Central Auditory Processing Disorders: Definition, Diagnosis, and Treatment

Teri James Bellis, Ph.D., CCC-A, FAAA, F-ASHA
Department of Communication Sciences and Disorders
The University of South Dakota
and
Division of Basic Biomedical Sciences
Sanford School of Medicine
Vermillion, SD

- Topics to be covered in this presentation
  - Current definitions of CAPD
  - Brain organization and neurobiological bases of CAPD
  - Prevalence of CAPD
  - Presenting symptoms of CAPD
  - Methods of diagnosing and treating CAPD in adolescents and adults

Current Definitions of CAPD

CAPD (ASHA, 2005; AAA, 1010):

- is a deficit in the perceptual processing of auditory stimuli, *and the neurobiological activity* underlying that processing
- may lead to or be associated with difficulties in higher-order language, learning, and communication function
- cannot be *attributed to* higher-order language, cognitive, or related confounds

- Affects the perceptual and neural processes in CNS underlying:
  - Localization/lateralization
  - Discrimination
  - Auditory pattern recognition
  - Temporal processing
  - Performance with competing/degraded acoustic signals

Abilities such as phonological awareness, attention to and memory for auditory information, auditory synthesis, comprehension and interpretation, and similar skills may be reliant upon or associated with intact central auditory function…

BUT

they are considered higher-order cognitive/ communicative and/or language-related functions and, thus, are *not included* in the definition of CAPD

The terms *auditory processing*, *phonological processing*, *language processing*, and *cognitive processing* are NOT synonymous, although the skills may be inter-related and the behaviors may be similar.

- CAPD is a diagnosis, NOT a descriptor!

Neurobiological Bases of CAPD

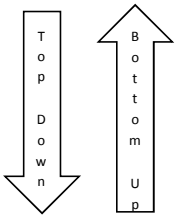
- Evidence supporting neurobiological bases of CAPD
  - Abnormal neurophysiologic representation of both speech and nonspeech signals
  - Atypical interhemispheric transfer
  - Atypical timing in system
  - Atypical hemispheric asymmetries
  - Neuromorphological abnormalities
  - Other

Fundamentals of Brain Organization

- Few, if any, entirely compartmentalized areas of the brain responsible for a single sensory modality – the whole brain works together!
- Resource allocation plays a huge role in listening, remembering, and understanding!

- Multimodality influences affect even the most basic neural encoding and manipulation of sensory stimuli

ATTENTION, COGNITION, MEMORY, LANGUAGE, EXECUTIVE FUNCTION



AUDITORY PROCESSING

Auditory processing is BOTH bottom-up and top-down. The relative influence of top-down or bottom-up processing is influenced by changing listening demands (resource allocation).

Modality Specificity

- Modality specificity as a criterion for diagnosing CAPD (McFarland & Cacace, 1995; Cacace & McFarland, 1998)
- CAPD is a disorder that is *specific to the auditory modality* (Jerger & Musiek, 2000).

Are definitions of CAPD that require complete modality specificity as a diagnostic criterion ecologically valid?

Is the demonstration of complete modality-specificity required for diagnosis of other disorders involving the auditory system?

Brain organization underlies comorbidity of CAPD with other disorders, e.g.:

- ADHD
- Learning Disability
- Phonological Disorder
- Language Disorder
- Others

- Multimodality influences affect even the most basic neural encoding and manipulation of sensory stimuli
- Processing of sensory data is interdependent and integrated, and supported by cognitive domains and language representations

- This is why so many individuals with CAPD may also exhibit problems with auditory working memory, phonological awareness, language comprehension, and other "higher-order" abilities.

- Substantial research supports the nonmodularity of central auditory dysfunction:
  - Bellis et al. Use of visual analogs to central auditory tests; auditory and multimodal findings in interhemispheric dysfunction.
  - Kraus et al. Impact of visual system, limbic system, and other factors on temporal processing at brainstem level.

Therefore:

Any definition of CAPD that specifies complete modality-specificity as a diagnostic criterion is neurophysiologically untenable.

Question #1

- The term (C)APD refers to:
  a) A set of symptoms that include listening and related communication difficulties
  b) A diagnosis characterized by evidence of a neurobiological disorder in the CANS
  c) A pattern of deficits observed in standardized neuropsychological, psychological, or speech/language tests that reveals greater difficulty in auditory-verbal tasks

Question #2

- Which of the following statements best reflects the ecological validity of purely modality-specific approaches to defining (C)APD?
  a) Brain organization and lack of modularity in the auditory system underlies comorbidity of disorders
  b) Although the expectation of modality-specific effects (C)APD is consistent with the underlying neuroscience, we simply don't have valid methods of demonstrating such modularity at the present time
  c) Auditory-specificity should be a criterion for the diagnosis of all auditory disorders

Definition/Nature of CAPD Informs Diagnosis:

Because of the interactive nature of auditory processing, to document a *central auditory deficit,* you must use:

- Test tools that have *documented* sensitivity and specificity to *known* dysfunction of the CANS
- Tools developed/validated for other purposes (i.e., learning disability, language impairment) CANNOT be used for this purpose!
- Because CAPD is an auditory disorder, the audiologist diagnoses CAPD.

Definition/Nature of CAPD Informs Intervention:

Intervention for CAPD should:

- be a multidisciplinary endeavor, and should address both bottom-up and top-down skills
- be individualized and deficit-specific (the diagnosis drives the treatment)

- focus on improving access to auditory information, strengthening central resources, and remediating the auditory deficit

Key Point!

- The presence of a CAPD as a causal or contributing factor to a language, learning, or related disorder will ABSOLUTELY change the intervention approach for that disorder!!!
- Determining integrity of the central auditory system is CRITICAL!!!

Prevalence of CAPD

- In school-aged children:
  - 2-3% of all school-aged children (Chermak & Musiek, 1997)
  - ~43% of children with learning disabilities (Iladau et al, 2009)
  - ~25% - 45% of children with reading disorders (Iladau et al, 2009; Banai et al, 2007)
  - Everyone with phonological-based reading disorders? (Billiet & Bellis, 2011)
- Up to 75% of older adults (Bellis & Wilber, 2001; Cooper & Gates, 1991)

- Males appear to be affected more than females (2:1)
- Childhood CAPD can persist into adolescence and adulthood, or CAPD can occur as part of the natural aging process
- The time course and nature of adult-onset CAPD differs by gender and point of time in the lifespan (Bellis & Wilber, 2001)
  - Males: Early adulthood; interhemispheric dysfunction
  - Females: Post-menopausal years; transient right-hemisphere dysfunction as well as interhemispheric dysfunction

Presenting Symptoms of CAPD

Associations between auditory processing and language/learning outcomes *depend upon the type of auditory deficit, type of language/learning difficulty, and unique confluence of the individual's bottom-up and top-down abilities* (e.g., Bellis & Ferre, 1999; Cestnick & Jerger, 2000; Heath et al, 1999)

- **Red flags MAY include:**
  - Difficulty hearing in noise
  - Difficulty following multi-step directions
  - Difficulty perceiving (and perhaps producing) prosodic elements of speech
  - Reading and spelling difficulties
  - Requesting repetitions/mishearing words
  - Difficulty understanding degraded speech
  - History of early non-developmental speech production errors
  - History of chronic otitis media, neurological insult, or other pertinent medical history
  - Difficulties with perception of music and prosody
  - And many others

Question #2

- Which of the following best represents the relationship between central auditory processing and language/learning disorders?
  a) All (C)APDs result in language/learning disorders
  b) All language/learning disorders likely have an underlying (C)APD
  c) The relationship between (C)APD and language/learning disorders may be causal or associated, or may be absent in many cases

Screening
for
CAPD

Screening for CAPD

- **Purpose:**
- **To determine need for further testing**
- **To reduce over-referrals**

- Review of “other systems” is a key component of screening
- Screening is focused on answering four primary questions:

1. Are the current evaluations sufficient in scope?
2. Is there a likelihood of CAPD?
3. Can the child participate in the evaluation?
4. Would results of assessment add information that would affect management?

Outcomes of Screening

- Referral for comprehensive assessment
- Referral for other testing/follow-up
- Interim Recommendations
- Other

Question #3

- Which of the following is NOT a possible outcome of the (C)APD screening process
  a) Recommendation for comprehensive (C)APD testing
  b) Preliminary diagnosis of (C)APD
  c) Development of interim intervention recommendations

Diagnosing CAPD

- Diagnosis of CAPD in adolescents and adults is through the SAME process as diagnosis of the disorder in younger children
- It is NEVER too late to diagnose (and treat) CAPD!!!

Diagnosing CAPD

- Purpose of Diagnostic Testing: To identify presence and delineate characteristics/nature of central auditory deficit
- Requires diagnostic tests of central auditory function that have been shown to be sensitive/specific for identification of disorders of the CANS

- Provides information regarding integrity of left-hemisphere, right-hemisphere, interhemispheric, and brainstem auditory structures

- May include psychophysical (behavioral) and/or neuro(electro)physiologic tests of central auditory integrity
- Leads directly to development of *deficit-specific* treatment and management plans

Behavioral Tests (Categories)

- Dichotic Speech Tests
  - Processes assessed: Binaural separation, binaural integration
- Temporal Patterning Tests
  - Processes assessed: Auditory patterning/contour recognition, nonspeech discrimination
- Tests of Other Temporal Processes
  - Process assessed: Temporal resolution/integration

- Monaural Low-Redundancy Speech Tests
  - Process assessed: Auditory Closure
- Auditory Discrimination Tests
  - Process assessed: Discrimination
- Tests of Localization/Lateralization
  - Process assessed: Localization (important for speech in noise)

Electrophysiologic Tests (Categories)

- Standard ABR, MLR, Corticals, P300
- Multi-channel MLR and Corticals to speech and nonspeech signals (electrode and ear effects and hemispheric asymmetries)
- Other (e.g., MMN, etc.)
- Brainstem responses to speech and other complex signals

- Electrophysiologic and related measures may play an important role in the objective demonstration of neural deficits in the auditory system in many cases, as well as in the documentation of treatment efficacy. They may also indicate which patients might benefit from training (e.g., speech-evoked/complex ABR!)

Test Battery Interpretation

- Norm-referenced criteria
- Using the patient as his/her own control (inter- and intra-test pattern analysis using neurophysiologic tenets)

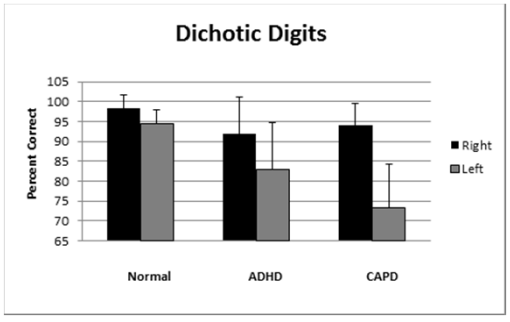
- A diagnosis of (C)APD is enabled only when performance on ≥ 2 tests is abnormal AND the pattern of findings is consistent with underlying neuroscience tenets (ASHA, 2005; AAA, 2010)
- Lack of a pattern (e.g., poor performance on all measures, inconsistent findings across tests) argues for more global or motivational deficit, not (C)APD

- Differential diagnosis requires administration of sensitized tests of central auditory function and multidisciplinary input to evaluate functioning across domains
- CAPD should never be diagnosed or treated "in a vacuum;" focus should always be on the whole person

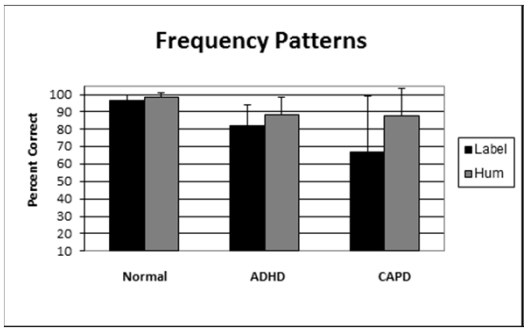
Patients with other, more global disorders (e.g., ADHD) typically:

- Exhibit no clear auditory pattern (all normal or uniformly depressed; inconsistency in test performance)
- Exhibit poor performance on vigilance tasks (auditory and visual)
- Often report that their complaints are improved or ameliorated by medication

- When overall performance is considered, individuals with ADHD may perform more poorly (and similarly to individuals with CAPD) on behavioral tests of central auditory function than typically developing individuals.



Bellis, Billiet, & Ross, 2011



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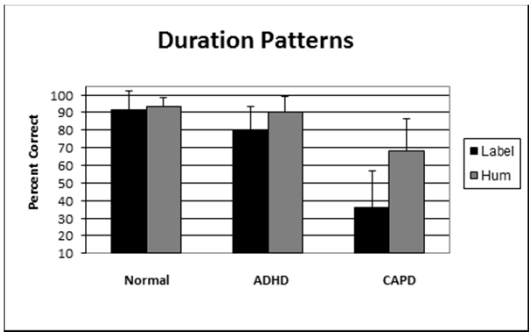
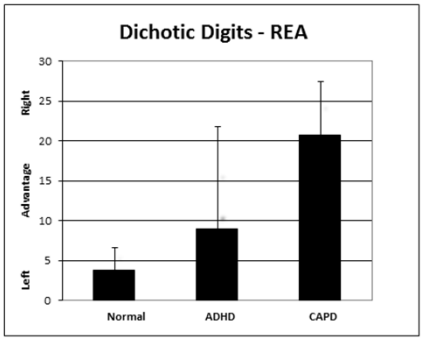


Bellis, Billiet, & Ross, 2011

- However, when intra-test analyses are carried out (ear differences, response condition differences), behavioral tests of central auditory function are sufficient to differentiate those with CAPD from those with ADHD and from typically developing individuals



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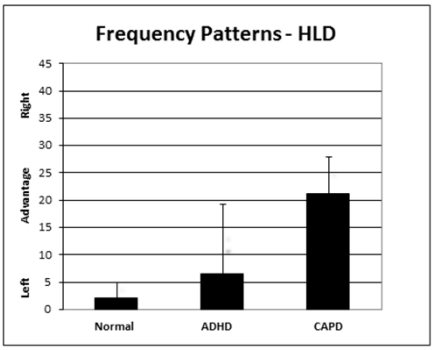

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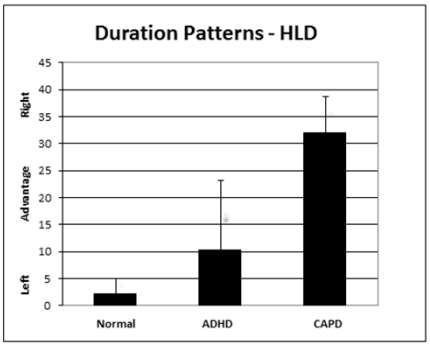


Bellis, Billiet, & Ross, 2011

- Therefore, analysis of inter- and intra-test patterns of performance is CRITICAL for differential diagnosis of CAPD and ADHD
- It should always be remembered that CAPD may (and often does) co-exist with other disorders; therefore, a multidisciplinary team approach is needed!

Levels of Interpretation

- Site-of-dysfunction-based interpretation
- Process-based interpretation
- Functional deficit profiling

Process-Based Interpretation

Purpose

- To identify the auditory deficits using results of behavioral central auditory testing and other data to determine specific areas of auditory dysfunction that need to be targeted

- **Auditory performance with competing acoustic signals**

  Binaural Separation – assessed by dichotic tests involving directed attention (e.g., Competing Sentences)

- **Auditory performance with competing acoustic signals**

  Binaural Integration – assessed by dichotic tests involving report of both ears (e.g., Dichotic Digits)

- **Auditory performance with degraded acoustic signals**

  Auditory Closure – assessed by tests of monaural low-redundancy speech and those involving ipsilateral competition (e.g., Filtered Speech, Time-Compressed Speech)

- **Auditory Pattern Recognition**

  Auditory Patterning/Temporal Ordering – assessed by temporal patterning tests (e.g., Frequency and Duration Patterns)

  Includes aspects of nonspeech discrimination, interhemispheric transfer, sequencing, and specific temporal processes

- **Auditory Discrimination**

  Complex auditory skill

  Element of virtually all central tests

  Can be directly assessed through difference limens for nonspeech stimuli, speech-sound discrimination tasks, etc.

- **Temporal Aspects of Audition**

  Critical for discrimination, localization/lateralization, prosody perception, etc.

  Can be assessed through direct measures of temporal resolution (e.g., gap detection), temporal masking, temporal integration/summation, etc.

Discrimination and temporal processing also can be assessed indirectly through electrophysiologic indicators of neural representation and discrimination (e.g., MLR, Cortical Responses, MMN, speech-evoked ABR)

****Remember: TIMING IS EVERYTHING!****

<u>ALL</u> CAPDs LIKELY HAVE SOME DEFICIT IN TEMPORAL PROCESSING!

- **Sound Localization/Lateralization**

  Critical for speech-in-noise skills and other auditory functions

  Tapped by tests such as MLD, binaural interaction tests, LISN

  Additional research needed

Question #4

- Binaural Separation refers to
  a) The ability to report input presented to both ears simultaneously
  b) The ability to report input presented to one ear while ignoring a competing signal presented to the other ear
  c) The ability to fill in missing components of a message

Question #5

- Auditory Closure refers to
  a) The ability to fill in missing components of a message
  b) The ability to process nonverbal acoustic contours over time
  c) The ability to detect very small silent gaps imbedded in a signal

Functional Deficit Profiling (includes site-of-dysfunction based interpretation)

- Involves examination of auditory and cross-discipline data for patterns that conform to well-established neurophysiologic and neuropsychologic tenets
- Not intended to be a "catch-all," cookie-cutter approach to interpretation and programming treatment

- Key to interpretation, diagnosis, and effective treatment: Presence of patterns that make sense based on scientific foundations and principles
- Functional deficit profiling serves as a guide for clinicians to assist them in understanding these patterns

ONE Subprofiling Method: The Bellis/Ferre Model

Involves integration and pattern analysis of auditory and multidisciplinary findings

Three primary profiles:

Auditory Decoding Deficit

- Auditory deficits indicate left-hemisphere (primary auditory cortex) pattern:
  - Bilateral or right-ear deficit on dichotic speech tasks
  - Poor performance on auditory closure tasks
  - Poor phoneme discrimination
  - Reduced LH electrophysiologic responses (MLR, cortical)
  - Poor temporal resolution abilities

- **Associated difficulties in left-hemisphere functions:**
  - Phonological decoding (word attack) difficulties
  - Speech-in-noise problems
  - Better performance with visual/multimodality cues
  - Other phonological and language-based concerns
  - Better Performance than Verbal IQ

Prosodic Deficit

- **Auditory deficits indicate right-hemisphere pattern:**
  - Left-ear deficit on dichotic speech tasks
  - Poor temporal patterning performance (BOTH humming and labeling)
  - Reduced RH electrophysiologic responses (MLR, cortical)
  - Elevated frequency, intensity, duration difference limens

- **Associated difficulties in right-hemisphere functions:**
  - Sight word reading and other Gestalt patterning difficulties
  - Problems with prosody perception
  - Poor pragmatic skills
  - Sequencing difficulties
  - Other RH difficulties (e.g., visual-spatial skills, math calculation, better verbal than performance IQ)

Integration Deficit

- **Auditory deficits indicate inefficient interhemispheric transfer:**
  - Left-ear deficit on dichotic speech tasks (opposite for nonspeech)
  - Poor temporal patterning performance (labeling ONLY)
  - Traditional electrophysiologic responses (MLR, cortical) often normal; may see reduced hemispheric asymmetry to speech stimuli

- **Associated interhemispheric difficulties:**
  - Poorer performance with multimodality or visual cues
  - Sound-symbol association difficulties
  - Speech-in-noise and localization difficulties
  - May have subtle difficulties in other interhemispheric tasks (bimanual/bipedal activites, etc.) but not "true" sensory integration dysfunction

A Fourth Subprofile

- Brainstem timing deficit
- Abnormal performance on speech-evoked ABR, associated with speech-in-noise complaints, reading deficits, and other symptoms
- Indicates potential for success with auditory training

- Note: Not everyone will fall into one of these "subtypes" – this is why interpretation (and subsequent intervention) must be individualized and based on the evidence!!!

Summary

- **Accurate assessment and diagnosis of CAPD requires:**

- Ecologically valid definitions of CAPD
- Evaluation of a variety of processes and CANS sites
- Multidisciplinary input

- **The key to interpretation and differential diagnosis:**

- Analysis of findings for neurophysiologically tenable PATTERNS consistent with CANS dysfunction

Question #6

- Which of the following is/are NOT typically associated with central auditory dysfunction in the primary (left) auditory cortex?
  a) Good word attack (phonological decoding skills) with poor sight word reading skills
  b) Difficulty with auditory closure and speech in noise
  c) Poor word attack skills with good sight word reading skills

Question #7

- Which of the following is/are NOT typically associated with central auditory dysfunction in the nonprimary (right) auditory cortex?
  - Poor word attack skills with good sight word reading skills
  - Difficulty with perception (and possibly production) of prosody
  - Associated math and visual-spatial abilities

Question #8

- Which of the following is/are NOT typically associated with central auditory dysfunction in the corpus callosum/interhemispheric pathways?
  a) Subtle difficulties in bimanual/bipedal skills
  b) Very poor speech-in-noise skills
  c) Difficulty with temporal resolution tasks, such as gap detection

Intervention for CAPD

Three critical components of comprehensive intervention for CAPD:

1. Environmental Modifications (bottom-up and top-down)
2. Central Resources Training (top-down)
3. Intensive Auditory Training (bottom-up)

- Note: The following suggestions are examples ONLY. The most effective interventions can only be determined via appropriate diagnosis and multidisciplinary team input, along with analysis of the individual's unique situation and difficulties. There is NO one-size-fits-all approach to intervention for CAPD.

Environmental Modifications

- Preferential seating and/or hearing assistive technology
- Provide instructions/information in writing
- Make frequent checks for understanding by observing performance
- Make appropriate use of multimodal cues
- Giving instructions one step at a time

- Make generous use of organizational aids (agendas, notepads, whiteboards, etc.)
- Be concrete; avoid hints
- Repeat rather than rephrase, unless language level is a concern
- Ensure a good listening environment and maximize attention

Central Resources Training

- Attribution Training – encouraging the person to take responsibility for his/her own listening success:
  - Attribute successes and failures to factors under his/her control
  - Encourage paraphrasing of instructions to clarify misunderstandings
  - Teach advance problem-solving techniques

- Engage metalinguistic and metacognitive skills
  - Metalinguistic: Involves intentional "thinking about language"
  - Metacognitive: Involves intentional "thinking about thinking." Also includes metamemory activities.

Direct Remediation

- Addresses specific auditory deficits via intensive auditory training
- To maximize neuroplasticity, auditory training activities must be:
  - Frequent
  - Intense
  - Challenging
  - Involve active participation and salient reinforcement

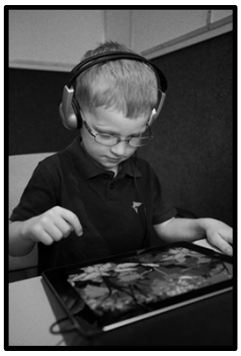
- Skills trained often generalizes to other, non-trained areas, including non-auditory skills such as reading comprehension!
- Remember: The ultimate goal of CAPD intervention is to treat the disorder, and it is NEVER too late to do so!

Question #9

- Which of the following is NOT a critical components of all comprehensive (C)APD intervention programs?
  a) Bottom-up and top-down environmental modifications
  b) Speech and language therapy
  c) Bottom-up targeted auditory training/remediation

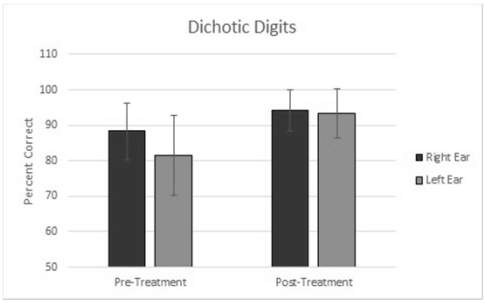
- One form of auditory training: Dichotic Listening Training (DLT)
- Recent research has shown that training in dichotic listening improves speech-in-noise and related skills, and also generalizes to other areas of difficulty (e.g., auditory closure, reading comprehension, spelling, social communication skills) (Bellis, Barker, Johnson, et al., 2015)

iPod-based DLT

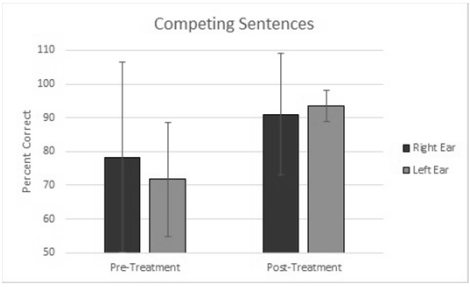


tablet/computer-based DLT

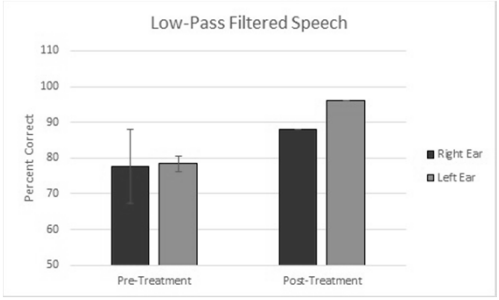
EFFECTIVENESS OF IPOD-BASED DLT IN CHILDREN AND ADULTS WITH CAPD



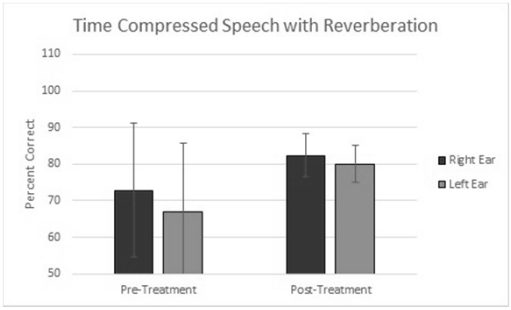
For the Dichotic Digits test, ANCOVA revealed:
***Significant main effect of DLT (F[1,41] = 16.05, p = .000; *d* = 1.05), with improved performance after treatment**
***Significant main effect of Ear (F[1,41] = 3.61, p < .05; *d* = .43), with poorer left-ear performance**
***No significant Treatment X Ear interaction**



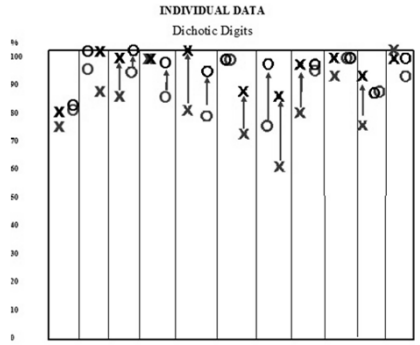
For the Competing Sentences test, ANCOVA revealed:
***Significant main effect of Treatment (F[1,35] = 8.68, p < .01; *d* = .93); with improved performance after treatment**
***No significant main effect of Ear (F[1,35] = .118, p = .773; *d* = .097)**
***No significant Treatment X Ear interaction**

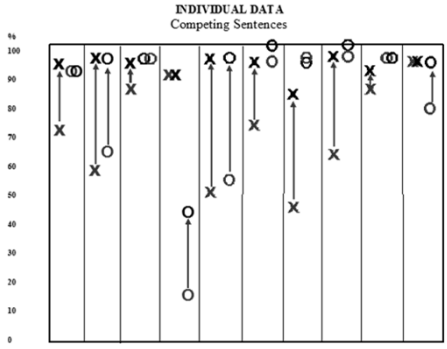


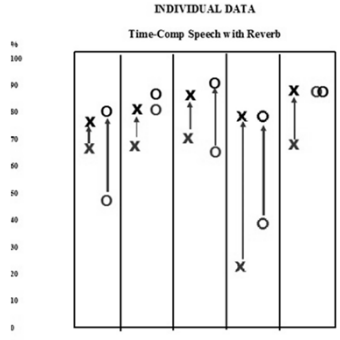
For the Low-pass Filtered Speech test, ANCOVA revealed:
***Significant main effect of DLT (F[1, 7] = 10.89, p < .01; *d* = 2.17), with improved performance after treatment**
***No significant main effect of Ear (F[1, 7) = 10.89, p = .21; *d* = 0.223)**
***No significant Treatment X Ear interaction**

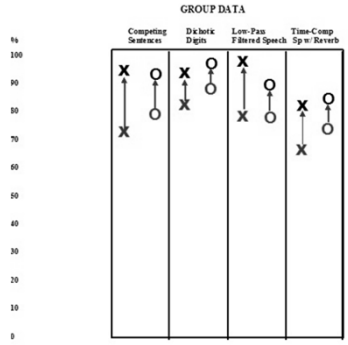


For the Time-Compressed Speech with reverberation test, ANCOVA revealed:
***Significant main effect of Treatment ($F[1, 26] = 3.62$, $p < .05$; $d = .868$), with improved performance after treatment**
***No significant main effect of Ear ($F[1,26] = 0.534$, $p = .24$; $d = .27$)**
***No significant Treatment X Ear interaction**









Discussion/Conclusions

- DLT resulted in significant improvements in binaural integration and binaural separation skills as measured by Dichotic Digits and Competing Sentences. Auditory closure skills (i.e., Low-pass Filtered Speech, and Time-compressed Speech with reverberation) also improved, despite not being explicitly trained.
- Individual data indicate that all participants exhibited significant improvement following DLT across all measures, and reported concomitant improvement in real-world listening and related skills.

- These results support the contention that DLT is an effective treatment for CAPD.
- Additional analyses suggest that improvements can occur even in skills that were not trained during DLT (e.g., auditory closure, speech in noise, reading skills, etc.).

EFFECTIVENESS OF TABLET/COMPUTER-BASED DLT (ZOO CAPER) FOR CAPD

AKA Zoo Caper

Available on an iPad app and/or on any browser through to acousticpioneer.com

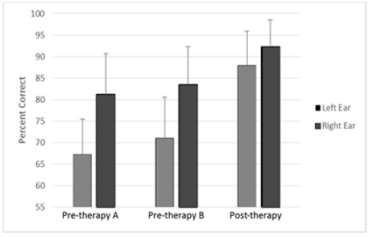
acousticpioneer

Zoo Caper

Design

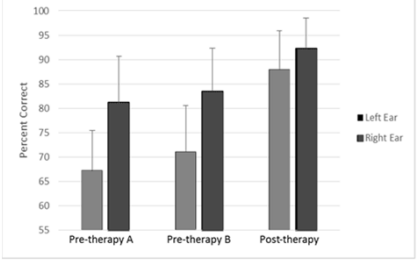
- **Baseline measure**
- **Baseline measure**
- **Training variable (Zoo Caper)**
- **Follow-up Measure**

Zoo Caper



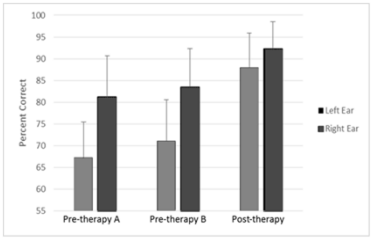
- **Significant main effect of Therapy [F(2, 77) = 36.46; p=.000] on dichotic scores**
- **Significant main effect of Ear on dichotic scores [F(1, 77) = 41.056; p = .000; d = .92} with left ear being worse than right**
- **No significant main effect of sex on dichotic scores [F(1,77) = 3.331, p = .032, d = .17]**
- **A significant Therapy X Ear interaction was found [F(2,77)=3.61; p<.05); however, no other significant interactions were noted**
- **No significant correlation between # of sessions and degree of improvement**

Zoo Caper



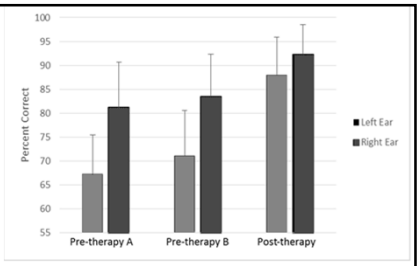
- **Post-hoc Bonferroni comparisons indicate**
  - **Pre-therapy A and Pre-therapy B were not significantly different from each other (p=0.369; d=0.28)**
  - **Pre-therapy A was significantly poorer than Post-therapy (p=0.000; d=1.68)**
  - **Pre-therapy B was significantly poorer than Post-therapy (p=0.000; d=1.38)**

Zoo Caper



- **LEFT ear:**
  - **A significant main effect of Therapy was seen [F(2,41) = 37.85, p = .000)**
    - **Post-hoc Bonferroni comparisons revealed that:**
      - **Pre-A was significantly poorer than post (p =.000; d = 2.58)**
      - **Pre-B was significantly poorer than post (p = .000; d = 1.94)**
      - **Pre-A and Pre-B were not significantly different from one another (p = .396; d = .44)**

Zoo Caper



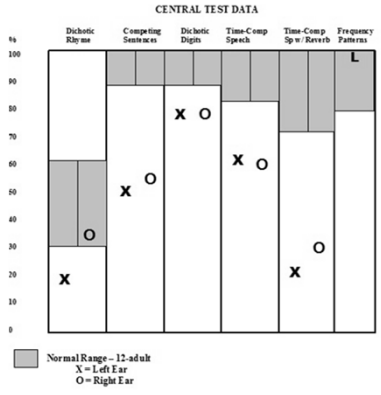
- **RIGHT ear:**
  - **A significant main effect of Therapy was seen [F(2,41) = 7.785, p < .01)**
    - **Post-hoc Bonferroni comparisons revealed that:**
      - **preA was significantly poorer than post (p < .01; d = 1.58)**
      - **preB was significantly poorer than post (p < .05; d = 1.15)**
      - **preA and preB were not significantly different from one another (p = .NS; d = .25)**

Discussion/Conclusions

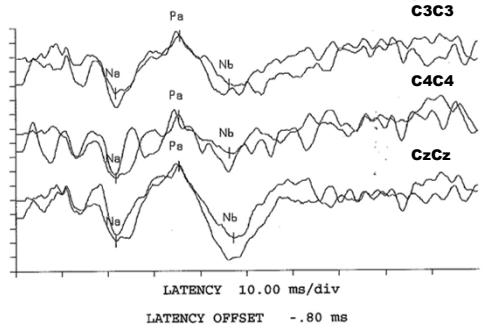
- **Left ear was worse than right overall.**
- **The pre-A and pre-B sessions did not significantly differ from one another when compared together nor for left or right ears independently**
- **The post-therapy measures were significantly better from both pre-A and pre-B when ears were collapsed together AND for both right and left ears independently (with the left-ear improvement being more pronounced).**
- **Number of sessions was not related to degree of improvement**
- **Improvement in real-world listening and learning abilities also were reported**

Case Study

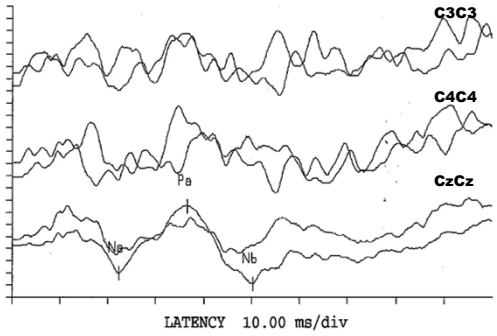
- Auditory and related complaints (age 17)
  - Significant difficulties hearing in noise
  - Reading/spelling difficulties
  - Reported nonpragmatic yet "social communication" difficulties (according to mother)
    - seemed not to understand what friends/others said and accepted poor treatment
  - Excellent musical abilities



MLR RE – Initial



MLR LE – Initial

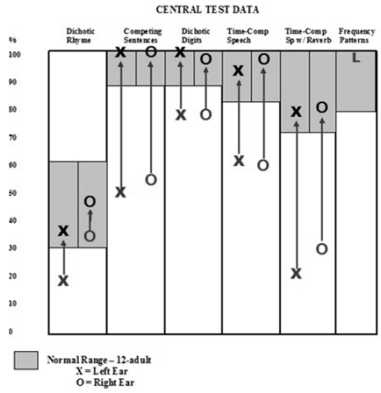


- Summary of pre-therapy test results:
  - CAPD affecting binaural integration/separation and auditory closure abilities with pattern consistent with right-hemisphere pathology site of dysfunction
  - Contralateral "ear effect" on MLR
  - Probable reversed cerebral dominance for auditory-language functions given pattern of symptoms (reading/spelling concerns with preserved musical abilities)

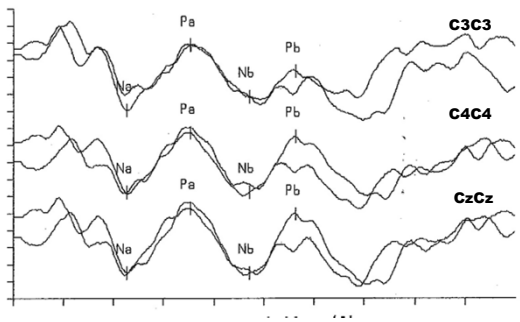
- Recommendations
  - Environmental Modifications
  - Central Resources Training
  - Direct auditory remediation: Dichotic Listening Training at home, 30-45 minutes per day, 5 days per week, 6 weeks

- Patient returned 12 weeks later
- Had completed 6 weeks of Dichotic Listening Training
- Engaged in DLT once per week thereafter as it seemed to “help her listen”

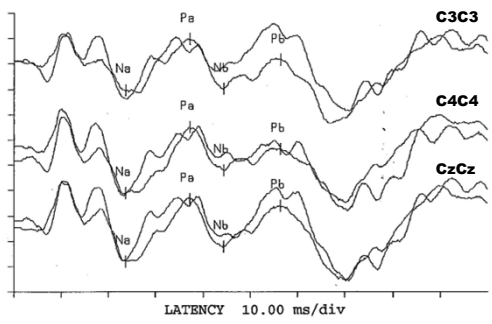
Post-Therapy Results



MLR RE – Post-Therapy



MLR LE – Post-Therapy



- Functional Report:
  - Significantly improved hearing-in-noise skills
  - Improved "comprehension" of friends' and others' communications – leading to "social/personal reorganization"
  - Significantly improved reading/spelling abilities within six months (rapid progress with treatment)
  - Note: Accommodations and central resources recommendations had not yet been implemented

Summary

- Dichotic Listening Therapy led to significantly improved binaural integration/separation and related "real-world" functioning
- Although not explicitly trained, auditory closure and reading/spelling skills improved, as well
- These improvements were reflected in electrophysiologic measures

Conclusions

- CAPD in school-aged children can cause or be associated with difficulties in language, learning, and related functions.
- Adolescents and adults with CAPD experience significant challenges in school/university and in the workplace
- CAPD can be diagnosed in older individuals using the same measures as for children
- Differential diagnosis and intervention for CAPD requires an individualized, holistic approach

- Treatment for CAPD can lead to improved or resolved auditory complaints along with improvements in other, related (but non-trained) skills
- It is never too late to diagnose and treat CAPD!

References

- AAA. (2010). Diagnosis, treatment, and management of children and adults with central auditory processing disorder. Available: http://www.audiology.org/resources/documentlibrary/Documents/CAPD%20Guidelines%208-2010.pdf
- ASHA.(2005). Position Statement and Technical Report on CAPD. Available: www.asha.org.
- Banai, K., Nicol, T., Zecker, S. G., & Kraus, N. (2005). Brainstem timing: Implications for cortical processing and literacy. *Journal of Neuroscience, 25*(43), 9850-9857.
- Bellis, T. J. (2003). *Assessment and management of central auditory processing disorders in the educational setting: From science to practice* (2nd ed.) Clifton Park, NY: Delmar Learning.
- Bellis TJ, & Wilber LA. (2001). Effects of aging and gender on interhemispheric function. *Journal of Speech Language Hearing Research,* (44), 246-263.

- Bellis, T.J., Billiet, C., & Ross, J. (2011). The utility of visual analogs of central auditory tests in the differential diagnosis of (central) auditory processing disorder and attention deficit hyperactivity disorder. *Journal of the American Academy of Audiology, 22,* 501-514.
- Bellis, T.J., Barker, M., & Johnson, M. (2015, November). The who, what, when, why, and how of dichotic listening training. *American Speech-Language-Hearing Association,* Denver, CO.
- Billiet, C. R., & Bellis, T. J. (2011). The relationship between brainstem temporal processing and performance on tests of central auditory function in children with reading disorders. *Journal of Speech, Language, and Hearing Research, 54,* 228-242.
- Cooper JC, & Gates GA. (1991) Hearing in the elderly – the Framingham cohort, 1983-1985. Part II. Prevalence of central auditory processing disorders. *Ear and Hearing,* (12), 304-311.