Central Auditory Processing Disorder

دکتر اکرم فراهانی

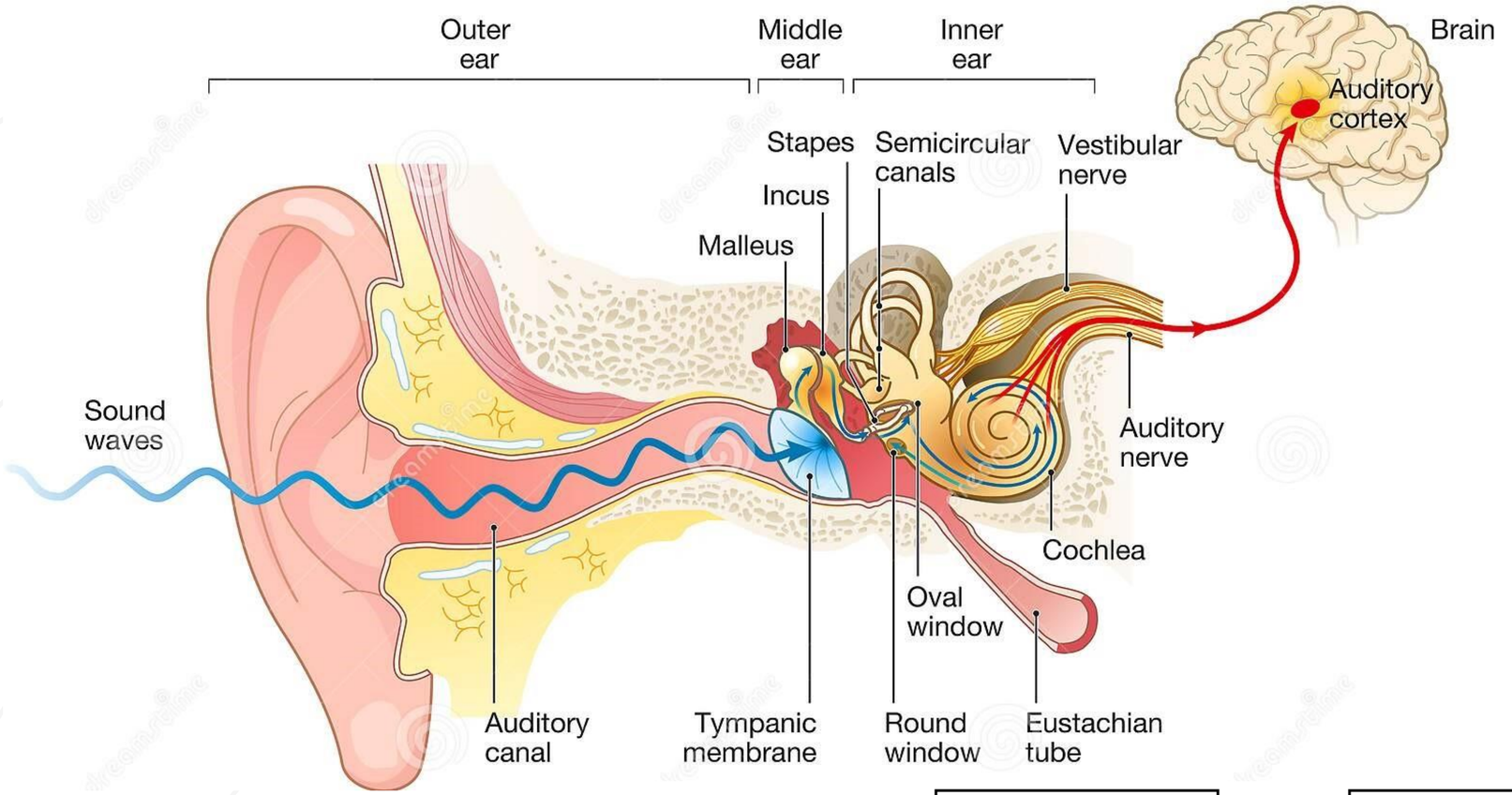
استادیار گروه شنوایی شناسی

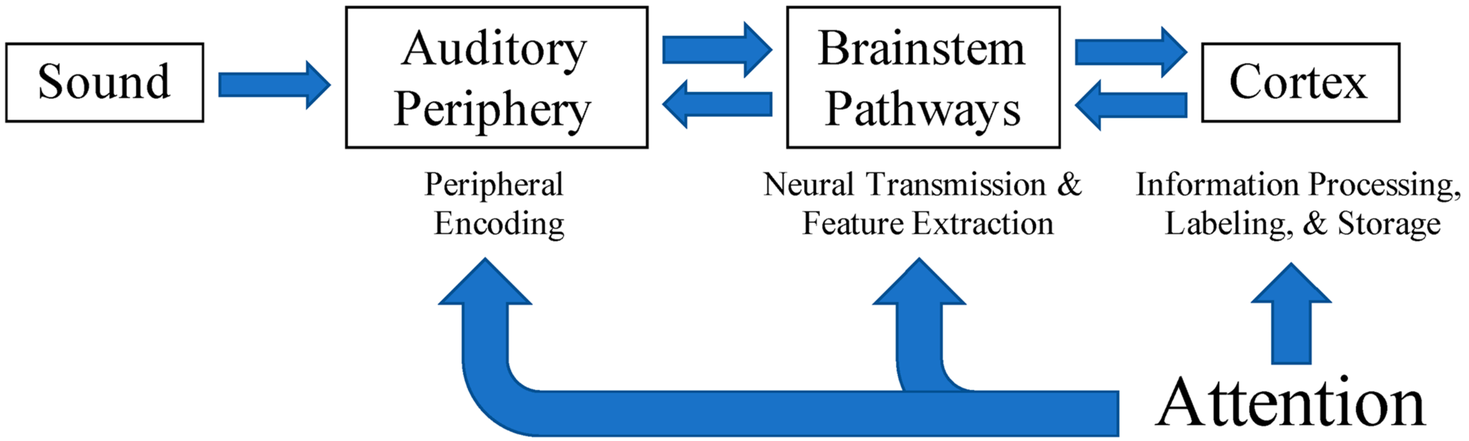
Definitions

- Central Auditory processing (CAP)

- Central Auditory processing disorder (CAPD)

Central Auditory Processing (CAP)

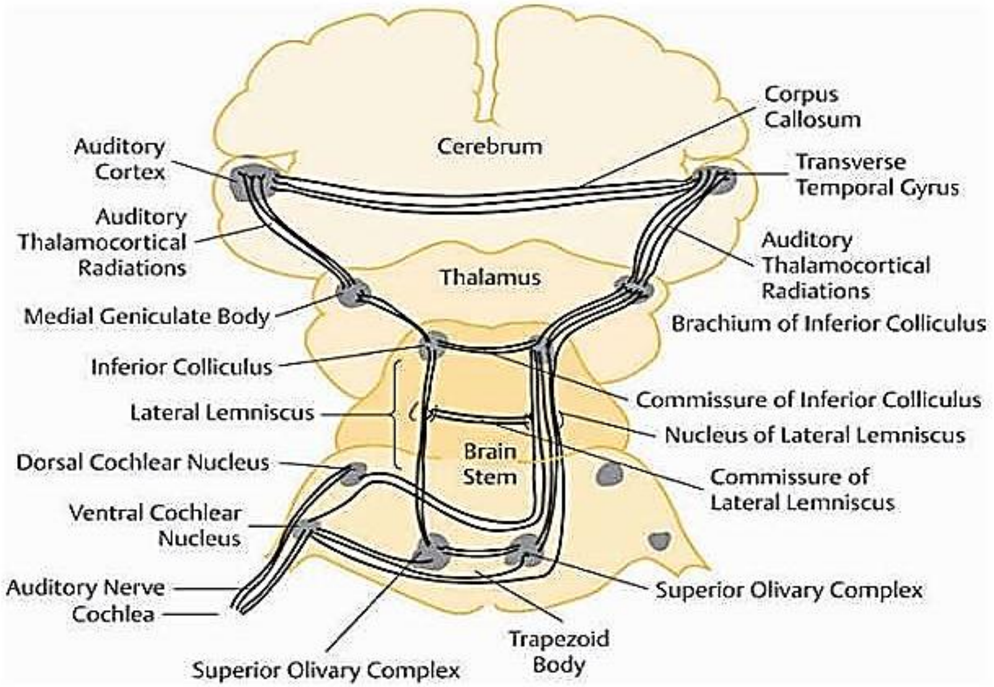

Outer ear
Middle ear
Inner ear
Brain
Auditory cortex
Stapes
Semicircular canals
Vestibular nerve
Incus
Malleus
Sound waves
Auditory nerve
Cochlea
Oval window
Auditory canal
Tympanic membrane
Round window
Eustachian tube


Sound
Auditory Periphery
Brainstem Pathways
Cortex
Peripheral Encoding
Neural Transmission & Feature Extraction
Information Processing, Labeling, & Storage
Attention

Central Auditory processing

The central auditory pathway processes incoming auditory stimuli through an intricate interaction between several structures in the central auditory nervous system.

The complexity of the central auditory nervous system (CANS) is unrivaled by other human sensory systems. Comprised of multiple parallel pathways consisting of many intricately interconnected nuclei, the system is capable of processing information with remarkable speed and efficiency.



Hierarchy of Auditory Processing Skills

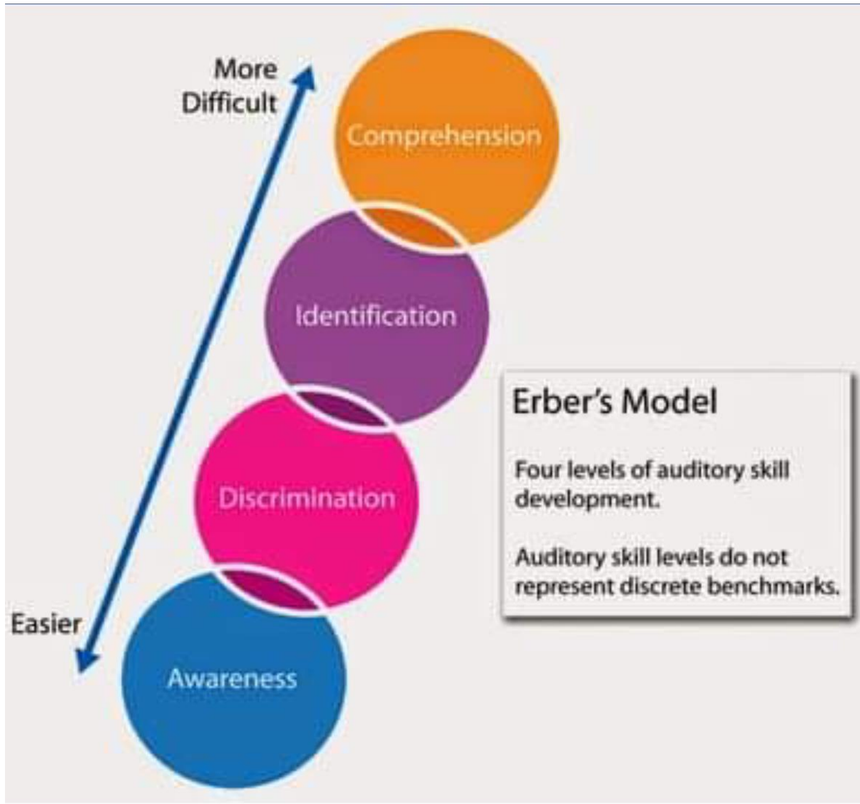
Step 1: Auditory awareness: includes being aware localizing, and attention

Step 2: Auditory discrimination: discriminating environmental sounds, suprasegmentals (non-speech sounds rate, prosody, pitch) and segmental (speech sounds).

Step 3: Auditory Identification: auditory association, auditory feedback, phonological awareness.

Step 4: Auditory Comprehension:

understanding longer conversations, stories, following directions, auditory closure (filling in the missing pieces), auditory memory, linguistic auditory processing (interpret, retain, organize, and manipulate spoken language for the purpose learning and communication)

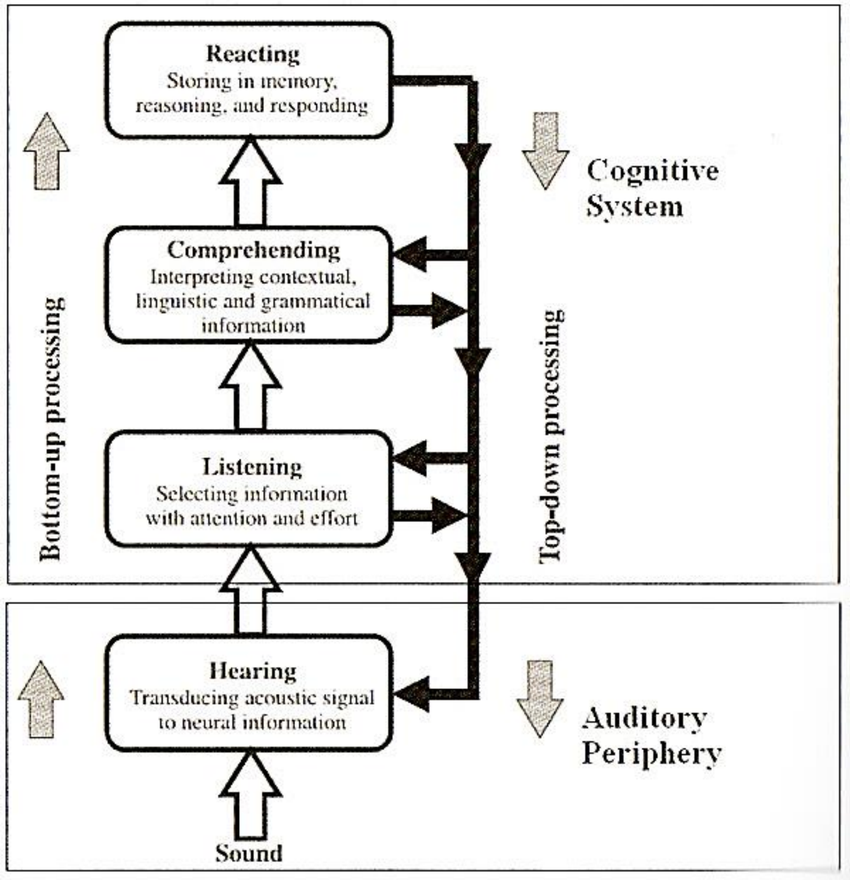


Bottom-up and Top-down Processing

Bottom-up: In order to be able to listen and understand what is being said, a person must detect the speech sound, focus on the speech sound, determine where the speech sound comes from, and separate it from background noise. Hearing and bottom-up auditory processing of the sound alone is not sufficient for interpreting and understanding the auditory stimulus.

Top-down: Various skills, such as guided attention, memory and language skills, that is, the so called top-down cognitive processes, play a role in correctly interpreting and understanding the message.

(Bellis, 2011; Moore, 2012)

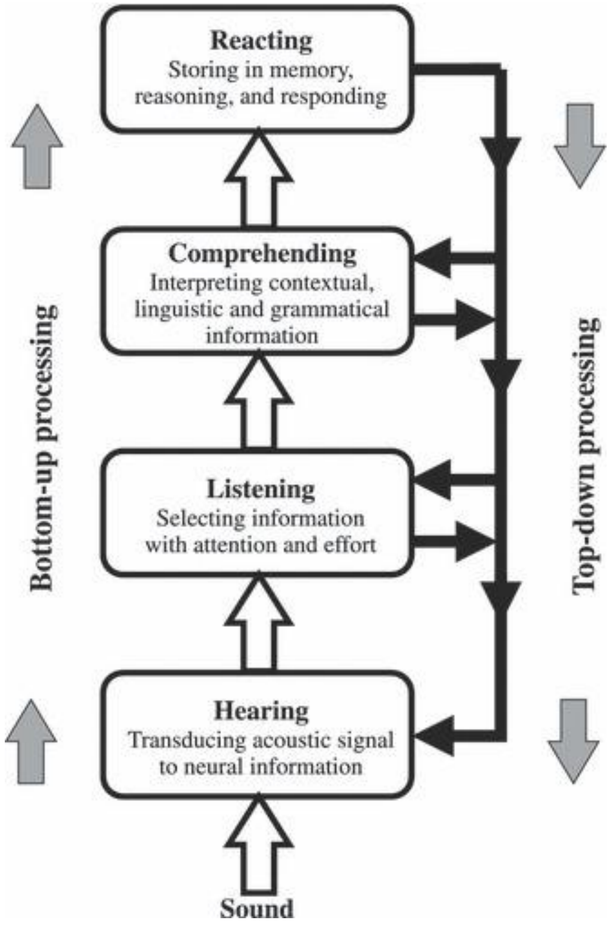


Bottom-up and Top-down Processing

In the ultimate processing of auditory input, both bottom-up factors (sensory encoding) and top-down factors (cognition, language and other higher-order functions) work together (Bellis, 2011). Even the simplest auditory signals are influenced by higher cognitive factors, such as memory, attention and learning.

Thus, in addition to a well-functioning peripheral hearing and well-processing of the auditory signal, listening requires focus to the speech stimuli and the involvement of memory, intelligence and language skills (British Society of Audiology (BSA), 2007).

Therefore, the processing of auditory information comprises both bottom-up and top-down processing.



Central Auditory processing

Hearing vs. listening

Hearing is a sense whereas the listening effort involved with listening comprehension, is a skill that requires attention and intention to access and use the information that is heard.

Comprehension involves the reception and interpretation of the meaning and intent of the information and reacting or communicating involves the effective use and transfer of information.

(Kiessling et al., 2003; Pichora-Fuller & Singh, 2006)

Central Auditory processing

Sound localization and lateralization: ability to know where sound has occurred in space.

Auditory discrimination: ability to distinguish one sound from another

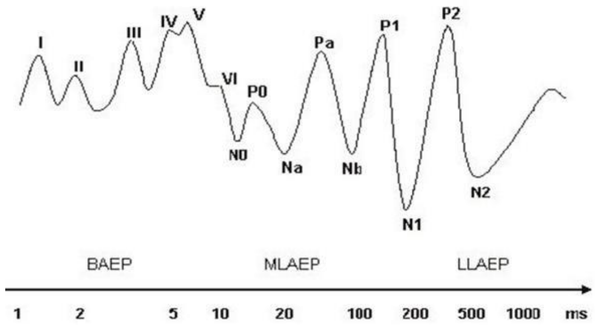
Auditory pattern recognition: ability to determine similarities and differences in patterns of sounds

Temporal aspects: abilities to sequence sounds, integrate a sequence of sounds into meaningful combinations, and perceive sounds as separate when they quickly follow one another

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

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

Development of Auditory Processing Abilities



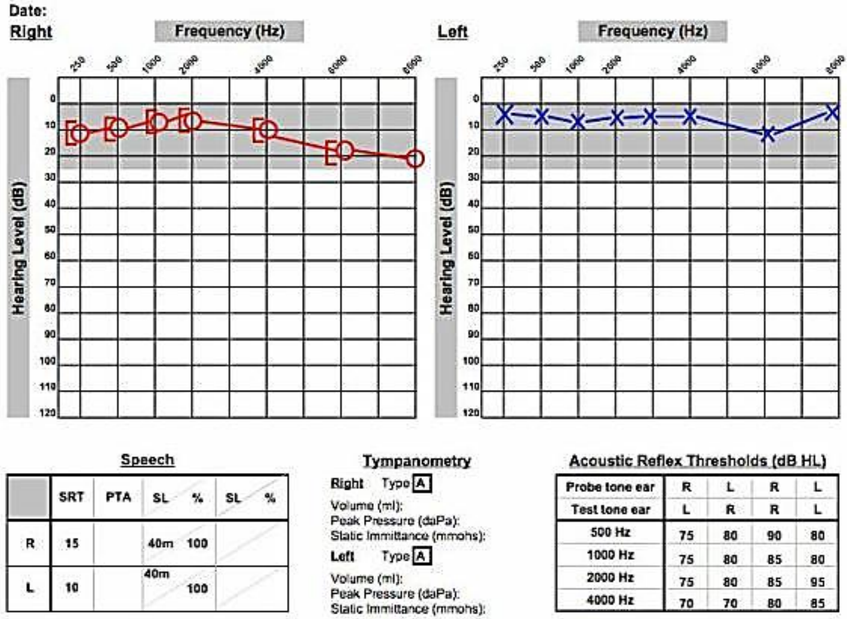
- cochlea is mature at birth
- adult-like listening skills take time to develop with some arising earlier in development than others.
- latency maturation of event-related potentials (ERPs) are developed by two-years-old and middle-latency ERPs by four-years-old (Ponton et al., 1992). Long latencies N1 and P1 were shown to continue maturing until at least the second decade of life (Ponton et al., 2000).

❖ These developmental trends in evoked potentials reflect a protracted period of development in the central auditory system, which may contribute to age-related differences in auditory task performance during development.

Central Auditory Processing Disorder (CAPD)

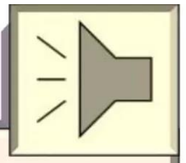
Central Auditory Processing Disorder

- 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.



Central Auditory processing

Auditory Processing vs. Hearing Sensitivity



Auditory processing tasks are designed to measure how well auditory information is processed.	Hearing sensitivity tests are designed to measure how well a person detects sound.

Example

A child may easily detect that the teacher is talking (sensitivity), but may not be able to process the message if the pencil sharpener is being used, classmates are talking, or if there are other distractions outside of the classroom.

(K. D., Au-D, CCC-A
Clinical Audiologist, July 17, 2007)

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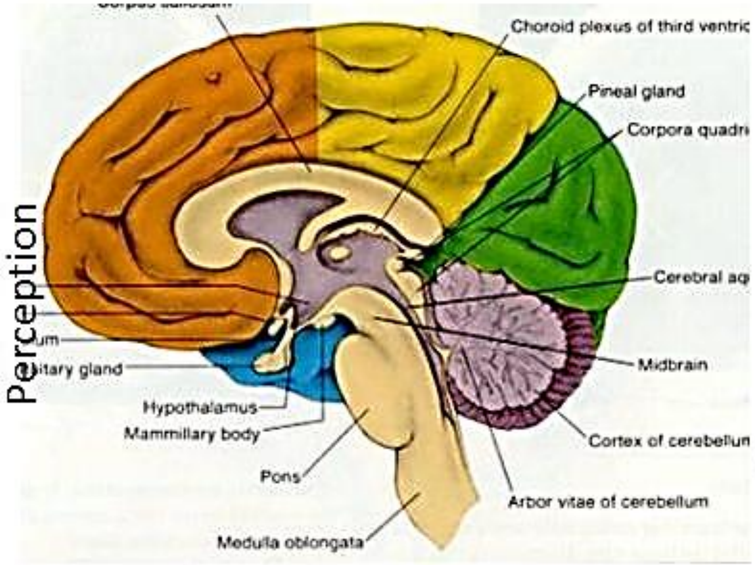
Central Auditory Processing Disorder

- 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.
- 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.

Central auditory pathway



Perception

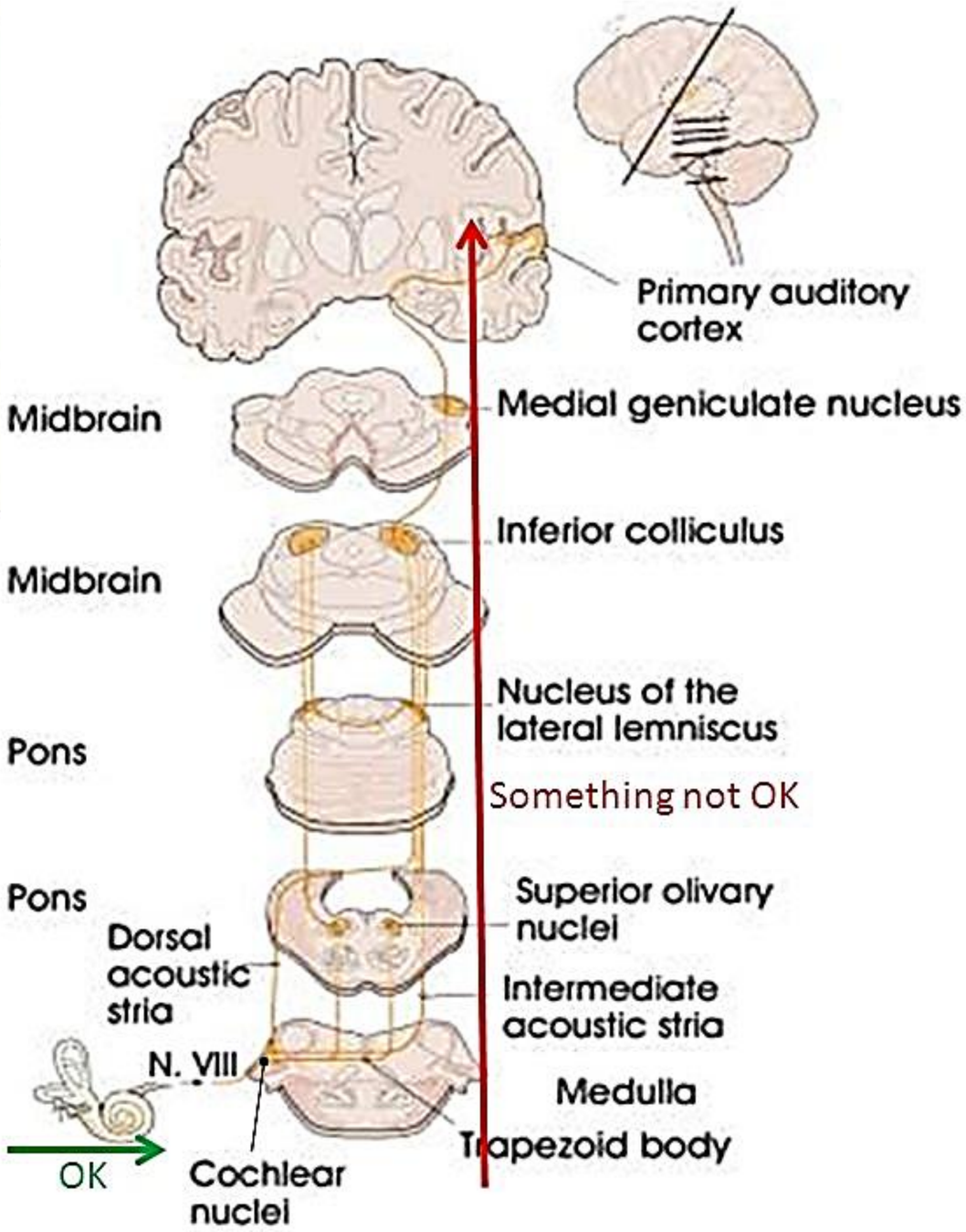
Sorting, comparing and categorizing

IC: Form full spatial map,
Parallel processing paths join,
History dependent

VNLL: Fed by contralateral CN

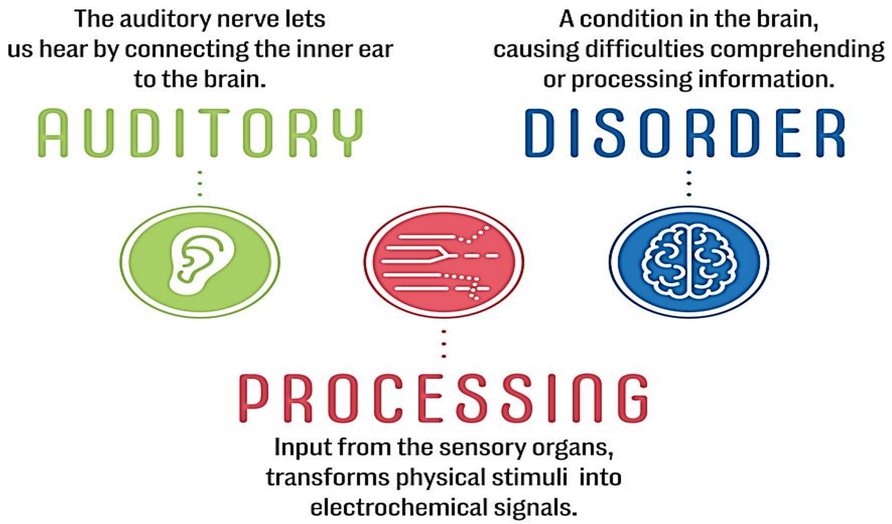
MSO: Detect interaural time
LSO: Detect interaural level

AVCN: Frequency analysis,
PVCN: Timing well preserved
DCN: Inhibitory circuits, pinna cue detection?
Parallel processing
Needs to be fed to develop & maintain



Central Auditory Processing Disorder

The term CAPD encompasses a broad range of deficits that occur when neural processes underlying the analysis of auditory information by the brain are functionally compromised.



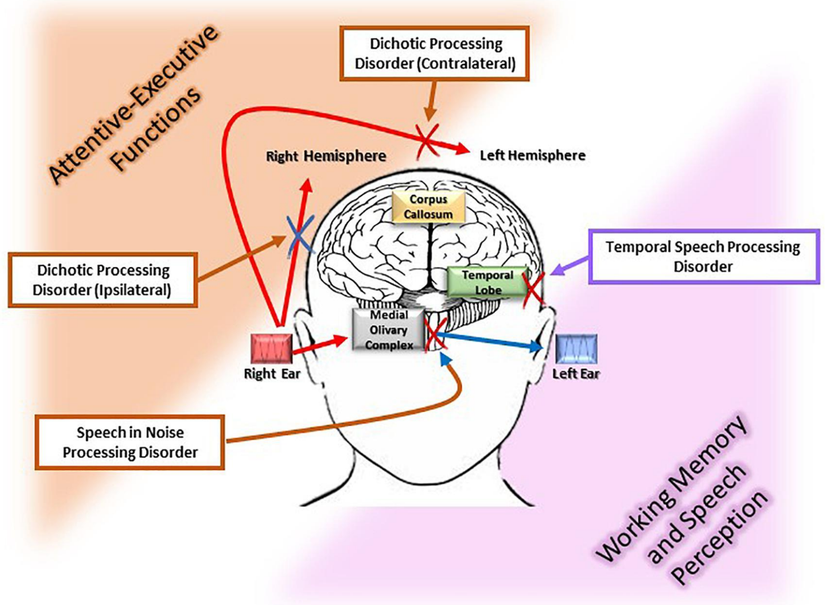
Central Auditory Processing Disorder

- CAPD was first proposed as a diagnostic label in adults with normal hearing sensitivity and acquired lesions in the central auditory system who experienced difficulties with sound perception (Hinchcliffe, 1992).
- The diagnosis was eventually expanded to include children who had normal peripheral hearing and academic difficulties without defined lesions of the auditory system (Dawes & Bishop, 2009).
- Auditory processing disorders take place in the brain, not in the ear.
- A child with CAPD may test “normal” on a hearing assessment but have tremendous difficulty processing sounds in a meaningful way.

Central Auditory Processing Disorder

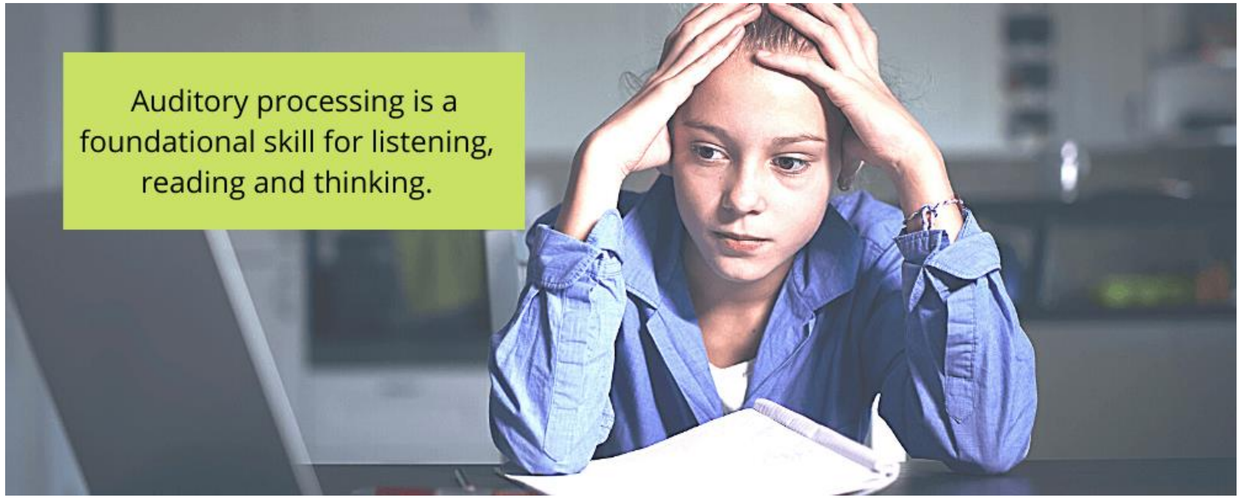
Difficulties in the processing of auditory information in the central nervous system (CNS) as demonstrated by poor performance in one or more of the following skills:

- sound localization and lateralization
- auditory discrimination
- auditory pattern recognition
- temporal aspects of audition
- auditory performance in competing acoustic signals
- auditory performance with degraded acoustic signals



Behavioral characteristics in 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.
- it should be recognized that the presence of a CAPD places the child at risk for developing many of these language and academic problems.



Behavioral characteristics in CAPD

- Appears to have hearing loss despite normal hearing
- Difficulty hearing in noise
- Difficulty following oral instructions
- School performance poorer than expected
- Easily distracted by noise
- Mishearing or misunderstanding
- Frequent requests for repetition
- Short attention span for listening
- Poor reading or spelling abilities
- Poor musical ability
- Disruptive behaviours
- History of multiple ear infections (OSLA, 2017)

Behavioral characteristics in 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 deficit hyperactivity disorder (ADHD)
- specific language impairment (SLI)
- global cognitive deficits
- hearing loss
- behavioral problems
- Learning difficulties (LD)
- 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.

Prevalence of CAPD

- **Children**: **3%–5%** (Chermak & Musiek, 1997; Palfery & Duff, 2007).
  7.3%–96% (Wilson & Arnott, 2013).

- **Male to female ratio of 2:1** (Chermak & Musiek, 1997; Palfery & Duff, 2007).

- **Adults 55 and older**: **23%–76%** (Cooper & Gages, 1991; Golding, Carter, Mitchell, & Hood,2004; Stach, Spretnjak, & Jerger, 1990).

Etiology of CAPD

- Age-related changes in CANS function
- Genetic determinants
- Neurological disorder, disease, or damage
- Brain injury (e.g., head trauma, meningitis)
- Cerebrovascular disorder (e.g., stroke)
- Degenerative diseases (e.g., multiple sclerosis)
- Exposure to neurotoxins (e.g., heavy metals, organic solvents)
- Lesions of the central nervous system (CNS)
- Seizure disorders
- Neuromaturational delay secondary to deafness/auditory deprivation
- Otologic disorder, disease, or injury (e.g., auditory deprivation secondary to recurrent otitis media)
- Prenatal/neonatal factors
- Anoxia/hypoxia
- Cytomegalovirus (CMV)
- Hyperbilirubinemia
- Low birth weight
- Prematurity
- Prenatal drug exposure

Diagnosing CAPD

following requirements for child/adult refer to diagnosing CAPD (Kent, 2002):

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

Diagnosing CAPD

- As myelination and maturation continue in children until age 10-12, sensory representations in the young brain may change in response to altered receptors, sensory environment, and learning (Bamiou, Musiek, & Luxon, 2001).
- From the age of six, the capacity to process information markedly increases and the control of attention and memory improves (Verhulst,2017).
- Central auditory processing assessments may not be appropriate for children with significant developmental delays (i.e., cognitive deficits) or children under the age of 7 years.

Diagnosing CAPD

- While several test norms require a child to be 7 years or older, a growing number of tests are aimed at identifying APD in younger ages where early intervention is likely to be more effective. Listening and communication checklists, and tests of language and cognition may be used to identify younger children “at risk” for auditory difficulties (Moore, Rosen, Bamiou, Campbell, & Sirimanna, 2013).

Assessment of CAPD

Initial Assessment

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

Assessment of CAPD

Initial Assessment

- thorough history
- baseline auditory evaluation which should include:
  - pure tone audiometry
  - immittance (tympanograms and acoustic reflexes)
  - otoacoustic emissions
  - auditory brainstem evoked responses
- This initial assessment should then be followed by a central auditory test battery.

Assessment of CAPD

CAPD test battery

- CAPD can be identified through the use of tests that are directed toward performance of auditory skills and the processing of auditory stimuli.
- There are numerous auditory tests that can use to assess central auditory function. These fall into two major categories:
  - behavioral tests
  - electrophysiologic tests

Assessment of CAPD

CAPD test battery

Behavioral tests are often broken down into four subcategories, including;

1. monaural low-redundancy speech tests
2. dichotic speech tests
3. temporal patterning tests
4. 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.

Assessment of CAPD

CAPD test battery

Electrophysiologic tests are measures the electrical potentials that arise from the central nervous system in response to an auditory stimulus.

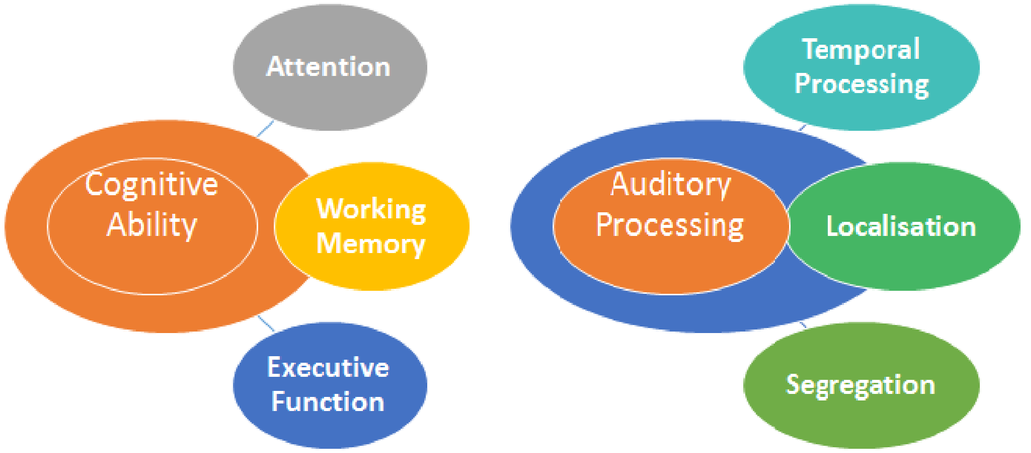
Some electrophysiologic tests are used to evaluate processing lower in the brain (auditory brainstem response audiometry), whereas others assess functioning higher in the brain (middle latency responses, late auditory evoked responses, auditory cognitive or P300 responses).

The results obtained on these tests are compared to age-appropriate norms to determine if any abnormalities exist.

Differential diagnosis

- Johnson et al (1997) discuss that most children with APD have normal intelligence and normal hearing sensitivity; however, it can co-exist with hearing loss or other cognitive or neurological deficits.

- CAPD may lead to or be associated with difficulties in higher order language, learning, and communication functions.



Differential diagnosis

- Each person is affected in a different way and to a different degree, so APD may be called a ‘spectrum’.
- Some children have a greater range of difficulties than others.
- The effect of APD can be worsened by the presence of other conditions, such as dyslexia, language processing difficulties, poor attention and poor short-term memory.

Differential diagnosis of CAPD

- APD must therefore be differentiated from impairment in higher order language, cognition, attention or memory.

- However, APD may coexist with such impairments, and the APD population may be quite heterogeneous, highlighting the need of a multi-disciplinary approach to assessment, differential diagnosis and intervention.

Assessment of CAPD

Interdisciplinary Contributions to Assessment

Various professionals may be involved in providing essential information during the assessment period.

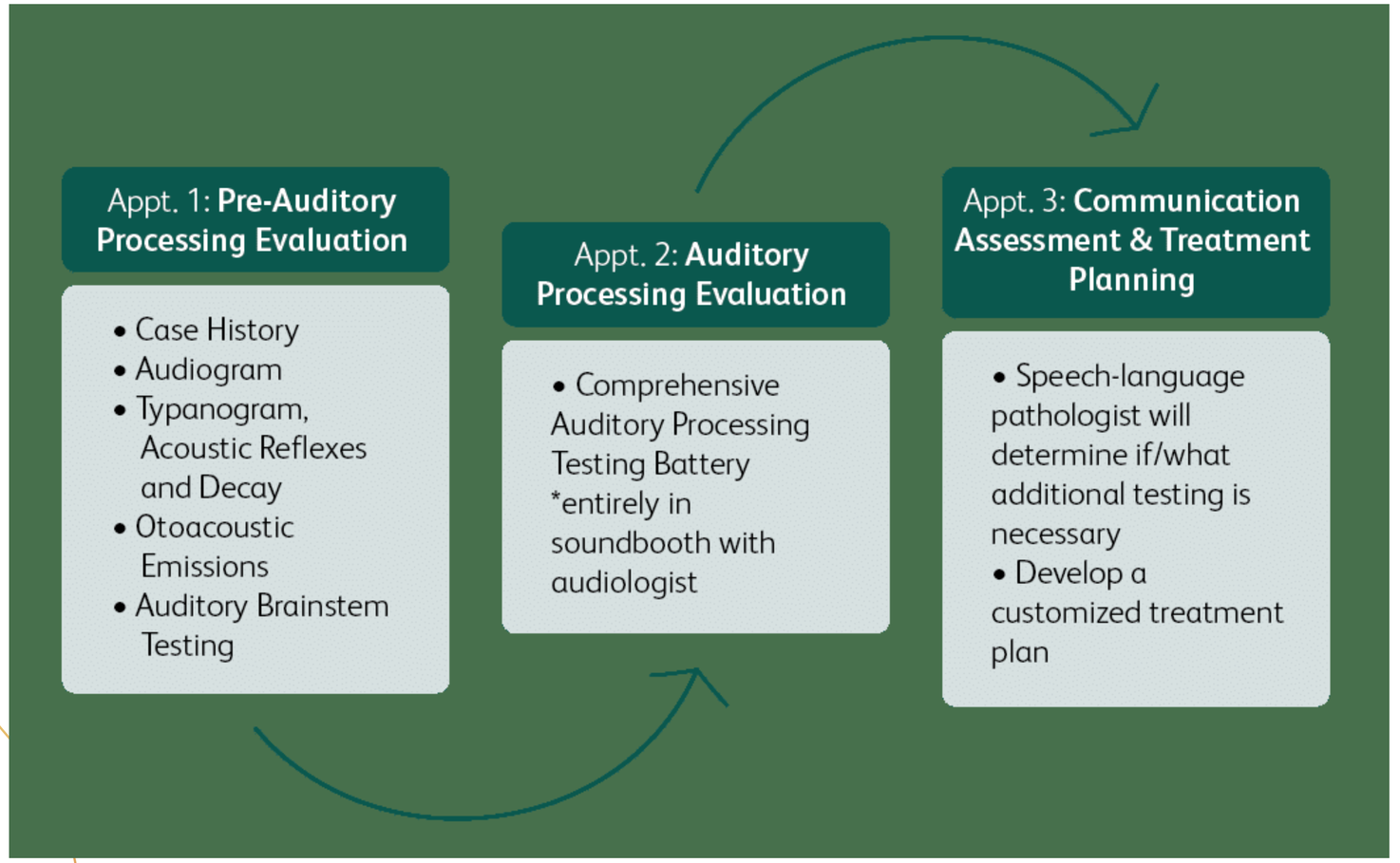
- ✓ **Speech language pathologist**, for evaluation and management of language disorders
- ✓ **Psychologist**, for goals similar to those children with any types of communication or learning disorder, including (Culbertson, 1981):
  - -Determining cognitive ability
  - - Examining perceptual modes of learning (auditory, visual, motor, etc)
  - - Observing child's communication style
  - - Evaluating academic strengths and weaknesses
  - -Examining social/emotional adaptation
- ✓ **Special Education**, for specialization in learning disabilities, especially in reading disorders

Assessment of CAPD

Interdisciplinary Contributions to Assessment

- ✓ **Pediatric Neurologist**, for evaluation of neurologic disorders such as seizure and developmental delay
- ✓ **Otolaryngologist**, for treatment of any middle ear disorder prior to APD assessment
- ✓ **Child Development Center**, for children with multiple psychoeducational, communicative, and/or medical problems
- ✓ **Classroom Teacher**, for implementation of educational modifications
- ✓ **Parents**, for implementation of home management and overseeing that all recommendations are implemented
- ✓ **Child advocate**, for assisting parents in ensuring an appropriate education plan is carried out fully

Assessment of CAPD



Brain plasticity

- The brain has an inherent capacity for plasticity, i.e. the sensory representations may change in response to altered receptors, sensory environment or use and learning.
- For example, it is well established that stimulation or deprivation of stimulation can alter the number of synapses and synaptic density of both the developing and the mature brain. Plasticity is underpinned by neurochemical, physiological as well as structural changes and may also be associated with behavioural change.

Brain plasticity

• In general, there are three types of plasticity:

- Developmental
- Compensatory (after lesions/damage)
- Learning related, which is highly task-specific

❑ Early identification of CAPD and intervention is important as brain plasticity is greater the younger the individual’s age.

Treatment of CAPD

- No pharmacologic agent has been demonstrated as effective specifically for CAPD.
- Interventions for CAPD focuses on improving the quality of the acoustic signal and the listening environment, improving auditory skills, and enhancing utilization of metacognitive and language resources.

Treatment of CAPD

- test-driven or profile-driven Intervention for APD is currently deficit specific, i.e. it is based on identification and treatment of the primary deficits caused by a disease in a ‘bottom-up’ manner.
- In addition, the disease related sequelae, e.g. language, learning, communication are addressed through ‘top-down’ intervention techniques.
- The ‘top-down’ refers to the use of the general knowledge shared by listeners in a communicative situation, which leads to the development of presuppositions and expectations, so that words heard in a certain context are interpreted on the basis of pre-existing knowledge.
- Bottom-up refers to use of acoustic information (decoding) combined to form meaningful auditory signals and then passed on to the higher processes for further analysis: from letters/words to a complete message, i.e. attaching meanings.

Treatment of CAPD

What Management Strategies Can Be Used To Remediate CAPD?

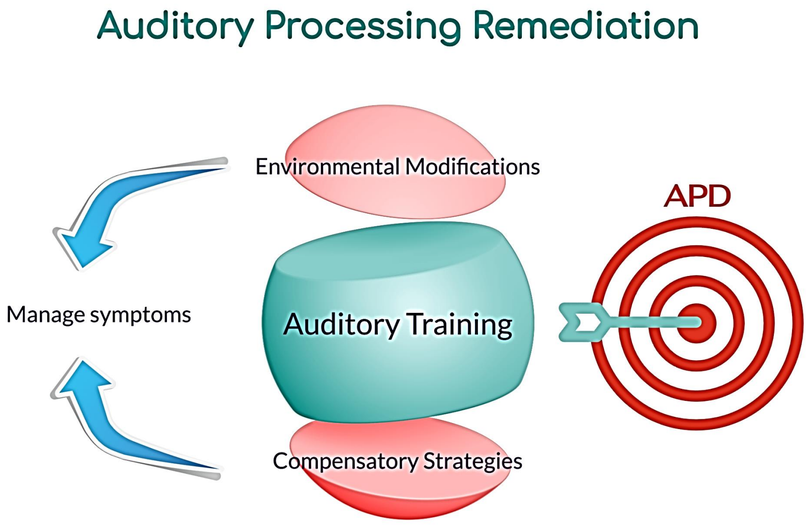
- The exact procedures or approaches used will depend upon a number of factors, including ***the exact nature of the CAPD***, ***the age of the child***, ***the co-existence of other disabilities and/or problems***, and the ***availability of resources***.

Treatment of CAPD

Treatment of APD generally focuses on three primary areas:

1. changing the learning or communication environment
2. recruiting higher-order skills to help compensate for the disorder
3. remediation of the auditory deficit itself

(Teri James Bellis, 2017)



Treatment of CAPD

- ***consideration of the following when selecting interventions for the management of CAPD:***

♣ No one intervention is appropriate for all individuals.

♣ May need a combination of strategies.

♣ intervention must correlate specifically to the presenting observable behaviors and underlying weaknesses that necessitated the original referral.

♣ intervention must correlate specifically to the individual person’s test results.

♣ intervention should be hierarchical in nature, rather than randomly selected “auditory” tasks.

♣ intervention effectiveness should be documented and reassessed at regular intervals.

Thank you!