Differential Diagnosis and Management of Central Auditory Processing Disorder and Attention Deficit Hyperactivity Disorder

Gail D. Chermak*  
James W. Hall III  
Frank E. Musiek

Abstract

Children diagnosed with attention deficit hyperactivity disorder (ADHD) frequently present difficulties performing tasks that challenge the central auditory nervous system. The relationship between ADHD and central auditory processing disorder (CAPD) is examined from the perspectives of cognitive neuroscience, audiology, and neuropsychology. The accumulating evidence provides a basis for the overlapping clinical profiles yet differentiates CAPD and ADHD as clinically distinct entities. Common and distinctive management strategies are outlined.

Key Words: Attention deficit hyperactivity disorder, central auditory processing disorder

Abbreviations: ADHD = attention deficit hyperactivity disorder, CAPD = central auditory processing disorder

Children diagnosed with attention deficit hyperactivity disorder (ADHD) frequently present difficulties performing tasks that challenge the central auditory nervous system. The association observed between attention deficits and performance on central auditory tests (Campbell and McNeil, 1985; Gascon et al, 1986; Cook et al, 1993; Pillsbury et al, 1995) has elicited suggestions of linkage between ADHD and central auditory processing disorder (CAPD). Some have questioned whether CAPD is a manifestation of impaired attention (Burd and Fisher, 1986; DeMarco et al, 1989; Robin et al, 1989) and whether CAPD and ADHD reflect a single developmental disorder (Gascon et al, 1986; Cook et al, 1993). Others have interpreted central auditory performance deficits among children with ADHD as a reflection of the co-occurrence or comorbidity of CAPD and ADHD (Keith and Engineer, 1991; Riccio et al, 1993, 1996). For example, finding low correlations between performance on the Staggered Spondaic Word Test and behaviors characteristic of ADHD (i.e., inattention, hyperactivity, and impulsivity), Riccio et al (1996) concluded that ADHD and CAPD are distinct entities that may nonetheless both involve deficits in auditory processing. It is also possible that the observed comorbidity of CAPD and ADHD reflects a shortcoming in the accuracy of differential diagnosis using current procedures and criteria (Riccio et al, 1994).

That central auditory performance deficits among children with ADHD may reflect the presence of CAPD rather than the ADHD per se is supported further by the frequently reported history of chronic otitis media in children with ADHD (Silva et al, 1982; Feagans et al, 1987; Roberts et al, 1989; Adesman et al, 1990; Pillsbury et al, 1995). The association between chronic otitis media and CAPD, with persistence of central auditory processing deficits even after resolution of the otitis media and return to normal hearing levels (Jerger et al, 1983; Silva et al, 1986; Adesman et al, 1990; Moore et al, 1991; Pillsbury et al, 1991; Gravel and Wallace, 1992; Hutchings et al, 1992; Hall

*Department of Speech and Hearing Science, Washington State University, Pullman, Washington; *Vanderbilt University School of Medicine, Nashville, Tennessee; *Section of Otolaryngology, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire

Reprint requests: Gail Chermak, Department of Speech and Hearing Science, Washington State University, Pullman, WA 99164-2420
and Grose, 1993, 1994; Brown, 1994; Hall et al, 1994, 1995), suggests that children with ADHD may experience central auditory performance deficits subsequent to chronic otitis media. Indeed, the frequently observed co-occurrence of CAPD and learning disability (Ferre and Wilber, 1986; Jerger et al, 1987; Elliott and Hammer, 1988; Breedin et al, 1989; Chermak et al, 1989) and CAPD and language impairment (Tallal and Piercy, 1973a; Sloan, 1980; Tallal, 1980a, b; Lubert, 1981; Tallal et al, 1985, 1996) has led to speculation that these deficits also may be causally related (Katz and Illmer, 1972; Tallal and Piercy, 1973a; Knox and Roeser, 1980; Sloan, 1980; Keith, 1981; Lubert, 1981; Tallal et al, 1985, 1996).

The literature is replete with reports of individuals with concurrent diagnoses of CAPD, attention deficits, and learning disabilities (Keith, 1986; Katz, 1992; Keller, 1992; Newhoff et al, 1992; Riccio et al, 1993, 1996; Pillsbury et al, 1995). However, the relationships among CAPD, ADHD, and learning disabilities are complex and not completely understood, and the primacy of any one of these disorders as causal to another remains unclear (Chermak and Musiek, 1997). Recent behavioral and neuroanatomical data, as well as a bottom-up model of information processing and the reconceptualization of ADHD as a behavior regulation disorder, provide fresh insights regarding probable linkages and distinctions. Drawing upon these converging lines of evidence, we argue that CAPD and ADHD reflect two distinct clinical disorders, notwithstanding some overlap in their behavioral profiles (Chermak and Musiek, 1997).

CENTRAL AUDITORY PROCESSING DISORDER

CAPD results from dysfunction of processes dedicated to audition; however, CAPD also may coexist with more global dysfunction that affects performance across modalities (e.g., attention deficit, neural timing deficit, language representation deficit) (ASHA, 1996). CAPD has also been observed in older adults, presumably due to nonpathologic neurologic changes associated with aging (Committee on Hearing, Bioacoustics, and Biomechanics [CHABA] Working Group on Speech Understanding and Aging, 1988; Gulya, 1991; Stach et al, 1990).

A CAPD involves a deficit in one or more of the central auditory processes responsible for generating the auditory evoked potentials and the behaviors of sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal processing (e.g., temporal resolution, temporal masking, temporal integration, and temporal ordering), auditory performance with competing acoustic signals, and auditory performance with degraded acoustic signals (Chermak and Musiek, 1997). Characteristically, patients with CAPD have difficulty comprehending spoken language in competing speech or noise backgrounds and in reverberation (Olsen et al, 1975; Musiek et al, 1982; Jerger et al, 1987, 1988). Children with CAPD ask frequently for repetitions, say “what” and “huh” a lot, show extreme auditory inattentiveness and have trouble paying attention, are easily distracted, often misunderstand messages, and have trouble following complex auditory directions or commands and localizing sound (Bornstein and Musiek, 1992).

CAPD is diagnosed on the basis of performance on a battery of auditory tests, which may include electrophysiologic as well as behavioral procedures, administered under acoustically controlled conditions (Jirsa and Clontz, 1990; Kraus et al, 1993; Musiek and Chermak, 1994; Chermak and Musiek, 1997).

Prevalence data for CAPD are sparse, particularly for children. Cooper and Gates (1991) estimated CAPD in 10 percent to 20 percent of older adults. Stach et al (1990) reported CAPD in 70 percent of clinical patients over age 60 years. Chermak and Musiek (1997) estimated that CAPD occurs in 2 percent to 5 percent of children, with a 2:1 ratio between boys and girls. Similarly, Musiek et al (1990) estimated prevalence of CAPD in children at 3 percent to 7 percent.

ATTENTION DEFICIT HYPERACTIVITY DISORDER

ADHD is characterized as the most common neurobehavioral disorder of childhood (Shaywitz et al, 1994). ADHD consists of a per-
Differential Diagnosis of CAPD and ADHD

Chermak et al

A consistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development; manifests in at least two settings; interferes with developmentally appropriate social, academic, or occupational functions; and is present since before age 7 years (APA, 1994).

Patterns of inattention, hyperactivity, and impulsivity are used to differentiate ADHD into three subtypes. The predominantly inattentive type presents primary symptoms of inattention (APA, 1994). The predominantly hyperactive-impulsive type is considered a behavioral regulation disorder (Barkley, 1990, 1994; APA, 1994). The combined type is characterized by hyperactivity-impulsivity (i.e., behavioral regulation disorder) and inattention (APA, 1994). Criteria for diagnosis of ADHD subtypes are listed in Table 1.

According to the DSM-IV, impulsivity is characterized by blurting out answers, failing to take turns, and interrupting or intruding on others. Hyperactivity is characterized by fidgeting with hands or feet or squirming in seat, difficulty remaining seated, running or climbing excessively in inappropriate contexts, difficulty engaging in quiet activity, constantly moving or engaging in activity, and talking excessively. Inattention in ADHD is marked by difficulty attending to details, sustaining attention to tasks, listening when spoken to, following through on instructions or finishing tasks, organizing tasks and activities, initiating tasks that require sustained mental effort, keeping track of objects needed for a task, ignoring extraneous stimuli, and remembering routine procedures or familiar information.

There are no empirical markers that identify ADHD (Taylor, 1986; Gordon, 1991; Reid et al, 1993). Therefore, diagnosis of ADHD is based on observational criteria defined as a cluster of behaviors involving impaired attention and distractibility, impulsivity, and hyperactivity (APA, 1994).

Some 3 percent to 4 percent of children, aged 2 to 8 years, may present with ADHD (APA, 1994). Szatmari (1992) estimated that 5 percent to 7 percent of the childhood population presents with ADHD. Among the school-aged population, 10 percent to 20 percent may present with ADHD (Shaywitz and Shaywitz, 1988; Szatmari et al, 1989). The prevalence of ADHD is higher among boys, with estimates ranging between 3:1 and 6:1 (Szatmari et al, 1989).

### Table 1 DSM-IV Criteria for Diagnosis of ADHD Subtypes

<table>
<thead>
<tr>
<th>Inattention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Poor attention to details or careless mistakes</td>
</tr>
<tr>
<td>2. Difficulty sustaining attention in tasks</td>
</tr>
<tr>
<td>3. Does not seem to listen when spoken to</td>
</tr>
<tr>
<td>4. Does not follow through on instructions or tasks</td>
</tr>
<tr>
<td>5. Difficulty organizing tasks</td>
</tr>
<tr>
<td>6. Difficulty with sustained mental effort</td>
</tr>
<tr>
<td>7. Loses things necessary for tasks</td>
</tr>
<tr>
<td>8. Often distracted by extraneous stimuli</td>
</tr>
<tr>
<td>9. Often forgetful in daily activities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hyperactivity-Impulsivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperactivity</td>
</tr>
<tr>
<td>1. Fidgets or squirms</td>
</tr>
<tr>
<td>2. Leaves seat in classroom</td>
</tr>
<tr>
<td>3. Runs or climbs excessively</td>
</tr>
<tr>
<td>4. Difficulty in engaging in quiet activity</td>
</tr>
<tr>
<td>5. “On the go” or acts as if “driven by a motor”</td>
</tr>
<tr>
<td>6. Talks excessively</td>
</tr>
<tr>
<td>Impulsivity</td>
</tr>
<tr>
<td>1. Blurts out answers</td>
</tr>
<tr>
<td>2. Difficulty waiting turn</td>
</tr>
<tr>
<td>3. Interrupts or intrudes on others</td>
</tr>
</tbody>
</table>

DSM-IV criteria for diagnosis of ADHD subtypes requires the presence of six or more symptoms of inattention and/or hyperactivity-impulsivity persisting for 6 or more months. ADHD, Combined Type (meets criteria A and B); ADHD, Predominantly Inattentive Type (meets criterion A, but not B); ADHD, Predominantly Hyperactive-Impulsive Type (meets criterion B, but not A).

### DIFFERENTIATING ATTENTION DEFICIT HYPERACTIVITY DISORDER AND CENTRAL AUDITORY PROCESSING DISORDER

#### Nature of Attention Deficits

Although attention deficits frequently characterize CAPD and ADHD (particularly the combined and predominantly inattentive types), there are distinctions to be drawn regarding the nature of the inattention observed in the two disorders. The attention deficits of ADHD typically are pervasive and supramodal, impacting more than one sensory modality (Keller, 1992; APA, 1994). In contrast, individuals with CAPD experience attention deficits that may be restricted to the auditory modality (Chermak and Musiek, 1997). As noted by Chermak and Musiek (1997), the commonly observed left-ear deficit on dichotic speech tests seen in individuals with CAPD, as well as their depressed auditory performance under conditions of either contralateral or ipsilateral competition as a function of the level of brain dysfunction, argues against a pervasive attention deficit in CAPD and helps
distinguish CAPD from ADHD (Musiek et al., 1984, 1994; Jerger et al., 1988). Nonetheless, further research is needed to ascertain the degree to which modality specificity of processing deficits characterizes CAPD (McFarland and Cacace, 1995).

Different types of attention deficits may be seen in ADHD and CAPD (Chermak and Musiek, 1997). Although the neural mechanisms underlying the different behaviors associated with various attention tasks are unknown, research suggests that attention deficits associated with the combined and predominantly hyperactive-impulsive ADHD subtypes may be restricted to sustained attention, albeit in multiple modalities (Seidel and Joschko, 1990; Hooks et al., 1994; Barkley, 1997a, b). Selective (focal) and divided auditory attention deficits characterize CAPD (Katz and Illmer, 1972; Lasky and Tobin, 1973; Cherry, 1980; Jerger and Jerger, 1984; Keith, 1986). Inclusion of a recently released test of sustained auditory attention (vigilance) in the central auditory test battery (Keith, 1994) should prove helpful in substantiating this distinction.

While additional research is needed to clarify differences in the nature and type of attention deficits observed in ADHD and CAPD, it is clear that the clinical inattention profiles differ significantly. The inattention profile of ADHD involves difficulty initiating, tracking, and remembering tasks (APA, 1994), in addition to sustaining allocation of attentional resources. The focused and divided attention deficits that characterize CAPD impact monaural and binaural separation and binaural integration tasks (Chermak and Musiek, 1997). Most importantly, the inattentiveness seen in CAPD is a primary deficit resulting from an input or information processing deficit. In contrast, the hyperactive-impulsive and combined ADHD subtypes are characterized as output or response programming and execution disorders (Barkley, 1997a, b). Behavioral disinhibition ultimately results in poor goal-directed persistence and defective resistance to distraction subsequent to poor self-regulation and executive control of behavior (Goodyear and Hynd, 1992; Barkley, 1997a, b). Consistent with this conceptualization, inattention is a secondary deficit in the combined and predominantly hyperactive-impulsive ADHD subtypes (Barkley, 1997a, b). As elaborated below, the ADHD inattention profile may indicate a primary executive control deficit, rather than an attention deficit per se. Differentiating the predominantly inattentive ADHD subtype from CAPD is more challenging since the inattention in both disorders is considered to be a primary and input or information processing deficit. Differential diagnosis requires examination of auditory test outcomes as discussed above.

Reconceptualization of ADHD

The recent shift in conceptualizing ADHD as a behavioral regulation disorder rather than a primary attention disorder further distinguishes CAPD and ADHD (Chermak and Musiek, 1997). Symptoms of impulsivity and behavioral disinhibition are considered the result of neurologically based, “developmental deficiencies in the regulation and maintenance of behavior by rules and consequences” (Barkley, 1990, p. 71). Deficits in rule-governed behavior, perhaps resulting from elevated arousal thresholds (Zentall, 1985) or elevated reinforcement thresholds (Haenlein and Caul, 1987), lead to problems initiating, inhibiting, or sustaining responses to tasks or stimuli (Barkley, 1990), which heretofore had been considered characteristics of attention deficits. Deficits in rule-governed behavior lead to problems in executive functioning and self-regulation (Barkley, 1990). Consistent with this reconceptualization, ADHD is seen, essentially, as a motivational deficit, rather than an attention deficit (Barkley, 1990, 1994; Chermak and Musiek, 1997). This reconceptualization of ADHD as one of poor rule-governed behavior may also explain the self-control problems, social skill deficits, and language disorders (e.g., difficulty topic switching, turn taking, and sustaining dialogue) so frequently observed in ADHD (Augustine and Damico, 1995).

Behavioral Differences

Despite some overlapping symptomatology, clinicians seem able to distinguish behavioral profiles for CAPD and ADHD. Chermak et al. (1998) found that pediatricians and audiologists view the predominant symptoms of ADHD and CAPD as being rather distinct, with only 2 (i.e., inattention and distractibility) of the 11 most frequently cited behaviors reported as common to both conditions (Table 2). Inattention and distractibility were ranked as the first and second most typical behaviors characterizing ADHD. Audiologists ranked these same behaviors as
Table 2  Rank Order of Behavioral Means Greater than 1 Standard Deviation above the Respective Grand Mean

<table>
<thead>
<tr>
<th>ADHD</th>
<th>CAPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inattentive</td>
<td>1. Difficulty hearing in background noise</td>
</tr>
<tr>
<td>2. Distracted</td>
<td>2. Difficulty following oral instructions</td>
</tr>
<tr>
<td>3. Hyperactive</td>
<td>3. Poor listening skills</td>
</tr>
<tr>
<td>4. Fidgety/restless</td>
<td>4. Academic difficulties</td>
</tr>
<tr>
<td>5. Hasty/impulsive</td>
<td>5. Poor auditory association skills</td>
</tr>
<tr>
<td>6. Interrupts/intrudes</td>
<td>6. Distracted</td>
</tr>
<tr>
<td>Grand mean</td>
<td>7. Inattentive*</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.90</td>
</tr>
</tbody>
</table>

*Note that inattentive was included based upon an "evens-down/odds-up" rounding rule; the standard deviation was 0.01 points below the criterion of +1 SD above the grand mean.


seventh and sixth, respectively, in cases of CAPD. CAPD was characterized by a selective attention deficit and associated language processing and academic difficulties; ADHD was characterized by inappropriate motor activity, restlessness, and socially inappropriate interaction patterns. Other investigators have reported that behavior problems, such as difficulty waiting one's turn, playing quietly, and excessive talking, more often characterize children with ADHD than CAPD (Newhoff et al, 1992). Similarly, severe socioemotional sequelae (i.e., conduct disorders, juvenile delinquency) are more common among children with ADHD (Newhoff et al, 1992). Interestingly, the predominantly inattentive ADHD subtype shares little if any comorbidity with disruptive behavior disorders, in contrast to the predominantly hyperactive-impulsive and combined ADHD subtypes (Barkley, 1997a).

RECONCILING THE COMORBIDITY OF ATTENTION DEFICITS AND CENTRAL AUDITORY PROCESSING DISORDERS

Modeling Information Processing

Insofar as attention is essential to higher level processing, poor attention can compromise listening. Musiek and Chermak (1995) proposed that viewing the relationship between attention and auditory processing within the top-down and bottom-up information processing models provides a theoretical framework that clarifies the nature of the relationship between ADHD and CAPD. The inability to sustain sufficient attention to auditory stimuli might cause auditory processing deficits (i.e., top down); conversely, deficient auditory processing (i.e., bottom up) might impair attention (Chermak and Musiek, 1997). Understanding the relationship between the attention deficits of ADHD and CAPD hinges on the interaction between perception and higher level cognitive processing (Chermak and Musiek, 1997). Most germane is whether an auditory processing deficit causes some attention deficit (as we argue occurs in CAPD) or whether a more global attention deficit impedes auditory processing (as we argue occurs in ADHD).

Consistent with a bottom-up model, attention is driven by incoming sensory stimulation and garnered by properly integrated and processed sensory stimuli (Musiek and Chermak, 1995; Chermak and Musiek, 1997). If acoustic stimuli are not properly processed, as occurs in CAPD, then optimal attention cannot be focused on these stimuli in a timely manner (Phillips, 1990). Attention deficits are seen as secondary to auditory perceptual processing deficits within the framework of a bottom-up model (Chermak and Musiek, 1997). In contrast, CAPD would be seen as a manifestation of a global attention deficit within a top-down information processing model (Chermak and Musiek, 1997).

While it is likely that bidirectional interactions between central auditory processing and attention are necessary for optimal listening comprehension, experimental evidence from basic science supports a bottom-up view of attention deficits whereby deficiencies in auditory perceptual processes trigger attention deficits (Hassamannova et al, 1981; Robertson and Irvine, 1989; Farah and Wallace, 1991; Harrison et al, 1992; Irvine et al, 1992; Mogdans and Knudsen, 1992, 1993, 1994; Recanzone et al, 1993; Phillips, 1995). Experimental evidence
regarding the plasticity of the central auditory nervous system supports the authors' bottom-up view of auditory perceptual deficits as causal to CAPDs. This evidence suggests that central changes are contingent on sensory function and experience (Moore, 1993). For example, cortical reorganization has been observed in young and adult mammals following induced cochlear lesions (Robertson and Irvine, 1989; Harrison et al., 1992; Irvine et al., 1992; Rajan et al., 1993; Schwaber et al., 1993; Willott et al., 1993).

Consistent with a bottom-up perspective, listening difficulties seen in CAPD result from specific auditory perceptual deficiencies rather than global attention deficits (ADD subtype) or behavioral regulation deficits (combined ADHD and predominantly hyperactive-impulsive ADHD subtypes) (Phillips, 1990, 1995; Tallal et al., 1996). As outlined in Table 3 and discussed earlier, CAPD is considered an input disorder that impedes selective and divided auditory attention. The combined and predominantly hyperactive-impulsive ADHD subtypes are seen as output disorders in response programming and execution that indirectly cause sustained attention deficits across modalities. Dual diagnoses of both CAPD and ADHD may result, therefore, from comorbid attention deficits at different levels and primacy of sensory and global dysfunction (Chermak and Musiek, 1997).

### Neuromorphologic Correlates

Brain imaging studies and postmortem examinations of individuals with dyslexia, learning disabilities, ADHD, and normal controls have revealed morphologic and structural differences in auditory areas of the brain that are activated when listening to simple tonal complexes, language, and music (i.e., superior temporal gyrus, Heschl's gyrus, planum temporale, posterior portion of the insula, sulcus of the corpus callosum) (Galaburda and Kemper, 1978; Hynd et al., 1990, 1991). The accumulating data suggest a neuroanatomical basis for the often observed co-occurrence of CAPD, auditory attention deficits, dyslexia, and learning disabilities.

Postmortem studies have documented brain abnormalities (e.g., nests of ectopic [misplaced] and underdeveloped cells) involving auditory regions of the brain in children with learning disabilities and dyslexia (Galaburda and Kemper, 1978; Galaburda and Eidelberg, 1982; Galaburda et al., 1985). Developmental abnormalities of the cerebral cortex were observed in all four brains studied of men diagnosed as dyslexic during life (Galaburda et al., 1985). Cerebrocortical abnormalities may be observed in normal brains, albeit in far smaller numbers and in different locations relative to the brains of abnormal subjects (see Kaufmann and Galaburda, 1989). Brain imaging studies have revealed morphologic and structural differences in auditory areas as well as motor regulation/behavioral inhibition areas (prefrontal lobes and striatum) of the brains of children with ADHD, as compared with the brains of normal children, implicating some deviation in normal brain development (Hynd and Semrud-Clikeman, 1989; Lou et al., 1989; Hynd et al., 1990; Zametkin et al., 1990; Weller, 1991; Mann et al., 1992).

The corpus callosum was reported smaller in children with ADHD relative to normal controls (Hynd et al., 1991). Hynd (personal communication, 1992) indicated that the morphology of Heschl's gyrus may also differ in children with ADHD, as compared with normal controls. The planum temporale was reported shorter in the left hemisphere and of reversed asymmetry (R > L) in subjects with dyslexia relative to normal controls (Hynd et al., 1990). Seventy percent of the normal children and the children with ADHD presented the expected left greater than right pattern of plana asymmetry, while only 10 percent of the children with dyslexia demonstrated this normal pattern (Hynd et al., 1990). Similarly, the insular region of the brains of children with dyslexia are smaller bilaterally than normal controls (Hynd et al., 1990).

<table>
<thead>
<tr>
<th>Table 3 Differentiating Attention Deficits in ADHD Disorder and CAPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHD Combined and Predominantly Hyperactive-Impulsive Subtypes</td>
</tr>
<tr>
<td>Output disorder</td>
</tr>
<tr>
<td>Sustained attention deficit secondary to behavioral disinhibition and poor self-regulation</td>
</tr>
<tr>
<td>Executive dysfunction</td>
</tr>
<tr>
<td>ADHD Predominantly Inattentive Subtype</td>
</tr>
<tr>
<td>Input disorder</td>
</tr>
<tr>
<td>Global attention deficit</td>
</tr>
<tr>
<td>Selective (focused) attention deficit</td>
</tr>
<tr>
<td>Reduced rate of information processing</td>
</tr>
<tr>
<td>CAPD</td>
</tr>
<tr>
<td>Input disorder</td>
</tr>
<tr>
<td>Specific auditory perceptual deficit</td>
</tr>
<tr>
<td>Selective (focused) and divided attention deficits</td>
</tr>
<tr>
<td>Executive dysfunction as secondary source of listening problems</td>
</tr>
</tbody>
</table>
Morphologic differences and possible dysfunction in areas of the brain associated with motor regulation and self-control (e.g., frontal region, caudate nucleus) suggest a neurobiological basis for co-occurring central auditory deficits and behavioral regulation problems in ADHD. Lou et al (1989) reported decreased metabolism in the caudate nucleus associated with ADHD. Mann et al (1992) found increased slow wave activity in the frontal regions and decreased beta activity in the temporal regions in boys with ADHD, compared to normal control subjects. Hynd et al (1990) reported bilaterally smaller anterior cortices in children with ADHD and dyslexia relative to a control group of children, reflecting significantly decreased right frontal lobe width. In addition, the children with dyslexia showed hemispheric symmetry in this region in contrast to the typical pattern of the right frontal lobe being larger than the left (Hynd et al, 1990).

Executive Function

Executive functioning provides a construct useful in understanding a wide range of symptoms observed across many disorders with overlapping clinical profiles (Pennington et al, 1996), including ADHD and CAPD. Because executive functions place significant demands on attention (both sustained and selective attention to enable sensory and perceptual processing of events) and memory to register, store, and make knowledge and experience available to the individual (Butterfield and Albertson, 1995; Barkley, 1996; Pennington et al, 1996), executive dysfunction may be related to deficits characterizing ADHD and CAPD.

Executive function is a component of metacognition that refers to a set of general control processes that ensure that an individual's behavior is adaptive, consistent with some goal, and beneficial to the individual (Brown et al, 1983; Sternberg, 1985; Borkowski et al, 1988; Denckla, 1996; Torgesen, 1996). Executive control processes coordinate knowledge (i.e., cognition) and metacognitive knowledge in support of task analyses, planning, and reflective decision making, ultimately transforming this knowledge into behavioral strategies (Butterfield and Albertson, 1995; Barkley, 1996). They are crucial to the execution of novel behavioral sequences; learning and problem solving; psychosocial function, including self-image, self-regulation of emotion, and motivation; and goal-directed behaviors, including listening (Grattan and Eslinger, 1992; Grattan et al, 1994; Borkowski and Burke, 1996). Executive function may be assessed by a variety of procedures and tests including auditory and visual continuous performance tests, the Wisconsin Card Sorting Test, the Stroop tasks, Matching Familiar Figures Test, and measures of verbal fluency (Denckla, 1989).

Executive function deficits have been described in a wide variety of clinical populations, often in association with brain disease or injury, and may underlie childhood neurologic disorders, in particular, the academic problems experienced by children with learning disabilities or ADHD (Stanovich, 1986; Pennington, 1991; Torgesen, 1994; Fletcher et al, 1995; Denckla, 1996; Graham and Harris, 1996). Executive function deficits also have been identified in children who do not meet eligibility criteria for learning disabilities or ADHD but experience significant difficulties in school (Denckla, 1989). The prevalence of CAPD in the latter group of children has not been determined (Chermak and Musiek, 1997).

Linkages among executive function, rule-governed behavior, and self-control (Hayes et al, 1996) have led to suggestions that executive dysfunction is the source of the behavioral regulation and inattention problems manifested in ADHD (Denckla and Reader, 1993; Barkley, 1994; Smith et al, 1995). Recognizing that pragmatic and metacognitive behaviors associated with communication are both language based and rule governed, Westby and Cutler (1994) reasoned that executive dysfunction also may explain language deficits in ADHD, such as poor topic maintenance, inappropriate topic switching, poor problem solving, and difficulty producing coherent extended discourse such as stories and expository texts (Heyer, 1995), as well as contribute to the pragmatic problems observed in individuals with ADHD, which include excessive talking, interrupting others, blurtting out answers, difficulty waiting one's turn, and difficulty negotiating peer interactions.

Although executive dysfunction in CAPD has not been examined, it is reasonable to expect that auditory perceptual deficits impede operation of executive functions (Chermak and Musiek, 1997). Difficulty organizing, monitoring, and understanding acoustic signals may reflect limited use of executive function. In contrast to the proposed causal role of executive dysfunction in ADHD (Denckla and Reader, 1993; Barkley, 1994; Smith et al, 1995), and consistent with a bottom-up processing model, executive dys-
function in CAPD would be considered a secondary feature, not a primary cause, of listening difficulties (Chermak and Musiek, 1997). These secondary deficits could compound auditory processing deficits, impede generalization of strategic listening behaviors across settings, and thereby jeopardize treatment efficacy (Borkowski and Burke, 1996; Chermak and Musiek, 1997). The distinctions we have posited between ADHD and CAPD are summarized in Table 3.

**IMPLICATIONS FOR ASSESSMENT AND INTERVENTION**

Linkages between ADHD and CAPD underscore the importance of thorough and multidisciplinary assessment with individuals suspected of these disorders. Individuals with diagnoses of CAPD, ADHD, and learning disabilities commonly experience some degree of spoken language processing deficit (Wiig and Semel, 1984; Gravel and Wallace, 1992; Westby and Cutler, 1994). Given the well-known relationship between structure and function, the emerging neuromorphologic data suggesting some dysfunction in auditory areas of the brain in cases of learning disability, dyslexia, ADHD, and CAPD offer compelling rationale for thorough assessment of the auditory system and auditory perceptual abilities. Clinicians must use sensitive measures to evaluate the integrity of underlying perceptual, linguistic, and cognitive systems to determine the predominant and primary deficits, as well as secondary problems that may underlie these deficits (McFarland and Cacace, 1995). Such an approach requires the interdisciplinary efforts of audiologists, speech-language pathologists, teachers, psychologists, and physicians for assessment and for intervention. Differentiating ADHD and CAPD hinges on accurate diagnosis of these conditions.

**Special Strategies for the Assessment of Central Auditory Processing in Children with Attention Deficit Hyperactivity Disorder**

Audiologic assessment of children with ADHD is clinically challenging. Valid behavioral measurement of auditory status requires that the child willingly cooperate in the assessment, understand the instructions, and attend to the task. Each of these requirements may be compromised in the ADHD population. The likelihood of successfully assessing central auditory nervous system function in children with ADHD or suspected ADHD is enhanced by several practical modifications in the test strategy. However, when behavioral audiometric findings remain incomplete, inconclusive, or invalid despite the implementation of these modifications, one must rely more on electrophysiologic techniques (Musiek et al, 1991; Hall, 1992; Chermak and Musiek, 1997). Indeed, electrophysiologic procedures may inform differential diagnosis of CAPD and ADHD. For example, children with CAPD present significantly delayed $P_{300}$ latencies and reduced $P_{300}$ amplitudes compared to children with ADHD whose $P_{300}$ latencies and amplitudes do not differ from those of normal control subjects (Jirsa and Clontz, 1990; Sangal et al, 1995).

Perhaps the single most important step in successful audiologic assessment of the child with diagnosed and medically managed ADHD is to ensure that the child received an effective dose of medication immediately before the test session. Although this statement seems obvious, it is important to specifically instruct caregivers to follow the typical school day routine for medication on the day of the audiologic assessment. Some might argue that audiologic assessment should be conducted with the child in his or her natural state (e.g., without medication). Others might express concerns about the possible confounding effects of the medication on test performance. Our clinical experience suggests at least three responses to these arguments. First, if the child is regularly given medication on school days, then following the prescribed medication schedule will result in a typical state. Second, there is no evidence that the medications used in management of ADHD (e.g., Ritalin, Cylert, Adderall) have any influence on the peripheral or central auditory nervous system functioning. Finally, for children with diagnosed ADHD who are treated medically, valid audiologic assessment would rarely be possible without medication. Therefore, it is advisable to verify that the child received appropriate medication on the test day. Also, the assessment is best scheduled to begin first thing in the morning (e.g., 8:30 or 9:00 AM).

Peripheral auditory function should be evaluated thoroughly, but expediently, prior to central auditory assessment. A feasible test sequence is immittance measurement (tympanometry and both uncrossed and crossed acoustic reflexes), pure-tone audiometry (including interoctave frequencies of 3000 and 6000 Hz), speech reception thresholds, word recognition perfor-
mance, and otoacoustic emissions. Since the overall objective is assessment of central auditory function, the evaluation of peripheral auditory function should be conducted as quickly as possible, without sacrificing vital information. To save test time, pure-tone audiometry is limited to air-conduction signal whenever immittance measurement yields findings consistent with normal middle ear function. As an aside, acoustic reflex thresholds should be measured very cautiously, or not at all, when history suggests the possibility of hyperacusis, or intolerance to loud sounds. Speech reception threshold measurement can be bypassed if pure-tone audiometry is reliable and entirely normal. Most patients have normal hearing sensitivity. If so, word recognition performance can be efficiently assessed with lists constructed with the most difficult 10 words first. If the child correctly recognizes these first 10 words, testing is discontinued. Twenty-five word lists are appropriate for children with peripheral hearing loss, or when performance for the shortened lists is less than 100 percent. Otoacoustic emissions recording with a cooperative child will generally require less than 2 minutes per ear, even with a protocol that is sensitive to cochlear dysfunction (e.g., distortion product otoacoustic emissions with L1 = 65 dB and L2 = 55 dB or transient evoked otoacoustic emissions with an 80 dB SPL click stimulus). By employing these test-time-saving strategies, the experienced audiologist can usually complete the peripheral assessment in less than 30 minutes.

A description of the CAPD test battery is beyond the scope of this paper. The overall objective of the test battery is to determine whether the child shows a deficit in one or more of the central auditory processes noted earlier in this paper (ASHA, 1996). Comparison of speech identification/recognition performance in quiet versus competition, as well as comparisons in the presence of ipsilateral versus contralateral competition, may inform differential diagnosis of attention deficits and CAPD. Phoneme processing difficulties in quiet are unlikely to be the result of a pervasive attention deficit (Jerger et al, 1987). Similarly, deficits in word identification in noise for phonemically similar words, but not for semantically similar words, argue against a pervasive attention deficit as the cause of the abnormal performance (Jerger et al, 1987). Likewise, speech recognition deficits seen only in the presence of either ipsilateral or contralateral competition or only under more challenging, but not all, signal-to-competition ratios would suggest a specific auditory perceptual deficit rather than a pervasive attention deficit. The reader is referred to recent textbooks by the authors for detailed discussions of CAPD assessment procedures and protocols and the analyses and interpretation of CAPD findings (Chermak and Musiek, 1997; Hall and Mueller, 1997). Throughout the audiologic test battery, attention level and cooperation will be enhanced by two or three breaks during which the child is given the opportunity to move about and, perhaps, have a light snack. In addition, test performance is often optimized when the child is given frequent praise for his/her efforts.

Implications for Intervention

The clinical utility of the CAPD and ADHD diagnoses is perhaps of most consequence relative to management. Management programming will depend on the diagnostic category of the primary disorder. Strategies for managing CAPD generally include acoustic signal modifications, auditory training, and metalinguistic and metacognitive approaches. Management of ADHD generally involves medication and metacognitive or executive control strategies. Some combination of these approaches may be required to effectively manage CAPD in individuals also diagnosed with ADHD.

Central Auditory Processing Disorders

A comprehensive approach to managing CAPD is designed to improve listening skills and spoken language comprehension (Chermak and Musiek, 1997). The complementary interventions listed in Table 4 target auditory skills, linguistic and metalinguistic skills and strategies, executive control strategies, and signal quality enhancement (Chermak and Musiek, 1997). Fundamental central auditory processing skills (e.g., auditory discrimination, temporal processing) are targeted through auditory training. Auditory training is directed toward improving the basic auditory skills listed in Table 5.

Table 4 CAPD Management

<table>
<thead>
<tr>
<th>Signal enhancement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory training</td>
</tr>
<tr>
<td>Environmental modifications</td>
</tr>
<tr>
<td>Metacognitive (executive) strategies</td>
</tr>
<tr>
<td>Linguistic strategies</td>
</tr>
<tr>
<td>Metalinguistic strategies</td>
</tr>
<tr>
<td>Collaboration</td>
</tr>
<tr>
<td>Learning strategies</td>
</tr>
</tbody>
</table>
These skills encompass both spectral processing (e.g., frequency discrimination) and temporal processing (e.g., gap detection) and underlie phonetic distinctions essential to spoken language processing (Chermak and Musiek, 1997). A concurrent emphasis on metacognitive or executive control (e.g., schema induction and self-instruction), as well as linguistic (e.g., vocabulary building) and metalinguistic knowledge (e.g., segmentation and closure) and strategy development, strengthens self-regulation of spoken language processing (Chermak and Musiek, 1997). To complement these remedial efforts, compensatory techniques (e.g., acoustic signal enhancement and environmental modifications) are recommended to address processing deficits considered more resistant to treatment (Chermak and Musiek, 1997). Given the range of listening and associated learning problems, all management efforts are conducted in collaboration with other professionals and the family. Learning difficulties often associated with CAPD and ADHD may require intervention by education specialists, learning specialists, and psychologists.

**Attention Deficit Hyperactivity Disorder**

Managing individuals with ADHD typically involves medication that in almost all cases requires additional intervention for success (Anastopoulos and Barkley, 1990). Recent reports suggest that stimulant medication may be the most effective treatment for the majority of children and adults with predominantly hyperactive-impulsive and combined ADHD (Barkley, 1997a). Indeed, reconceptualizing ADHD as a developmental disorder of self-regulation related to defective motor inhibition supports the use of pharmacologic management. Metacognitive or executive control strategy training (e.g., self-regulation, cognitive behavior modification), social-pragmatic skills training (e.g., role playing in use of appropriate language in social and academic interactions, developing vocabulary, social cognition, and pragmatics for reflection, planning, and problem solving), and collaboration with teachers and families, especially in regard to medication and contingency management systems (i.e., structuring the environment, reinforcement schedules, token systems), are essential (Anastopoulos and Barkley, 1990; Guevremont, 1990; Westby and Cutler, 1994; Heyer, 1995; Maag and Reid, 1996). Barkley (1997b) emphasized the use of behavioral performance programs in natural settings. Typical goals include increasing on-task behavior, task completion, compliance, and impulse control. Metacognitive strategies involve the use of language as an internal and self-regulating control to foster sustained attention and control impulsivity and hyperactivity. Approaches to managing ADHD are listed in Table 6.

**CONCLUSIONS**

Attention deficits, listening deficits, and poor academic achievement associated with both ADHD and CAPD (Willeford and Burleigh, 1985; Chermak and Musiek, 1992, 1997; Keller, 1992; APA, 1994; Chermak et al, 1998) render differential diagnosis especially challenging. The data and perspectives reviewed in this paper, however, support the clinical utility of CAPD and ADHD as valid clinical diagnoses, notwithstanding overlapping clinical profiles.

Differences in auditory areas of the brain, relative to normal controls, suggest a neuroanatomical basis for the frequently observed central auditory performance deficits among children diagnosed with ADHD. Providing additional insight as to the observed comorbidity of CAPD and ADHD is the reconceptualization of ADHD as a behavioral regulation disorder associated with executive dysfunction (Denckla and Reader, 1993; Barkley, 1994; Smith et al, 1995), coupled with the suggestion that the auditory perceptual deficits of CAPD may impede exec-
utive functions and thereby serve as a secondary source of the difficulties seen in CAPD in organizing, monitoring, and understanding acoustic signals (Chermak and Musiek, 1997).

The distributed nature of information processing may lead to auditory attention deficits at sensory and/or cognitive levels. ADHD and CAPD may differ in the extent of the attention deficit (i.e., cognitive and supramodal vs sensory and restricted to the auditory modality), as well as the type of attention deficit (i.e., sustained vs selective and divided attention). Within an information processing framework, the sustained attention problems observed in ADHD are seen as the consequence of a supramodal cognitive deficit, whereas CAPD results from a specific auditory perceptual deficit. Inattention in ADHD may reflect deficiencies in behavioral regulation rather than attention per se. In contrast, the selective auditory attention deficits of CAPD result from deficient auditory perceptual processing.

Additional research is needed to determine the neurologic mechanisms and associated behavioral criteria consistent with these clinical diagnoses. Such information will improve the differential diagnosis of ADHD and CAPD, as well as subtype ADHD, where a unidimensional perspective on diagnosis has been shown to be inadequate in explaining behavior (Schaughency and Hynd, 1989; Goodyear and Hynd, 1992). More definitive diagnostic information should lead to more effective intervention.

Acknowledgment. Portions of this paper were presented at the 9th Annual Convention of the American Academy of Audiology, Ft. Lauderdale, FL, April 18, 1997.

REFERENCES


