Multidimensional Approach to the Differential Diagnosis of Central Auditory Processing Disorders in Children

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Abstract

Central auditory processing disorder (CAPD) may be viewed as a multidimensional entity with far-reaching communicative, educational, and psychosocial implications for which differential diagnosis not only is possible but also is essential to an understanding of its impact and to the development of efficacious, deficit-specific management plans. This paper begins with a description of some behavioral central auditory assessment tools in current clinical use. Four case studies illustrate the utility of these tools in clarifying the nature of auditory difficulties. Appropriate treatment options that flow logically from the diagnoses are given in each case. The heterogeneity of the population presenting with auditory processing problems, not unexpected based on this model, is made clear, as is the clinical utility of central auditory tests in the transdisciplinary assessment and management of children's language and learning difficulties.

Key Words: Central auditory processing disorder, children

Abbreviations: ADD = attention deficit disorder, ALD = assistive listening device, BF = binaural fusion, BF-CVC = consonant-vowel-consonant binaural fusion, CAPD = central auditory processing disorder, CST = Competing Sentences Test, DD = Dichotic Digits, DP = Duration Patterns, DR = Dichotic Rhyme, FP = frequency patterns, LPFS = low-pass filtered speech, RASP = Rapidly Alternating Speech Perception, SPN = speech in noise, SSW = Staggered Spondaic Words, TC = time-compressed speech, TCR = time-compressed speech with reverberation

The validity of a diagnosis of central auditory processing disorder (CAPD) has often been questioned. Indeed, some have asserted that CAPD, as a singular entity affecting language and learning abilities, may not exist at all (Rees, 1973, 1981; Cacace and McFarland, 1998). Others have focused on the modality-specific nature of the disorder, suggesting that CAPD is best viewed as an auditory-specific dysfunction in sensory encoding and/or speech sound perception that may underlie a variety of learning difficulties (Willeford, 1977; Katz and Wilde, 1985; McFarland and Cacace, 1995; Kraus et al, 1996). However, it has been difficult to demonstrate that a specific auditory deficit exists among the children in whom CAPD is suspected, or whether such a deficit may be an underlying cause for their learning difficulties (Watson and Miller, 1993; McFarland and Cacace, 1995; Cacace and McFarland, 1998).

We contend that the unitary view of CAPD as a deficit in the processing of acoustic-phonetic features of speech is unrealistically narrow and that it is this narrow viewpoint that has allowed the clinical utility of central auditory tests in the assessment and management of language-learning disabled children to be undervalued. If one approaches these disorders from a transdisciplinary perspective, in which multimodality information from a variety of disciplines is considered, the underlying bases and functional manifestations of a given child's learning difficulties are illuminated. The audiologist's con-

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trIBUTION TO THIS PROCESS IS THE ADMINISTRATION OF WELL-CONTROLLED AUDITORY ASSESSMENT TOOLS THAT HAVE BEEN SHOWN TO BE SENSITIVE TO DYSFUNCTION IN SPECIFIC BRAIN REGIONS AND THAT ARE USEFUL IN QUANTIFYING AND QUALIFYING THE AUDITORY DIFFICULTIES EXPERIENCED BY THE CHILD WITH A COMMUNICATIVE AND/OR LEARNING DISABILITY. IN NO WAY DO WE ASSUME THAT DYSFUNCTION IN THE AUDITORY SYSTEM ALONE IS RESPONSIBLE FOR A CHILD'S PRESENTING DIFFICULTIES. TO THE CONTRARY, DEPENDING ON THE PARTICULAR PRESENTING DISORDER AND UNDERLYING REGION OF DYSFUNCTION, MULTIMODALITY INVOLVEMENT IS EXPECTED. HOWEVER, BECAUSE PROCESSING OF AUDITORY INFORMATION IS CRUCIAL TO LANGUAGE COMPREHENSION AND LEARNING, AUDITORY-BASED COMPLAINTS ARE OFTEN THE PRIMARY AND MOST DISRUPTIVE PRESENTING FACTOR RESULTING IN A REFERRAL FOR CENTRAL AUDITORY ASSESSMENT. THE CAP EVALUATION PROVIDES FOR AUDITORY-DEDICATED TESTING NOT TYPICALLY AVAILABLE THROUGH ANY OTHER DISCIPLINE, PROVIDES DIAGNOSTIC INFORMATION REGARDING AUDITORY BEHAVIOR THAT CANNOT BE OBTAINED THROUGH OTHER MEANS, AND HAS IMPORTANT IMPLICATIONS FOR INTERVENTION AND SERVICE DELIVERY.

THE PURPOSE OF THIS PAPER IS TO PROVIDE THE READER WITH AN INTRODUCTION TO AN INTERACTIVE, MULTIDIMENSIONAL APPROACH TO CAPD. FOUR CASE STUDIES WILL BE PRESENTED THAT WILL ILLUSTRATE HOW RESULTS OF THE BEHAVIORAL CENTRAL AUDITORY TEST BATTERY CAN BE USED TO IDENTIFY THE UNDERLYING NATURE OF THE AUDITORY DIFFICULTIES EXHIBITED BY A PARTICULAR CHILD. IT IS OUR HOPE THAT THIS PAPER WILL SERVE TO ILLUMINATE THE SIGNIFICANT CONTRIBUTION OF CENTRAL AUDITORY ASSESSMENT TO THE OVERALL MULTIDISCIPLINARY EVALUATION PROCESS.

CENTRAL AUDITORY ASSESSMENT TOOLS

INTERPRETATION OF CENTRAL AUDITORY ASSESSMENT RESULTS REQUIRES AN UNDERSTANDING OF THE AUDITORY SKILLS IMPORTANT FOR EFFECTIVE LISTENING, THE TASK DEMANDS OF THE TOOLS USED TO ASSESS THOSE SKILLS, AND THE CENTRAL AUDITORY REGIONS ASSOCIATED WITH THE SKILLS/TOOLS. ALTHOUGH THERE LIKELY ARE MANY, AS YET UNIDENTIFIED, AUDITORY-DEDICATED SKILLS AND TESTS TO ASSESS THEM, THE INFORMATION PRESENTED HERE REPRESENTS IMPORTANT SKILLS IDENTIFIED TO DATE AND GENERALLY ACCEPTED MEANS TO ASSESS THOSE SKILLS THAT ARE, AT PRESENT, COMMERCIALLY AVAILABLE. IT SHOULD BE REMEMBERED, HOWEVER, THAT IDENTIFICATION OF THE VARIOUS PROCESSES THAT UNDERLIE AUDITION AND THE DEVELOPMENT OF ASSESSMENT TOOLS TO TAP THEM CONTINUE TO BE CRITICAL AREAS OF NEEDED RESEARCH.

THE CENTRAL AUDITORY PROCESSES IMPORTANT TO EFFECTIVE LISTENING INCLUDE SOUND LOCALIZATION AND LATERALIZATION, AUDITORY DISCRIMINATION, AUDITORY PATTERN RECOGNITION, USE OF TEMPORAL ASPECTS OF THE AUDITORY SIGNAL, AND USE OF COMPETING OR DEGRADED ACOUSTIC SIGNALS (ASHA, 1996). THE TOOLS CURRENTLY AVAILABLE FOR CENTRAL AUDITORY ASSESSMENT INCLUDE MEASURES OF RECOGNITION OF AUDITORY STIMULI IN WHICH THE EXTERNAL REDUNDANCY HAS BEEN REDUCED, TEMPORAL PATTERNING, INTERHEMISPHERIC TRANSFER OF AUDITORY INFORMATION, BINAURAL INTERACTION OF DIOTICALLY PRESENTED ACOUSTIC STIMULI, DISCRIMINATION OF FINE-GRAINED ACOUSTIC DIFFERENCES, AND MEASURES OF BASIC SENSORY ENCODING AND NEUROPHYSIOLOGIC REPRESENTATION ALONG THE CENTRAL AUDITORY PATHWAYS. THESE TOOLS CAN PROVIDE A MEANS OF ASSESSING THE FUNCTIONAL INTEGRITY OF RIGHT- AND LEFT-HEMISPHERE CORtical REGIONS, CORPUS CALLOSUM, AND SUBCORTICAL STRUCTURES. MORE IMPORTANTLY, RESULTS OF CENTRAL AUDITORY ASSESSMENT ALLOW US TO DETERMINE THE INDIVIDUAL PATIENT'S AUDITORY STRENGTHS AND WEAKNESSES AND TO RELATE AUDITORY BEHAVIORS TO OVERALL COMMUNICATIVE AND LEARNING DIFFICULTIES, THEREBY PROVIDING GUIDANCE FOR THE DEVELOPMENT OF MANAGEMENT PLANS THAT WILL TARGET THE UNDERLYING DYSFUNCTIONAL PROCESSES.

IT SHOULD BE EMPHASIZED THAT THE SPECIFIC TESTS IDENTIFIED IN THE FOLLOWING SECTIONS ARE NOT INTENDED TO REPRESENT ALL OF THE COMMERCIALLY AVAILABLE MEASUREMENT TOOLS FOR THE BEHAVIORAL ASSESSMENT OF CENTRAL AUDITORY PROCESSING IN CHILDREN. HOWEVER, ALTHOUGH THE CHOICE OF SPECIFIC TESTS USED IN THE CENTRAL AUDITORY ASSESSMENT VARIES AMONG AUDIOLoGISTS, THERE IS GENERAL AGREEMENT THAT A BEHAVIORAL CAP TEST BATTERY SHOULD INCLUDE AT LEAST THE FOLLOWING: DICHOTIC SPEECH TASKS, MONaurAL LOW-REDUNDANCY SPEECH TASKS, TESTS OF TEMPORAL PATTERNING, AND BINAURAL INTERACTION TASKS (BELLIS, 1996; CHERMAK AND MUSElK, 1997).

DICHOTIC LISTENING TASKS

THESE TESTS INVOLVE THE PRESENTATION OF STIMULI TO BOTH EARS SIMULTANEOUSLY, WITH THE INFORMATION PRESENTED TO ONE EAR BEING DIFFERENT FROM THAT PRESENTED TO THE OTHER. THE PATIENT'S TASK MAY BE EITHER TO REPORT ALL STIMULI HEARD OR TO ATTEND TO ONE EAR AND IGNORE THE OTHER. THESE MEASURES HAVE BEEN SHOWN TO BE SENSITIVE TO DISRUPTION OF INTERHEMISPHERIC TRANSFER OF INFORMATION VIA THE CORPUS CALLOSUM (MUSEIK Et AL, 1984, 1989), AS WELL AS TO BRAINSTEM AND CORtICAL DYSFUNCTION (KATZ, 1962; JERGER AND JERGER, 1975; KEITH, 1977; MUSEiK, 1983a; WILLEFOiRD AND BURLEIGH, 1994). THE TESTS REFERRED TO IN THE
following case studies include the Dichotic Digits test (DD; Musiek, 1983a), Dichotic Rhyme test (DR; Musiek et al, 1989), Competing Sentences test (CST; Willeford and Burleigh, 1994, but see Bellis, 1996, for alternative quadrant scoring method), and the Staggered Spondaic Word test (SSW; Katz, 1962).

**Monaural Low-Redundancy Speech Tests**

These tests involve the presentation of monosyllabic words that have been distorted in some way to reduce the extrinsic redundancy of the signal. Methods of distortion may include low-pass filtering, time compression, and addition of reverberation, among others. The purpose of monaural low-redundancy speech testing is to evaluate the listener's ability to achieve closure when the auditory signal is less than clear. Monaural low-redundancy speech tasks have been shown to be sensitive to a variety of central disorders, including brainstem and cortical dysfunction. Bilateral deficits on monaural low-redundancy speech tasks have been found in cases of pathology involving the primary auditory cortex (Baran et al, 1985). Tests referred to in the following case studies include low-pass filtered speech (LPFS; Willeford, 1977; Tonal and Speech Materials for Auditory Perceptual Assessment, 1992), 45 percent time-compressed speech (TC; Tonal and Speech Materials for Auditory Perceptual Assessment, 1992), and TC speech with reverberation (TCR; Tonal and Speech Materials for Auditory Perceptual Assessment, 1992).

**Temporal Patterning Tests**

Two commercially available tests of temporal patterning are the Pitch Pattern Sequence Test or Frequency Patterns test (FP; Pinheiro and Ptacek, 1971; Ptacek and Pinheiro, 1971) and the Duration Patterns test (DP; Pinheiro and Musiek, 1985). These tests are not designed to assess fine temporal acuity per se but rather to assess the listener's ability to perceive a pattern of auditory events occurring over time. For these tests, the listener hears triads of tone bursts that differ in frequency or duration. In the first test condition, the listener is required to report the pattern heard verbally (e.g., high-high-low or long-short-long, etc.), requiring efficient interhemispheric transfer of acoustic information from right hemisphere to left. In the second condition, the listener is required to hum the pattern, thus removing the linguistic labeling and interhemispheric transfer-component. These tests challenge the processes of frequency and/or duration discrimination, temporal ordering, and linguistic labeling. They have been shown to be sensitive to cortical and interhemispheric disruptions, and a comparison of the two test conditions has been shown to be instrumental in separating right-hemisphere-based disorder from interhemispheric and/or left-hemisphere-based processing disorders (Musiek et al, 1980, 1984).

**Binaural Interaction Tests**

Tests of binaural interaction assess the ability of the listener to process disparate, but complementary, information presented to the two ears. The input to each ear consists of a portion of the target message so that interaction between the two ears is required to achieve a unified percept. Binaural interaction, alternatively called binaural fusion, tasks have been shown to be sensitive only to gross brainstem pathology (Lynn and Gilroy, 1977; Musiek, 1983b). The binaural interaction tests referred to in the following case studies include Rapidly Alternating Speech Perception (RASP; Willeford and Bilger, 1978), consonant-vowel-consonant (CVC) binaural fusion (BF-CVC; Tonal and Speech Materials for Auditory Perceptual Assessment, 1992), and high-pass/low-pass binaural fusion (BF; Wilson and Mueller, 1984; Tonal and Speech Materials for Auditory Perceptual Assessment, 1992).

**CASE STUDIES**

The case studies given here illustrate the use of behavioral central auditory assessment in the overall evaluation of the child with language or learning difficulties. Interpretation of test findings involves an examination of patterns or constellations of behavior across various tasks and modalities. In each case, the central auditory assessment was included in the overall evaluation of these clients in order to clarify the nature of auditory-language processing difficulties that were noted on speech-language, educational, or neuropsychological evaluation or had been observed by parents or teachers. Each comprehensive central auditory evaluation was conducted in a sound-treated room and included standard audiometric and immittance testing (i.e., pure-tone air and bone conduction, speech reception threshold, word recognition, immittance, and acoustic reflex testing) prior to administration of central audi-
tory measures. Likewise, each child and his or her parents were interviewed prior to testing, and information regarding presenting complaints, academic and nonacademic abilities (including music and art skills, fine and gross motor abilities, social skills, and related information), and medical history was obtained. Recorded materials (tape or CD) were routed through a clinical audiometer to circumaural headphones. Normative data for central auditory tests are given in the figures accompanying each case.

The reader will note that all four children exhibited similar, although not identical, presenting complaints. Even so, findings on central auditory assessment were different for each child, providing a rational framework for the design of individualized management plans that targeted the specific processing deficits and areas of weakness that were identified by the evaluation results.

Case 1

This 9-year, 10-month-old girl was referred for central auditory assessment following comprehensive educational diagnostic testing that suggested deficits in listening comprehension, auditory word memory, and auditory sequencing. Fluid reasoning, comprehension-knowledge, and visual processing were significantly better developed than auditory-language skills and well above average for age, as were expressive language skills. Fine and gross motor skills were reported to be areas of relative strength, and no concerns regarding music, art, or visuospatial skills were expressed. Overall psychoeducational testing suggested broad cognitive ability well within the normal range for age; however, a significant discrepancy was noted between verbal and performance scales, with verbal lower than performance. Academically, this child exhibited difficulty in reading, spelling (specifically, phonics-based word attack skills), and written language. She complained of extreme difficulty hearing in noise and reported that the addition of visual cues was helpful to her. Medical history included multiple ear infections from a very early age; pressure equalizing (PE) tubes had been inserted on three occasions. At the time of testing, PE tubes were in place and patent and hearing sensitivity was well within normal limits bilaterally, with excellent word recognition abilities in quiet. Acoustic reflex testing could not be performed due to the presence of the PE tubes.

Central auditory testing revealed abnormal performance for three of six measures used (Fig. 1). Scores for frequency patterns were normal for each ear and both response conditions, ruling out interhemispheric and right-hemisphere dysfunction. Normal performance on consonant-vowel-consonant binaural fusion indicated grossly intact brainstem function. Scores were depressed bilaterally on low-pass filtered speech testing, and a bilateral deficit was noted on both Dichotic Digits and Competing Sentences testing, with the right ear slightly worse than the left. Errors for speech tests tended to be phonemically similar to the target (e.g., hop for hot, nine for dime) and included both consonant and vowel errors.

The pattern of bilaterally depressed scores on both dichotic speech and monaural low-redundancy speech tasks revealed a deficit in the process of auditory closure and implicated the primary auditory cortex as the presumed region of dysfunction. Because of the primary auditory cortex's role in auditory closure skills and in the analysis of acoustic-phonetic features of speech, both of which are necessary for decoding of auditory input, we have termed this deficit pattern the Auditory Decoding Deficit (Ferre, 1987, 1997; Bellis, 1996; Bellis and Ferre, 1996).

Likely the most "purely auditory" subtype among CAPDs, as well as frequently considered to be the "classic" manifestation of CAPD,
Auditory Decoding Deficit may be the behavioral manifestation of poorly formed neural representation of acoustic features, particularly those important for phonemic discrimination (Koch et al., 1999) and auditory closure. Academically, this child's difficulty with spelling and reading decoding skills presumably was due to inefficient phonemic representation secondary to poor speech-sound discrimination abilities. In the classroom, children with Auditory Decoding Deficit are at risk for marked listening difficulties in situations in which external phonemic representation is presented without sufficient contextural or visual cues, or noise or reverberation is present. Auditory fatigue is excessive compared to peers and listening behaviors will deteriorate over time as auditory "overload" increases. The child depicted in case 1 exhibited all of these difficulties.

Management focused on those areas found to be dysfunctional on central auditory testing and included classroom modifications to improve signal quality and provide visual augmentation, including the use of an FM system during academic classes. Although the use of assistive listening devices (ALDs) is one of the most frequently recommended interventions for children with CAPD, it has been our experience that use of such devices is appropriate primarily for those children for whom signal clarity is at issue, as is the case with Auditory Decoding Deficit. Aural rehabilitation activities focused on consonant and vowel discrimination training and auditory closure activities, including training in the use of contextual cues to facilitate closure. The child was counseled with regard to compensatory strategies, including recognition of adverse listening conditions and how to address them, methods of clarification of auditory instructions, and self-advocacy. At the same time, reading resource services focused on a visualization and verbalization approach to spelling and reading decoding skills that reinforced association of the sound with the orthographic symbol on the page. At the 1-year child study meeting to assess progress, a significant improvement in spelling and reading skills was reported, as was an improvement in overall listening behaviors and abilities within the classroom and at home.

### Case 2

Case 2 was a 9-year, 3-month-old boy referred for central auditory assessment because of concerns regarding listening comprehension and academic performance. Previous cognitive testing had suggested overall cognitive abilities to be in the mildly deficient range, and, at the time of testing, this child was in a self-contained classroom for students with limited intellectual functioning. However, comprehensive neuropsychological testing suggested that, when intellectual capacity was assessed using measures that were considered not to be linguistically biased, actual cognitive capacity was well within the average range. Areas of weakness were noted across modalities, including bimanual fine and gross motor abilities, graphomotor skills, visual/auditory association, and carrying out motor responses to verbal commands.

Academically, this child exhibited difficulty in virtually all academic areas, as well as in nonacademic areas such as art, music, and physical education. Furthermore, the more assistance he was given (i.e., via the addition of visual or tactile cuing), the more his difficulties appeared to be exacerbated, resulting in rapid regression. Neuroimaging and electroencephalographic (EEG) studies revealed a region of volume loss deep in the right cerebral hemisphere accompanied by abnormal electrical activity. The etiology could not be determined but was suspected to be due to possible perinatal stroke. Audiologic evaluation revealed hearing sensitivity to be well within the normal range bilaterally, with excellent word recognition abilities in quiet. Likewise, results of immittance testing revealed normal, type A tympanograms bilaterally, and contralateral and ipsilateral acoustic reflexes were obtained at normal levels to 500-, 1000-, 2000-, and 4000-Hz tones.

The results of central auditory assessment are presented in Figure 2. Of six central auditory tests administered, this child performed within the normal range for age on low-pass filtered speech, indicating intact auditory closure/decoding skills, and BF, indicating grossly intact binaural interaction abilities. On both Competing Sentences and Dichotic Digits testing (both single- and double-digit versions), he demonstrated almost complete left-ear suppression, as well as a left-ear suppression/right-ear enhancement on the DR test. On DP testing, his performance was at the chance level in the linguistic labeling condition; however, his ability
to mimic the acoustic patterns nonverbally was well within the normal range for his age, indicating intact duration discrimination and temporal patterning/sequencing abilities.

Overall, the pattern of left-ear suppression on dichotic speech tasks, combined with a deficit on temporal patterning tests in the linguistic labeling condition and intact functioning on monaural low-redundancy speech tasks, was consistent with a deficit in the interhemispheric transfer of information via the corpus callosum (Musiek et al., 1984), which we have termed Integration Deficit (Bellis, 1996; Bellis and Ferre, 1996; Ferre, 1997).

Children with Integration Deficit often demonstrate difficulty across modalities with any task that requires efficient interhemispheric communication. Both sight word and word attack skills may be poor, as such skills require both right-hemisphere-based gestalt patterning skills as well as left-hemisphere-based linguistic labeling skills, thus necessitating both hemispheres to be able to interact efficiently. The ability to link suprasegmental (i.e., prosodic) aspects of speech to the linguistic content of the message may be compromised, leading to difficulty processing ongoing discourse and in following verbally presented directions (Dimond et al., 1977; Klouda et al., 1988). Integration of multimodal-
dichotic speech and temporal patterning tests provided a measure of corpus callosum integrity that was not available via any other means. Thus, central auditory assessment, in this case, allowed for the development of a management plan that took into full consideration the deficits exhibited by this particular child, and, as a result, improvement currently is being seen both in his ability to comprehend verbal information presented in the classroom, as well as in performing a variety of tasks across modalities.

Case 3

This was a 9-year, 2-month-old boy referred for central auditory assessment because of concerns regarding difficulty in understanding verbally presented information, particularly in backgrounds of competing noise, as well as difficulty in sequencing verbally presented instructions. Although he had been classified previously as speech-language impaired for educational purposes, his classification was rescinded shortly before central auditory assessment. However, his mother continued to express concerns regarding his communication abilities. In particular, it was noted that he frequently misinterpreted the nature and intent of others' communications, resulting in emotional outbursts and hurt feelings.

Cognitive evaluation revealed intellectual capacity to be in the average range, with no significant discrepancies between overall verbal and performance abilities; however, some scatter in skills was found. A weakness was noted in his ability to use practical judgment in social situations. Other limitations were noted in graphomotor skills and in synthesizing concrete parts into meaningful wholes. Psychoeducational testing revealed adequate word attack skills; however, sight word abilities were an area of relative weakness. Overall reading comprehension abilities were determined to be consistent with age and grade level.

Speech-language evaluation revealed average vocabulary and generally intact receptive and expressive language skills for simple linguistic messages. However, as auditory messages became more complex, mild receptive language difficulties were noted. Expressively, this child tended to communicate in phrases rather than complete sentences, and frequently omitted the subject of the sentence. His language skills were described as "unusual" by both his mother and his speech-language evaluator in that they appeared to be qualitatively different from the norm, but not in a manner that affected his performance on standardized measures of expressive language to a great extent. The subject exhibited little vocal affect and spoke in a monotone much of the time. Music skills were reported to be poor, with inability to carry a tune and dislike for singing and listening to music. He also reported that he disliked engaging in art and puzzle completion activities, as such activities were difficult for him. Finally, this child was noted to exhibit clinical signs of depression much of the time, and he had very few friends with whom he socialized on a regular basis.

As in the previous case studies, this child exhibited hearing sensitivity well within normal limits bilaterally, accompanied by normal findings on immittance and acoustic reflex testing and excellent word recognition abilities in quiet.

Results of central auditory assessment are presented in Figure 3. The child performed within the normal range for his age on three of the five tests administered, including Dichotic Rhyme, Competing Sentences, and low-pass filtered speech. A slight left-ear deficit was noted on Dichotic Digits testing and his performance on Frequency Patterns was at chance level in both the linguistic labeling and humming conditions. In fact, the subject reported that he was

![Central Test Data](image)

**Figure 3** Case 3: results of central auditory assessment. Findings indicate slight left-ear deficit on Dichotic Digits (DD) and deficit on Frequency Patterns (FP) in both the linguistic labeling (L) and humming (H) conditions.
completely unable to discriminate the frequency differences in the stimuli, and that they "all sounded the same" to him. It should be noted that his binaural interaction skills were screened using 10 items from the consonant-vowel-consonant binaural fusion test and were judged to be intact; however, full binaural interaction testing was not completed because the child became fatigued and noncompliant.

Overall, these test results were consistent with essentially intact left-hemisphere and corpus callosal functioning; however, the inability to perceive acoustic contours, as evidenced by poor performance on Frequency Patterns testing, combined with the slight left-ear deficit on Dichotic Digits testing, suggested right-hemisphere involvement. This finding was consistent with the other above-mentioned testing that revealed difficulty in additional right-hemisphere-based tasks, including gestalt patterning and spatial abilities, pragmatic communication skills, sequencing, social judgment, and expressive prosody (Tomkins, 1995). Thus, from an auditory perspective, it was determined that the auditory manifestations of CAPD exhibited by this child met the criteria for a prosodic deficit type of disorder.

Children with Prosodic Deficit often demonstrate communicative sequelae that are difficult to describe or define precisely. These children may exhibit little or no expressive affect and may be described as "flat" or "monotonic" speakers and readers. Because the recognition and extraction of key words from a verbal message relies on the perception of subtle prosodic cues such as rhythm, stress, and intonation, children with Prosodic Deficit may have difficulty comprehending linguistically complex messages, not because of deficient auditory discrimination or receptive language skills but because they are unable to isolate the key words in a sentence from those surrounding them. Furthermore, these children may demonstrate a difficulty or inability to perceive the prosodic cues that underlie communicative exchanges involving humor, sarcasm, question forms, and other types of exchange that rely primarily on intonational cues to gauge communicative intent. Thus, these children may have difficulty in social communication situations and often may respond inappropriately.

Intervention techniques that have been useful for the child presented in case 3 have included placement with "animated" teachers and addition of visual augmentations in the classroom, specific training in key word extraction (i.e., searching for and recognition of the subject, verb, object, and modifiers of both written and spoken sentences of increasing linguistic complexity), prosody training (including sentences and words in which subtle differences in stress lead to differences in meaning, such as convict versus convict; "I saw the snow drift by the window" versus "I saw the snowdrift by the window;" Musiek and Chermak, 1995), and reading aloud with exaggerated prosodic features. In addition to these auditory-based interventions, this child has received speech-language intervention focusing on pragmatics as well as psychological counseling for social and depression-related concerns.

Case 4

Case 4 is a 10-year, 9-month-old boy referred for central auditory evaluation following neuropsychological testing. Parents reported classroom listening difficulties including difficulty following directions and inattentiveness. Neuropsychological testing found significantly better visual/performance skills than auditory-verbal skills. Academic evaluation revealed difficulties in language arts, note taking, and reading. The neuropsychological report noted the possibility that observed behavior was secondary to either central auditory disorder or to attention deficit disorder (ADD). This child exhibited completely normal findings on the peripheral audiologic evaluation, including
hearing sensitivity well within the normal range, excellent word recognition abilities in quiet, and normal tympanometric and acoustic reflex findings.

As seen in Figure 4, this child performed well within normal limits for all central auditory tests, suggesting age-appropriate CAP abilities. Results tended to rule out significant central auditory nervous system dysfunction as a contributing factor to reported and observed educational and listening difficulties. Results of the central auditory evaluation were used by the child's neuropsychologist to justify a referral for pediatric neurologic evaluation for ADD. Based on the results of all testing, ADD was diagnosed and a medication trial was initiated with noted improvements in classroom performance. This case illustrates the importance of not ascribing the label of CAPD without benefit of a central auditory assessment, even when behavioral and academic sequelae may be suggestive of auditory dysfunction.

**DISCUSSION**

This paper has described an interactive, multidimensional approach to differential diagnosis of auditory processing disorders in children. Through the use of case studies, we have demonstrated the utility of central auditory tests in uncovering the presence and nature of underlying auditory deficits that may be contributing to a child's communication and learning difficulties.

These case studies demonstrate that not all children presenting with similar listening behaviors and academic difficulties display the same underlying auditory deficits. For these children, patterns of findings on central auditory testing emerged that provided valuable information regarding each child's areas of auditory strengths and weaknesses and how these auditory characteristics may relate to the presenting academic and behavioral complaints. This information allowed for the development of individualized management plans that addressed the particular needs of each child. These cases demonstrate the inherent heterogeneity of the population of children with auditory processing problems and the need for the inclusion of behavioral central auditory assessment in the transdisciplinary evaluation of the child with language and learning difficulties. Furthermore, these cases emphasize the need for a test battery approach to central auditory assessment, as the finding of an abnormality on one test alone (e.g., dichotic listening) is not sufficient to determine region of dysfunction and underlying processing deficit.

When comparing the case studies presented in this paper, the reader will note that it was the specific pattern of findings across the combination of tests that led to appropriate diagnosis and management. For example, the presence of a left-ear deficit on dichotic speech testing for the child in case 2 was interpreted far differently than was the same finding for the child in case 3, due to differences in performance on Frequency Patterns testing and other psychoeducational and cognitive findings.

Finally, as illustrated in case 4, not all children referred for central auditory evaluation and who exhibit "listening" difficulties demonstrate dysfunction in CAP. In our experience, many children either perform normally or poorly across all measures, with no clear score or error pattern emerging, a finding that argues against specific auditory processing dysfunction and suggests, instead, that the child's presenting difficulties may be due to higher level cognitive, linguistic, or even emotional factors that require intervention by professionals from other disciplines.

Taken together, these cases underscore the notion that CAP encompasses far more than basic sensory-based processing of acoustic-phonetic features of speech, that behavioral central auditory assessment measures are useful in clarifying the nature of the auditory deficit and providing direction for intervention efforts, and that the audiologist can play a unique and pivotal role in identifying these disorders and ameliorating their negative effects.

**REFERENCES**


