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Original Article

Practical guidelines to minimise language and cognitive confounds in the diagnosis of CAPD: a brief tutorial

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Abstract

Objective: To provide audiologists with strategies to minimise confounding cognitive and language processing variables and accurately diagnose central auditory processing disorder (CAPD). *Design:* Tutorial. *Study sample*: None. *Results*: Strategies are reviewed to minimise confounding cognitive and language processing variables and accurately diagnose CAPD. *Conclusions*: Differential diagnosis is exceedingly important and can be quite challenging. Distinguishing between two or more conditions presenting with similar symptoms or attributes requires multidisciplinary, comprehensive assessment. To ensure appropriate interventions, the audiologist is a member of the multidisciplinary team responsible for determining whether there is an auditory component to other presenting deficits or whether one condition is responsible for the symptoms seen in another. Choice of tests should be guided both by the symptoms of the affected individual, as established in an in-depth interview and case history, the individual's age and primary language, and by the specific deficits reported to be associated with specific clinical presentations. Knowing which tests are available, their strengths and limitations, the processes assessed, task and response requirements, and the areas of the central auditory nervous system (CANS) to which each test is most sensitive provides the audiologist with critical information to assist in the differential diagnostic process.

Key Words: Central auditory processing disorder, confounds, differential diagnosis, central auditory nervous system

Central auditory processing disorder (CAPD) is a disorder of the central auditory nervous system (CANS) (i.e. beyond the level of the auditory nerve), which presents as deficits in the perceptual processing of auditory stimuli and in the underlying neurobiological activity that gives rise to the electrophysiological auditory potentials. The predominant deficits characterising CAPD manifest in the auditory modality (AAA, 2010). Functional deficits associated with CAPD include: difficulty understanding spoken language in competing message or noise backgrounds, in reverberant acoustic environments, or when rapidly presented; difficulty localising the source of an auditory signal; misunderstanding messages; responding inconsistently or inappropriately; frequently requesting repetitions; difficulty with subtle intonation and prosodic cues; difficulty with similar sounding words; difficulty following complex auditory directions/commands; difficulty ''hearing'' on the phone; difficulty learning songs, nursery rhymes; poor musical and singing skills and/or appreciation of music; difficulty learning foreign language or novel speech materials, especially technical language; listening difficulties; and academic difficulties (e.g. reading, spelling and/or learning problems; Musiek & Chermak, 2014). Clearly, many of these behavioural deficits also are seen in individuals diagnosed with other disorders, including peripheral hearing loss, language disorders and cognitive disorders. However, these functional deficits observed in individuals with CAPD derive from bottom-up (i.e. sensory, data-driven) processing deficits, although they bidirectionally interact with language and cognitive deficits. Auditory discrimination difficulties and difficulties processing rapid spectrotemporal acoustic changes may lead to poor speech sound representation, which has been linked to poor reading and spelling skills, as well as to difficulties in phonological awareness skills (Kraus et al, 1996; Bellis, 2002; Power et al, 2013; Tierney & Kraus, 2013). Poor speech perception gives rise to ''fuzzy'' or ''underspecified'' lexical and phonological representations and to weak verbal short term memory (Studdert-Kennedy, 2002).

CAPD frequently is diagnosed in children and adults presenting other comorbid or primary diagnoses, including peripheral hearing

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Abbreviations

6-CIT	Cognitive Impairment Test
ADHD	attention deficit hyperactivity disorder
CAPD	central auditory processing disorder
CANS	central auditory nervous system
DPT	Duration Pattern Test
DR	directed report
FPT	Frequency Pattern Test
FR	free report
LiSN-S	Listening in Spatialised Noise-Sentences Test
MLR	Middle Latency Response
MMSE	Mini-Mental State Exam
MoCA	Montreal Cognitive Assessment

loss (Khavarghazalani et al, 2016), confirmed CANS deficits (e.g. multiple sclerosis – Musiek et al, 2005; Musiek & Weihing, 2011), traumatic brain injury (Gallun et al, 2012; Saunders et al, 2015), cerebrovascular accidents (e.g. Koohi et al, 2016), psychiatric conditions (e.g. schizophrenia – Iliadou & Iakovides, 2003; Iliadou et al, 2013; Ramage et al, 2015), cognitive deficits (e.g. Alzheimer's disease – Griffiths et al, 2012; Quaranta et al, 2015) and developmental disorders (e.g. attention deficit hyperactivity disorder [ADHD], dyslexia, language disorder). Sharma et al (2009) reported comorbidity of CAPD, language impairment, and reading disorders in 47% of a sample of school-age children (7–12 years) diagnosed with CAPD. Iliadou et al (2009) reported CAPD co-morbid with developmental dyslexia in 25% of cases. Atypical N1-P2 (i.e. flatter slopes) to tones, vowels, and CVs was seen in 38% of 6–12 year-old children with specific language impairment or specific reading disability (McArthur et al, 2009). Subcortical differentiation of stop consonants (speech auditory brainstem response) correlated with phonological awareness, reading and speech-in-noise perception in children 8–13 years (Banai et al, 2009). It should be noted that the fundamental relationships among auditory processing, language, and cognitive measures may differ in typical compared to non-typically developing populations (e.g. Grube et al, 2014), and as a function of age as well (e.g. Besser et al, 2015).

The co-morbidity of CAPD with neurodevelopmental disorders, as well as with acquired central nervous system conditions (e.g. traumatic brain injury, cerebral vascular accidents, etc.) can be most easily explained on the basis of brain organisation and function. Our current understanding suggests that perceptual, language and cognitive functions rely on extensive networks of shared neurophysiologic and vascular substrate. Networks are nonmodular, temporally coupled, interfacing, polymodal or multisensory, overlapping, interconnected, and synchronised (Willott, 1991; Musiek et al, 2005; Price et al, 2005; Buschman & Miller, 2007). The brain is organised in terms of multipurpose representations that different regions support. A given brain region can be useful for many different functions – e.g. regions within the brain's putative perceptual system also play a role in (attention) and memory (López-Aranda et al, 2009). For example, proper functionality of the posterior temporal gyrus is found to be critical for both short-term memory and language (Leff et al, 2009; Acheson et al, 2011). To distinguish between two or more conditions presenting with similar symptoms or attributes requires multidisciplinary, comprehensive assessment. To ensure that the most appropriate interventions are employed, the audiologist is a member of the multidisciplinary team responsible for determining whether there is an auditory component to other presenting deficits or whether one condition is responsible for the symptoms seen in another.

Differential diagnosis is exceedingly important and can be quite challenging. To further illustrate this challenge consider the potential sources of speech understanding deficits in noise, which can result from peripheral (cochlear) auditory issues, central auditory issues, cognitive issues (including working memory deficits, attention deficits), language issues and age (i.e. younger children and older adults experience greater difficulty understanding speech in noise). Among individuals with CAPD, auditory processing deficits may vary in different cohorts of affected individuals. Choice of tests should be guided by the symptoms of the affected individual, as established by an in-depth interview and case history, the individual's age and primary language, and by the specific deficits reported to be associated with specific clinical presentations (e.g. Goll et al, 2010; Cumming et al, 2015). In selecting tests, the audiologist must recognise that one symptom (e.g. understanding speech in noise) can result from many underlying central auditory processing deficits (e.g. temporal processing, localisation, spatial release from masking, performance with competing/degraded auditory signals), as well as language processing or cognitive issues. The audiologist should select a battery of tests that assess the multiple central auditory processes potentially implicated in a patient's presenting complaints. Speech-in-noise or competition and dichotic listening tests would be obvious first line tests to examine difficulties hearing in noise. Similarly, compressed speech (a type of monaural low-redundancy measure) would be helpful to examine complaints of difficulty following rapid speech. The masking level difference (MLD), the Listening in Spatialised Noise-Sentences Test (LiSN-S) (Cameron & Dillon, 2007; Cameron et al, 2009), and localisation tasks would be useful to examine difficulties localising sound and spatial processing difficulties. Frequency pattern and duration pattern tests (DPT) (Musiek, 1994), as well as the complex auditory brainstem response (cABR) may provide insights regarding music appreciation difficulties. We discuss below tests and strategies to examine central auditory processing to minimise the influence of cognition and language. When cognitive or language processing deficits are suspected or confirmed, the audiologist should consider the use of auditory evoked potentials rather than behavioural auditory tests, interpreted within the context of multidisciplinary evaluations. Knowing which tests are available, their strengths and limitations, the processes assessed, task and response requirements, and the areas of the CANS to which each test is most sensitive provides the audiologist with critical information to assist in the differential diagnostic process. A summary of recommended tests and their strengths and weaknesses is provided in Table 1.

The remainder of this brief tutorial provides strategies to minimise confounding cognitive and language processing variables and accurately differentially diagnose CAPD. The audiologist and other members of the multidisciplinary team must determine whether a central auditory processing deficit (e.g. temporal resolution deficit) is adversely impacting attention, whether a more global attention deficit (e.g. faulty temporal synchronisation of attention) is impeding central auditory processing, or both issues are impacting the patient's processing of acoustic signals. Similarly, the audiologist in cooperation with the speech-language pathologist and psychologist must determine whether reported listening difficulties result from an auditory problem, a language processing disorder, a cognitive deficit (e.g. attention, executive function or

Table 1. Strengths and weaknesses of recommended tests.

Test	*Stimuli*	*Language load*	*Cognitive load*	*Response mode*	*Strengths*	*Weaknesses*
DD-DR	Digits	Low Verbal/ Small Closed Set	May Be Greater Re: DD-FR	Verbal	Good sensitivity/specificity particularly for cortical dysfunction; norms for ages 7 years to adult consistent across studies; minimally influenced by mild hearing losses	Working memory may be a factor, but linkage is weak to modest
DD-FR	Digits	Low Verbal/ Small Closed Set	May be Lower Re: DD-DR	Verbal	Good sensitivity/specificity particularly for cortical dysfunction; norms for ages 7 years to adult consistent across studies; minimally influenced by mild hearing losses	Working memory may be a factor, but linkage is weak to modest
DPT/FPT	Tones	Non-verbal	Low	Hum/Label	Good sensitivity/specificity for cortical dysfunction; norms for ages 8 years to adult; minimally influenced by mild hearing losses	Difficult task for young children and elderly
GIN	Noise	Non-verbal	Low	Press Response Button	Good sensitivity/specificity for brainstem and cortical dysfunction; consistent norms across studies and essentially the same for ages 7 years to adult; appropriate for use with English 2nd language speakers	Minimal data on cochlear hearing loss
LiSN-S	Sentences	Verbal	Low	Repeat Sentences	Tests spatial processing; large normative data base; derived measures may be more resilient to language factors; may be administered in presence of hearing loss	Sensitivity/specificity to neuroauditory lesions not yet established; influenced by cochlear hearing loss
MLD	Tone or Spondee	Non-verbal/Low Verbal	Low	Press Response Button	Sensitive to brainstem dysfunction; threshold test; appropriate for use with English 2nd language speakers	Influenced by cochlear and/or asymmetric hearing loss
PSI	Words and Sentences	Low Verbal	Low	Picture Pointing/ Closed Response Set	Norms for children 3–6 years old; sensitive to confirmed CNS lesions; incorporates intra-test performance intensity (PI) functions; compares word vs. sentence performance and ipsilateral vs. contralateral competition to differentiate auditory v. non-auditory factors	English language only

DD-DR: Dichotic Digits – Directed Recall. Requires listening to two pairs of single syllable digits presented to each ear simultaneously and verbally reporting the digits heard in either the right or left ear (the process is less cognitively loaded when repeating digits from the right than the left ear in the typically developing child). This response mode is more cognitively loaded than the free recall mode; DD-FR: Dichotic Digits – Free Recall. Requires listening to two pairs of single syllable digits presented to each ear simultaneously and verbally reporting the digits heard in both ears. This response mode is less cognitively loaded than the directed recall response mode; DPT/FPT: Duration Pattern Test/Frequency Pattern Test. Both tests measure temporal sequencing ability in response to stimuli presented in sets of three tones differing in duration (DPT) or in frequency (FPT). DPT generally is more challenging than FPT in children younger than 8 years old; GIN: Gaps-In-Noise. Assesses temporal resolution by requiring detection of short gaps (absence of sound) in noise; LiSN-S: Listening in Spatialised Noise-Sentences Test. Assesses binaural interaction (spatial release from masking) by requiring repetition of target sentences presented together with a background distractor (looped children's stories) which vary in location relative to the target sentences; MLD: Masking Level Difference. Measures binaural interaction (release from masking) by requiring detection of a low-frequency tone or spondee presented in noise binaurally at various signal-to-noise ratios when the signals are in phase (homophasic) or 180° out of phase (antiphasic); PSI: Paediatric Speech Intelligibility Test. Assesses speech recognition in competition by requiring pointing to pictures of words (simple nouns) or simple sentences presented in a closed set with competing sentences in the ipsilateral or contralateral ear at various message to competition ratios.

working memory), or some combination of these deficits. While there is some disagreement between professional associations in the United States and European associations (e.g. the British Society of Audiology [BSA, 2011]) as to the standard test battery to be used to diagnose CAPD, the two major sets of guidelines published by the American Speech-Language-Hearing Association (ASHA) and the American Academy of Audiology (AAA) present consistent positions and recommendations (i.e. ASHA, 2005; AAA, 2010). Notwithstanding the potential interactions among auditory, linguistic and cognitive factors, it is our position, as well as that of professional associations in the United States that listening difficulties seen in CAPD result primarily from auditory perceptual deficiencies rather than from global attention deficits or behavioural regulation deficits (AAA, 2010). This was underscored recently by Gyldenkaerne et al (2014) who reported a weak correlation between auditory processing and cognitive tests, concluding that poor auditory processing certainly is not the mere reflection of attention deficits. Similarly, Weihing et al (2015) concluded that central auditory tests are not likely governed by cognition given the results of their factor analysis in which central auditory tests loaded on separate factors, suggesting a unique variance associated with each test. Indeed, a number of studies have examined the relationship between CAPD and cognitive function; however, the studies use different auditory and cognitive test batteries, and some studies rely on auditory tests with no documented sensitivity to CAPD. Some studies conclude that cognitive disorders and CAPD exist independently (e.g. Tillery et al, 2000; Sharma et al, 2009; Rosen et al, 2010), while others suggest that CAPD is itself a cognitive disorder (e.g. Moore et al, 2010; Ferguson et al, 2011). The reader is referred to Tomlin et al (2015) and Weihing et al (2015) for reviews of studies examining the interaction between cognition and central auditory processing.

Controlling extraneous variables and test selection

In general, confounds can be minimised by controlling extraneous variables. The audiologist must select central auditory tests that are appropriate to the patient's age, education, linguistic background and cognitive ability. One should consider task requirements, including the modalities used, and the task's language and cognitive demands. The patient's cultural and linguistic backgrounds also are important as these factors can affect response time and accuracy of verbal responses (Pimentel & Inglebret, 2014). For example, individuals from some cultural backgrounds may pause for an extended period before responding to a stimulus item (Wallace et al, 1997). (Not surprisingly, the strategies and approaches reviewed here may be useful as well when testing non-native English speakers.) Selecting central auditory tests that are less influenced by peripheral hearing loss (e.g. frequency patterns, duration patterns) and considering the influence of medications (e.g. central nervous system stimulants or depressants) is important as well. Peripheral auditory function should be evaluated thoroughly prior to the central auditory evaluation (Iliadou et al, 2015). Perhaps the single most important step in successful audiologic assessment of the child with diagnosed and medically-managed ADHD is to ensure that the child received an effective dose of medication immediately before the test session, since for children with diagnosed ADHD who are treated medically, valid audiologic assessment is difficult without medication (Chermak et al, 1999). It is not uncommon, however, to see children diagnosed with ADHD who are not taking prescribed medication who nonetheless still perform within normal limits on central auditory processing tests, thereby confirming the absence of comorbid CAPD.

Behavioural tests using nonverbal or simple speech stimuli (e.g. frequency or duration patterns, gaps-in-noise, dichotic digits), as well as tests that minimise memory load, and employ a simple response mode (e.g. gap detection, MLD) reduce the influence of language and cognitive factors. The linguistic load of instructions also should be minimised to ensure the patient understands the task requirements. One might question why speech stimuli are used at all, given the potential confound with language. With few exceptions (e.g. Paediatric Speech Intelligibility Test; Jerger & Jerger, 1984), most central auditory tests are not appropriate for use with children under seven years of age due to the extremely challenging nature of the tests and the large performance variability seen among children younger than seven years, despite normal auditory processing function. Young (7–9 years old) patients may attend less to non-speech tasks, which are more abstract than speech tasks, which would inject a confound of inattention for non-speech stimuli. Moreover, speech and language signals provide access to different CANS processing mechanisms than do non-speech/language stimuli (Grossmann et al, 2010). Speech stimuli have greater ecological validity given the degree of temporal processing required for accurate perception of spoken language, which is significantly greater than required for perception of non-speech sounds (Shannon et al, 1995; Fitch et al, 1997; Griffiths, 1999; Zatorre & Belin, 2001). Finally, processing of speech signals may be more vulnerable to CANS dysfunction and central auditory deficits may only be revealed with speech tasks (e.g. Benavidez et al, 1999; Johnson et al, 2005; Russo et al, 2005). The reader is referred to the American Academy of Audiology Clinical Practice Guidelines (2010) for an overview, and to Musiek & Chermak (2014) for a more expanded description of the central auditory tests mentioned in this tutorial.

Test design, intra-test comparisons, psychometric functions, and performance interpretation

Intra-subject comparisons (e.g. interaural differences), which control in part for non-auditory factors, also maximise the potential to assess auditory function by holding contributions from cognitive or language systems constant between ears. Designing tests that rely on tasks that differ in the demands placed on central auditory processing skills, but differ minimally in the demands they place on cognitive abilities are more likely to produce performance more reflective of auditory function. The LiSN-S (Cameron & Dillon, 2007; Cameron et al, 2009) employs this strategy by measuring the ability of the auditory system to take advantage of the spatial separation of the target (simple sentences) and competing sounds (children's stories).

Other intra-test comparisons (e.g. performance-intensity functions in which one varies presentation levels or response mode) (e.g. humming vs. labelling in the Frequency Pattern Test (FPT) and DPT) also offer insights (Musiek & Pinheiro, 1987; Musiek et al, 1990). If a patient can perform at some intensity level or can hum, but not label, the audiologist knows that the subject understands the directions and the task. Assessing performance in non-manipulated conditions (e.g. monaural versus dichotic, non-filtered versus filtered, etc.) ensures that performance deficits seen on central auditory tests are due to the acoustic manipulations rather than to lack of familiarity with the language and/or significantly reduced memory skills. The use of electrophysiological measures also assists the audiologist in sorting out potential confounds. For example, the P300 is absent with lesions in auditory (temporal–parietal junction) areas (Knight et al, 1989), while damage to lateral parietal cortex or prefrontal cortex does not interfere with P300 generation. Similarly, Kileny et al (1987) demonstrated the effects of temporal lobe, but not frontal lobe lesions, on the middle latency response (MLR).

The influence of cognition on central auditory test performance is rather minimal. Correlations between central auditory tasks and attention are weak, accounting for minimal shared variance, which indicates that CAPD does not merely reflect attention deficits (Weihing et al, 2015). For some central auditory tests, no significant correlations are seen with attention, indicating that attention may play no significant role in some central auditory test outcomes (Shinn et al, 2005; Gyldenkaerne et al, 2014). Nonetheless, in addition to following the approaches recommended above (i.e. ensuring that the patient understands the directions and the task, minimising language load, and using a simple response mode) there are several other strategies that will minimise the cognitive demands of the task and thereby lessen the potential for cognitive confounds, allowing a more singular focus on auditory capacities.

Before administering a central auditory test, the audiologist should ensure that the task does not exceed the patient's working memory capacity. For example, one should confirm that the patient's digit span exceeds the threshold level of four in a noncompeting condition (i.e. non-manipulated condition) prior to presenting the stimuli in the dichotic, competing condition. This provides at least one within-patient control for possible confounding effects of cognition on central auditory test performance and assists in ensuring that any observed dichotic deficit is due more to the auditory processing of the dichotic competition rather than to generalised memory problems. In addition, as noted above, designing tests (e.g. LiSN-S) that rely on tasks that differ in the demands placed on central auditory processing skills, but differ minimally in the demands placed on cognitive abilities should produce performance more reflective of auditory function.

Dichotic testing offers an interesting opportunity to differentiate cognitive from auditory effects. Specifically, the directed report (DR) or divided-attention condition in which the patient repeats stimuli in one or both ears in a specified order correlates most closely with cognitive function, as this condition requires the listener to recruit additional cognitive (e.g. attention, memory) mechanisms to accurately perform the task. The free report (FR) condition in which the patient repeats stimuli directed to both ears, usually in any order, is less susceptible to cognitive confound, even though the paradigm may require the listener to report a greater number of stimuli (Cowell & Hugdahl, 2000; Hällgren et al, 2001; see Hugdahl et al, 2009 for review). While the role of cognition might not be directly extrapolated across dichotic tasks using different stimuli (e.g. Shinn et al, 2005), performance decrements in the FR condition are more likely to be a consequence of true auditory perceptual asymmetries than are performance decrements in the DR condition. Nonetheless, the laterality indexes for the DR of dichotic digits and (non-rhyme) words follow a similar developmental trajectory (Moncrieff, 2011), and similar to what is observed for CVs (Hugdahl et al, 2009), directing attention to one ear strongly modulates the laterality index for digits and this modulation is cognitive dependent (Bouma & Gootjes, 2011). These findings support our assertion that for a given dichotic task, the DR mode depends more on cognitive resources that the FR condition. It should also be noted that the DR condition involves an additional degree of auditory complexity in that it requires lateralisation of the stimuli. This suggests that while DR is more cognitively dependent than FR, DR requires transfer of sounds across the corpus callosum and therefore still provides an index of sensory demands (Rauschecker & Tian, 2000). As the two report conditions tap into different underlying auditory processes (i.e. binaural integration vs. binaural separation), and cognitive factors confound to different degrees, the use of both FR and DR conditions for the same stimuli, may, when administered and interpreted appropriately, provide useful insight into the specific auditory processes (i.e. binaural integration vs. binaural separation) that are impacted by a given central auditory disorder. Jerger and Martin (2006) argued that using divided and directed attention dichotic listening procedures incorporating the same test stimuli may be helpful in sorting out the relative contributions of cognitive and auditory specific factors influencing interaural asymmetry, suggesting that auditory-specific deficits should lead to poor dichotic performance under both modes of administration (Martin et al, 2007).

Language and cognitive screening

In addition to peripheral hearing testing prior to central auditory testing, it is helpful for the audiologist to have some sense of the language and cognitive function of patients seen for central auditory evaluation. Patients should be at least screened, if not more fully assessed in the multidisciplinary evaluation of patients referred for CAPD. For children, such screens might include the Clinical Evaluation of Language Fundamentals, 5th edition (CELF-5) (Wiig et al, 2013), the auditory backward and forward digit span subtest for working memory (Wechsler, 2014), auditory vigilance (attention), e.g. Integrated Visual and Auditory Continuous Performance Test (IVA-CPT) (Sandford & Turner 2009), and nonverbal intelligence, e.g. Test of Nonverbal Intelligence (4th edition) TONI-4 (Brown et al, 2010). These screening tests must be administered by the member of the multidisciplinary team in whose scope of practice such testing falls. For adults, cognitive screening measures include: the Montreal Cognitive Assessment (MoCA) (Nasreddine et al, 2005); Mini-Mental State Exam (MMSE) (Folstein et al, 1975), and the 6-CIT (Cognitive Impairment Test) Kinghill Version (Brooke & Bullock, 1999). Results of any of these cognitive screens should be interpreted with caution when CAPD or hearing loss is suspected as their results may be showing deficits that may be at least partly explained by these auditory disorders (Lin, 2011; Bush et al, 2015). This potential confound underscores the importance of collaborating with the physician or psychologist who is administering the cognitive tests to ensure that the environment in which these cognitive tests are administered is as optimal acoustically as possible.

Use of questionnaires

Questionnaires do not predict risk for CAPD and present only weak to moderate correlations with only certain central auditory measures in children (Wilson et al, 2011). Questionnaires may be used to highlight concerns about a child, identify additional areas that require assessment, or supplement the diagnostic process, but not to determine whether a diagnostic central auditory processing assessment is warranted, nor do questionnaires differentially diagnose disorders (Iliadou & Bamiou, 2012; Tomlin et al, 2015).

Questionnaires lack sensitivity for a number of reasons that include: (1) lack of relevant range of items; (2) qualitatively similar symptoms of difficulty could result from many underlying causes besides CAPD; and (3) respondents' estimates of severity may be imprecise, and/or they might not be able to reliably gauge severity, and/or responses may be influenced by other factors, including respondents' interpretation of the question or their desire for a diagnosis (Tomlin et al, 2015). However, adult studies in both neurological (e.g. Bamiou et al, 2012) and non-neurological CAPD populations (Bamiou et al, 2015) show stronger correlations between self-reported listening difficulties and central auditory processing tests than those reported in paediatric studies. More recently developed questionnaires (e.g. Evaluation of Children's Listening and Processing Skills [ECLiPS]) may ultimately prove to be of greater utility in the diagnostic process (Barry et al, 2015), pending additional research with a large number of children diagnosed with CAPD, rather than only referred for central auditory evaluation or suspected of CAPD, but not ultimately diagnosed with CAPD.

Use of multimodal analogue measures

Some have suggested the need for multimodal analogue tests to differentially diagnose CAPD. Research has demonstrated, however, that the addition of visual tasks offers little to augment differential diagnosis (Bellis et al, 2011). The reader is referred to several key publications for in-depth discussion of the limited contributions of multimodal tests for the differential diagnosis of CAPD, as well as the difficulties in designing such tests (Musiek et al, 2005; Bellis et al, 2011; Chermak, 2013; Chermak & Bellis, 2014; Dillon et al, 2014; Moore & Ferguson, 2014).

Summary and conclusions

The purpose of this brief tutorial was to provide audiologists with strategies to minimise confounding cognitive and language processing variables and accurately differentially diagnose CAPD. We suggest that audiologists select central auditory tests that are appropriate to the patient's age, education, linguistic and cultural background, and cognitive ability and select central auditory tests with low language and cognitive demands. Prior to central auditory testing, we recommend that other professionals be engaged to assess an individual's basic cognitive function and language skills (the latter being particularly important with children). In addition to selecting tests with minimal cognitive and linguistic demands, we suggest intra-subject (e.g. inter-aural) and intra-test (e.g. hum vs. label) comparisons to further minimise confounds. Proper test selection and use of the strategies recommended here will help the audiologist and other members of the multidisciplinary team determine the source(s) of listening difficulties and other functional deficits. The audiologist in cooperation with the speech-language pathologist and psychologist must determine whether reported listening difficulties result from an auditory problem, a language processing disorder, a cognitive deficit (e.g. attention, executive function or working memory), or some combination of these deficits. The strategies and approaches reviewed here are useful to minimise counfounds; however, they are not intended as a substitute for appropriately normed tests with documented sensitivity, validity and reliability with such populations. When behavioural audiometric findings remain incomplete, inconclusive, or invalid despite the implementation of the approaches recommended in this tutorial, the audiologist may rely more on electrophysiological techniques, as well as findings provided by other multidisciplinary team members to determine the relative contributions of cognition, language processing, and auditory processing to educational, workplace, and everyday functional listening demands, and develop intervention plans. The reader is referred to Chermak (2013) and Chermak & Bellis (2014) for detailed discussions of differential diagnosis of CAPD and ADHD.

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