(Central) auditory processing disorders: Overview and amplification issues

By Douglas L. Beck and Teri James Bellis

Central auditory processing disorder (CAPD) is defined as "a deficit in the perceptual processing of auditory stimuli and the neurobiological activity underlying that processing."[1] (C)APD likely arises from abnormal neural representation of speech and non-speech sounds in the central auditory nervous system (CANS). This type of disorder may occur in pediatric and adult patients with normal hearing or may co-exist with, or occur secondary to, peripheral hearing loss.

(C)APD may lead to difficulties in various auditory functions that are important for listening and comprehending spoken language, especially in noisy backgrounds. As such, (C)APD deficits may include difficulty with lateralization, localization, auditory discrimination, auditory pattern recognition, other temporal processing deficits, and more.[1]

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Generally, patients with (C)APD are children presenting with listening problems in the classroom and difficulty in academic pursuits. (C)APD may be associated with learning disorders, especially in the areas of reading, spelling, articulation problems, difficulty following directions, and significant challenges regarding communicating and comprehending.[2,3] (C)APD is more common in boys than girls and even more common in children with a significant history of otitis media.[4] Roughly 7% of children are estimated to have (C)APD.[5]

(C)APD must be diagnosed using tools previously shown to have validity for identification of CANS dysfunction.[1] Unfortunately, diagnostic tools currently available do not allow evaluation of (C)APD in children below 7 years of age, secondary to variability in the development of the brain and central nervous system.

Other common disorders can mimic or co-exist with (C)APD. For example, attention deficit hyperactivity disorder (ADHD), autism, language processing disorder, and various cognitive disorders may lead to listening behaviors similar to those of (C)APD. However, the diagnosis of (C)APD is not appropriate when listening difficulties arise from, or are due to, higher-order, pan-sensory or global disorders, unless concomitant dysfunction in the CANS can be demonstrated.[1]

Therefore, with respect to pediatric applications, a multidisciplinary team-based approach involving the audiologist, parent(s), physician, speech-language pathologist, teacher, school psychologist, and possibly others is critical to ensure that all behaviors, actions, and observations have been addressed and considered, prior to arriving at a differential diagnosis.[1-3]

DIAGNOSTIC ISSUES

It is no simple matter to diagnose (C)APD. Test results can be ambiguous, unique, or difficult to interpret. Because (C)APD often cannot be seen on neuron-imaging tests (for example, an MRI or CT), some professionals have argued that the disorder may not exist as an exclusive entity.

However, recent scientific findings have clearly demonstrated the reality of (C)APD, and its existence can no longer be doubted.[1,6,7] (see Bellis[2,3] and Chermak and Musiek[8,9] for reviews). Indeed, patients with (C)APD exhibit extreme difficulty with audition, which may negatively impact their educational, social, and work situations. These deficits cannot be accounted for by hearing loss or other factors. Central auditory testing in these individuals reveals patterns of findings known to be associated with dysfunction in the CANS. Further, neural representation of sound within the brains of people with (C)APD often is different from that of the normal population.

Jerger and Musiek noted that the primary challenge in (C)APD is arriving at an accurate diagnosis.[7] Two other important (C)APD challenges are: (1) Children can fail central auditory tests for non-auditory reasons, and (2) there is a tendency to diagnose (C)APD based on screening tests, rather than diagnostic tests, which is inappropriate.

Bellis[3] and Katz et al.[10] noted that diagnostic tests of (C)APD must have age-appropriate norms. Katz et al. suggested that tests of (C)APD be validated using children suspected of the disorder.[10] However, Jerger and Musiek emphasized that, although sensitivity and specificity are critical attributes of any diagnostic test, children suspected of (C)APD may not have the disorder at all.[11] Thus, as (C)APD represents dysfunction in the CANS, tests used to diagnose (C)APD must be validated using cases of known CANS dysfunction.[1,3,8]

TREATMENT ISSUES

Jerger and Musiek noted that the efficacy of a given treatment is best determined by a randomized, double-blind trial.[11] Unfortunately, we do not have such data related to the majority of treatment paradigms for (C)APD. Nonetheless, neuroplasticity research provides a solid scientific foundation upon which to base several general principles of (C)APD intervention.

First, there is no "one size fits all" approach to (C)APD treatment. Rather, treatment should be individualized and deficit-specific. Second, intervention for (C)APD should focus on bottom-up (e.g., auditory training, acoustic signal enhancement) and top-down (e.g., central resources training) activities. Finally, intervention for (C)APD should include three primary components[1] (see Bellis[2,3] and Chermak and Musiek[9] for reviews):

(1) Changing the learning/communication environment to improve access to auditory signals. For some individuals with (C)APD, FM systems, amplification, or other hearing assistive technology may be appropriate. In addition, methods of communicating and teaching can affect signal acquisition in a top-down manner. Thus, instructional modifications often are indicated.
(2) Central resources training to buttress higher-order meta-linguistic, metacognitive, and related skills to compensate for the auditory deficit.
(3) Remediation of the specific auditory deficit through targeted auditory training activities, which may include computer-based programs or other specific stimulation activities.

(C)APD and FM technology

As noted above, improving access to the auditory signal is a key component of (C)APD intervention for many individuals. One of the most effective ways to accomplish improved access is by using an FM system. Beck, Doty-Tamasula, and Sexton noted three distinct advantages provided via FM.[12] FM reduces the deleterious effects of distance, reverberation, and noise. As a result, a cleaner auditory signal with an improved signal-to-noise ratio (SNR) is presented to the listener, making the listening task easier, less stressful, and more enjoyable.

Smaldino and Crandell suggested that for children who have difficulty attending to the teacher's voice in a noisy classroom, technology designed to maximize the SNR may be required.[13] The authors reported that normal-hearing children require a 10-dB better SNR than do adults to perform at the same level. Further, children with hearing loss often require an additional 15-dB SNR to achieve the same results.

Weihing reported that, regardless of age, most people, even those with extremely poor unaided auditory performance, experienced vast improvements (nearly 100%) in auditory performance through use of an FM system alone.[14] Although Weihing focused on individuals with hearing loss rather than those with (C)APD, the report underscored the importance of signal-to-noise ratio as a major component of listening success.

Although a great many advantages are associated with FM, it and other hearing technologies may not be indicated or recommended for everyone diagnosed with

(C)APD. Rather, the decision to employ such technologies should be highly individualized with consideration for people (patient, teacher, and others), the overall classroom or other communicative acoustic environment[15] (see Crandell and Smaldino for review[16]), and the time and place of the communicative event. Importantly, efficacy of treatment, peripheral hearing, and hearing instrument use must be monitored carefully with regular evaluation and re-evaluation.

(C)APD and hearing aids

Regarding fitting hearing aids on children with (C)APD, one must consider the needs of hearing-impaired children as well as those of normal-hearing children. (C)APD can co-exist with, or occur secondary to, peripheral hearing loss. The American Academy of Audiology suggested that special consideration be given to hearing aid amplification when fitting children with unilateral, mild, minimal, or profound hearing loss and auditory neuropathy.[17] In particular, based on the probability that children with mild/minimal hearing loss will experience academic difficulties, these children "should be considered candidates for amplification and/or personal FM…or sound field use in school."[17]

Indeed, if a child has normal peripheral hearing sensitivity and (C)APD (or auditory neuropathy, or unilateral hearing impairment), hearing aid amplification with appropriate monitoring of hearing sensitivity and a cautious approach to the hearing aid output may be warranted.[17]

Regarding older adults, it should be recognized that (C)APD may affect up to 75% of the elderly population and can compromise success with hearing aids, particularly binaurally fitted hearing aids[18] (see Bellis 2006 for a review[19]). Of course, hearing aid fittings impact more than hearing; they impact the central nervous system.

Pichora-Fuller and Singh suggested that rehabilitative audiology for aged patients should acknowledge and perhaps maximize "compensatory brain reorganization" as patients acclimatize to modern hearing aid fittings.[20] Neuroplasticity facilitates connections between auditory and cognitive processes and allows hearing aid users to form new "mappings" between stored knowledge and acoustic information.

Cognition and audition appear related in at least two ways. First, cognitive performance appears to worsen as hearing loss and auditory perceptions decrease. Second, cognitive ability appears to impact hearing aid performance.[20] Pichora-Fuller and Singh suggested working memory capacity as a likely bridge between cognition and audition, with due consideration to hearing aid fittings as the conduit that fosters these changes.[20]

Additionally, directed auditory training focused on specific central auditory skills, including inter-hemispheric transfer of auditory information and other focused auditory training activities, may assist in maximizing success with binaural amplification in elderly patients.[18,21]

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SUMMARY

(C)APD is a disorder of perceptual processing of auditory signals in the CANS. It impacts children and adults and can co-exist with hearing loss and other disorders. Intervention for (C)APD is highly dependent on accurate diagnosis and should focus on improving the acoustic and communicative environment, strengthening central resources to compensate for the disorder, and directly stimulating the CANS via auditory training.

One of the common primary treatment goals for children and adults diagnosed with (C)APD is the improvement of the signal-to-noise ratio. An improved SNR can be accomplished via FM systems and also through modern, non-occluding, noise-reduction, directional hearing aids.

Hearing assistive technology, in addition to targeted auditory training, other communicative environmental modifications, and compensatory strategies, can vastly improve day-to-day functioning of individuals with (C)APD.

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