Auditory Processing Disorder in Children

Indexing Metadata/Description

- **Title/condition:** Auditory Processing Disorder in Children
- **Synonyms:** Central auditory processing disorder (CAPD); King-Kopetzky syndrome (KKS); auditory processing disorder, central; developmental APD
- **Anatomical location/body part affected:** Central auditory system (CAS)
- **Area(s) of specialty:** Child Speech and Language Disorders, Hearing Impairment, Learning Disabilities
- **ICD-9 codes**
  - 315.32 central auditory processing disorder
- **ICD-10 codes**
  - H93.25 central auditory processing disorder

_IDs are provided for the readers’ reference, not for billing purposes_

- **Reimbursement:** Reimbursement for therapy will depend on insurance contract coverage; no specific issues or information regarding reimbursement have been identified
- **Presentation/signs and symptoms:** Auditory processing disorder (APD) (also referred to as central auditory processing disorder [CAPD]) has been described as “a deficit in neural processing of auditory stimuli that is not due to higher order language, cognitive, or related factors.”(1) This processing includes skills such as auditory discrimination, auditory performance with competing acoustic signals (e.g., understanding speech in noisy environments), sound localization and lateralization, auditory pattern recognition, and temporal aspects of audition (e.g., temporal integration, temporal discrimination, temporal ordering, temporal masking).(1) In school, children with APD have been reported to have difficulty following directions, understanding speech in noisy environments, and discriminating between similar sounds. They might also have difficulty with reading and spelling.(1,4,14) There is no single definition of APD, nor is there agreement among researchers, experts, and clinicians as to an appropriate set of diagnostic criteria.(33,48) APD is not the result of a language or learning disorder or hearing impairment; however, decreased performance in auditory skills can interfere with speech perception and attention as well as contribute to language and/or learning difficulties.(1,41) APD is primarily diagnosed in young children, but it can also be present in adults who were not previously diagnosed with developmental APD as children or those who have a diagnosis of “acquired” APD as a result of aging, medical conditions, or head-related traumas.(41)
- **APD is not considered a sensory disorder, as hearing is intact; it is instead classified as a disorder of the central nervous system (CNS) as the impairment is thought to come from the brain’s inability to process the sounds heard(2)**
  - There are at least two hypotheses about the origins of developmental APD; some researchers believe that it results from a sensory processing problem involving the central auditory nervous system, and others believe that it is a top-down problem of cognitive functioning resulting from deficits of the front, parietal, and anterior temporal lobes in the brain(32)
**Associated conditions:** APD in children is associated with difficulties with language and higher order cognitive functions\(^{(1)}\)

- Attention deficit disorder (ADD) or attention deficit hyperactivity disorder (ADHD)\(^{(3,36)}\)

In a study conducted in the United States, researchers compared test performance among children with APD, children with ADHD, and typically developing children on three different tests of central auditory function and their visual analogs.\(^{(16)}\) Participants included three groups of right-handed children: children without language, auditory, or learning disorders\(n = 10;\) mean age, 12.6 years), children with ADHD \(n = 10;\) mean age, 13.2 years), and children with CAPD \(n = 7;\) mean age, 10.9 years) with typical hearing sensitivity and visual acuity. The authors found that deficits in children with CAPD were not isolated to the auditory domain. The children with CAPD as well as the children with ADHD performed worse on all tests in both visual and auditory domains compared with typically developing children.\(^{(16)}\) Intratest comparisons showed that children with CAPD showed different patterns of performance on auditory tests than children with ADHD. Researchers concluded that deficits in children with CAPD are not specific to the auditory modality, a finding consistent with the “nonmodular” view of CAPD. They also concluded differentiation of children with CAPD from children with ADHD can be accomplished by using auditory tests alone as long as intratest comparisons are applied.

Researchers in Australia investigated the link between auditory processing and attention by examining the performance on an auditory and visual sustained attention task of 101 children aged 7 to 12 years with listening difficulties (experimental group) and 18 children without listening difficulties (control group).\(^{(36)}\) They found a low but significant correlation between auditory processing scores and sustained attention scores, suggesting that performance on these tests is affected by the same underlying trait. Nearly 50% of the children in the experimental group had either APD or attention deficit disorder, but not both. The researchers concluded that poor performance on auditory processing tests is not just a consequence of attention deficit disorder, and that the two conditions are separate and largely independent.

- Developmental dyslexia\(^{(3,4,5,47)}\)
- Specific language impairment (SLI)\(^{(3,6,53)}\)
- Learning disability\(^{(1)}\)

### Causes, Pathogenesis, & Risk Factors

**Causes:** The cause of APD is usually unknown and is referred to as “developmental APD”. In a few cases, APD is due to CAS injury caused by traumatic brain injury (TBI), tumors, degenerative disorders, infections, surgical complications, or hypoxia and is referred to as “acquired APD.”\(^{(2)}\) Many children with APD present with difficulties in learning, attention, articulation, spoken language, and written language. It is important to note that APD is correlated with but is not a result of dysfunction in these modalities\(^{(1)}\)

- Some studies have found a genetic component to APD; however, a specific gene responsible for APD has not been identified\(^{(1)}\)

**Pathogenesis:** Although it is likely that APD arises from a neurological difficulty with processing auditory information, it is not currently possible to identify the exact part(s) of the brain responsible for the development of APD\(^{(2)}\)

- Authors of a case study in the United States identified CAPD in an 8-year-old male who had an arachnoid cyst in the left temporal lobe\(^{(8)}\)

**Risk factors**
- There is evidence that long-term otitis media with effusion (OME) can result in reduced auditory processing ability in children due to auditory sensory deprivation\(^{(2,41,50)}\)
- Males are twice as likely to be diagnosed with APD than females\(^{(10)}\)

### Overall Contraindications/Precautions

- The diagnosis of APD requires specific knowledge of topics that are generally not within the scope of the typical training of a speech-language pathologist (SLP) (e.g., cognitive neuroscience, neuropsychology, auditory neuroscience). Only an audiologist with the appropriate training and skills (not an SLP) can make the diagnosis of APD\(^{(1,41)}\)
- The SLP’s role is to collaborate in the assessment and provide assistance in the differential diagnosis of APD from other disorders with similar symptoms (e.g., language disorder due to hearing loss). A multidisciplinary assessment is recommended to guide treatment of the disorder and related deficit\(^{(3)}\)
- A child’s parent(s) and/or caregiver(s) should be involved in all aspects of evaluation, including case history
Examination

History

- **History of present illness/injury:** Document history of APD; additional pertinent historical information can be obtained from evaluation reports by the primary care physician, teacher(s), psychologist, otolaryngologist, neurologist, audiologist, or previous SLP

  - **Mechanism of injury or etiology of illness:** When was the patient diagnosed with APD and by whom?
    - Questions regarding medical history are intended to identify any medical factors that might have affected speech and language development: complications during pregnancy or delivery, head injury, extended hospitalizations, other diagnoses, current health status, and medications. A medical history should also include questions about hearing and ear infections and whether the patient is currently receiving any type of intervention services\(^1\)
    - History of mother’s pregnancy and delivery: Did the child’s mother have any illnesses, accidents, or complications while pregnant with the child? Did the mother take any medications during the pregnancy? What was the length of the pregnancy? What was the duration of the delivery? What was the child’s weight at birth? Were there any complications or unusual circumstances during birth or shortly after? What were the Apgar scores?

- **Communication history:** The answers given by parents/caregivers to questions about communication should determine any evidence of delay of communication milestones (e.g., babbling, first words, two-word combinations), listening behaviors, or history of hearing difficulties (including ear infections). Questions should also establish the caregivers’ level of concern. In addition, a communication history should identify other language(s) spoken at home, daycare or school by the child and caregivers\(^1\)
    - Was the child a quiet or vocal infant? Did the child coo, babble, or imitate sounds as an infant? At what age did these behaviors begin? When did the child say his or her first word? At what age did the child begin to name objects or people? At what age did the child start to put words together (e.g., “Daddy up”)? Were the child’s first words easy or difficult to understand?

- **Course of treatment**
  - **Medications for current illness/injury:** Determine what, if any, medications the physician has prescribed; are they being taken?
  - **Diagnostic tests completed:** Review school and medical records, noting any pertinent diagnostic testing information
  - **Home remedies/alternative therapies:** Document any use of home remedies or alternative therapies (e.g., acupuncture) and whether or not they help
    - Musical auditory training has been used in patients with APD to improve auditory discrimination\(^1\)
  - **Previous therapy:** Document whether patient has had speech, occupational, or physical therapy for this or other conditions and what specific treatments were helpful or not helpful. If a child, has the patient received special education services?
  - **Aggravating/easing factors:** Are there certain times of day that the patient has more difficulty understanding? Are there specific situations in which the patient reports more or less difficulty?
  - **Nature of symptoms:** Describe the nature of the symptoms; in which situations does the patient have difficulty? Specifically inquire about functional deficits in terms of listening ability in a variety of contexts.\(^48\) Ask the parent/caregiver or child about the following symptoms:
    - Difficulty understanding speech in noisy environments or in the presence of competing messages\(^1,41\)
    - Difficulty with sound localization and lateralization\(^1,41\)
    - Frequent misunderstanding or inconsistent understanding of messages\(^1,41\)
    - Frequent requests for repetitions\(^1,41\)
    - Difficulty following complex auditory directions or commands\(^1,41\)
    - Difficulty maintaining attention\(^1,36,41\)
    - Being easily distracted\(^1,36,41\)
    - Difficulty learning songs or nursery rhymes\(^1\)
    - Poor musical or singing skills and/or appreciation of music\(^1,41\)
    - Difficulty learning a foreign language or technical language\(^41\)
    - Difficulty following rapid speech\(^41\)
- Difficulty hearing on the phone
- Difficulty understanding subtle changes in prosody that indicate humor or sarcasm
- Children with APD might also have visual processing deficits; inquire about vision and refer to reports from ophthalmologist or other vision specialist if available
- Difficulty with reading and spelling

- **Sleep disturbance:** Document any difficulty sleeping

- **Psychosocial status:** Briefly assess psychosocial status; if there are concerns regarding psychosocial status, including social anxiety or frustration, refer to psychiatric professional for additional assessment and treatment as needed

- In a study conducted in the United States, researchers compared 19 children (ages 9.5–17.8; mean = 11.9) with APD to 20 gender- and age-matched children with no evidence of APD and found that the children with APD exhibited increased psychosocial difficulties compared to those without.

- Children with APD were more likely to display negative emotional symptoms than those without APD

- Parents of the children with APD reported significantly more social and emotional difficulties for their children versus the parents of the children without APD

- **Hearing:** Does the patient have a peripheral hearing loss? A referral to audiology should be made for a full audiological evaluation for patients with suspected APD who have not yet undergone audiological testing

- **Barriers to learning**
  - Are there any barriers to learning? Yes___ No___
  - If Yes, describe _______________________

- **Medical history**
  - **Previous history of same/similar diagnosis:** Has the patient been diagnosed with a speech or language disorder? Does the patient have a history of any motor or learning disorders? Has the patient been previously diagnosed with APD? If so, by whom? If APD has been previously diagnosed by anyone other than an audiologist, it might not be a valid diagnosis
  - **Comorbid diagnoses:** Inquire about comorbid diagnoses, including ADHD, autism spectrum disorder (ASD), hearing loss, learning disabilities, diabetes, cancer, head injury, psychiatric disorders, and orthopedic disorders
  - **Medications previously prescribed:** Obtain a comprehensive list of medications prescribed and/or being taken (including over-the-counter drugs)
  - **Other symptoms:** Ask the patient and caregiver about other symptoms the patient is experiencing

- **Social/occupational history**
  - **Patient’s goals:** Document what the patient and family/caregiver hope to accomplish with therapy and in general
  - **Academic/school history:** Did the child attend daycare or nursery school? Has the child received early intervention services, including speech, physical, or occupational therapy? Have teachers ever reported any problems with the child’s speech or language or made recommendations about speech therapy? In what grade is the child? What kind of grades or test scores does the child usually achieve? In which subjects does the child perform best? In which subjects does the child perform worst? How does the child feel about school? Does the child receive special classes or instruction at school? Does the child make friends easily? Does the child interact with other children? Adults?
  - **Vocation/avocation and associated repetitive behaviors, if any:** What interests, hobbies, or other activities does the patient have?
  - **Functional limitations/assistance with ADLs/adaptive equipment:** Does the patient have hearing loss that requires hearing aids or cochlear implants? Does the patient require/wear glasses? Does the child require any classroom modifications? Does the patient use a frequency modulation (FM) system? Is the classroom equipped with a whole-class sound system?
  - **Living environment:** To determine the quality and quantity of a child’s opportunities to communicate, obtain information regarding his or her living environment (e.g., number of siblings and level of caregiver involvement) and educational environment
  - With whom does the patient live (e.g., caregivers)?
  - Describe the noise level of the child’s home environment on a scale of 1 to 10 (1 = quiet all of the time, 10 = loud with constant environmental sounds such as the television, video games, or other children)
  - Is the patient exposed to any other languages at home or at school? If so, what percentage of time is the patient’s primary language spoken around/to the patient? What percentage of time is another language spoken around/to the patient?
Relevant tests and measures: (While tests and measures are listed in alphabetical order, sequencing should be appropriate to patient medical condition, functional status, and setting.) Only an audiologist with the appropriate training and skills can make the diagnosis of APD. Assessment procedures include a battery of behavioral tests and electrophysiologic procedures as well as observations and detailed case history. For children suspected of having APD, a comprehensive assessment of speech, language, and literacy abilities is recommended.

• Screening
  – Screening checklists/questionnaires: Screening measures provide preliminary assessment of auditory behaviors related to academic achievement, listening skills, and communication. At present, there are no universally accepted methods of screening for APD, and it is important that screening measures not be used for diagnostic purposes. The American Academy of Audiology reported that screening measures for APD often result in over-referral of individuals and have not been validated.

  - Screening measures: Screening for APD often involves observation of listening behavior and/or performance on tests of auditory function and can be completed by any of the professionals involved in the patient’s multidisciplinary team. Examples of screening measures include:
    - Differential Screening Test for Processing (DSTP): Used to screen children aged 6 to 12 years to determine if the child has difficulty with auditory or language processing and if further assessment is needed
    - SCAN-C: Test for Auditory Processing Disorders in Children-Revised: Used as a screening or diagnostic test. Includes four tests of auditory processing for children aged 5 to 11 years
    - Questionnaires: In 2013, a Special Interest Group of the British Society of Audiology advocated for a validated questionnaire to screen for APD to replace or supplement clinical histories and to use as a functional benchmark against behavioral and electrophysiologic tests of auditory processing; as of this time, no validated questionnaires for screening for APD exist. Deficits investigated with questionnaires include: difficulty understanding spoken language in noisy backgrounds, inconsistent responding, difficulty following complex instructions, difficulty localizing sound, and related reading, spelling, and learning problems

• Arousal, attention, cognition (including memory, problem solving): Refer to reports from school or clinical psychologist, neuropsychologist, teacher, physician, or learning disability specialist for detailed information regarding cognitive strengths and weaknesses as well as information on the child’s ability to engage in social interactions. Although part of the diagnostic criteria for APD states that auditory processing difficulties cannot be explained by a “higher order” cognitive deficit, there is evidence that cognitive abilities influence performance on both auditory processing tasks as well as on real-world, functional tasks. Significant deficits in attention and working memory are frequently reported among children with APD or suspected APD.

  – Researchers in the United Kingdom performed a factor analysis from the results of multimodal tests administered to 110 children (6 and 11 years of age) with listening difficulties despite normal pure-tone audiograms (“suspected APD”) to identify factors that might underlie listening difficulties. Researchers identified two cognitive factors: 1) “working memory and executive attention” and 2) “processing speed and alerting attention” (maintaining a state of alertness). Nonverbal intelligence was not found to be an underlying dimension of APD. They concluded that children with APD need to have a multimodal assessment to rule out comorbid conditions (e.g., language delay) and to ensure adequate treatment for associated conditions

• Speech and language examination (including reading): A full assessment of communication skills with formal and informal measures is appropriate for patients with APD or suspected APD. For detailed information on assessment procedures for speech, language, voice, fluency, and reading disorders, see the series of Clinical Reviews on these topics
  – Speech: Perform tests of articulation skills as well as phonological awareness. For detailed information on assessment of speech sound disorders, see the series of Clinical Reviews on these topics
  – Language: Assess receptive and expressive language skills. For detailed information on assessment of language disorders, see the series of Clinical Reviews on these topics
  – Voice: Document the presence of dysphonia, quality of breath support, and maximum phonation time. For detailed information on voice disorders in children, see Clinical Review...Voice Disorders in Children: an Overview; Topic ID Number: T709181
  – Fluency: Note moments of dysfluency/stuttering behaviors. For detailed information on assessment of fluency disorders, see the series of Clinical Reviews on stuttering and cluttering
• Sensory testing: Document the results of any audiological and visual testing that has been completed and ensure that the patient has had an audiological evaluation prior to a communication evaluation.

• Special tests specific to diagnosis: An audiologist performs an assessment for and makes the diagnosis of APD. In general, tests for central auditory processing abilities are those that “overload” the auditory system. Although most audiologists believe it is necessary to use multiple tests to differentially diagnose APD, there is no “gold standard” test battery or minimal set of tests that is universally agreed upon by audiologists. Because there is no standardized criteria or test battery, the audiologist should qualify the diagnosis of APD with an explicit statement of the criteria used for diagnosis so that all professionals working with the patient have a shared understanding of his or her deficits, needs, and goals. The test battery should include measures that examine a variety of central auditory nervous system processes in a sound-treated room. Measures include both nonverbal (e.g., tones, clicks) and verbal stimuli in the individual’s native language to examine differences in auditory processing. In addition, assessment of children in an educational setting should include organized classroom observations and diagnostic testing for language and academic achievement. The presence of a comorbid speech or language disorder can negatively affect the results of auditory processing tests.

Below are some of the possible tests that will completed by the audiologist during a diagnostic workup for APD.

- **Peripheral hearing tests**: A complete peripheral hearing evaluation including evaluation of hearing thresholds with pure tone and bone conduction audiometry, immittance measures, and otoacoustic emissions should be performed to rule out or establish the coexistence of peripheral hearing loss.

- **Auditory discrimination tests**: To assess an individual’s ability to differentiate acoustic stimuli that differ in frequency, intensity, and/or temporal parameters.

- **Auditory temporal processing and patterning tests**: To assess an individual’s ability to analyze acoustic events over time (e.g., sequencing patterns, forward and backward masking).

- **Dichotic speech tests**: To assess the ability to separate or integrate different auditory stimuli presented to both ears simultaneously.

  - **Dichotic Digits difference Test (DDdT)**: A test commonly used in research studies on APD in which different numbers are presented simultaneously to both ears and the individual is asked to say back all of the numbers heard. Test developers caution interpretation of results in children with known cognitive impairment, especially with respect to memory and attention. This test would likely not be appropriate for a child with a comorbid diagnosis of ADHD for example.

  - **Monaural low-redundancy speech tests (also called low-pass filtered speech tests [LPFSTs])**: To assess the ability to recognize poor quality speech stimuli presented to one ear at a time; the listener hears speech stimuli that has been degraded in some way (e.g., increased speed) and has information missing and is asked to repeat what they hear.

  - **Binaural interaction tests**: To assess binaural processes that are dependent on intensity or time differences of acoustic stimuli (e.g., localization, lateralization); binaural tests assess the ability for both ears to work together.

  - **Electroacoustic measures**: To assess acoustic signals in the ear canal that are generated spontaneously or in response to acoustic stimuli (e.g., OAEs).

  - **Electrophysiologic measures**: Recordings of electrical potentials that are reflective of CNS activity in response to acoustic events (e.g., cortical auditory evoked potentials).

  - **Speech Perception In Noise (SPIN) test**: Language-based test with 10 recorded lists of 50 sentences spoken against a background of babbling noise; half of the sentences are “highly predictable” (e.g., Hot wax dripped from the candle.) and half are “low predictable” (e.g., Paul doesn’t need a candle.). Subject listens to the sentences with the speech babble noise and repeats the final word in each sentence; the recognition score of key words for the highly predictable words represents...
the ability to use semantic cues to understand the sentence and the score for the low predictable words represents the bottom-up auditory processing of the acoustic signal.\textsuperscript{17,45}

In a retrospective study conducted in the United States with 56 children who were referred for CAPD assessment, researchers examined the failure rates of different combinations of tests commonly used in APD assessments. Of the 56 children included in the study, 28 had been diagnosed with CAPD after these tests were administered and the other 28 were considered to have “normal processing” because they passed all or all but one of these tests. The test failed most frequently by the children with CAPD was the frequency pattern test (in which the child is asked to listen to different patterns and determine what they have just heard [e.g., “high-low-high”]) with an 82% failure rate. The combination of an LPFST with a frequency pattern test had the highest failure rate among the children with CAPD at 60%. When either of these two tests was combined with a competing sentences test (i.e., dichotic speech tasks), the failure rate was approximately 50%. Researchers concluded that it is essential to assess a range of auditory abilities with a variety of tests when differentially diagnosing CAPD because no single test or combination of tests will accurately diagnose all children with CAPD.\textsuperscript{46}

**Assessment/Plan of Care**

- **Diagnosis/need for treatment:** The diagnosis of APD is made by an audiologist and requires a level of performance at least two standard deviations below the mean in at least one ear on two or more tests in the battery.\textsuperscript{1,41}

- **Rule out:** Fatigue or lack of motivation can contribute to inconsistent test results and it is important to distinguish APD from these contributing factors. Hearing loss should be ruled out prior to the administration of a APD examination.\textsuperscript{10} In addition, APD must be distinguished from language impairment due to other factors (e.g., hearing loss), ASD, and ADHD.\textsuperscript{4,10}

- **Prognosis:** Prognosis will vary depending on factors such as chronological and developmental age, cognitive abilities (e.g., attention and memory), language age and experience, cultural and social background, motivation, and medications. Treatment is highly individualized and deficit-specific. It is difficult to determine the degree to which improvement in auditory processing abilities will occur. Some children do not have auditory deficits in adulthood while others continue to have residual deficits.\textsuperscript{42}

- **Referral to other disciplines:** Refer to an audiologist. Referral to ophthalmologist, learning disability specialist, and/or social work/psychologist might be appropriate for patients with APD.

- **Other considerations:** In countries with linguistically and culturally diverse populations such as India and South Africa, audiologists are challenged in their ability to accurately assess for and diagnose APD due to the appropriateness of available diagnostic tests. There is a lack of culturally and linguistically appropriate standardized tests for APD in diverse populations.\textsuperscript{54}

- **Treatment summary:** APD has been recently recognized as an “other health impairment” under the Individuals with U.S. Disabilities Education Act (IDEA). A child is legally entitled to receive free and appropriate public education in consideration of this disability and the services/accommodations required.\textsuperscript{43} Therapy for APD focuses on three areas: 1) environmental modifications, 2) addressing high-order skills to help compensate for APD (“top-down”), and 3) remediating the auditory deficit itself (“bottom-up”). It has been recommended that therapy using a “top-down” approach focus on the specific language-based symptoms of a patient with APD, including poor word-finding problems, reading difficulties, or thought organization deficits.\textsuperscript{13,14,15,18} For example, school-aged children with APD can benefit from learning how to analyze expository text and how to use self-monitoring strategies to better understand spoken and written language.\textsuperscript{18} For detailed information on treatment of language and reading disorders, please see the series of Clinical Reviews on these topics.

- There is no one specific treatment method or therapy that improves functional abilities for all individuals with APD. Treatments must be tailored to each individual and there should be frequent reevaluations during the course of treatment to determine the effectiveness of the specific treatment program.\textsuperscript{45}

- Authors of a systematic review of 6 studies (total of 121 participants) examined the effectiveness of interventions designed to improve oral and written language and/or auditory processing abilities in school-age children with APD. The authors concluded: \textsuperscript{19}

  - Only 6 studies met the criteria for inclusion; 4 were exploratory and reported outcomes for auditory measures only; 2 focused on effectiveness of specific therapeutic interventions on spoken or written measures in addition to auditory measures.\textsuperscript{19}

  - There is weak evidence that intensive, short-term auditory interventions (e.g., traditional auditory interventions, Fast For Word, and Earobics) are associated with improvement on auditory measures among school-aged children with APD.\textsuperscript{19}
There is less evidence that these interventions positively affect oral and written language performance of children with APD. Current treatment approaches that specifically address auditory abilities include the following:

- Amplification: Improving the quality of the acoustic signal for the listener by providing personal amplification

  - Authors of a review of the effects of amplification using remote microphone hearing aids for children with APD found that amplification can be therapeutic as well as assistive. Remote microphone hearing aids are hybrid devices that can be worn without a conventional hearing aid or cochlear implant. They can include FM devices as well as devices that use DM (digital modulation) wireless technology. The reviewers reported that these systems enhance hearing and learning, improve psychosocial adjustment, and can lead to lasting improvements in hearing skills. Teacher cooperation and participation is an essential component of this treatment

  - FM systems: Personal FM systems have been used to improve the signal-to-noise ratio in the classroom for children with APD. The teacher is fitted with the microphone and the child wears a receiver that resembles a behind-the-ear hearing aid

    - In a randomized controlled trial conducted in Australia with 55 children (ages 7 to 13 years) with suspected APD, researchers compared four separate treatment interventions to a no-treatment (control) group

      - The children in the study were allocated to one of the following five groups: 1) discrimination (bottom-up) training plus FM; 2) discrimination training; 3) language (top-down) training plus FM; 4) language training; 5) no treatment/control (these subjects were offered treatment at the conclusion of the study)

      - Intervention

        - Took place over the course of 6 weeks

        - Each group was provided with a weekly 1-hour treatment session with an audiologist as well as five 15-minute per day homework assignments

        - Activities in discrimination (bottom-up) group

          - Stimuli for the following presented on a computer using LabVIEW software

          - Gap detection, frequency discrimination (same or different), and intensity training (same or different)

          - Phonological awareness training (Earobics software program)

          - Identifying syllables, segmenting words, and rhyming

          - Reading aloud with emphasis on decoding

        - Activities in language (top-down) group

          - Following and giving instructions, scrambled sentences, rhythm building with musical instruments, circumlocution tasks, building a story with pictures, summarizing stories in their own words, identifying key words in paragraphs, discriminating word meaning differences due to difference in stress patterns, reading aloud with parent/caretaker, and visualization and rehearsal

        - For the intervention + FM system groups, the children wore bilateral Phonak personal FM units during the school day only

        - Of the nine measures of language ability that showed improvement following the intervention, the core language measure improved for both groups receiving FM and non-FM for the discrimination intervention group (only the non-FM language training group improved in this measure)

        - All of the intervention groups showed positive outcomes compared with the control/no treatment group; however, it was unclear from the results which treatment intervention was the best. Researchers recommended further studies with larger sample sizes

    - Hearing aids: Hearing aids with mild gain, noise reduction capability and directional microphone technology have been suggested as an alternative to FM devices; however, substantial research on the use of hearing aids with this population is lacking
- Environmental modifications: Accommodations can include preferential seating (to improve access to the visual and acoustic signal), reduction of competing auditory signals, use of visual aids, use of a whole-classroom amplification system, and modification of speaker’s language (e.g., increased pause time, emphasis on key words, slower rate)\(^{(1,28)}\)

- Improving the listener’s ability to make use of the acoustic signal through improvement of direct skills (e.g., auditory training)\(^{(1)}\)
  - Auditory training – direct skills remediation\(^{(1)}\)
    - Auditory training consists of treatment approaches that target “bottom-up” skills such as discrimination of intensity, frequency, and duration of the acoustic signal; phoneme discrimination; rhyming; syllable discrimination; segmenting words; blending words; dichotic listening; temporal gap discrimination; temporal ordering and sequencing; and pattern recognition. In addition, training exercises also target localization/lateralization and recognition of auditory information presented in background noise.\(^{(1)}\) Several studies that have targeted direct skills have used language and reading measures rather than specific auditory tests as their primary dependent measures. The rationale for the use of these measures is the correlation between APD and language/reading difficulties
    - In a single group (N = 8) study conducted in the United States, researchers examined the effect of auditory training on dichotic listening ability in children aged 7-13 years who demonstrated interaural asymmetry due to poor left ear performance during dichotic listening tasks. The intensity of the signal was lowered in the right ear so that children were able to better discern the signal in the left ear during dichotic training tasks. During 11 sessions of training, the signal in the right ear was gradually raised, increasing the difficulty of the task. Participants demonstrated significant gains in dichotic left ear performance after training.\(^{(23)}\) Previous studies have found that this type of dichotic interaural intensity difference training (DIID) was beneficial for children with auditory processing disorder\(^{(24)}\) and an adult with a head injury\(^{(25)}\)
  - Computer-based auditory training (CBAT)
    - Authors of a literature review analyzed 16 studies that utilized CBAT in children with a diagnosis of APD and/or reading disorder\(^{(26)}\)
      - Thirteen studies used a program called Fast ForWord-Language\(^{(26)}\), an Internet- and CD-ROM–based program
      - It is claimed that FFW-L will increase an individual’s ability to perceive fast-changing acoustic input by providing interactive and adaptive exercises using acoustically processed speech and speech sounds\(^{(26,27)}\)
      - Three studies that utilized Earobics, a series of computer programs that targets the following skills: following directions, auditory memory, sound recognition, blending and segmenting sounds, discrimination of vowel and consonant sounds, recognition of word endings and beginnings\(^{(26,27)}\)
      - Researchers concluded that there is some evidence that these programs can improve auditory processing and phonological awareness; however, they found little evidence that the programs were effective in improving language and reading skills.\(^{(26)}\) They noted that paired audiovisual stimuli yielded promising results for improving reading skills
      - Also, there is some evidence to suggest that these programs can be beneficial for children with APD; however, much more research is needed to determine the full effect on patients with APD\(^{(26)}\)
    - In a prospective randomized controlled trial conducted in the United Kingdom with 39 children (ages 7 to 11) with APD, researchers found that participation in a 3-month intervention with a CBAT resulted in significant improvements in auditory processing abilities. The intervention in this trial was a 5-day per week, home-based CBAT with listening exercises for speech in noise. Both control group (n = 19) and intervention group (n = 20) continued to receive typical APD school and home-based treatments (e.g., environmental modifications) during the 3-month intervention period. Immediately after the intervention, the intervention group had significantly improved scores on a speech perception in noise test and the control group did not. Three months after the conclusion of the trial, the intervention group was re-tested and the gains in speech perception with competing noise were maintained\(^{(44)}\)

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<tr>
<td><strong>Difficulty understanding information in noisy environments</strong></td>
<td><strong>Enhance listening, attention, comprehension in noisy environments (e.g., classroom)</strong></td>
<td><strong>Amplification</strong></td>
<td>Improved hearing and learning in noisy environments as well as lasting changes in hearing skills[^35]</td>
<td><strong>Amplification may be used in other noisy environments outside of school[^35]</strong></td>
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<td>Remote microphone hearing aids for children in the classroom can help the child overcome acoustic barriers such as background noise, reverberation, and distance from the teacher[^35]</td>
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<tr>
<td><strong>Difficulty understanding information in various environments</strong></td>
<td><strong>Enhance the listening environment to improve access to information in the classroom, workplace, or home</strong></td>
<td><strong>Environmental modifications</strong></td>
<td>Progression based on individual patient goals and needs and response to therapeutic activities</td>
<td><strong>Modifications can be used in the home. Counseling of family members is considered critical in implementing environmental modifications at home</strong></td>
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<td>Accommodations can include preferential seating (to improve access to the visual and acoustic signal), reduction of competing auditory signal, use of visual aids, use of whole-classroom amplification system, and modification of speaker’s language (e.g., increased pause time, emphasis on key words, slower rate[^1,28])</td>
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| Difficulties in expressive/receptive language and reading | Improve the individual’s ability to communicate more effectively in everyday environments (e.g., school, work)\(^1\) | **Auditory training – direct skills remediation**

Auditory training consists of treatment approaches that target “bottom-up” skills such as discrimination of intensity, frequency, and duration of the acoustic signal, phoneme discrimination, dichotic listening, temporal gap discrimination, temporal ordering and sequencing, and pattern recognition. In addition, training exercises also target localization/lateralization and recognition of auditory information presented in background noise.\(^1\)

Several studies (see Treatment summary, above) that have targeted direct skills have used language and reading measures rather than specific auditory tests as their primary dependent measures. The rationale for the use of these measures is the correlation between APD and language/reading difficulties; however, research evidence documenting that these tasks improve language and reading is lacking.\(^{19}\) | Progression based on individual patient needs and response to therapeutic activities | Continue prescribed exercises at home as indicated |

| Difficulties in expressive/receptive language and reading | Directly address deficits in language and reading ability | **Language and reading intervention**

For detailed information on language and reading intervention, see the series of Clinical Reviews on these topics | Progression based on individual patient needs and response to therapeutic activities | Continue prescribed strategies at home as indicated |
**Desired Outcomes/Outcome Measures**

- Improved auditory discrimination
  - Measurements of auditory performance (e.g., pattern tests, dichotic digits, speech recognition tests)\(^{(1)}\)
  - SPIN test
- Improved language abilities
  - Specific assessments of language or metalanguage\(^{(1)}\)
  - Global assessments of listening and communication\(^{(1)}\)
- Increased phonemic awareness
- Improved reading ability
- Improved quality of life

**Maintenance or Prevention**

Early, accurate diagnosis and early intervention can improve long-term outcomes for children with APD.\(^{(29)}\) Any child with suspected APD should be referred to an audiologist

**Patient Education**


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### Coding Matrix

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<th>Reference Type</th>
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<th>R</th>
<th>C</th>
<th>G</th>
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<td>Published meta-analysis</td>
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<td>QI</td>
<td>PGR</td>
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<tr>
<td>Published systematic or integrative literature review</td>
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<td>Published research (randomized controlled trial)</td>
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<tr>
<td>Published research (not randomized controlled trial)</td>
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<td>Case histories, case studies</td>
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<td>Published guidelines</td>
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<td>Practice exemplars, stories, opinions</td>
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<td>Unpublished research, reviews, poster presentations or other such materials</td>
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<td>Conference proceedings, abstracts, presentation</td>
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### References


