Central auditory processing: a current literature review and summary of interviews with researchers on controversial issues related to auditory processing disorders

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Central Auditory Processing: A Current Literature Review (Part I) and Summary of Interviews with Researchers on Controversial Issues Related to Auditory Processing Disorders (Part II)

A Current Review (Part I)

Introduction

Consider the following scenario: A third grader seems to pay attention to his teacher when working one-on-one. During group discussions, however, he spends most of his time looking out the window or at classroom decorations. In turn, the student receives a low grade in class participation. Now contemplate this situation: A seventh grader was supposed to arrive home at 4:00 pm to be on-time for an appointment. When she walks through the door at 5:30, she is surprised to hear about her appointment and has no recollection of her mother reminding her about it that morning. Are these normal child and adolescent behaviors, or is there an underlying problem or deficiency? In the past several decades, auditory processing disorder (APD) has become a popular discussion topic among audiologist and speech pathologist clinicians and researchers. Different issues related to APD evaluation and management are addressed in Part I and II of this paper, each in an attempt to provide a current summary and insight to the reader regarding APD, focusing mainly on the disorder in children:

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>PAGE #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition and Description</td>
<td>1-4</td>
</tr>
<tr>
<td>Associated Anatomy, Pathogenesis and Incidence</td>
<td>4-7</td>
</tr>
<tr>
<td>Associated Disorders and Typical Profile</td>
<td>8-11</td>
</tr>
<tr>
<td>Screening</td>
<td>11-14</td>
</tr>
<tr>
<td>Formal Assessment</td>
<td>14-21</td>
</tr>
<tr>
<td>Classification Models</td>
<td>21-24</td>
</tr>
<tr>
<td>Intervention and Remediation</td>
<td>24-31</td>
</tr>
<tr>
<td>Closing Remarks</td>
<td>31-32</td>
</tr>
<tr>
<td>Summary of Interviews (Part II)</td>
<td>33-41</td>
</tr>
<tr>
<td>Appendix</td>
<td>42-53</td>
</tr>
<tr>
<td>References</td>
<td>54-58</td>
</tr>
</tbody>
</table>
**Definition and Description**

Assigning a concrete definition to APD is a task that has been approached by many organizations. The American Speech-Language-Hearing Association’s (ASHA) Committee on APD devised the following description in the 1992:

“Central auditory processing disorders are deficits in the information processing of audible signals not attributed to impaired peripheral hearing sensitivity or intellectual impairment. This information processing involves perceptual, cognitive, and linguistic functions that, with appropriate interaction, result in effective receptive communication of auditorily presented stimuli. Specifically, APD refers to limitations in the ongoing transmission, analysis, organization, transformation, elaboration, storage, retrieval, and use of information contained in audible signals” (ASHA, 1992).

ASHA formally reconvened on the topic again in 1996, creating Task Force on Central Auditory Processing Consensus Development. This group identified central auditory process as the auditory system mechanisms and processes responsible for the following behaviors:

- **Sound localization and lateralization**, or ability to know where sound has occurred in space
- **Auditory discrimination**, or ability to distinguish one sound from another
- **Auditory pattern recognition**, or ability to determine similarities and differences in patterns of sounds
- **Temporal aspects**, or abilities to sequence sounds, integrate a sequence of sounds into meaningful combinations, and perceive sounds as separate when they quickly follow one another
Matson

- Auditory performance decrements, or ability to perceive speech or other sounds when another signal is present

- Auditory performance with degraded acoustic signals, or ability to perceive a signal in which some of the information is missing.

The Task Force considered APD to be a deficiency in one or more of these abilities (ASHA, 1996).

At the 2000 Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children, scientists and clinicians also offered their interpretation on the disorder: “An auditory processing disorder (APD) may be broadly defined as a deficit in the processing of information that is specific to the auditory modality. It may be associated with difficulties in listening, speech understanding, language development, and learning” (Jerger & Musiek, 2000). Researchers at this conference were also responsible for changing the traditionally used term “CAPD” to “APD”. Their reasoning included maintaining operational definitions, avoiding the imputation of anatomical loci, and emphasizing the interactions of disorders at both peripheral and central sites (Jerger & Musiek, 2000). Perhaps one of the simplest perspectives on central auditory processing is suggested by Kelly (1995). The author describes the concept as “what we do with what we hear”, and “…receiving [auditory] information and acting upon it meaningfully”.

Auditory processing can also be considered in terms of functional units or areas of the brain (Santucci, 2003), graphically represented by the diagrams within Figure I (*see Appendix for figures). The arousal unit (Diagram B) encompasses the subcortex area and the reticular formation, the mechanism which alters the brain to a novel stimulus within a stream of stimuli. This unit’s operations include arousal, selective attention, divided attention, orienting reflex,
localization, acoustic filtering, and registration. In contrast, the *sensory reception* unit (**Diagram C**) is associated with the temporal, occipital, and parietal lobes of the brain. Its responsibilities involve detection, discrimination, short-term memory, recognition, acoustic analysis, perception, and consolidation. Finally, the *output planning* unit (**Diagram D**) encompasses the frontal lobe. Operations such as concentration, comprehension, long-term memory, recall and retrieval, cognition, language, metalanguage, organization, input-output coordination, integration, and sequencing are performed by the output planning unit.

**Associated Anatomy, Pathogenesis and Incidence**

Before APD can be discussed at levels beyond its definition, it is beneficial to have a basic understanding of its associated anatomy. Bamiou, Musiek, and Luxon (2001) provide a comprehensive overview of the anatomy of the central auditory nervous system (CANS). This system extends from the cochlear nucleus in the brainstem to the auditory cortex. Important relay stations along this pathway include the superior olivary complex, lateral lemniscus and inferior colliculus, medial geniculate body, and the reticular formation. The cortical and subcortical areas associated with auditory processing are known as Heschl’s gyrus and the Sylvian Fissure. Further, the corpus callosum connects the two cerebral hemispheres. The authors also make note of the characteristic plasticity of the brain of young children. As myelination and maturation continue in children until age 10-12, sensory representations in the young brain may change in response to altered receptors, sensory environment, and learning (Bamiou, Musiek, & Luxon, 2001).

APD is thought to occur primarily in young children and older adults. Reports on the pathogenesis of the disorder vary greatly throughout research. Stach (1998) offers that, in children, the majority of APD cases are not the result from documented, discrete neuropathologic
impairments. Rather, the pathogenesis of the resulting hearing disorder is largely an idiopathic dysfunction of the central auditory nervous system. Further, the author supports that, although some children may be genetically predisposed to APD, it is more likely a developmental result of inconsistent auditory input during auditory perceptual development.

On the other side of the spectrum, other research has suggested that APD in children may be categorized based upon its pathogenesis. Chermak (1992) states that there are three types of central auditory disorders in children: diseased CANS, maturational delayed CANS, and disorganized CANS. Although it is difficult to distinguish between those with maturationally delayed and disorganized CANS, some researchers argue that some tests, such as ABR and acoustic reflexes, have the ability to identify the site of lesion in children with diseased CANS (Johnson et al, 1997).

Shapiro (2003) describes one possible cause of diseased CANS in the pediatric population. Bilirubin toxicity remains a significant problem in newborns despite recent medical advances in treatment of such condition. Excessive amounts and duration of exposure to free, unconjuagated bilirubin at different stages of neurodevelopment may result in a variety of neurologic sequelae, including auditory neuropathy and other central auditory processing disorders. Associated manifested central auditory pathology may involve the brainstem auditory structures, such as the dorsal and ventral cochlear nuclei, superior olivary complex, nuclei of lateral lemniscus, and inferior colliculi. These central nervous system abnormalities have been confirmed by decreased binaural fusion and cases of patients labeled as “deaf” when objective tests indicate normal thresholds (Shapiro, 2003). It is important to note that, regardless of the type or patheogenesis of the CANS disorder, all children with APD are treated with essentially the same approach in terms of management and treatment strategies.
The existence of APD in the pediatric population seems to be less controversial than when speaking or reading about the disorder occurring within the older adult community. As Stach contends (1998), the processes of aging induce change to many bodily structures and functions, including the peripheral and central auditory system. In terms of central auditory processing, this presents as degradation of auditory processing. In contrast to characteristics of the disorder in children, APD in the aging population is often combined with peripheral cochlear effects in the form of attenuation and distortion.

The difficulty experienced by hearing-impaired elderly is often greater than expected given the amount of hearing loss. While many researchers support the APD "hypothesis" to explain this, other research, such as that by Humes et al (1992) offers other possibilities: the peripheral-distortion hypothesis and the cognitive hypotheses. Using a peripheral hypothesis, the authors maintain that individual differences in speech understanding performance result from individual variation in the peripheral encoding of sound by the outer, middle, and inner ears. Individual differences in spectral and temporal resolution would be an example of this. The cognitive hypothesis, on the other hand, explains that individual variation in cortical functions, such as information processing, labeling, storage, and retrieval, is what underlies differences in speech understanding in the elderly.

The exact prevalence of APD in the adult and pediatric population has not been firmly established for several reasons. First, the lack of standard definition of terminology of APD has caused difficulty establishing an accurate number, leading to a variance in prevalence estimates. (Keith, 1995). In children, mild cases of auditory processing disorders may be inconspicuous, as the affected student may learn to compensate in various academic and social situations. According to the Association of Children and Adults with Learning Disabilities (ACLD),
between 8,000,000 and 12,000,000 children in the United States have a learning disability; many of these children have APD (Keith, 1995). Some research estimates have offered the current prevalence of APD in the pediatric population to be around 3-5% (Santucci, 2003).

In addressing APD prevalence specifically in older adults, the simultaneous presence of peripheral auditory deficits also increases the difficulty in deciphering purely central auditory disorders. Reports of prevalence of APD in the older adult population vary, ranging from well over 50% in clinical studies (Stach et al, 1990) to around 23% in a longitudinal population study (Cooper & Gates, 1991). Golding et al (2004) conducted a population study of age-related hearing loss in an urban Australian community. The subjects, 2,015 Australians aged 55 year and older, were assessed using a battery of auditory tests. In addition to pure-tone audiometry and speech recognition testing, the Australian versions of the Synthetic Sentence Identification test and the Dichotic Sentence Identification test were also administered. These tests are further described later in this paper.

The results from these tests showed a high overall prevalence rate (76.4%) of auditory processing abnormalities, compared to previous clinical studies. Further, the number of abnormal test outcomes increased systematically with age, as indicated by Figure II. This figure demonstrates that, with increasing age, there were proportionally more participants with an increasing number of abnormal test outcomes. The mean age differences between these groups were highly significant. Hearing loss was not found to increase systematically with the number of abnormal test outcomes. Golding et al (2004) concluded that central auditory processing (CAP) abnormality is a highly prevalent condition in their population of study when defining prevalence as abnormality on any one of a number of test measures. Needless to say, the various
interpretations across research in defining “prevalence” constitute another confounding factor in
determining an accurate incidence.

Associated Disorders and Typical Profile

Patients with APD generally show normal bilateral pure tone sensitivity. *Figure III*
shows averaged audiograms from 21 patients, ranging from 6-57 years old, with surgically or
radiographically confirmed brain stem or temporal lobe lesions. (Jerger, 1981). In both groups
of patients, the pure tones were bilaterally normal and symmetric, with the exception of a mild
loss at 4000 Hz in both ipsilateral and contralateral conditions in the temporal lobe group. One
group of APD patients provide an exception to this case; however. Those rarely afflicted with
bilateral, rather than unilateral, temporal lobe disease may result in “cortical deafness”,
presenting audiometrically as a bilateral hearing loss of varying degree (Jerger, 1981).

Normal pure tone thresholds in the presence of central auditory deficits were also
confirmed by Baran et al (2004). The author’s case study involved a 46-year-old female who had
suffered a cerebral vascular accident (CVA). The MRI revealed that the damage occurred in the
primary auditory area of the left hemisphere, as evidenced by the MRI in *Figure IV*. Before the
CVA, no auditory problems were noted; however several auditory difficulties were reported by
the subject post-trauma. In addition to normal pure tone thresholds, as shown in *Figure V*,
speech recognition testing scores were also within normal limits. In contrast, right ear deficits on
the auditory fusion tests, and the digits and rhymes dichotic speech tests were evidenced.
Further, duration pattern, intensity discrimination, and middle latency responses proved to be
abnormal for both ears.

Johnson et al (1997) discuss that most children with APD have normal intelligence and
normal hearing sensitivity; however, it can co-exist with hearing loss or other cognitive or
neurological deficits. A list of behaviors commonly shown by children with APD is provided in

**Figure VI.** The authors note that, although children do not usually display all of the behaviors
listed, they tend to evidence several of them.

Children with APD present with many of the same behaviors compared to children with Attention Deficit and Hyperactivity Disorder (ADHD). These disorders are likely separate, but may occur independently or in conjunction with each other (Keller, 1998). According to Barkley (1990), approximately 25-40% of children with ADHD also are impaired with a learning disability (LD). Acknowledging the relationship between ADHD and LD, and also the relationship between ADHD and APD, it is likely that a relationship between APD and the occurrence of LD exists. To test this hypothesis, Katz (1992) sampled 94 children with various LDs. Of this sample, only one child’s results reflected an absence of CAP dysfunction, a result that has been replicated in other studies, as well. Clearly, a strong relationship between APD, LD, and ADHD is evident.

The types of classroom management strategies and remediation techniques that are effective for a child with APD also tend to be effective for a child with ADHD (Keller, 1992). Although it is generally accepted that the two disorders are independent of one another, as previously mentioned, their similarities in terms of behavioral manifestations have led some researchers to question whether or not APD and ADHD are a single developmental deficit. These common behavioral manifestations may include distractibility, hyperactivity, short attention span, forgetfulness, restlessness, problems following directions, inappropriate social behavior, excessive talking, and inability to complete assignments (Keller, 1992).

King et al (2003) investigated the extent of comorbid APD in a group of adults with developmental dyslexia. The researchers also compared performance on auditory tasks to
reading ability in an attempt to generate a profile of developmental dyslexics with APD. The two subject groups consisted of eleven persons with developmental dyslexia and fourteen control persons. To test for evidence of comorbid APD, the frequency-pattern test (FPT) and the duration-pattern test (DPT) were administered monaurally, and a score of 70% or below was considered indicative of APD. A gap detection test was also performed, using narrowband noise centered at 1000 Hz in an adaptive two-alternative forced choice paradigm. Finally, reading ability was measured through administration of standardized tests of reading.

Results from the King et al (2003) study indicated that persons with developmental dyslexia performed significantly poorer than the control groups for the FPT and DPT test; approximately half of these subjects scored below 70%, suggesting the presence of comorbid APD. In terms of the gap detection test, however, there was no significant group difference. Further, the authors found no significant correlations between performance on auditory tasks and the standardized reading tests; thus, the attempt to identify a behavioral profile among the participants with developmental dyslexia of behaviors that were also predictive of APD was unsuccessful. In their concluding recommendations, King et al (2003) offered that, although it is highly improbable that all persons with developmental dyslexia have comorbid APD, their data suggest the need to be alert to the possible co-occurrence of dyslexia with auditory processing deficits. Specifically for audiologists, it is important for the managing professional to make appropriate referrals for reading evaluations when warranted.

Figure VII provides a summary for the close relationship between APD, LD, ADD, and dyslexia, in light of their common (or not) behavioral manifestations. It is important for the clinician to remain cogniscente of these associated disorders in terms of proper diagnosis. In summary, Keith (2004) offers the following to represent a typical profile of children with APD:
Mostly male

Normal pure tone hearing thresholds

Inconsistent response to auditory stimuli

Short attention span and quickly fatigue with complex auditory stimuli

Easily distracted by (non-target) auditory stimuli

Difficulty with auditory localization skills

Difficulty following complex verbal commands or instructions

Difficult remembering information presented verbally

Slow responders to auditory information

**APD Screening**

The identification of APD is a challenging, complex, and multi-step process. Initial and secondary screenings often take place before any formal diagnostic testing is conducted. The purpose of the initial screening is to identify those children suspected of having APD, while the second screening aims to determine who should be referred for the formal APD evaluation (Johnson et al, 1997).

In terms of the initial screening, the efficacy of a mass screening, such as for peripheral hearing loss, has been greatly debated. On one hand of the argument, some researchers feel that undiagnosed APD leads to communication and academic difficulties; thus, mass screening is justified. However, other authors stress the variance in defining APD, in addition to its close association to attention, cognitive, and language disorders. The latter viewpoint seems to take precedence in academic settings, as mass APD screenings are rarely performed. Often, the initial screening takes the form of referrals from teachers or parents. Characteristic profile checklists often aid these teachers and parents in their referrals.
Prior to attempting a second screening, it is necessary to rule out peripheral hearing loss as the cause of the suspected communicative behaviors. Keith (1995) provides an overview of possible causes of various types of hearing loss. For example, conductive hearing losses may result from otitis externa, otitis media, impacted cerumen, and occlusion of the outer ear canal by a foreign body, while sensorineural hearing loss may be the result of causes such as a virus, head trauma, or genetic factors. A mild, flat peripheral hearing loss, or a sloping high frequency hearing loss are the configurations most likely to present in behaviors similar to those produced by APD, such as poor auditory attention and inconsistent auditory responses. The author also note that there is growing evidence that prolonged otitis media with static or fluctuating hearing loss can lead to central auditory problems that can cause language and learning delays long after the middle ear disorder is treated (Keith, 1995). In turn, this suggests that children with histories of chronic colds, sinus problems, and middle ear infection should be carefully monitored in their auditory, language, and learning abilities.

In addition to pure tone testing, acoustic reflex testing may prove valuable in terms of differential diagnosis. These reflexes are thresholds measured by presenting a sound to either ear and varying its intensity level until the lowest hearing level that produces the stapedial reflex is determined (Jerger, 1981). One benefit of this test is that sensorineural hearing loss can be detected by comparing the acoustic reflex thresholds for pure tones versus broadband noise. In patients with normal hearing, reflex thresholds are around 70 dB SPL for broadband noise, and approximately 95 dB SPL for pure tones; however, this difference disappears when sensorineural hearing loss exists. Acoustic reflex testing is also useful in its sensitivity to the presence of auditory disorder at the brainstem level (Jerger, 1981). In patients with normal brainstem function, crossed and uncrossed reflex thresholds are similar between 70-100 dB SPL. However,
in patients with brain stem auditory disorders, uncrossed reflexes are usually normal, but crossed reflexes tend to be abnormally elevated.

Once a peripheral hearing loss has been ruled out, a secondary, more formal screening is necessary to decide candidacy for in-depth evaluation of APD (Johnson et al, 1997). This secondary screening usually takes on of the following two forms: auditory processing screening tests and teacher checklists. Three popular auditory screening tests include the Screening Test for Auditory Processing Disorders (SCAN), Test for Auditory Processing Disorders in Adolescents and Adults (SCAN-A), and the Selective Auditory Attention Test (SAAT). Audiologists, speech-pathologists, and learning specialists are all qualified professionals to administer these tape-recorded tests (Johnson et al, 1997).

Alternatively, teacher checklists are useful in collecting and quantifying observed auditory behaviors. One widely used example of such is the Children’s Auditory Processing Performance Scale (CHAPPS), a scaled questionnaire used to rate listening behaviors in a variety of conditions. Fisher’s Auditory Problems Checklist is also useful to describe listening, attending, and auditory memory skills. In addition, Keith (2004) recommends The Evaluation of Classroom Listening Behaviors (ECLB) and the Screening Instrument for Targeting Educational Risk (SIFTER) as useful inventories for describing a child’s auditory performance in an educational setting.

It is apparent that a lack of standardization exists for screening protocols of APD. In response, some clinics have set guidelines to improve the quality of referrals for diagnostic APD testing by attempting to eliminate possible confounding variables. For example, the following requirements for student referral were established in the Houston area (Kent, 2002):

- Be at least 7 years old
- Have passed a hearing screening within the year
- Have English as their primary language
- Have an IQ of 85 or higher
- Have had a recent psychoeducational assessment to determine learning disability, attention deficit, or emotional problems and performance related to cognitive ability
- Have had a speech and language assessment within the year that examines auditory processing skills
- Have intelligible speech
- Be able to follow directions and complete the APD testing

**APD Formal Assessment**

If a child fails both the auditory processing checklist and/or the teacher checklist, a formal APD evaluation is the next step. A thorough case history is necessary to obtain pre-assessment. Items for questioning should include information on the family, pregnancy and birth, developmental milestones and general health, general behavioral and socioemotional development, speech and language development, hearing and auditory behavior, nonauditory behavior, and educational progress. (Keith, 1995). *Figure VIII* is an information model for taking a case history with parents of a child suspected of having APD.

In addition to case history obtained by the audiologist, information obtained from other professionals, as resulting from independent evaluations, allows for a variety of perspectives on the disorder. Further, patients should be referred to other specialists for additional assessment when appropriate. The following are examples of other related professionals who may contribute
to the case history, or may be consulted by the audiologist for evaluation or in accordance with remediation (Hall & Mueller, 1997):

- Speech language pathologist, for evaluation and management of language disorders
- Psychologist, for goals similar to those children with any types of communication or learning disorder, including (Culbertson, 1981):
  - Determining cognitive ability
  - Examining perceptual modes of learning (auditory, visual, motor, etc)
  - Observing child’s communication style
  - Evaluating academic strengths and weaknesses
  - Examining social/emotional adaptation
- Special Education, for specialization in learning disabilities, especially in reading disorders
- Pediatric Neurology, for evaluation of neurologic disorders such as seizure and developmental delay
- Otolaryngology, for treatment of any middle ear disorder prior to APD assessment
- Child Development Center, for children with multiple psychoeducational, communicative, and/or medical problems
- Classroom Teacher, for implementation of educational modifications
- Parents, for implementation of home management and overseeing that all recommendations are implemented
- Child advocate, for assisting parents in ensuring an appropriate education plan is carried out fully
At least two approaches for evaluating central auditory abilities have evolved over the years: non-audiometric tests that constitute a “speech-language pathology model”, and audiometric tests that make up an “audiology model” (Keith, 2004). The speech-language pathologist’s scheme applies the cognitive perspective and focuses on information processing strategies, following a “top-down” model of auditory processing. The audiologist’s approach, however, targets deficiencies specific to the auditory system. In this model, the individual’s auditory processing abilities are evaluated along the entire peripheral and central pathway. Thus, the audiologist’s approach follows a “bottom-up” model.

The most comprehensive, thorough assessment is likely accomplished by a test battery consisting of both audiometric and non-audiometric measures. The following is a breakdown of constituents of each category of assessment (Johnson et al, 1997):

**Behavioral Audiometric tests**

- Monotic speech tests

  Low-pass filtered speech, time-altered speech, and speech-in-noise tests characterize monotic speech tests. Their purpose is to determine how distortions of speech affect the child’s ability to understand language with each ear separately.

  Examples of monotic speech tests include Filtered Words subtest and Auditory Figure Ground (speech in noise) subtest of *SCAN*, and Synthetic Sentence Identification with Ipsilateral Competing Message (*SSI-ICM*).

- Monotic tone tests

  These test use tones to assess the child’s ability to use each ear separately. Their goal is in examining the child’s pattern perception and temporal functioning abilities.

  The *Durations Patterns Test* is an example of a monotic tone test.
Dichotic speech tests

In these tests, a different stimulus is presented simultaneously to each ear for evaluating either the binaural interaction or the binaural separation skills. Typically, a right-ear advantage is evident in younger children; however, the left-ear score improves throughout auditory maturation. Examples of these tests include Competing Sentences subtest of SCAN-A, Competing words subtest of SCAN or SCAN-A, the SSI with Contralateral Competing Message (SSI-CCM), Dichotic Digits, Dichotic Sentence Identification (DSI), and the Staggered Spondaic Word Test (SSW).

Electrophysiologic Assessment

The electrical potentials of the auditory brainstem response (ABR) reflect activity of the auditory nerve and successive brainstem auditory nuclei and tracts (Jerger, 1981). Patients with both normal and disordered peripheral hearing and brainstem integrity present with characteristic patterns in terms of morphology, absolute latencies, and interpeak wave latencies. In patients with disordered brain stems, ABR waveforms are generally poor in morphology with delayed peak latencies or absent peaks responses. Temporal lobe disorder, in contrast, typically produces normal ABR waveforms and peak latencies (Jerger, 1981).

Keith (2004) describes that the use of electrophysiologic assessment of APD was addressed by both the ASHA task force (1996), and the AAA Consensus Conference (2000). ASHA concluded that, “Electrophysiologic procedures can be used in the diagnosis of APD. The brain stem response is well understood and applied routinely in the detection of lesions of the brainstem. The middle, late, and event-related
auditory potentials are still in the developmental stage, but can be of considerable value in certain clinical situations” (AHSA, 1996).

At the AAA Consensus Conference, Jerger and Musiek (2000) recommended that the minimal test battery include both an ABR and middle latency response (MLR), as each measure the status of auditory structures at the brain stem and cortical levels, respectively. Other researchers such as Katz et al (2002) question the usefulness of physiologic measures, especially the MLR, in assessing APD in terms of their contribution to the remediation of the disorder. Figure IX provides a summary of audiometric tests and subtests for formally assessing APD.

**Nonaudiometric tests**

- **Attending**

  These skills involve the ability to maintain attention purposefully over an extended period of time (Kelly, 1995). Overall attention as a function of time, setting, and content of information can be observed throughout assessment, such speech-in-noise testing, but may also be analyzed during observation of the child in the classroom or in other environments. An example of a test assessing auditory attention is the *Auditory Continuous Performance Test*.

- **Discrimination**

  Auditory discrimination is involved the ability to note minor phonemic differences (Kelly, 1995). Typically administered in the test booth by the audiologist. The *Wepman Auditory Discrimination Test, Test of Auditory Discrimination*, and *Test of Auditory Perceptual Skills (TAPS)* are example of tests that examine auditory discrimination.
Memory

Auditory memory involves the ability to recall a variety of auditorily sequenced units (Kelly, 1995). The auditory number, word, and sentence recall subtest of the TAPS-R assess auditory memory.

Integration

Integration tests assess the child’s sound blending and auditory integration skills. Deficits in these areas often cause difficulty in reading and spelling. Examples of these tests include the Lindamood Auditory Conceptualization (LAC) test.

Language Comprehension

This skill is considered by some professionals to be the highest level of auditory processing. Language comprehension may be assessed by tests such as the TALC-R and CELF.

Kelly (1995) suggests a test battery blending both the audiologists’ bottom-up perspective and speech pathologists’ top-down perspective by focusing on auditory memory, auditory discrimination, auditory figure-ground, auditory cohesion, and auditory attention.

Regardless of the specific diagnostic tests utilized, a test-battery approach is always suggested in every APD evaluation (Stecker, 1992). A multiple test-battery approach is recommended because multiple tests will evaluate more of the CANS, leading to higher flexibility in addressing individual auditory difficulties. Electrophysiologic data may also be useful in supplementing these measures. Finally, a multidisciplinary team approach to the evaluation of APD is optimal for contribution of several professional points of view.

Figure X shows the most common central auditory test used with children and adults from a 1987 survey (Oliver, 1987). Emmanuel (2002) also published results from a recent
survey on most commonly used tests by audiologists in evaluating APD. The survey revealed that the SSW, SCAN-C, and SCAN-A (CW and CS) were the most popular tests nationally included in APD evaluation batteries.

The 2000 Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Age Children suggested a list of the minimum amount of information necessary for the diagnosis of APD in school-age children. They also note that some clinicians may choose to carry out additional testing, such as visual continuous performance measures and the P300 electrophysiological response; however, the set of procedures listed below is essential in diagnosis (Jerger & Musiek, 2000):

**Behavioral Measures:**

a. **Pure-tone audiometry:** Essential for assessing presence and degree of peripheral hearing sensitivity loss

b. **Performance-intensity functions for word recognition:** Essential for the exploration of word recognition over a wide range of speech levels, and for comparing performance on the two ears

c. **A dichotic task** (e.g., Dichotic digits, dichotic words, or dichotic sentences): A sensitive indicator of an auditory processing problem

d. **Frequency or duration pattern sequence test:** A key measure of auditory temporal processing

e. **Temporal gap detection:** A key measure of auditory temporal processing

**Electroacoustic and Electrophysiological Measures**
a. Immittance audiometry:

b. Otoacoustic emissions:

c. Auditory brain stem response (ABR) and middle latency response (MLR):

**Classification Models**

Two primary models for APD evaluation, classification, and remediation have emerged in the literature: The Bellis Model and the Buffalo Model.

**Bellis Model**

Dr. Teri Bellis considers her model framework of APD to be based “both on the underlying neurophysiology and the relationship among different types of APD and language, learning, and communication difficulties” (Bellis, 2002b). The model consists of three primary and two secondary subtypes of APD:

**Primary Subtypes**

1. *Auditory Decoding Deficit*, which can result from improper function of the language-dominant hemisphere of the brain (specifically the primary auditory cortex). Associated test results may evidence in the following pattern: bilateral or right-ear deficit on dichotic tests combined with poor perception of distorted or rapidly presented speech (auditory closure abilities), poor auditory discrimination, and probably normal electrophysiology. Educational effects may include difficulties in spelling, hearing in noise, sound blending, and poor analytic skills (mimics hearing loss). Proposed remediation strategies are to improve acoustic clarity, speech sound training, auditory closure activities, and speech-to-print skills training.

2. *Prosodic Deficit*, which is associated with right-hemispheric dysfunction. Associated test results may evidence in the following pattern: left-ear deficits on dichotic speech
tasks combined with difficulty perceiving, humming, and labeling nonverbal tonal stimuli (e.g., pitch and duration differences), good auditory discrimination, and probably abnormal electrophysiology (especially if over right hemisphere).

Educational effects may include difficulties spelling, judging communicative intent, perception and use of prosody. Proposed remediation strategies are animated teacher placement, prosody training, and attention social emotion areas.

3. *Integration Deficit*, which may result from the way the two hemispheres interact and communicate with one another. Associated test results may evidence in the following pattern: left-ear deficits on dichotic speech tasks combined with difficulty labeling nonverbal tonal stimuli, but ability to hum tonal patterns intact, good auditory discrimination, likely normal electrophysiology, left ear deficit on dichotic speech tasks, and deficits on temporal patterning tasks in linguistic labeling condition only. Proposed remediation strategies include interhemispheric exercises, provision of notetaker, and sensory integration therapy.

**Secondary Subtypes**

1. *Associative Deficit*, which is the result of dysfunction of the auditory association cortex; and is also thought of as an auditory-based receptive language disorder. Associated test results may evidence in the following pattern: (bilateral or right ear dysfunction on dichotic speech tasks), normal auditory closure and speech sound discriminations due to good functioning of primary auditory cortex, and probably normal electrophysiology.

2. *Output-Organization Deficit*, which involves the efferent auditory system and/or the frontal lobes that control execution. This deficit may result in difficulty organizing
and following through on information presented verbally, (often presents as expressive language disorder), extreme difficulty hearing in noise, difficulty on any central auditory task that requires the report of more than two critical elements. Finally, contralateral acoustic reflexes are often absent.

**Buffalo Model**

Dr. Jack Katz of Buffalo, New York, has focused on the relationship between patterns of performance on the SSW test and learning difficulties in children. The foundation for the Buffalo model is grouping the children into “functional” auditory processing categories (Katz, 1992): Katz (1992) has suggested a combination of strengthening perceptual skills and management of the environment remediation techniques based upon specific outcomes of the SSW test.

1. **Decoding**- The *decoding* category of SSW tests assesses utilization of phonemic information. Those children scoring below average in the decoding category generally have difficulty reading, spelling, and with receptive language and articulation. The associated remedial strategy suggested is improving knowledge of phonemes and language, using commercial programs such as Phoneme Synthesis or Auditory Discrimination in Depth (ADD).

2. **Tolerance-Fading Memory** The *tolerance-fading memory* category of SSW tests assesses listening in noise and short term memory. Children failing under this category generally present with reading comprehension, expressive language, handwriting, and distraction problems. Remedial strategies Katz (1992) suggests for this population include speech-in-noise desensitization, the commercially available programs *Listening to the World* and *Auditory...*
Perception Training-Auditory Figure Ground, and use of assistive listening devices. Keith (1995) also supports the use of FM systems for severe auditory figure ground impairments.

3. Integration (Types I and II)- The integration category of SSW examines ability to combine auditory and visual information. Associated problems under this category include severe reading and spelling disability and very poor handwriting. Type II is a less severe form. Remedial approaches include strengthening phonemic knowledge through use of Phonemic Synthesis ADD.

4. Organization- the organization category tests ability to maintain sequence and organization of information. Associated difficulties include disorganization at school and at home, reversals in spelling and in reading, and poor handwriting. Sequencing activities and written outlines and lists are strategies that may prove effective in terms of remediation (Katz, 1992). Figure XI is a summary of academic intervention strategies as a function of the specific auditory processing deficit.

Intervention and Remediation

Remediation for children with APD generally falls into three categories: compensatory training to strengthen perceptual skills, management of the environment, and cognitive therapy in which the clinician assists the subject in learning strategies for dealing with their disorder (Keith, 1995).

Strengthening perceptual skills

- Phonemic training
Phonemic synthesis is one phonemic training strategy used as part of a complete management approach to APD remediation. The tasks begin as closed set, familiar two and three phoneme picture identification. Tape recordings are used to present the stimuli, and unintelligible responses are met with appropriate modeling by the implementer. As training progresses, open-set words with a more complex phonemic structure are used. Training consists of showing the child how to blend the sounds together and how to respond to the tapes (Katz & Harmon, 1981). These methods may be an effective remediation strategy for several reasons. First, the child receives positive reinforcement during any speech improvements. Secondly, the child may develop a more clear understanding about speech sounds because the stimuli are prolonged, clear, and repeated, helping the child establish phoneme boundaries. This is especially useful in processing co-articulated sounds. In addition, the child learns that words are made up of units that may be manipulated. Improvement in processing will likely expand to decoding new words, which in turn improves spelling and reading (Katz & Harmon, 1981).

Phonemic analysis is another type of phonemic training, and is best implemented using the Auditory Discrimination in Depth training program. (Schneider, 1992). This program is made up of four categories, each increasing in level of difficulty. In easier levels, test items involve deciding if two phonemes heard were “same” or “different”. The child will also detect the sequence of several phonemes. During harder tasks, the child practices detecting subtle differences between two nonsense syllables.
During this speech-in-noise drill type activity, monosyllables are played in the presence of increasingly noxious and intense noise (Schneider, 1992). When noise reaches a level where it produces poor discrimination, it is eliminated for several test items. Then, the noise is raised in small steps as the test monosyllables are played. The training seems to be most successful when it is reinforced on a weekly basis at home following completion of clinic training.

- **FastForWord**

This training program is intended to target the central auditory deficiencies that may underlie a language delay. *FastForWord* is based on the grounds that brief, closely-spaced acoustic events are perceived poorly in language-learning impaired children, resulting in poor phonology. Stimuli containing target elements of speech, such as stop consonants, are lengthened in time and amplified. Phillips (2002) offers some cautions to the critical reader. First, since the program targets both auditory and linguistic levels of analysis, but measure outcome using language performance, then it cannot be clear which of these training components is responsible for the outcome. Further, the differential effectiveness of *FastForWord* depends on the appropriate control for the participant’s attention, motivation, and duration of treatment as independent variables (Phillips, 2002).

**Management of the Environment**

- **Personal FM Systems**

Personal FM amplification seems to be most appropriate for APD children who have particular difficulty listening and understanding speech in the presence of background noise. These units consist of a transmitter, worn by the classroom teacher, and a receiver, worn by the student. There are three main benefits an FM system may provide to the
child (Schneider, 1992). First, the signal to noise ratio will be improved by the signal 
 enhancement of the signal and the noise reduction at the child’s ear. In addition, an FM 
 system results in more uniform intensity level of the teacher’s voice. This uniform 
 intensity is minimally compromised by the teacher’s physical position in the classroom. 
 Finally, the final product signal of the FM system is a wideband frequency response, 
 allowing the high-frequency spectral information of the teacher’s voice to be preserved in 
 the signal. Figure XII is a summary of diagnostic tests that may indicate benefit from an 
 FM system (Stein, 1998).

- Classroom sound reinforcement systems

Similar to the advantages produced by personal FM systems, classroom sound 
 reinforcement systems provide enhanced audibility of the teacher’s voice to the entire 
 classroom (Schneider, 1992). The system consists of a central speaker, an FM 
 microphone for the teacher, and an amplifier-equalizer. Sarff (1981) studied the 
 academic effects of an addition of sound field amplification systems in three southern 
 Illinois public schools. The students under observation were all had learning disabilities. 
 Their study revealed greater academic gains from the children in the sound field 
 amplification classrooms than those without.

- Strategies for the teacher

Since APD often involves language-learning difficulties, providing additional means 
 of reinforcing, defining, clarifying, and organizing language tasks are beneficial to the 
 student (Kelly, 1995). Further, when using these strategies in a manner that allow the 
 student to anticipate or predict outcomes or sequences, there is optimal chance for
success. Taking these points into consideration, Kelly (1995) offers the following suggestions to teachers of children with APD:

- Seat the student towards the front of the room, with clear visual access to both the teacher and the chalkboard, and with the back to the window area.
- Have the student look at the speaker’s face
- Limit background distractions
- Present directions in short, concrete segment, with visual cues
- Rephrase directions
- Maintain structure and schedules
- Preview materials to be presented, using a variety of media
- Build student’s self-esteem at every opportunity

*Figure XIII* is another summary of classroom modifications for children with APD, including preferential classroom seating, peer assistance, alerting skills, teaching techniques, and self-esteem building activities.

*Cognitive Therapy*

Chermak (1998) describes four metacognitive approaches found to be useful in managing APD: attribution training, cognitive behavior modification, reciprocal teaching, and assertiveness training. First, attribution training targets motivation. Due to their chronic listening problems, academic or workplace failures, and social frustrations with friends or family, those afflicted with APD are at risk for developing motivational problems. At the heart of this therapy is the clinician giving the patient feedback during auditory testing. Every incorrect or correct response is associated with inadequate or satisfactory effort, respectively. In this light, feedback acknowledging hard work, while
encouraging even greater effort, should motivate the client and result in improved performance.

The goal of cognitive behavior modification is to promote active, self-controlled listening and learning. The first phase of the therapy is self-instruction. The steps and statements involved in this first phase is summarized in Figure XIV. During the next phases of cognitive problem solving and self-regulation, the patient is encouraged to analyze the situation and generate a variety of potential solutions or responses, followed by conscious maintenance of the productive response. In the final phase, cognitive strategy training, the patient is made more aware of the specific productive strategy underlying effective performance.

Reciprocal teaching involves alternating the roles of the student and clinician to facilitate learning. This approach is likely to boost self-esteem and self-efficacy, increasing motivation. Further, the clinician and student have opportunities to share their metacognitive processes by verbalizing their use of strategies.

Finally, the goal of assertiveness training is for the student to attain personal effectiveness via verbal communication. Self-confidence and self-esteem are prerequisite to assertiveness; thus, daily affirmations are helpful. Figure XV is an example list of daily self-affirmations that may lead to increased self-esteem.

Suggestions for Parents, Students, and Counseling Techniques

- Strategies for parents and students

In addition to modifications and efforts on the part of the teacher and classroom to improve the success of the child with APD, it is equally important for the child to learn to self-advocate and create an optimal learning environment for him or herself. Figure XVI
is a list of classroom strategies for the child to use as a self-check or reminder throughout the day.

Efforts made in the classroom by the teacher and the student should extend into the home and in extracurricular activities. By practicing remediation strategies throughout the entire day, these skills are more likely to be generalized and learned. *Figure XVII* is an example of a self-checklist for parents, while *Figure XVIII* is a chart for students to track monthly progress related to use of remediation strategies at school and in the home environment.

- Counseling techniques for the Clinician

  Before, during, and after the diagnosis of APD or any type of auditory deficit, parents are likely to experience some degree of grief reaction. Feelings involved in this reaction include, but are not limited to, fear, anger, guilt, and vulnerability (Luterman, 2004). The following suggestions may be useful in working with parental feelings:

  - Listening enables the parent to work things out within a supportive framework
  - People are not fragile; sensitive and reflective listening elicits feelings that need only to be acknowledged and validated
  - Feelings are neither good or bad; they just are.
  - We all have need to control events in our lives.

  One way that parents may feel “in control” is by attaining knowledge about their child’s APD. In addition to information provided by the clinician, parents may also choose to research on the internet or get in touch with parents who are in a similar situation. The National Coalition on Auditory Processing Disorders is a non-profit group supported by parents and professionals involved with APD. On the organization’s
website, www.nAPD.org, the user can experience a simulation of various specific auditory processing disorders, enter on online chat room, obtain information about upcoming conferences, and participate in surveys.

**Closing Remarks**

Bellis (2002a) provides an insightful summary to management techniques of APD. The intervention for APD should arise from the nature of the individual’s auditory deficit, and this philosophy arises from three assumptions. First, certain basic auditory skills or processes underlie more complex listening, learning, and communication abilities. Secondly, the capability exists for identifying those auditory processes that are dysfunctional in a given individual through the use of diagnostic tests. The final assumption (2002a) describes regarding deficit-specific intervention for APD is that remediation of the underlying, disordered processes will facilitate improvement in associated higher-order, complex functional ability areas.

Given all of the assumptions, theories, and perspectives related to APD, many researchers have identified future research needs. At the 2000 Consensus Conference (Jerger & Musiek), researchers and professionals noted the high importance of establishing solid efficacy in the treatment of APD, specifically in the relationship between test outcomes and management strategies, outcomes of early intervention, and the relative efficacy of intervention approaches at various ages. In addition to effective screening, diagnostic tests, and management strategies related to APD, optimal remediation of the disorder is also dependent on the efforts of many professionals. Regardless of age the patient, the intervening audiologist, speech pathologist, or other health care professional must be educated in the area of APD in order to treat and refer appropriately. In addition to responsibilities of the health care professional, the individual with APD and his or her family also must have motivation to learn and work for success. Through
continued research in the area of APD, information and resources are available for these families and health care professionals to best manage these cases.
Part II: Summary of Interviews

Auditory Processing Disorders (APD) continues to be a controversial topic in the field of Communication Disorders. This section (Part II) outlines a summary of interviews with leading professionals in the area of APD. An open ended interview questions were selected based on the number of issues that were found to be consistently controversial. Three professionals were selected and responded to the questions. Two interviews were conducted via e-mail (Drs. Gail Richard and Robert Keith); these professionals’ exact responses are recorded below. The third interview (Dr. Gayle Santucci) was a phone interview, to which a summary of responses given is provided. The following is a list of the interviewees and their respective positions:

1. Gail J. Richard, Ph.D.
   Eastern Illinois University
   Dept. of Communication Sciences & Disorders, Chair

2. Gayle Santucci, Ph.D.-CCC/A
   Listening for Learning, LC
   Audiologist/Educational Consultant

3. Robert Keith, Ph.D.
   University of Cincinnati Medical Center, Professor and Director
   Division of Audiology & Vestibular Testing

The interview questions and their corresponding answers are summarized. Please note that each professional’s responses are coded by their initials of the first and last name. For each question, my overall impressions and comments based on the response elicited are also included in italics.
1. What is your opinion of mass screening for APD in environments like schools, like we do for peripheral hearing loss?

GR: “I don’t believe it is a good idea. I think you would get a lot of false positive readings that would result in more adversarial relationships between the school and parents. I believe there is already an over-diagnosis of APD when the real problem is language, ADD/ADHD or other issues. There is not good agreement among audiologists as to what APD is, so it would be very difficult to get a definitive criteria for screening.”

GS: There are two many other factors for it to be realistic. Cognitive factors, diagnosis of autism spectrum, and other variable make mass screening too complicated. Obtaining background information is very important, and also knowing if the child’s hearing is normal or not. Speech articulation also plays a factor. Cultural differences may also play a role during testing. The SIFTER has been one proposed test to screen kids, but this is also is a way to identify children with hearing loss.

RK: “I think that it is premature, we do not have agreement on the techniques to use, and a good handle on what to do for followup when we find a child who fails the screening, i.e., what screening measures to use, what diagnostic tests to use, what remediation procedures to implement, etc. The fact is that many schools/states etc. do not recognize APD as a diagnostic treatable entity at this time.”

There is an agreement between all three responses that mass screening for APD is not advisable this time for reasons including lack of standardized screening procedures and other coexisting issues.

2. What are your thoughts on the use of electrophysiologic measures in the assessment of APD? Which electrophysiologic measures do you incorporate in your test battery, if any?
GR: “I think the electrophysiological measurements are good; they provide more concrete neurological evidence for transference of the acoustic signal through the Central Auditory Nervous System. However, the behavioral measurements are still needed in conjunction with the tests. Structures can measure physiologically ‘normal’ while functionally still experiencing problems.”

GS: I do not incorporate these tests into my test battery, but I do think they have their place. There is a lack of normative data, however, in addition to questions related to cost effectiveness. They are good for an objective measure, but behavioral responses show how APD manifests itself in children. I can’t see school districts being able to support necessary electrophysiological financially.

RK: “I occasionally use ABR, MLR, and P-300. I found that MMN is useless for diagnosis of individuals. My experience is that electrophysiology works for group research, not for individual diagnosis. There is no agreement on how to interpret MLR for example. I have several patients with profound APD who have normal electrophysiology findings. I think that electrophysiology should not be mandated as part of the diagnostic battery, it should be used only occasionally when you have evidence of neurologic damage.”

The researchers seem to agree that, although electrophysiologic data is useful to provide objective measures, their incorporation into a test battery is not recommended for reasons such as lack of normative data and interpretation parameters and cost-effectiveness.

3. Is APD assessment in the elderly population justified, or are there too many other variables (i.e. coexisting conditions) to confound the diagnosis?

GR: “I don’t feel it is justified. Many elderly are likely to experience difficulty as a
component of aging. If the APD has never been diagnosed previously, then obviously the individual was able to function effectively. Treatment would be minimally effective in the elderly. Conducting APD on elderly seems to primarily serve as a way to generate revenue.”

GS: I think there are other factors, such as hearing loss in itself. But, dichotic studies in the elderly have shown brain imaging studies that show decline in speech processing that are similar to underdeveloped brain structures in children with APD. We need to look at auditory processing abilities in the elderly and think that it may contribute to the success or failure of hearing aid fittings. This may explain how some hearing aid fittings don’t go as well as anticipated. What has been traditionally referred to as phonemic regression, where speech perception is much worse than expected from looking at the audiogram, may be a reflection of central components of hearing loss.

RK: “There are too many variables to diagnose APD in the elderly at this time.”

All of the professionals suggest that there other existing variables in the elderly could confound the diagnosis of APD. However, although she does not recommend specifically testing for APD in the elderly, Dr. Santucci discusses the importance of thinking about auditory processing abilities during difficult or unexpected circumstances during speech perception testing or hearing aid fittings.

4. What are your thoughts on assessment of APD with an existing peripheral hearing loss?

GR: “I think the audiologist has to be very careful in interpreting the results and not jump to conclusions of an APD. I have unilateral deafness, which creates some unique problems. I can’t localize sound because it all goes into the same place. I have very poor discrimination with background noise, so avoid noisy environments. I do a lot of lip-
reading to compensate, which results in most people having no idea that I have a hearing problem. The most effective tests for APD appear to be the dichotic condition. That is not an assessment possibility in evaluating me. I think I would fail most APD evaluations, but not because of APD. I also compensate very well, due to the onset of my loss at a young age (5 years old). That would also skew results.”

GS: The SSW has corrected scores for hearing loss. However, one must question how you can you factor out peripheral vs central hearing abilities simply with a formula. Duration pattern tests may still be able to be used if the child can hear the tone, but this can still present with difficulties during testing. There are kids with peripheral hearing loss with central processing disabilities, but it is not clear what the best way is to measure this.

RK: “With creative thinking there are many tests that can be used to assess APD in subjects with peripheral hearing loss. Many of the tonal tests can be used for example.”

Although there is not uniformity among the answers, each researcher alludes to the importance of skill on the part of the audiologist in picking appropriate tests and making appropriate interpretations from the results.

5. What are important issues to keep in mind when assessing APD with existing ADD?

GR: “APD can exist as part of ADD, but the evaluator needs to be very careful about interpreting impulsive responses associated with ADD/ADHD as evidence of neurological deficits associated with APD. Directions can be complex also, which may be a factor during testing.”

GS: The clinician should know if the ADD is being managed, if the ADD is hyperactive ADD. Kids with ADD often have other coexisting problems. If you can manage the
attention, it is easier to see the distinct auditory processing problems. Some people questions whether Inattentive ADD specifically is different from APD, however I think of Inattentive ADD as a self regulation disability, accompanied by impulsivity. This is different from APD, which is being able to pay attention but unable to extract necessary information.

**RK:** “This question cannot be answered in a paragraph, they range from history to performance on tests like the ACPT, and behaviors observed during testing including results of the APD battery.”

*Each professional provides a different perspective on the issue, exemplifying the complex nature of the question at hand. It seems that obtaining as much knowledge as possible about the manifestations of the child’s specific type of ADD allows the audiologist to better evaluation the child.*

### 6. What is the most useful assessment tool for APD?

**GR:** “Since I do not do evaluations in audiology, I am not really qualified to answer this question. I do believe the dichotic tasks are the most sensitive for discrimination of auditory processing disorders.”

**GS:** I do not believe there is a single tool that is most useful; you need to have a battery of tests. Temporal processing test, SSW, SCAN, are all good tests. We do not have any one test, one that encompasses all the areas that are necessary to evaluate.

**RK:** “There is no single most useful tool. A dichotic battery like the competing words and competing sentences test of SCAN would be high on my list. But you need a battery.”

*The answers indicate the high importance on having a battery of tests in order to obtain an accurate picture of the child’s auditory processing skills.*
7. How does an SLP approach to APD compliment that of an audiologist?

GR: “The audiologist assessment instruments tend to be non-functional. The SLP assessment instruments tend to apply auditory skills into functional tasks. The SLP approach tends to evaluate what actual skills the client is able to do, as opposed to isolated skills usually evaluated by the audiologist.”

GS: If children have auditory processing problems, there are almost always language weaknesses present. The area of most weakness defines treatment management, and sometimes a particular child may be served best by an SLP. There is a link between type of auditory process and type of language difficulties the child is having.

RK: “They assess top down, we measure bottom up.”

_A speech language pathologist and an audiologist are both important professionals in the diagnosis and management of APD. Since each often has different views of APD in terms of assessment and remediation, collaboration of ideas and test results may be a beneficial and comprehensive approach when combined._

8. What are the areas of research you think are critical in enhancing the reliability and validity APD assessment?

GR: “It is critical that audiologists and SLPs reach some agreement on diagnosis and definitions within the area of auditory processing disorders. For example, some use auditory processing to cover the entire area of attaching meaning to an auditory stimulus, with central auditory processing involving the central auditory nervous system (CANS) and language processing involving cortical interpretation of the acoustic signal. Until there is some agreement on terms/definitions, it is impossible to design effective treatment. We need agreement on what APD is so we can treat the appropriate disorder.”
GS: We probably need to have some studies done with measures we use now, other than by people who developed the test. Objective electrophysiologic measures, specific to related auditory processing difficulty (such as decoding vs. integration problem) would certainly be useful research.

RK: “This is a complex question. The answer ranges from developing norms for tests we use, standard protocols, different approaches using psychoacoustic paradigms, etc.”

The researchers all suggest more development for what we are doing now in assessing APD before moving forward. Examples include establishing agreement on terminology and obtaining more data and norms for currently used assessment tests.

9. What are the research areas you think are critical in enhancing the management efficacy of APD?

GR: “Again, agreement on terms. Most audiologists evaluate and then generate generic lists of recommendations. Most include an FM system, which is very expensive for a school district and often only frustrates the child further and doesn’t address the problem. Management usually falls on the SLP, who has not conducted the assessment and has little information to guide the treatment plan. Better collaboration, communication, and delineation of the problem needs to precede treatment.”

GS: Knowing what techniques work best for which types of problems. Not everything works for everybody. We often make remediation strategies for home and school, and then, and let the kids go. However, if these strategies don’t work, we need to figure out what we can we do instead to make things efficient for child. It is frustrating when, as the clinician, you don’t know what happens to kids once they leave the office. How much is implemented? We need post-treatment and outcome measures other than assuming that
techniques will work. For example, it would be good to know if in a year, have things improved? Is gap of difficulty widening or narrowing? What is the final outcome and has anyone measured this outcome? Some kids same IEP objectives every year, which is not good; there are too many blanket recommendations for kids. Our tests are good enough now that we can make specific recommendations based on the assessment test.

RK: “There are none, so the sky is the limit.”

The answers shed light on the fact that remediation continues to be an area in need of research development. It seems that professionals are frustrated by a “blanket approach” of remediation strategies for every type of auditory processing difficulty.
Appendix

Figure I (Santucci, 2003)

Figure II (Golding et al, 2004)

<table>
<thead>
<tr>
<th>Grouped Test Outcomes</th>
<th>N</th>
<th>≤ 64 (532)</th>
<th>65–74 (689)</th>
<th>75+ (355)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>372</td>
<td>35.8</td>
<td>21.8</td>
<td>9.1</td>
</tr>
<tr>
<td>One to two abnormal</td>
<td>462</td>
<td>33.6</td>
<td>29.9</td>
<td>21.7</td>
</tr>
<tr>
<td>Three to four abnormal</td>
<td>399</td>
<td>21.6</td>
<td>26.2</td>
<td>29.3</td>
</tr>
<tr>
<td>Five to seven abnormal</td>
<td>343</td>
<td>9.0</td>
<td>22.1</td>
<td>39.9</td>
</tr>
</tbody>
</table>
Figure III (Jerger, 1981)

Figure IV (Baran et al, 2004)
Figure V (Baran et al, 2004)

![Frequency (Hz) vs. DB HL re: ANSI-96 graph]

Figure VI (Johnson et al, 1997)

Table 5–1. Characteristics of children with central auditory processing disorders.

- Has poor concentration/attention span
- Gives inconsistent responses to auditory stimuli
- Has difficulty following directions
- Gives slow or delayed responses to verbal stimuli
- Frequently requests repetition of what is said
- Often misunderstands what is said
- Is easily distracted by auditory and visual stimuli
- Has difficulty listening in presence of background noise
- Has memory deficits, both long-term and short-term
- Has language deficits
- Has academic difficulties, particularly with reading and spelling, despite normal intelligence
- Exhibits behavior problems
- Relies on visual cues when attempting to communicate (e.g., watches speaker's face closely)
- Has difficulty localizing the source of sounds
- Has history of chronic middle ear infections and possible fluctuating hearing loss
- Has lowered self-esteem
Figure VII (Kelly, 1995)

<table>
<thead>
<tr>
<th></th>
<th>CAPD</th>
<th>LD</th>
<th>ADD</th>
<th>Dyslexia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperactivity</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Attention deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Language deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Motor deficits</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept development deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Impulsivity</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Memory deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Spatial relationship deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Temporal relationship deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reading deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Writing deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Math deficits</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Articulation/phonology deficits</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pragmatic deficits</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Low frustration tolerance</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Low self-esteem</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Disorganization</td>
<td>✓</td>
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<td>✓</td>
<td></td>
</tr>
<tr>
<td>Related family history</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Poor social relationships</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Difficulty with logic</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Figure VIII (Keith, 2004)

Table 6-2. Information Model for Taking a Case History

<table>
<thead>
<tr>
<th>Area</th>
<th>Information Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family history</td>
<td>History of any family member’s difficulty in school achievement</td>
</tr>
<tr>
<td></td>
<td>The primary language spoken in the home</td>
</tr>
<tr>
<td>Pregnancy and birth</td>
<td>Unusual problems during pregnancy or delivery</td>
</tr>
<tr>
<td></td>
<td>Abnormalities present at the child’s birth</td>
</tr>
<tr>
<td>Health and illness</td>
<td>Childhood illnesses, neurological problems, psychological disorders, head trauma</td>
</tr>
<tr>
<td></td>
<td>or injury, middle ear disease, allergies</td>
</tr>
<tr>
<td>General behavior and social-emotional</td>
<td>Drugs or medications prescribed by a physician</td>
</tr>
<tr>
<td>development</td>
<td></td>
</tr>
<tr>
<td>Speech and language development</td>
<td>Age-appropriate play behavior</td>
</tr>
<tr>
<td></td>
<td>Social isolation or withdrawal</td>
</tr>
<tr>
<td></td>
<td>Impulsiveness</td>
</tr>
<tr>
<td></td>
<td>Aggression, tact, and sensitivity to others</td>
</tr>
<tr>
<td></td>
<td>Self-discipline</td>
</tr>
<tr>
<td>Hearing and auditory behavior</td>
<td>Evidence of articulation, voice, or fluency problems</td>
</tr>
<tr>
<td></td>
<td>Ability to communicate ideas verbally</td>
</tr>
<tr>
<td></td>
<td>Ability to formulate sentences correctly</td>
</tr>
<tr>
<td></td>
<td>Appropriateness of verbal expression to subject or situation</td>
</tr>
<tr>
<td></td>
<td>Ability to identify the source of sound and listen selectively in the presence</td>
</tr>
<tr>
<td></td>
<td>of noise</td>
</tr>
<tr>
<td></td>
<td>Reaction to sudden, unexpected sound</td>
</tr>
<tr>
<td></td>
<td>Ability to ignore environmental sounds</td>
</tr>
<tr>
<td></td>
<td>Consistency of response to sound</td>
</tr>
<tr>
<td></td>
<td>Need to have spoken information repeated</td>
</tr>
<tr>
<td></td>
<td>Ability to follow verbal instructions</td>
</tr>
<tr>
<td></td>
<td>Ability to listen for appropriate length of time</td>
</tr>
<tr>
<td></td>
<td>Ability to remember things heard</td>
</tr>
<tr>
<td></td>
<td>Ability to pay attention to what is said</td>
</tr>
<tr>
<td></td>
<td>Ability to comprehend words and their meaning, to understand</td>
</tr>
<tr>
<td></td>
<td>multiple meanings of words, and to understand abstract ideas</td>
</tr>
<tr>
<td></td>
<td>Discrepancies between auditory and visual behavior</td>
</tr>
</tbody>
</table>

Figure IX (Willeford & Burleigh, 1985)

Central Auditory Processing Tests

- Monotic Tests
  - Frequency limited (filtered speech)
  - Time altered (compressed speech)
  - Pattern recognition (frequency)
  - Performance-intensity function
  - Ipsilateral competing signals (speech vs. speech or noise)

- Dichotic Tests
  - Competing digits
  - Competing words (consonant-vowel-consonants, spondees)
  - Nonsense sentences vs. discourse
  - Real sentences vs. real sentences
  - Competing consonant-vowels

- Binaural Interaction Tests
  - Binaural fusion
  - Rapidly alternating speech
  - Masking level differences

- Electrophysiological Tests
  - Aural reflex test
  - Brainstem evoked response
  - Cortical evoked response
Figure X (Oliver, 1987)

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staggered Spondaic Word test</td>
<td>63</td>
</tr>
<tr>
<td>Willeford Competing Sentence test</td>
<td>55</td>
</tr>
<tr>
<td>Willeford Filtered Speech test</td>
<td>46</td>
</tr>
<tr>
<td>Willeford Binaural Fusion test</td>
<td>45</td>
</tr>
<tr>
<td>Willeford Rapid Alternating Speech Perception</td>
<td>44</td>
</tr>
<tr>
<td>Speech-in-noise ipsilateral</td>
<td>42</td>
</tr>
<tr>
<td>ABR</td>
<td>36</td>
</tr>
<tr>
<td>Speech-in-noise contralateral</td>
<td>24</td>
</tr>
<tr>
<td>Pitch pattern sequence test</td>
<td>18</td>
</tr>
<tr>
<td>SSI-ICM</td>
<td>16</td>
</tr>
<tr>
<td>SSI-CCM</td>
<td>13</td>
</tr>
<tr>
<td>Time-compressed Speech tests</td>
<td>11</td>
</tr>
<tr>
<td>Dichotic Digits</td>
<td>7</td>
</tr>
<tr>
<td>Phonemic Synthesis Test</td>
<td>4</td>
</tr>
<tr>
<td>Masking level difference</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure XI (Stein, 1998)

<table>
<thead>
<tr>
<th>Test</th>
<th>Skill Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSW</td>
<td>Binaural integration</td>
</tr>
<tr>
<td>SCAN subtests:</td>
<td></td>
</tr>
<tr>
<td>Auditory figure ground</td>
<td>Auditory figure ground</td>
</tr>
<tr>
<td>Filtered words</td>
<td>Auditory closure</td>
</tr>
<tr>
<td>Dichotic digits</td>
<td>Binaural integration</td>
</tr>
<tr>
<td>SSI-ICM</td>
<td>Auditory figure ground</td>
</tr>
<tr>
<td>SSI-CCM</td>
<td>Binaural separation</td>
</tr>
<tr>
<td>Time-compressed speech</td>
<td>Auditory closure</td>
</tr>
</tbody>
</table>
**Figure XII (Stecker, 1998)**

<table>
<thead>
<tr>
<th>TABLE 1.6 Intervention Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Audiological/Speech Language</strong></td>
</tr>
<tr>
<td><strong>Decoding</strong></td>
</tr>
<tr>
<td>Improve phonemic and</td>
</tr>
<tr>
<td>metaphonological skills:</td>
</tr>
<tr>
<td>Phonemic Synthesis Program</td>
</tr>
<tr>
<td>Auditory Discrimination in Depth</td>
</tr>
<tr>
<td>Hooked on Phonics</td>
</tr>
<tr>
<td>Rhyming, syllable, and phoneme</td>
</tr>
<tr>
<td>segmentation</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Tolerance-Fading Memory</strong></td>
</tr>
<tr>
<td>Improve the signal-to-noise ratio:</td>
</tr>
<tr>
<td>Assistive Listening device</td>
</tr>
<tr>
<td>Alter classroom acoustics</td>
</tr>
<tr>
<td>Noise desensitization practice</td>
</tr>
<tr>
<td>Compensatory strategies for auditory memory:</td>
</tr>
<tr>
<td>Identify classroom scripts</td>
</tr>
<tr>
<td>Rehearsal strategies</td>
</tr>
<tr>
<td>Imposing a delay</td>
</tr>
<tr>
<td>Teach outlining and notetaking</td>
</tr>
<tr>
<td>Mnemonics and chunking</td>
</tr>
<tr>
<td><strong>Integration</strong></td>
</tr>
<tr>
<td>Improve phonemic and</td>
</tr>
<tr>
<td>metaphonological skills</td>
</tr>
<tr>
<td>Improve signal-to-noise ratios</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Organization</strong></td>
</tr>
<tr>
<td>Discourse therapy: sequence,</td>
</tr>
<tr>
<td>information</td>
</tr>
</tbody>
</table>
Table 5–3. Classroom modifications for children with CAPD.

**Preferential Classroom Seating**
- Seat student away from distracting noises
- Seat student near teacher's area of instruction
- Allow flexibility of seating if area of instruction changes
- Seat student so that better ear, if there is one, is favored
- Isolate student, using study carrels if available, for individual seatwork, tests, or tutoring
- Allow the student to use earmuffs or earplugs when working individually

**Peer Assistance**
- Use a "buddy system" to alert the student to attend and to be sure student has assignments and special instructions
- Use a notetaker to take or copy notes

**Alerting: Look and Listen**
- Gain eye contact with student before giving class instructions
- Touch student gently to gain attention
- Call student by name
- Use "secret sign" to remind student to listen

**Teaching Techniques**
- Speak distinctly and at a moderate rate
- Give clear and concise directions
- Use familiar vocabulary and less complex sentence structures when giving instructions
- Simplify information by giving it in small segments
- Rephrase or restate instructions in simple terms
- Require student to repeat instructions to ensure understanding
- Preview topic to be presented by introducing new vocabulary and outlining new subjects
- Use visual aids such as overhead projectors, illustrations, and maps
- Use concrete, experiential lessons when possible
- Write assignments on board, as well as giving them orally
- Be sure student writes assignments in a specific place
- Allow breaks between intense periods of instruction
- Alternate difficult instruction with simpler activities to avoid fatigue
- Use a consistent routine of activities to allow student to have a smoother transition from one subject to the next

**Self-esteem**
- Be positive and encouraging when working with student
- Provide praise for effort and successes
- Encourage student to pursue activities in which he or she can excel

---

**Figure XIV (Chermak, 1998)**

**FIGURE 4.1 Self-Instruction: Steps and Statements**

**Attend, Plan, Reflect**
1. How do I listen carefully? I have to pay attention. I must not let myself become distracted. I must listen for important key words as well as content.
2. What is the primary purpose of this message? To tell a story? To describe an event? To explain? To argue a point?

**Problem Solving**
3. What key words have been stated? What do these key words tell me?
4. What about the context? What experience do I bring to this message?
5. What is the main message? What predictions or inferences are appropriate?

**Monitoring, Evaluation, and Feedback**
6. Are my conclusions, predictions, and inferences correct? Do they follow from the spoken words? Are they logical?
7. Yes, they are correct. I am an effective listener.
Figure XV (Kelly, 1995)

**Self-Affirmations**

1. I am a terrific person.
2. I am bright and talented.
3. I feel very good about myself.
4. I can do well.
5. I enjoy the positive strokes my parents and teachers give me when I do well.
6. I am in control of what I do in school and at home.
7. Although grades are important, *I am not my grades.* I am a worthwhile, terrific person even if I have some school problems sometimes.
8. I can make changes in my listening surroundings that make listening easier for me.
9. When I make changes in my listening surroundings, it has nothing to do with how smart I am.
10. Many people have the same challenges as mine.
11. I make progress in my goals when I identify them and take an active part in dealing with them.
12. Many famous and successful adults had similar challenges when they were younger.
13. I like myself no matter what—and with good reason!
14. I choose to make changes. I choose to be more successful. My attitude directly affects my choices throughout the day.
15. Today is a brand-new day. Changes can begin right now.
16. How I did last year in school has nothing to do with how well I can do in school today.
17. Nobody is perfect. It's important to do my best, but I don't need to be perfect.
18. I am very proud of myself. I like who I am as a person.
19. Everyone is different. Many bright and talented people have had to learn some strategies in order to do well. They “chose” to learn about and use these strategies.
20. Mom and Dad (or ________) are proud of me. They are even more proud now that I've made the choice to succeed.
Strategies for Change in the Classroom

1. Sit in the right place. Sit toward the front of the room or near the chalkboard with your back to the windows. Make sure you can see the teacher.

2. Limit extra movements. Do not chew gum, fidget, talk to your neighbor, look out the window, or otherwise distract yourself. Extra movements drain away the energy you need for your listening job.

3. Use a tape recorder. Tape long lectures. Take notes, and write a summary as soon as possible.

4. Choose to work in a small group or with a single partner whenever possible. It will be easier to understand information, and there will be fewer distractions.

5. If you have an auditory trainer, use it exactly as your speech-language pathologist has taught you.

6. Reduce background noise. Identify noisy settings. Whenever possible, ask people to lower their voices, talk one at a time, shut off the television or radio, or reduce the noise that is causing the problem.

7. Speech-reading—Look at the speaker's face. Learn to "read" the extra clues the speaker gives (facial expressions, tone of voice, gestures, and so on).

8. Use clues from the listening surroundings and routines, and guess. (For example, "It's 9:00 Friday morning. My teacher is probably going to tell us about the spelling test soon"; or, "She can't be talking about the Social Studies project. I heard the word protractor and we usually do math after lunch. She's probably talking about a math project.")

9. Use the Buddy System. Find a friend in class that you work well with, someone you can ask to sometimes repeat directions and information for you, someone you can share your special skills with (for example, perhaps you are a better artist and can help your friend with book report covers).

Figure XVII (Kelly, 1995)

How Am I Doing?
A Checklist for Parents

Have I . . .

1. Limited background noises at home whenever possible?
2. Set up schedules with time for homework, telephone, TV, and fun?
3. Spoken in simple sentences with expression in my voice?
4. Kept ongoing contact with teachers and therapists?
5. Set up lists for my child’s chores?
6. Modeled good behavior by keeping my own appointments on time?
7. Provided my child with an assignment pad, tape recorder, and other aids?
8. Praised my child’s successes?
9. Made an effort to improve my child’s self-esteem?
10. Encouraged my child to make choices, accept responsibilities, and use logic?
11. Presented a positive and realistic view of therapy and school experiences?
12. Used daily activities as opportunities to improve skills?
13. Used daily activities as opportunities to problem-solve, organize, categorize, predict, sequence, synthesize, and simplify?
14. Used daily experiences as opportunities to develop good habits and patterns?
15. Encouraged my child to set goals for himself or herself, rather than to achieve goals that I have set? (For example, does my child see the value of getting better grades in school?)
16. Encouraged my child to keep a clean room, neat work area, and organized clothes closet?
17. Provided my child with a quiet, distraction-free work area?
18. Worked with the other parent or close relative in my child’s life to present a unified plan of goals, strategies, and praise?
19. Maintained mutual eye contact with my child when conversing?
20. Encouraged healthy habits such as eating good foods and getting enough sleep?
Figure XVIII (Kelly, 1995)

<table>
<thead>
<tr>
<th>Skill</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following directions at home</td>
<td></td>
</tr>
<tr>
<td>Following directions at school</td>
<td></td>
</tr>
<tr>
<td>Ignoring background noises</td>
<td></td>
</tr>
<tr>
<td>Changing the listening surroundings (for example, moving my seat)</td>
<td></td>
</tr>
<tr>
<td>Remembering chores and appointments</td>
<td></td>
</tr>
<tr>
<td>Remembering homework assignments</td>
<td></td>
</tr>
<tr>
<td>Keeping a neat desk</td>
<td></td>
</tr>
<tr>
<td>Keeping neat and organized notebooks</td>
<td></td>
</tr>
<tr>
<td>Preparing ahead for long-term assignments</td>
<td></td>
</tr>
<tr>
<td>Using strategies and techniques</td>
<td></td>
</tr>
<tr>
<td>Using self-affirmations</td>
<td></td>
</tr>
<tr>
<td>Improving spelling skills</td>
<td></td>
</tr>
<tr>
<td>Improving reading decoding skills</td>
<td></td>
</tr>
<tr>
<td>Improving reading comprehension</td>
<td></td>
</tr>
<tr>
<td>Wearing a watch</td>
<td></td>
</tr>
</tbody>
</table>

What can I do this month to improve my performance?
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