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Central Auditory Processing Disorders - An Overview of Assessment and Management Practices

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Hearing is a complex process that is often taken for granted. As sounds strike the eardrum, the sounds (acoustic signals) begin to undergo a series of transformations through which the acoustic signals are changed into neural signals. These neural signals are then passed from the ear through complicated neural networks to various parts of the brain for additional analysis, and ultimately, recognition or comprehension. For most of us, when someone talks about hearing abilities, we think primarily of the processing that occurs in the ear; that is, the ability to detect the presence of sound. Likewise, when someone is described as having a hearing loss, we assume that this individual has lost all or part of the ability to detect the presence of sound. However, the ability to detect the presence of sounds is only one part of the processing that occurs within the auditory system.

There are many individuals who have no trouble detecting the presence of sound, but who have other types of auditory difficulties (e.g., difficulties understanding conversations in noisy environments, problems following complex directions, difficulty learning new vocabulary words or foreign languages) that can affect their ability to develop normal language skills, succeed academically, or communicate effectively. Often these individuals are not recognized as having hearing difficulties because they do not have trouble detecting the presence of sounds or recognizing speech in ideal listening situations. Since they appear to "hear normally," the difficulties these individuals experience are often presumed to be the result of an attention deficit, a behavior problem, a lack of motivation, or some other cause. If this occurs, the individual may receive medical and/or remedial services that do not address the underlying "auditory" problem.

Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioral phenomena.

1. Sound localization and lateralization
2. Auditory discrimination
3. Temporal aspects of audition including: temporal resolution, temporal masking, temporal integration and temporal ordering.
4. Auditory performance with competing acoustic signals
5. Auditory performance with degraded signals

These mechanisms and processes apply to nonverbal as well as verbal signals and may affect many areas of function, including speech and language (ASHA, 1996, p. 41).

WHAT IS MEANT BY THE TERM "CENTRAL AUDITORY PROCESSING?"

Katz, Stecker & Henderson (1992) described central auditory processing as "what we do with what we hear." In other words, it is the ability of the brain (i.e., the central nervous system) to process incoming auditory signals. The brain identifies sounds by analyzing their distinguishing physical characteristics frequency, intensity, and temporal features. These are features that we perceive as pitch, loudness, and duration. Once the brain has completed its analysis of the physical characteristics of the incoming sound or message, it then constructs an "image" of the signal from these component parts for comparison with stored "images." If a match occurs, we can then understand what is being said or we can recognize sounds that have important meanings in our lives (sirens, doorbells, crying, etc.).

This explanation is an oversimplification of the complicated and multifaceted processes that occur within the brain. The complexity of this processing, however, can be appreciated if one considers the definition of central auditory processing offered by the American Speech-Language-Hearing Association (ASHA).

This definition acknowledges that many neurocognitive functions are involved in the processing of auditory information. Some are specific to the processing of acoustic signals, while others are more global in nature and not necessarily unique to processing of auditory information (e.g., attention, memory, language representation). However, these latter functions are considered components of auditory processing when they are involved in the processing of auditory information.

WHAT IS CENTRAL AUDITORY PROCESSING DISORDER (CAPD)?

CAPD can be defined as a deficiency in any one or more of the behavioral phenomena listed above. There is no one cause of CAPD. In many children, it is related to maturational

delays in the development of the important auditory centers within the brain. Often, these children's processing abilities develop as they mature. In other children, the deficits are related to benign differences in the way the brain develops. These usually represent more static types of problems (i.e., they are more likely to persist throughout the individual's life). In other children, the CAPD can be attributed to frank neurological problems or disease processes. These can be caused by trauma, tumors, degenerative disorders, viral infections, surgical compromise, lead poisoning, lack of oxygen, auditory deprivation, and so forth.

The prevalence of CAPD in children is estimated to be between 2 and 3% (Chermak & Musiek, 1997), with it being twice as prevalent in males. It often co-exists with other disabilities. These include speech and language disorders or delays, learning disabilities or dyslexia, attention deficit disorders with or without hyperactivity, and social and/or emotional problems.

WHAT ARE SOME OF THE BEHAVIORAL MANIFESTATIONS OF CAPD?

Below is a listing of some of the common behavioral characteristics often noted in children with CAPD. It should be noted that many of these behavioral characteristics are not unique to CAPD. Some may also be noted in individuals with other types of deficits or disorders, such as attention deficits, hearing loss, behavioral problems, and learning difficulties or dyslexia. Therefore, one should not necessarily assume that the presence of any one or more of these behaviors indicates that the child has a CAPD. However, if any of these behaviors are noted, the child should be considered at risk for CAPD and referred for appropriate testing. Definitive diagnosis of a central auditory disorder cannot be made until specialized auditory testing is completed and other etiologies have been ruled out.

1. Difficulty hearing in noisy situations
2. Difficulty following long conversations
3. Difficulty hearing conversations on the telephone
4. Difficulty learning a foreign language or challenging vocabulary words
5. Difficulty remembering spoken information (i.e., auditory memory deficits)
6. Difficulty taking notes
7. Difficulty maintaining focus on an activity if other sounds are present child is easily distracted by other sounds in the environment
8. Difficulty with organizational skills
9. Difficulty following multi-step directions

10. Difficulty in directing, sustaining, or dividing attention
11. Difficulty with reading and/or spelling
12. Difficulty processing nonverbal information (e.g., lack of music appreciation)

There are a number of behavioral checklists that have been developed in an effort to systematically probe for behaviors that may suggest a CAPD (Fisher, 1976; Kelly, 1995; Smoski, Brunt, & Tannahill, 1992; Willeford & Burleigh, 1985). Some of these checklists were developed for teachers, while others were designed for parents. These checklists can be helpful in determining whether a child should be referred to an audiologist for a central auditory processing assessment.

HOW IS CAPD ASSESSED?

CAPD is assessed through the use of special tests designed to assess the various auditory functions of the brain. However, before this type of testing begins, it is important that each person being tested receive a routine hearing test for reasons that will become obvious later.

There are numerous auditory tests that the audiologist can use to assess central auditory function. These fall into two major categories: behavioral tests and electrophysiologic tests. The behavioral tests are often broken down into four subcategories, including monaural low-redundancy speech tests, dichotic speech tests, temporal patterning tests, and binaural interaction tests. It should be noted that children being assessed for CAPD will not necessarily be given a test from each of these categories. Rather the audiologist will select a battery of tests for each child. The selection of tests will depend upon a number of factors, including the age of the child, the specific auditory difficulties the child displays, the child's native language and cognitive status, and so forth. For the most part, children under the age of 7 years are not candidates for this type of diagnostic testing. In addition, central auditory processing assessments may not be appropriate for children with significant developmental delays (i.e., cognitive deficits).

Space limitations preclude an exhaustive discussion of each of the central tests that are available for clinical use. However, a brief overview of the major test categories is provided, along with an abbreviated description of a few tests that are considered representative of the many tests available for use in central auditory assessments.

Electrophysiologic tests

Electrophysiologic tests are measures of the brain's response to sounds. For these tests, electrodes are placed on the earlobes and head of the child for the purpose of measuring electrical potentials that arise from the central nervous system in response to an auditory stimulus. An auditory stimulus, often a clicking sound, is delivered to the child's ear and the

electrical responses are recorded. Some electrophysiologic tests are used to evaluate processing lower in the brain (auditory brainstem response audiometry), whereas others assess functioning higher in the brain (middle latency responses, late auditory evoked responses, auditory cognitive or P300 responses). The results obtained on these tests are compared to age-appropriate norms to determine if any abnormalities exist.

Behavioral tests

Monaural Low-Redundancy Speech Tests: Due to the richness of the neural pathways in our auditory system and the redundancy of acoustic information in spoken language, a normal listener is able to recognize speech even when parts of the signal are missing. However, this ability is often compromised in the individual with CAPD. **Monaural low-redundancy speech tests represent a group of tests designed to test an individual's ability to achieve auditory closure when information is missing. The speech stimuli used in these tests have been modified by changing one or more of the following characteristics of the speech signal: frequency, temporal, or intensity characteristics.**

An example of a test in this category is the Compressed Speech test (Beasley, Schwimmer, & Rintelmann, 1972). This is a test in which the speech signals have been altered electronically by removing portions of the original speech signal. The test items are presented to each ear individually and the child is asked to repeat the words that have been presented. A percent correct score is derived for each ear and these are compared to age-appropriate norms.

Dichotic Speech Tests

In these tests different speech items are presented to both ears either simultaneously or in an overlapping manner and the child is asked to repeat everything that is heard (divided attention) or repeat whatever is heard in one specified ear (directed attention). The more similar and closely acoustically aligned the test items, the more difficult the task.

One of the more commonly used tests in this category is the Dichotic Digits test (Musiek, 1983). The child is asked to listen to four numbers presented to the two ears at comfortable listening levels. In each test item two numbers are presented to one ear and two numbers are presented to the other ear. For example, in figure one, 5 is presented to the right ear at the same time 1 is presented to the left ear. Then the numbers 9 and 6 are presented simultaneously to the right and left ears. The child is asked to repeat all numbers heard and a percent correct score is determined for each ear and compared to age-appropriate norms.

Dichotic Digits



(For text only readers: Figure 1 shows numbers 1,6 entering the left ear and numbers 5,9 entering the right ear).

Temporal Patterning Tests

These tests are designed to test the child's ability to process nonverbal auditory signals and to recognize the order or pattern of presentation of these stimuli. A child can be asked to simply "hum" the patterns. In this case, the processing of the stimuli would occur largely in the right half of the brain. If on the other hand, the child is asked to describe the patterns using words; then the left side of the brain is also involved, as well as the major auditory fibers that connect the auditory portions of both sides of the brain.

The Frequency Pattern Sequences test (Musiek & Pinheiro, 1987) is one of the temporal patterning tests used frequently with children. The test items are sequences of three tone bursts that are presented to one or both ears. In each of the sequences two tone bursts are of the same frequency, while the third tone is of a different frequency. There are just two different frequencies used in this test: one is a high-frequency sound and the other a low-frequency sound. The child therefore hears patterns, such as high-high-low or low-high-low, and is asked to either hum or describe the patterns heard. As with other central tests, the test items are presented at levels that are comfortable for the child and percent correct scores are obtained and compared to norms.

Binaural Interaction Tests: Binaural interaction tests are sometimes referred to as binaural integration tests. These tests tap the ability of structures low in the brain (brainstem) to take incomplete information presented to the two ears and fuse or integrate this information in some manner. Most of the tests in this category present different parts of a speech signal to each ear separately. If only one part of the signal is presented, the child usually cannot recognize the test item. However, if the two different parts of the stimuli are presented simultaneously, with one portion going to one ear and the other portion to the other ear, the child with normal processing abilities has no difficulty recognizing the test item. This is because the two parts (which are unrecognizable if presented in isolation) are integrated into a single identifiable stimulus by the auditory nervous system.

An example of a test in this category is the Rapidly Alternating Speech Perception test (Willeford, 1976). For this test, sentence materials are divided into brief segments which are alternated rapidly between the two ears. The example below is a rough approximation of what happens to a sentence when it is segmented in this manner. In this example, the first sound in the sentence "Put a dozen apples in the sack" (represented by pu) is presented to the right ear, then the t sound is presented to the left ear, and so forth and so

on. If the child hears only the segments presented to the right ear or left ear, he or she is unlikely to be able to recognize the sentence. However, if the right ear and left ear segments are presented in a cohesive fashion to the child, sentence recognition improves dramatically as long as this particular function of the brain is intact.

Rapidly Alternating Speech Perception

PU A ZE AP S N SA T DO N PLE I THE CK



(For text readers only: Figure 2 shows a visual representation of the above example, with the letters PU, A, ZE, AP, S, N, SA, presented to the right ear and letters T, D, O, N, PLE, I, THE, CK, presented to the left ear).

WHAT ARE THE EDUCATIONAL IMPLICATIONS OF CAPD?

The list of behavioral observations provided earlier in this article highlights many of the academic and/or speech and language problems that might be experienced by the child with CAPD. Since speech and language skills are developed most efficiently through the auditory sensory modality, it is not unusual to observe speech and language problems, as well as academic problems (many of them language-based), in children with CAPD. If a child experiences difficulty in processing the brief and rapidly changing acoustics of spoken speech, he or she is likely to have problems recognizing the "speech sounds" of language. If problems are encountered in recognizing the sound system of language, then additional problems are likely to be encountered when the child is asked to begin to match "speech sounds" to their alphabetic representations (a skill that serves as the foundation for the development of subsequent reading and writing skills). This in turn can lead to comprehension problems and poor academic performance. It is worth reiterating at this time that not all children with CAPD will experience all of these problems. There is a wide range of variability in the problems experienced by children with CAPD; however, it should be recognized that the presence of a CAPD places the child at risk for developing many of these language and academic problems.

WHAT MANAGEMENT STRATEGIES CAN BE USED TO REMEDIATE CAPD?

There are several different ways to help children overcome their CAPD. The exact procedures or approaches used will depend upon a number of factors, including the exact nature of the CAPD, the age of the child, the co-existence of other disabilities and/or problems, and the availability of resources. In general, the approaches to remediation or

management fall into three main categories: (a) enhancing the individual's auditory perceptual skills, (b) enhancing the individual's language and cognitive resources, and (c) improving the quality of the auditory signal.

The following discussion presents some of the procedures that may be used with a child with CAPD. More detailed information is beyond the scope of this article, but may be found in the various resources listed at the end of this article.

Many children with CAPD will benefit from auditory training procedures and phonological awareness training. Intervention may also involve the identification of (and training in the use of) strategies that can be used to overcome specific auditory, speech and language, or academic difficulties. A number of actions can be taken to improve the quality of the signal reaching the child. Children can be provided personal assistive-listening devices that should serve to enhance the teacher's voice and reduce the competition of other noises and sounds in the classroom. Acoustic modifications can be made to the classroom (e.g., carpeting, acoustic ceiling tiles, window treatments) which should help to minimize the detrimental effects of noise on the child's ability to process speech in the educational setting.

Finally, teachers and parents can assist the child in overcoming his or her auditory deficits by speaking clearly, rephrasing information, providing preferential seating, using visual aids to supplement auditory information, and so forth. The program should be tailored to the child's individual needs, and it should represent an interdisciplinary approach. Parents, teachers, educational specialists, and other professionals, as appropriate, should be involved in the development and implementation of the child's management program.

DO CHILDREN WITH CAPD HAVE HEARING LOSS?

Children with CAPD do not have hearing loss if the term is used to refer to a loss of hearing sensitivity. Most children with CAPD have normal hearing sensitivity and their auditory difficulties will not be detected during routine hearing testing unless some of the special "sensitized" tests (see discussion above) are administered. These children, however, have hearing loss in the sense that they do not process auditory information in a normal fashion. They have auditory deficits that can be every bit as debilitating as unidentified hearing loss. If the auditory deficits are not identified early and managed appropriately, many of these children will experience speech and language delays, academic failure and/or underachievement, loss of self-esteem, and social and emotional problems.

CAN A CHILD HAVE BOTH A HEARING LOSS AND A CAPD?

Children can have both a hearing loss and a CAPD. Fortunately, most children seen for

central auditory testing have normal hearing (i.e., detection) abilities. However, children with hearing loss can also have a CAPD. In fact, the presence of a hearing loss may place a child at risk for CAPD. This is because the auditory pathways and centers in the brain develop as they are stimulated with sound. The presence of a hearing loss may limit the amount and type of auditory stimulation that is necessary to promote optimal development of the auditory nervous system. If this happens, then auditory deficits are likely to result.

A question frequently asked of audiologists is "whether or not a child with a hearing loss can be tested for CAPD?" The answer is not a simple "yes" or "no." Many children with hearing losses can be tested as long as they have some hearing (i.e., detection) abilities. Interpretation of the test results does become somewhat more difficult for the audiologist who is conducting the testing if a hearing loss is present, but there are distinct patterns of test results that can indicate the presence of a CAPD. Moreover, there are certain tests that the audiologist can use that are not affected to the same degree as other tests by the presence of a hearing loss. These tests should be used whenever feasible. Unfortunately, there are some individuals with losses so severe that testing cannot be completed. As a general rule, central auditory testing cannot be done if the individual being tested has a hearing loss falling in the severe- to-profound range.

WHERE CAN I GO FOR ADDITIONAL INFORMATION?

The books listed in the reference section are good sources of information. In addition, we have provided a list of web sites that you may find helpful.

Selected Web Sites for Teachers and Parents

- www.kidspeech.com/tips.html
- www.ldanatl.org/factsheets/Auditory.html
- www.healthtouch.com/level1/leaflets/aslha/aslha024.htm
- www.ldonline.org/ld_indepth/process_deficit/table_deficits.html
- www.ldonline.org/ld_indepth/process_deficit/pro_deficits.html
- www.Kidshealth.org/parent/healthy/central_auditory.html

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