform any behavioural task. For example, digit span forward and backwards are commonly administered tests of intellectual functioning designed to assess rote short-term memory for numbers, and working memory respectively. The dichotic digits test discussed in Step 4c is often recommended in the literature as a test of APD designed to assess binaural integration abilities. In the dichotic digits test, double digits are presented to each ear simultaneously. The child's task is to repeat back as many digits as possible. If a child is unable to perform within the normal range for their age on the digit span test, it is not possible to conclude that the child has a binaural processing deficit if they also perform poorly on a dichotic digits test, as higher order memory issues are likely to be influencing the central auditory processing test results.

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In respect to attention, the effect of a disorder such as ADHD can certainly affect the ability to process auditory information. However, the accumulating evidence differentiates APD and ADHD as clinically distinct entities (Chermak, Hall & Musiek, 1999; Chermak, Tucker & Seikel, 2002). Bellis (2003) notes, for example, that the child with inattentive type ADHD typically has difficulty with sustained attention, whereas the child with APD demonstrates deficits in the ability to attend selectively to auditory signals in the presence of background noise.

The diagnosis of attention, memory and cognitive abilities is a highly specialized area of assessment which should be undertaken by a registered educational psychologist. The Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003), is an excellent test of cognitive abilities, which provides a comparison of verbal and performance IQ. Children with APD have been found to have a differential performance on these scales, with verbal IQ characteristically lower than performance IQ (Bellis, 2003; Cameron, Dillon & Newall 2005a, in review).

Step 3: Rule out a language disorder

Deficits, such as poor phonological awareness abilities, have been associated with certain profiles of APD (Bellis, 2003; Stecker, 1998). A significant delay in general language acquisition should not, however, be interpreted as an auditory processing deficit, even though the child will probably fail most of the cental auditory processing test battery (Richard, 2001). According to Singh and Kent (2000), language disorders can either be organic in nature (that is, associated with physiological causes such as brain damage or hearing loss), or appear unrelated to organic causes or any other general disability – a condition referred to as specific language impairment (SLI).

Jerger & Musiek (2002) point out that it is very difficult to say that poor performance on a test which involves speech understanding is due to an auditory-specific perceptual deficit such as APD, rather than to a language disorder such as SLI. According to Friel-Patti (1999), it is imperative that the speech-language pathologist make every effort to distinguish APD from a subtle language comprehension deficit. APD has been defined as an auditory-specific perceptual deficit in the processing of speech input – usually in hostile acoustic environments (Jerger & Musiek, 2002). Therefore, as noted by Friel-Patti (1999), many children referred for APD assessment do not exhibit problems in one-to-one conversations, but they do have trouble in multi-talker situations or in conversations with competing background noise. For this reason, language comprehension measured in a quiet, highly structured, one-to-one testing situation will be better than functional performance in the classroom. Specifically, Friel-Patti (1999) notes that, the speech-language evaluation of a child with suspected APD should include general language performance (receptive and expressive); articulation; phonology; morphology; syntax; pragmatics; and phonological awareness. In addition "...the speech-language pathologist needs information from the classroom teacher about classroom achievement in speaking and listening as well as in reading, spelling, writing, and attention. When possible, information about the classroom environment, including classroom acoustics and visual distractions, should be obtained" (p. 348).

A wide range of speech and language tests are listed in Bellis (2003). The Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF-IV; Semel, Wiig & Secord, 2003) is widely used by speech pathologists for investigating overall language-related abilities.

Step 4: Diagnostic Audiological Assessment

Once you have established that neither peripheral hearing, global IQ, attention, nor language deficits are contributing your client's listening difficulties, a comprehensive diagnostic assessment can be conducted.

Many peer-reviewed articles and text books have discussed the recommended test battery for APD (Bellis, 2003; Bellis & Ferre, 1996, 1999; Domitz & Schow, 2000; Jerger & Musiek, 2000; Katz & Smith, 1991; Musiek & Chermak, 1994; Musiek, Geurkink, & Keitel, 1982; Richard, 2001; Stecker, 1998; Vanniasegaram, Cohen, & Rosen, 2004). The behavioural assessment tools described in Steps 4(a) to 4(e) are offered as a guideline only, and were chosen in an attempt to evaluate processes of the auditory system that, if defective, can contribute to an auditory processing disorder (ASHA, 1996).

Whilst not asserting a preference for any particular assessment tool over another, the behavioural tests described below have been chosen to sample a range of abilities, and to avoid duplication of tests for which performance is highly correlated (Cameron, Dillon & Newall, 2005b, in review; Schow, Seikel, Chermak & Berent, 2000). The battery therefore facilitates a differential diagnosis, and allows for skill-related management options to be devised. The tests documented in Steps 4(a) to (e) have been extensively researched in the literature; are available for clinician use; have suitable normative data; can be used reliably with children from 7 years; and can be utilized for native Australian-English speaking children. Normative data for the tests are provided in Table 1.

Before embarking on APD assessment, it is important consider the limitations of tests of central auditory function which utilize speech stimuli. As noted by Keith (1995) many tests purported to measure specific auditory skills are actually measures of language, and are often affected by the client's auditory closure skills. Auditory closure is the ability to fill in missing or distorted auditory information - a skill that requires integration with vocabulary knowledge and contextual cues. To perform well on tests which involve auditory closure, a child must have developed relatively sophisticated language skills, and the more advanced the child's language, the better the child will perform.

Jerger and Allen (1998) explain that evidence from various models of speech perception indicate that linguistic knowledge may influence the processing of word stimuli. Thus, abnormal performance on global measures of word recognition that are used to assess APD could reflect either an auditory disorder with good linguistic skills or a linguistic disorder with good auditory skills. Such a lack of specificity can complicate the remediation and management of children diagnosed as having APD on the basis of such measures,

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and a lack of clarity about APD probably results from the common use of global behavioral tests without appropriate control conditions and/or manipulated variables.

In light of these concerns, the newly developed Listening in Spatialized Noise – Continuous Discourse test (LISN-CD™; Cameron & Dillon, 2005) described in Step 4(d), was created using difference scores, or advantage measures, in order to assess binaural interaction skills, and the ability to selectively attend to one talker based on spectral and temporal differences between talkers, in children with suspected APD. By using difference scores, variability between children in supra-modal abilities, such as language skills, are minimized, if not eliminated, as part of the test design. For example, the LISN spatial advantage measure is calculated by comparing a listener's thresholds in two LISN conditions where the vocal quality of the speakers of the distracters and target story are identical, and the test stimuli differ only in the apparent physical location of the distracter sentences in auditory space. Figure 1 illustrates this concept.

A further complication of tests employing speech stimuli to assess central auditory function is the potentially deleterious effects of using North American-accented tests with unfamiliar semantic items on performance in other populations (Golding, Lilly and Lay, 1996; Marriage, King, Brigg & Lutman, 2001; Sockalingam et al., 2004). The potential problems associated with North American-accented tests, along with the difficulties discussed above in respect to using global behavioral tests without appropriate control conditions and/or manipulated variables, has been considered in compiling the audiological battery that follows in steps 4 (a) to (e).

Step 4a: Diagnosing temporal resolution deficits

Temporal resolution is a general term for a range of skills involving perception of the time course of an auditory signal. It includes the ability to detect changes in the duration of auditory stimuli, and the ability to detect silent gaps between auditory stimuli (Singh & Kent, 2000). If temporal resolution is poor, a listener's ability to distinguish and identify rapidly presented speech sounds may be affected. The Random Gap Detection Test (RGDT; Keith, 2000), specifically assesses the ability to detect small gaps in an auditory signal that does not differ in frequency, and is referred to as a within-channel gap detection test (that is, all necessary information falls within the one auditory filter band).

In the administration of the RGDT, pairs of tones ranging from 500 to 4000 Hz are presented binaurally at 55 dB HL. Each tonal pair is presented with a silent gap between them, ranging in duration from 0 to 40 msec. One each of nine gap durations between 0 and 40 msec are tested for each stimulus. The gap detection threshold is defined as the lowest inter-pulse interval at which two tones are consistently identified. One practice trial of nine tone pairs is provided. Normative data on the RGDT in Table 1 is provided by Keith (2000), however in line with Keith (2000) and Bellis (2003), a participant is only considered to be outside normal limits on the RGDT if his or her gap detection threshold exceeds 20 milliseconds. The RGDT is available for purchase from AUDiTEC at www.auditec.com.

Step 4b: Diagnosing temporal sequencing deficits

Temporal sequencing involves the perception and processing of the order of two or more auditory stimuli as they occur over time. Temporal sequencing helps a listener to recognise the acoustic contours of speech. This contributes to his or her ability to extract and use prosodic cues – such as rhythm, stress and intonation – to identify and segment the key words in a sentence. Temporal sequencing can be assessed using the child's version of the Pitch Pattern Sequence test (PPS; Pinheiro, 1977).

In the administration of the test, various pitch patterns are presented under headphones at 50 dB SL (re PTA for 500, 1000 and 2000 Hz tones). Each consists of 3 consecutive tone bursts made up of high-pitch and low-pitch tones. The listener is required to verbalise the pattern, eg high-low-high. If the child is unable to complete the verbal condition, a non-verbal condition is administered whereby the child is required to hum the pattern. Twenty tone pairs are presented binaurally to ensure the child can distinguish high and low tones. Ten tone triplets are then presented to the right ear as practice. Thirty triplets are scored for each ear.

Although the ability to score within normal limits on the PPS requires the listener to discriminate differences in pitch, as well as to perceive and recall order, the frequencies used are sufficiently far apart that pitch perception is not believed to limit ability in the PPS test.
According to Medwetsky (2002), the non-verbal condition of the PPS provides an indicator of a child's overall pattern perception and temporal sequencing ability, whilst the verbal task provides additional information on auditory-linguistic integration. Normative data for the PPS test in Table 1 were taken from Singer, Hurley & Preece (1998). The PPS is available for purchase from AUDiTEC at www.auditec.com.

Step 4c: Diagnosing binaural integration deficits

Binaural integration is the ability of a listener to process different information presented to the two ears at the same time. This process also involves working memory and divided attention. Poor performance in binaural integration may be expressed in the behavioural symptoms of difficulty hearing in background noise, or difficulty listening to two conversations at the same time (Bellis, 2003). Binaural integration can be assessed using the dichotic digits test. I use the version by Wilson and Strouse (1998).

In the administration of the dichotic digits test, two different pairs of sequential digits are presented under headphones to each ear simultaneously at 50 dB SL (re PTA). The child is required to repeat back all digits heard, regardless of order. Ten single digits, and 10 double digits are presented dichotically as practice. Forty double digits are then presented and scored for each ear. Normative data for the dichotic digits test presented in Table 1 were taken from Singer, Hurley & Preece (1998). The test is available from Audiology Section, Department of Veterans Affairs Medical Centre, Mountain Home, Tennessee, USA. Contact Richard Wilson at Richard.Wilson2@med.va.gov for details.

An Australian recording of dichotic digit stimuli is not, to my knowledge, currently

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available. However, due to the closed-set nature of the stimuli, the North American-accented version of the test can be used in the absence of a more culturally-relevant recording. The need for development of Australian-accented tests of both binaural integration and separation - with normative data provided for a wide age range - is are an important future research area. Binaural separation refers to the ability to process an auditory message coming into one ear while ignoring a different message being presented to the opposite ear at the same time (Bellis, 2003). Some information on other tests in this area, such as the Macquarie Pediatric Speech Intelligibility Test (MPSI; Cameron, Barker & Newall, 2003) is available at http://www.ling.mq.edu.au/centres/audiology/Paediatric.htm.

Step 4d: Diagnosis of binaural interaction deficits

Binaural interaction refers to auditory processing involving both ears and their neural connections (Singh & Kent, 2000). Two auditory functions that are important in everyday listening conditions that rely on binaural interaction are localization of auditory stimuli, and detection of signals in noise (Bellis, 2003). The ability to locate the source of a sound depends on the capacity of the central auditory nervous system to detect, perceive and compare small differences in the arrival time and intensity of signals reaching the two ears. The ability to understand speech in a background of noise can be related to the ability of the listener to use binaural cues to differentiate the location of the sound source from the location of the noise. According to Bellis (2003) whereas binaural interaction can be assessed by tasks such as binaural fusion or the masking level difference (MLD) test, there is an apparent need for more efficient tests in this category.

Binaural interaction can be assessed using the Listening in Spatialized Noise – Continuous Discourse test (LISN-CD; Cameron & Dillon, 2005). The LISN-CD produces a virtual three-dimensional auditory environment under headphones and runs on software on a personal computer. The processing simulates a target talker and some competing talkers' voices arriving from various directions in auditory space (0° and ±90°). The child's task is to follow the story being spoken by the target talker, and the audiologist adaptively adjusts the signal-to-noise ratio to find the "just understandable" threshold. By comparing the thresholds under different conditions (same talker versus different talkers, and same direction versus different directions) a diagnosis can be made of the ability to use different cues to suppress noise, and if there is a disability, the type of processing skill that seems to be deficient (tonal or spatial skills). A unique feature of the test is the use of difference scores to measure performance, which is scored as a difference in signal-to-noise ratio between a baseline condition, and three conditions where either spatial, tonal, or a combination of both spatial and tonal cues are provided. Thus, variation between children arising from many other factors, such as their knowledge of language, have little or no effect on the outcome.

Normally-hearing adults and children could understand the story at a significantly lower SNR (by up to 10 dB) when it was spatially separated from the noise by ±90° (Cameron, Dillon & Newall, 2005c, in review. See figure 2). In a study of ten children with no peripheral hearing loss or intellectual deficit, thought to have APD on the basis of their presenting profiles and comments by teachers and school counsellors, nine of the children were outside normal limits (on average by five standard deviations from the mean) on the "spatial advantage" measure of the LISN-CD, and the tenth child was borderline. As the speaker of both the target and the distracters is the same, the spatial advantage measure specifically assesses a listener's ability to use spatial cues, such as interaural time and intensity differences, to distinguish the target from the distracters (Cameron et al., 2005b, in review). These results support the assumption by Jerger (1998) that APD results from deficits in rapid temporal processing and "... in the accurate representation of auditory space" (p.394). The implication is that an inability to adequately combine information at the two ears to directionally suppress noise coming from non-target directions is a major cause of APD, and presumably of listening difficulties in classrooms.

Normative data for the LISN provided in Table 2 was collected from a group of 48 normally-hearing 7, 8 and 9 year old children described in Cameron et al., (2005c, in review). There were no significant differences found between the 7, 8, or 9 year olds on any LISN SNR or advantage measure. However, as there was a trend of improved performance with age across measures in the normally-hearing population, the cut-off scores were adjusted for age using the following formula: cut-off score = intercept + (B-value * age) – (2 * standard deviations of residuals from the age-corrected trend lines). The LISN-CD will be available for purchase shortly from the National Acoustic Laboratories. A version of the test requiring repetition of target sentence stimuli is also currently under development. Any enquiries can be forwarded to me at Sharon.Cameron@nal.gov.au.

A 500 Hz MLD test is also available on CD for testing binaural interaction deficits (Wilson, Moncrieff, Townsend & Pillion, 2003). This test assesses a listener's ability to use information sent to each ear to be able to separate tones from a background of noise. Stimuli consist of thirty-three 500 Hz tones presented in three-second bursts of 200-800 Hz noise at various fixed signal-to-noise ratios. Stimuli are presented binaurally at 50 dB HL in either a homophasic (SoNo), antiphasic (SpNo), or no signal condition. The child's task is to indicate whether or not they heard the tone. MLD is calculated as the score on the SoNo condition minus the score in the SpNo condition.

In the study by Cameron et al (2005b, in review), no child with suspected APD failed the MLD test and passed the LISN-CD spatial advantage measure. Five children, however, failed the spatial advantage measure and passed the MLD test. It is suggested that hierarchical binaural processing within the central auditory nervous system may explain these results, with the MLD limited to measuring performance at the lower structures of the brainstem, as reported by Bellis (2003), whilst the more complex LISN stimuli may measure binaural processing involving higher structures, including the auditory-spatial maps in the cortex. Normative data for the 500 Hz MLD test was obtained from Aithal, Yonovitz, Aithal and Yonovitz (2004). The MLD test is available from the Audiology Section, Department of Veterans Affairs Medical Centre, Mountain Home, Tennessee, USA. Contact Richard Wilson at Richard.Wilson2@med.va.gov for details.

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Step 4e: Evaluation of overall listening performance

Overall listening performance can be assessed using the Children's Auditory Performance Scale questionnaire (CHAPS; Smoski, Brunt, & Tannahill, 1998). This questionnaire is completed by the child's teacher, who is asked to judge the amount of listening difficulty experienced by the child, compared to a hypothetical reference population of children of similar age and background, for six listening conditions. These comprise listening in ideal conditions; in quiet; in noise; and when there are multiple inputs; as well as an assessment of auditory memory/sequencing, and auditory attention span. Degree of difficulty is determined on a scale ranging from (+1); where there is less difficulty than in the reference population, to (-5), indicating that the child cannot function at all. A child's total overall score can range from +36 to -180. Each individual listening condition score is divided by the number of questions for that condition to obtain an average condition score. The total overall score is divided by 36 to obtain an average overall score. Normative data for the CHAPS is provided by Smolski et al (1998), who report that a score of -1.0 or less overall, or for any condition, puts the child "at risk" for APD.

Cameron et al. (2005b, in review) found that six out of 10 children with suspected APD scored -1.0 or less on the CHAPS, however no significant positive correlation was found between performance on the CHAPS and any APD assessment tool. It is therefore suggested that whilst the CHAPS may provide valuable information in assessing overall auditory function, it is not, in itself, a valid indicator of APD. Rather, all aspects of the child's performance must be analysed in determining their suitability for diagnostic testing, or in categorizing a child with APD.

Step 5: Management of APD

Profiles based on the skill-specific deficits detected by the various central tests described above can be used to determine management options. Some of these options are discussed in Steps 5 (a) to (d), which outline auditory training for temporal resolution, temporal sequencing, binaural integration, and binaural interaction deficits. General management options, dealing with environmental modification and compensatory strategies, are discussed in Steps 6 (a) to (d).

It must be stressed that management of auditory processing disorders is a complex and developing area, where extensive research is needed to be undertaken, and the recommended strategies and approaches intervention discussed below are intended as a guideline only. While these recommendations are consistent with current beliefs, there is an inadequate evidence base to be sure that the particular exercises are either effective in overcoming the specific deficit measured, or in improving speech perception in noise as a consequence. There is, however, electrophysiological and behavioural evidence to support the idea that training does affect performance and neurological structures (for example, see Hayes, Warrier, Nichol, Zecker and Kraus, 2003). For more information on auditory training in general, and specific exercises, see Bellis (2002); Bellis (2003); Heine (2004); and Heine and Panayiotou (2004); Keith (1999); Mokhemar (1999); Musiek (1999).

The auditory training strategies discussed below are to be performed under the supervision of a speech pathologist. If their child is not already undertaking speech therapy, parents can contact Speech Pathology Australia on (03) 9642 4899, or visit their website at www.speechpathologyaustralia.org.au, to find a therapist dealing in APD management in their area.

Step 5a: Management of temporal resolution deficits

Auditory training for temporal resolution deficits can included the following exercises:

i. Phonological awareness training: phoneme discrimination, blending and segmentation.

ii. Temporal resolution training using non-speech sounds: Training involves "same/different" judgements of tones, or narrow- or broadband sounds that differ in frequency and/or temporal gaps.

Step 5b: Management of temporal sequencing deficits

Auditory training for temporal sequencing deficits can included the following exercises:

i. Temporal pattern training: These activities strengthen the ability to perceive non-linguistic changes in rhythm, stress and pitch. For example, imitating the rhythm of a series of claps, or tones (such as notes on a keyboard) of increasing complexity and length. The child identifies which clap is louder than the others, and which tone is higher or lower than the others.

ii. Prosody training: Specific therapy for interpreting tone-of-voice cues, for example learning to differentiate the meaning of a sentence based on word stress. Drills are also given to make spoken language more prosodically expressive.

Step 5c: Management of binaural integration deficits

Auditory training for binaural integration deficits can included the following exercises:

i. Auditory binaural integration exercises, such as singing and drawing, which help the two halves of the brain to work together.

ii. Formal dichotic listening training: These exercises are conducted over headphones using audiological equipment (a two channel audiometer is required). Training material should be targeted towards the interests of the child undergoing the training.

a. The target stimulus is presented to the weaker ear, and the competing message is presented to the stronger ear, with ear strength determined by dichotic test results.
b. The child's task is to describe the target. For example, summarize the plot of a target story.
c. The signal-to-noise ratio is increased if the child is unable to complete the task, and decreased when the task is accomplished.

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Step 5d: Management of binaural interaction deficits

Auditory training for binaural interaction deficits can included the following exercises:

i. Informal auditory training in localization skills: The child is asked to close his or her eyes, and sounds are presented to his or her left or right. The child must point to the direction the sound is coming from. When this activity is mastered, the target stimulus is delivered simultaneously with noise presented at 90o from the target. As the child becomes better at this task, the sound and noise are brought closer together. Also see Heine and Panayiotou (2004, pp. 55-56).

ii. Informal noise desensitisation therapy: The child learns to listen to instructions and stories in the presence of background noise. The child completes the instruction, or answers questions about the story. These activities can be conducted in noise at various signal-to-noise ratios and degrees of spatial separation. Also see Heine and Panayiotou (2004, pp. 51-52).

Step 6: Strategies to improve the listening environment and compensate for deficits

As, in most cases, a deficit in one of the auditory skills described in Step 4 will result in difficulties listening in class that will be exacerbated when the signal is masked by background noise, some general strategies can be applied to modify a child's environment in order to improve his or her access to auditory information - including recommendations for assistive listening devices. Strategies can also be taught to help the child to compensate for their listening difficulties. A review of some of these strategies is provided below. For a comprehensive discussion see Bellis (2003); Heine (2004); and Heine and Panayiotou (2004).

Step 6a: Modification of Environment

i. Modify the classroom if acoustic characteristics do not confirm to recommended standards. For example, place mat and cloth poster boards around the classroom to minimize reverberation.

ii. Preferential seating in the classroom, close to the teacher will make facial expressions clearly visible, and maximise the ratio of direct sound to reverberant sound. The seating position should also be away from noisy equipment, such as overhead fans, to maximize the signal-to-noise ratio.

iii. An assistive listening device, particularly one that conveys the sound from a microphone near the teacher's mouth directly to the child, may also be helpful.

Step 6b: Classroom-Based Strategies

Various classroom based strategies can also be helpful in assisting children with listening difficulties to extract as much information from the auditory signal as possible. These strategies include speaking in short, simple sentences; repeating a message if not comprehended, slowing the speed of delivery; providing visual cues and hands-on demonstrations, as multimodal cues add to the auditory information so that the whole message can be understood; pre-teaching new information/vocabulary; gaining attention prior to speaking; frequently checking for comprehension; using positive reinforcement generously; and planning regular listening breaks to avoid auditory fatigue.

Step 6c: Compensatory Strategies

The following compensatory strategies are designed to help the child to take control of their listening environment.

i. Attribution training: The child is taught to anticipate difficult listening or learning situations and develop plans for avoiding or alleviating them. This is especially important if the child has secondary motivational problems. The child should be taught to:

a) understand the nature of the problem (for example, an inability to hear clearly, or lack of comprehension of spoken instructions).
b) determine the possible cause of the problem (e.g. noises outside the classroom, children chatting).
c) create a solution (e.g. move to another location, ask for repetition or clarification of instructions).
d) apply the most appropriate solution.
e) evaluate the effectiveness of that solution.
f) self-reinforcement if the solution was successful, or reanalysis of the problem if the solution was unsuccessful.

ii. Whole body listening techniques: These techniques are especially useful if there are motivational concerns. I also implement these strategies during diagnostic testing.

a) Place the body in an alert position by straightening the spine.
b) Incline the upper body and head toward the speaker.
c) Keep eyes firmly on the speaker.
d) Avoid any activity, such as fidgeting, that diverts attention from the speaker.

Step 6d: Direct Intervention

Direct intervention strategies can also be implemented by a speech pathologist. These techniques aim to strengthen "top down" mechanisms to assist in comprehension of the auditory signal. Examples are provided in Heine (2004); Heine and Panayiotou (2004); and Mokhemar (1999), and include context-based auditory closure training; vocabulary building; and drills in speech-to-print skills to improve any spelling and reading deficits.

Conclusion

The assessment and management of children with APD is an evolving area, and one which requires much further research and evaluation. It is hoped, however, that this article has provided audiologists who are interested in cental auditory assessment of children with suspect APD with a basic and practical framework from which to deal with referrals for assessment from parents, school counsellors, and other professionals.

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References

Aithal, V., Yonovitz, A., Aithal, S., & Yonovitz, L. (2004). Tonal masking level difference in children. Manuscript submitted for publication.

American Speech-Language-Hearing Association (1996). Central auditory processing: Current status of research and implications for clinical practice. *American Journal of Audiology, 5(2)*, 41-54.

Bamiou, D-E., Musiek, F.E., & Luxon, L.M. (2001). Aetiology and clinical presentations of auditory processing disorders – a review. *Archives of Disease in Childhood, 85(5)*, 361-365.

Bellis, T.J. (2002). *When the brain can't hear. Unraveling the mystery of auditory processing disorder.* New York, NY: Pocket Books.

Bellis, T.J. (2003) Assessment and management of central auditory processing disorders in the educational setting. From Science to practice. New York, NY: Delmar Learning.

Bellis, T.J., & Ferre, J.M. (1999). Multidimensional approach to the differential diagnosis of central auditory processing disorders in children. *Journal of the American Academy of Audiology, 10 (6)*, 319-328.

Bellis, T.J., & Ferre, J.M. (1996). Assessment and management of central auditory processing disorders in children. *Educational Audiology Monograph, 4,* 23-27.

Cameron S, Barker R, Newall P. (2003a). *The Macquarie Pediatric Speech Intelligibility Test [CD].* Sydney, NSW: Speech, Hearing and Language Research Centre, Macquarie University.

Cameron, S., & Dillon, H. (2005). *The Listening in Spatialized Noise Test (LISN)™ – Continuous Discourse* (Version 1.0.0) [Computer software]. Sydney, NSW: National Acoustic Laboratories.

Cameron, S., Dillon, H., & Newall, P. (2005a). Three case studies of children with suspected auditory processing disorder: Screening, diagnosis, and management. Manuscript submitted for publication.

Cameron, S., Dillon, H., & Newall, P. (2005b). The Listening in Spatialized Noise Test: Auditory processing disorder study. Manuscript submitted for publication.

Cameron, S., Dillon, H., & Newall, P. (2005c). The Listening in Spatialized Noise Test: Normative data for children. Manuscript submitted for publication.

Chermak, G.D., Hall III, J.W., & Musiek, F.E. (1999). Differential diagnosis and management of cental auditory processing disorder and attention deficit hyperactivity disorder. *Journal of the American Academy of Audiology, 10,* 289-303.

Chermak, G.D., Tucker, E., & Seikel, J.A. (2002). Behavioral characteristics of auditory processing disorder and attention-deficit hyperactivity disorder: predominantly inattentive type. *Journal of the American Academy of Audiology, 13,* 332-338.

Domitz, D.M. & Schow, R.L. (2000). A new CAPD battery – multiple auditory processing assessment: Factor analysis and comparisons with SCAN. *American Journal of Audiology, 9 (7),* 101-111.

Friel-Patti, S. (1999). Clinical decision-making in the assessment and intervention of central auditory processing disorders. *Language, Speech & Hearing Services in Schools, 30(4),* 345-352.

Golding, M., Lilly, D.J., & Lay, J.W. (1996). A Staggered Spondaic Word (SSW) Test for Australian use. *The Australian Journal of Audiology, 18(20),* 81-88.

Hayes, E.A., Warrier, C.M., Nichol, T.G., Zecker, S.G., & Kraus, N. (2003). Neural plasticity following auditory training in children with learning problems. *Clinical Neurophysiology, 114,* 673-684.

Heine, C. (2004). Listening Now! *An intervention program for children and adolescents with (central) auditory processing disorder.* South Perth, WA: Unicom Education.

Heine, C., & Panayiotou, V. (2004). The CAPEL *Program - An Auditory Processing and Language-Learning Program for Speech Pathologists and Educators.* South Perth, WA: Unicom Education.

Jerger J. (1998). Controversial issues in central auditory processing disorders. *Seminars in Hearing,* 19, 393-398.

Jerger, S., & Allen, J. (1998). How global behavioural tests of central auditory processing may complicate management. In F. Bess (Ed.), *Children with hearing impairment* (pp. 163-177). Nashville: Bill Wilkerson Centre Press.

Jerger, J., & Musiek, F. (2002). On the diagnosis of auditory processing disorder. A reply to "clinical research concerns regarding Jerger & Musiek (2000) APD recommendations". *Audiology Today, 14(2),* 19-21.

Jerger, J., & Musiek, F. (2000). Report of the consensus conference on the diagnosis of auditory processing disorders in school-aged children. *Journal of the American Academy of Audiology, 11,* 467-474.

Katz, J., & Smith, P.S. (1991). The Staggered Spondaic Word Test. A ten minute look at the central nervous system through the ears. In R. Zappula, F.F. LeFever, J. Jaeger, & R. Bilder (Eds.), Windows on the Brain: Neuropsychology technical frontiers. *Annals of the New York Academy of Science, 620,* 1-19.

Keith, R.W. (2000). *Random Gap Detection Test [CD].* St Louis, MO: AUDiTEC.

Keith, R.W. (1995). Tests of central auditory processing. In R.J. Rosser, & M.P. Downs, (Eds.), *Auditory disorders in school children* (pp. 101-116). Baltimore: Lippincott Williams & Wilkins.

Marriage, J., King, J., Briggs, J., & Lutman, M.E. (2001). The reliability of the SCAN test: Results from a primary school population in the UK. *British Journal of Audiology, 35,* 199-208.

Medwetsky, L. (2002). Central auditory processing testing: A battery approach. In J. Katz (Ed.), *Handbook of clinical audiology* (pp. 510-531). Baltimore: Lippincott Williams & Wilkins.

Mokhemar, M. (1999). *The central auditory processing kit™.* East Moline, IL: LinugiSystems.

Musiek, F. (1999). Habilitation and management of auditory processing

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disorders: Overview of selected procedures. *Journal of the American Academy of Audiology, 10 (6),* 329-342.

Musiek, F.E., & Chermak, G.D. (1994). Three commonly asked questions about central auditory processing disorders: Assessment. *American Journal of Audiology, 3 (3),* 23-27.

Musiek, F.E., Geurkink, N.A., & Kietel, M.A. (1982). Test battery assessment of auditory perceptual dysfunction in children. *Laryngoscope, 92,* 251-257.

Pinheiro, M.L. (1977). Tests of central auditory function in children with learning disabilities. In: R. Keith (Ed.), *Central Auditory Dysfunction* (pp. 223-256). New York, NY: Grune & Stratton, 223-256.

Richard, G.J. (2001) *The source for processing disorders.* East Moline, IL: LinguiSystems, Inc.

Schow, R.L., Seikel, J.A., Chermak, G.D. & Berent, M. (2000). Central auditory processes and test measures: ASHA 1996 revisited. *American Journal of Audiology, 9 (7),* 63-68.

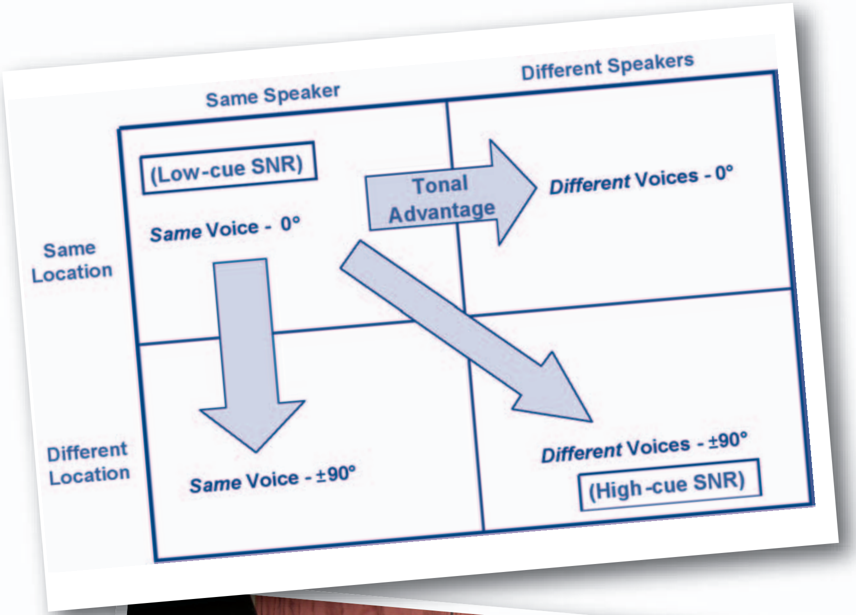
Semel, E., Wiig, E., & Secord, W. (2003). *Clinical Evaluation of Language Fundamentals – Fourth Edition.* San Antonio, TX: Psychological Corporation.

Singer, J., Hurley, R.M., & Preece, J.P. (1998). Effectiveness of central auditory processing tests with children. *American Journal of Audiology, 7(2),* 73-84.

Singh, S., & Kent, R.D. (2000). *Illustrated dictionary of speech-language pathology.* San Diego, CA: Singular Publishing Group, Inc.

Smoski, W.J., Brunt, M.A., & Tannahill, J.C. (1998). *Children's Auditory Performance Scale.* Tampa, FL: The Educational Audiology Association.

Sockalingam, R., Murrison, R., Cole, D., James, S., Morin, S., & Potter, S. (2004). Comparing SCAN-A scores between speakers of standard Australian English and American English: A preliminary study. *The Australian and New Zealand Journal of Audiology, 26 (2),* 110-115.



Above Top: Figure 1. Illustration of LISN-CD conditions, and SNR and advantage measures.

Above Bottom: Figure 2. Collection of normative data for LISN-CD study in the Macquarie University sound-attenuated mobile laborator

Stecker, N.A. (1998). Overview and update of central auditory processing disorders. In M.G. Masters, N.A. Stecker & J. Katz (Eds.), *Central auditory processing disorders. Mostly management* (pp. 1-14). Needham Heights, MA: Allyn & Bacon.

Vanniasegaram, I., Cohen, M., & Rosen, S. (2004). Evaluation of selected auditory tests in school-age children suspected of auditory processing disorder. *Ear & Hearing, 25(6),* 586-597.

Wechsler, D. (2003). Wechsler Intelligence Scale for Children – Fourth Edition. San Antonio, TX: Psychological Corporation.

Wilson, R.H., & Strouse, A. (1998). *Tonal & speech materials for auditory perceptual assessment disc 2.0 [CD].* Mountain Home, TN: VA Medical Centres.

Wilson, R.H., Moncrieff, D.W., Townsend, E.A., & Pillion, A.L. (2003). Development of a

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Table 1.
Mean scores and standard deviations, based on normative data for the PPS, dichotic digits, RGDT, and 500Hz MLD test, with cut-off scores calculated as two standard deviations from the mean, for either right ear and left ear, or bilateral presentation.

Test	Age	Mean			SD			Cut-Off Score		
		RE	LE	Bilateral	RE	LE	Bilateral	RE	LE	Bilateral
PPS	7	78%	76%	-	7%	8%	-	64%	60%	-
	8	87%	76%	-	5%	8%	-	77%	60%	-
	9	91%	91%	-	5%	5%	-	81%	81%	-
Dichotic Digits	7	74%	74%	-	6%	6%	-	62%	62%	-
	8	92%	89%	-	5%	6%	-	82%	77%	-
	9	93%	91%	-	6%	5%	-	81%	81%	-
RGDT	7	-	-	7.3 msec	-	-	4.8 msec	-	-	16.9 msec
	8	-	-	6 msec	-	-	2.5 msec	-	-	11 msec
	9	-	-	7.2 msec	-	-	5.3 msec	-	-	17.8 msec
MLD	All	-	-	11.2 dB	-	-	1.7 dB	-	-	7.8 dB

Table 2.
Normative data used in calculation of LISN cut-off scores

Measure	Mean [a]	SD (Residuals)	Intercept	B-Value
	dB	dB		
Low-Cue SNR	2.0	1.9	6.93	-0.58
High-Cue SNR	-8.4	2.3	- 1.08	0.86
Tonal Advantage	6.7	2.1	5.73	0.50
Spatial Advantage	10.0	1.8	1.62	0.60
Total Advantage	10.4	2.4	8.01	0.28

[a] n = 48

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500-Hz masking-level difference protocol for clinical use. *Journal of the American Academy of Audiology, 4(1)*, 1-8.

Wilson, W.J., Heine, C., & Harvey, L.A. (2004). Central auditory processing and central auditory processing disorder: Fundamental questions and considerations. *Australian and New Zealand Journal of Audiology, 26(2)*, 80-93.

Corresponding Author

Sharon Cameron, PhD (Graduand)
Research Scientist
National Acoustic Laboratories
126 Greville Street
Chatswood, NSW, 2067
Australia
Phone: +61 2 9412 6851
Fax: +61 2 9411 8273
e-mail: Sharon.Cameron@nal.gov.au