“How can he have a hearing problem when he overhears everything we say from three rooms away? He has the sharpest ears in the house.”

That was the startled response of one typical couple when their son's preschool teacher suggested he might be deaf.

We know.

We were the couple.

And that was our first encounter with Central Auditory Processing Disorders, or CAPDs.

That experience was one of the crucial factors that lead us to focus our medical careers on helping children - especially gifted children - with learning difficulties. In the years since we have had many more encounters with CAPDs, and we are constantly surprised both by their prevalence and by the many difficulties they create in children's lives. Published reports suggest CAPDs affect roughly 2-3% of children (Chermak, G., and Musiek, F; 1997) but the real numbers may be significantly higher. In our clinic, CAPDs are some of the most common disorders underlying school difficulties, and some of the most disabling.

Despite the significance of these disorders, children with CAPD often go undiagnosed and untreated. Indeed, many doctors, teachers, and therapists have never even heard of CAPD, and many who have heard have only a vague knowledge of this often confusing field. In this paper, we would like to provide a basic understanding of the brain processes that constitute central auditory processing and the signs that might suggest that a child is suffering from CAPD.

**PHYSIOLOGY OF CENTRAL AUDITORY PROCESSING**

CAPDs are impairments in brain function that hinder the extraction of useful information from the neural impulses transmitted by the ears. In contrast to problems of the peripheral or sensorineuronal hearing system (ears and auditory nerves) CAPDs cannot be detected by routine audiometric exam. In fact, many children with CAPD will show ‘hyperacusis’ or exceptionally acute hearing when tested in the absence of background noise or other competing signals.

In most persons with CAPD, the ears perform their work flawlessly, converting sound waves to impulses in the auditory nerves. The problem comes downstream, in the parts of the brain responsible for processing these impulses. Errors can occur at any step, leading to a variety of difficulties.
In 1996, the American Speech Language Hearing Association (ASHA) Task Force on Central Auditory Processing published a report identifying the processes that together comprise the central auditory processing system. (American Speech Language Hearing Association, 1996). Although their terminology can seem rather arcane, it is still widely used by researchers and clinicians in the field, and as such is important for anyone interested in helping children with CAPD. Those who find it impenetrable can skip ahead to the section Clinical Presentations of CAPD.

According to the report, "Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioral phenomena:

- Sound localisation and lateralisation
- Auditory discrimination
- Auditory pattern recognition
- Temporal aspects of audition, including
  - temporal resolution
  - temporal masking
  - temporal integration
  - temporal ordering
- Auditory performance decrements with competing acoustic signals
- Auditory performance decrements with degraded acoustic signals."

These terms require varying degrees of explanation. **Sound localisation and lateralisation** (also called Binaural interaction) refer to the ability to locate the source of a sound in space. These skills also underlie the ability to identify a signal in background noise. This latter function arises from the ability to discern that sounds are coming from different sources or locations. The most common symptom of localisation defects is difficulty hearing with background noise. Children with localisation problems may also have difficulty identifying or looking toward speakers, or appear easily distractible with competing noise. Symptoms vary greatly between auditory environments.

**Auditory discrimination** is the ability to distinguish between different sounds. It covers both the broad distinctions between train whistle and baby’s cries, and the fine phonological differences between *canned* and *can't* or *tamp* and *damp*. These skills affect an equally broad range of auditory behaviors, like word recognition and speech comprehension in quiet and noisy environments, or the ability to distinguish the musical or prosodic aspects of speech (see below).

**Auditory pattern recognition** is the ability to recognise patterns in the duration, pitch, and volume of sounds, and in the intervals between sounds. Because of the inextricable links between such patterns and characteristics of timing, they are now most commonly grouped with the next category.

**Temporal aspects of audition** refers to the processes dealing with time-related cues in acoustic signals. These processes cover many functions, from the ability to determine
sound order in words (e.g., *past* versus *pats*), to the ability to perceive the earlier ‘voicing’ in *dime* versus *time*. They also underlie the ability to hear the rhythmic and melodic (or prosodic) elements of speech and music. We will discuss these functions in more detail below.

**Auditory performance decrements with competing acoustic signals** is the ability to process an auditory stimulus in the presence of background noise, such as a teacher talking over other students or the air conditioner. We will discuss this more below.

**Auditory performance decrements with degraded acoustic signals** is the ability to process signals that are incomplete or corrupted. Problems in this area cause difficulty filling-in missing word fragments when the cell phone is cutting in and out, or understanding someone speaking softly or with a strong accent, or understanding messages when a portion of the sound spectrum has been removed or obscured.

### CAPD CATEGORIES AND AUDIOLOGICAL TESTING

The ASHA report has been useful in a number of respects. Its terminology has allowed persons interested in CAPD to communicate in a common language. It has also provided researchers in the field a common conceptual framework for organising their studies and discussions of CAPD.

Soon after it was published, though, it was recognised that the ASHA report had one serious shortcoming: it failed to define how its behavioral categories corresponded to the test measures clinicians had available to diagnose CAPDs. Consequently, even after clinicians determined that a patient had abnormal CAPD test results, they often could not classify that patient within the ASHA scheme.

To bridge this gap, Schow et al. (2000) used factor analysis to determine which of the ASHA categories were being measured by which available tests. Although this report introduces a new layer of terminology, it is essential reading for anyone interested in CAPD, because audiologists frequently employ terms from both ASHA and Schow in their writings and clinical reports.

Schow et al. analysed the results of 11 tests commonly used to diagnose CAPD and found four distinct ‘factors’ (or behavioral processes) that seemed to account for most of the variation in the test results. Importantly, most of these factors did not align perfectly with any of the ASHA categories.

Schow et al’s first category (or factor) contained two closely related functions, which they called **Auditory closure** and **Monaural separation**. These functions relate most closely to the ASHA category of *auditory performance with degraded acoustic signal*, but they also involve *auditory discrimination*, *auditory performance with competing signal*, and *auditory pattern recognition*.

**Auditory closure** is the ability to fill gaps in a message whose information is missing or distorted. **Monaural separation** is the ability to understand a message that’s delivered to
one ear, while another competing signal is delivered to the same ear. Both functions allow listeners to construct complete messages from scattered fragments of auditory signals. They play an important role in many everyday listening activities, including listening in background noise, listening to garbled electronic (such as radio, TV, or phone) communications, or listening to speakers with difficult accents, poor diction, or quiet voices.

Auditory closure skills involve more than the acoustical information in a message, or what’s known as its ‘intrinsic redundancy’. They also involve an individual’s store of topical information and language skills - material known as ‘extrinsic redundancy’. A person with good topical understanding, a strong vocabulary, good phonological skills, and a powerful command of the rules of language, will have a much better chance of understanding a degraded message than a person without such skills. This is one reason gifted children with CAPD are notoriously difficult to test - they can often correctly answer test questions based on extrinsic knowledge or pattern inference rather than on the basis of what they’ve actually heard. Unfortunately, their ability in a noisy classroom to infer meanings and achieve closure is often inferior to their ability to outthink a test, so considerable care must be taken when testing gifted children with clear symptoms of impaired closure in their everyday environment. A normal or borderline test may not provide definitive proof that their auditory processing system is intact.

Schow et al’s (2000) next category is Binaural separation, which is the ability to process an auditory message delivered to one ear while ignoring a different message delivered to the other ear. It corresponds to the ASHA category auditory performance with competing acoustic signal. Binaural separation requires ‘directed attention’, or the ability to attend to some information while ignoring other information. School children must use this skill constantly to attend to the teacher while ignoring the other children.

The next category, Binaural integration, is important in similar settings, and is also an aspect of auditory performance with competing signals. Binaural integration is the ability simultaneously to process two different messages, when one is presented to each ear. This function underlies a child’s ability to hear instructions to “come in from the playground” when listening to a companion’s pleas to “kick the ball”. Problems of binaural integration - like those of binaural separation - usually present as difficulties hearing with background noise or competing speakers. Background noise problems are also the most common complaints of children with defective auditory closure, yet such children yield very different CAPD batteries and require very different clinical interventions. This is one example of why children with clinical signs of CAPD need comprehensive testing to evaluate the full range of CAP functions.

The fourth Schow et al’s (2000) category is Auditory pattern temporal ordering, or APTO. APTO combines aspects of the ASHA categories auditory discrimination, auditory pattern recognition, and temporal aspects of audition, and is essential for recognising and employing the musical or prosodic aspects of speech, such as rhythm, stress, and intonation. APTO skills are crucial for identifying nuanced meanings or key words in sentences, moods or intentions of speakers, and even differences in word
meanings, such as project and project. Persons with difficulties in this area often have ‘flat’ or poorly contoured prosody when speaking. They may also have difficulties ordering words or sounds in messages in their proper sequence.

Schow et al. (2000) also mentioned three ASHA categories that did not seem to line up with any of the four factors they identified. These were sound localisation/lateralisation or binaural interaction, auditory discrimination, and other temporal aspects. The first two categories were well described above. The third (consisting of temporal tasks not included in APTO) contains primarily the functions of temporal resolution or gap detection, and release from masking. Children with gap detection problems have difficulty sensing the gaps or silences in sounds. As such they are particularly sensitive to background noise that makes detecting such gaps harder. Children with masking difficulties have similar problems, and also have difficulty localising sound in space. Audiologists performing CAPD batteries now commonly add tests to those used by Schow et al. (2000) to assess these categories.

Even though many tests are available to evaluate children with CAPDs, there are still significant gaps in our ability to evaluate important aspects of central auditory processing. This is especially true in areas such as auditory discrimination and sound localisation. As a result, a typical CAPD battery cannot be considered proof of the presence or absence of CAPD. However, we will discuss this further in the next issue of Gifted.

**CLINICAL PRESENTATION OF CAPD**

We now turn to the clinical signs and symptoms of CAPD. Children with different CAPD subtypes will show different patterns of dysfunction, and most children with CAPD will show only a few of the following symptoms. (For those interested in a more detailed discussion of CAPD aimed at the general reader we recommend Teri James Bellis' *When the Brain Can’t Hear*. For a professional level discussion read the same author's *Assessment and Management of Central Auditory Processing Disorders in the Educational Setting*.) No child will show all symptoms.

As infants or pre-schoolers, children with CAPD may show diminished response to voices or loud noises, or seem unable to hear with background noise. They may also appear hypersensitive to sounds that don’t bother others. They may begin prefer quiet and solitary activities to group situations like birthday parties, preschool or Sunday School classes, indoor malls, or swimming pools. In noisy environments they may become withdrawn or anxious, cover their ears, appear highly distractible, or become severely anxious or explosive. They may have difficulties developing socially appropriate communication, or speak with abnormally flat, formal, or ‘pedantic’ voices. They may avoid talking with others, may not enjoy being read to, or may appear to ‘tune out’ or ‘daydream’ a lot. They may have unusual difficulty following directions, repeatedly say "What?" or "Huh?", often ask for clarification, or become frustrated or confused when spoken to. Parents may perceive that these children just don’t ‘get it’ when things are asked of or explained to them.
They may do better with visual demonstrations.

Such children may be suspected of having autism spectrum disorders, though they are usually affectionate and loving with their families. They may also show delays in speech, persistent articulation errors, or difficulty learning nursery rhymes, poems, or songs.

School aged children with CAPD may show problems following oral instructions or organising behaviors. They may be quiet, distracted, or off-topic during group discussions. They may show long delays before responding to questions or instructions. They may prefer nonverbal tasks, and show a significant difference between higher performance and lower verbal IQ scores. As oral instruction and receptive language demands increase they may show worsening performance, diminished attention, difficulty following lectures, or decreased participation in discussions. Difficulties may worsen when required to take notes or copy from a board.

Often, children with CAPD are suspected of having attention deficit/hyperactivity disorder (ADHD). Like children with ADHD, children with CAPD can appear distractible or inattentive. CAPD children with auditory hypersensitivities who become over-stimulated by noise are especially likely to be diagnosed with ADHD. Many children with CAPD also have dysfunctional sensory integration (DSI), which can cause motor hyperactivity, sensory seeking, and sensory distractibility. However, there are behavioral characteristics that help differentiate children with ADHD and CAPD (Chermak, G., Hall, J., and Musiek, F., 1999). Children with ADHD have a higher incidence of hyperactivity, restlessness, impulsivity, and interruptions or intrusions. Children with CAPD are more likely to show difficulty hearing in background noise, difficulty following directions, poor listening skills, and poor auditory association skills. In our own work with children, we have also found that children with CAPD typically show distractibility and inattentiveness during tasks with significant auditory demands, while children with ADHD are inattentive across more situations.

Children with certain CAPD subtypes may show difficulties with reading, phonology, and spelling. There is a close connection between the ability to process the sound structures of words, and the ability to learn to read and spell. In fact, nearly 60% of dyslexics show significant deficits on CAPD testing.

Children with CAPD may also have significant social and emotional difficulties. As mentioned, children with hypersensitivities may become agitated or anxious, and are often labeled as attention-seeking or immature. Other children have difficulties engaging in social communication. They are often unable to follow the thread of a rapidly changing conversation, and are forever off-topic or one step behind. They may have difficulty adopting the tone of social communication among their peer group, and may speak with distinctive diction, cadence, tone or emphasis. They may have difficulty speaking interactively, or following up on another person's interests. They may hinder discussions with repeated requests for clarification, or by returning to points others have already left. They may have difficulty catching the point of a joke or laugh only after a long delay. They may show significantly prolonged ‘processing times’ and an equally prolonged lag
before answering. They may appear to others to be rude, unresponsive, stupid, slow, ‘uncool’, or just no fun to be around.

Consequently, children with CAPD frequently receive discouraging and disparaging feedback from others. Parents and teachers may berate them for their slowness, failures to listen or follow directions, their apparent selfishness, self-absorption, or lack of interest in others. Often they will be suspected of having -and in our experience be mistakenly diagnosed with - Asperger’s Syndrome or autism spectrum disorders (See Notes) despite the fact that they are affectionate and caring and have no fundamental deficit in theory of mind (See Notes).

This is especially true among gifted children who often have vocabularies and interests that appear unusual for age, and who pursue their interests with an intensity bordering on obsession. When such children show unusual timing or prosody in their speech, or difficulties with social interactions due more to inability to process sound than to empathise with or understand the feelings of others, they are almost invariably categorised as having autism spectrum disorders. Often they are mistakenly assumed to be emotionally cold or distant, or unable to perceive human feelings of all kinds, and are treated with distance, coldness, and social exclusion by others. The emotional toll of such treatment is unsurprisingly grave. Often these children suffer from feelings of guilt and low self-esteem. They feel unloved, unlovable, a burden to others, and somehow deserving of the hostile treatment they receive for reasons they are helpless to understand. All too often they become anxious, depressed, and socially withdrawn, and when help is offered, most often it is in the form of counselling or medications to treat the emotional and behavioral consequences of their misdiagnosis and resulting mismanagement, while the underlying and ultimately responsible CAPD goes undiagnosed and untreated.

Fortunately, the story of CAPD does not stop here. We are in the midst of an exciting time of growth both in our understanding of these complex disorders, and in our ability to treat them. In the next issue of Gifted, we will discuss how children suspected of having CAPD should be evaluated and managed.

References


Notes
Tony Attwood's *Asperger's Syndrome: A Guide for Parents and Professionals* contains excellent sections dealing with auditory and prosodic speech difficulties in persons diagnosed with Asperger's syndrome. Many of these difficulties are common in persons with CAPD, as well. Whether these similarities arise from similar causes requires further investigation.

For a moving narrative from a parent's perspective we would recommend *Like Sound Through Water* by Karen J. Foli.

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