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CAPD: An Interdisciplinary Approach – Evidence-Based Management Approaches, in partnership with Salus University

Jennifer Gonzalez, Au.D., Ph.D., CCC-A

Jennifer Gonzalez, AuD, PhD

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Disclosures

- **Presenter Disclosure**: Financial: Jennifer Gonzalez is employed by the Mayo Clinic in Arizona and is an adjunct faculty member at Arizona State University and Salus University. She received an honorarium for presenting this course. Non-financial: Jennifer Gonzalez is a member of American Speech-Language-Hearing Association (ASHA). She holds the Certificate of Clinical Competence in Audiology (CCC-A) from ASHA, is a member of American Academy of Audiology (AAA), American Board of Audiology Certified (ABAC) from AAA, Member-at-Large, ASHA SIG 6 Coordinating Committee and an Editorial Board Member, ASHA Journals (American Journal of Audiology).
- **Content Disclosure**: This learning event does not focus exclusively on any specific product or service.
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Learning Outcomes

As a result of this course, participants will be able to:

- Describe how effective intervention strategies for CAPD exist and are documented in peer-reviewed literature.
- Describe how and why CAPD intervention strategies are effective.
- Explain how to determine which intervention strategies are most likely to be effective based on a patient's specific central auditory processing deficits and site of involvement.

CAPD:

- Clinical Case Review
- CAPD Management Basics
- Training Approaches: Deficit-Specific (Bottom-Up) & Strategy-Driven (Top-Down)
- Device-Based Intervention
- Accommodations

Clinical Case Review

Case Study

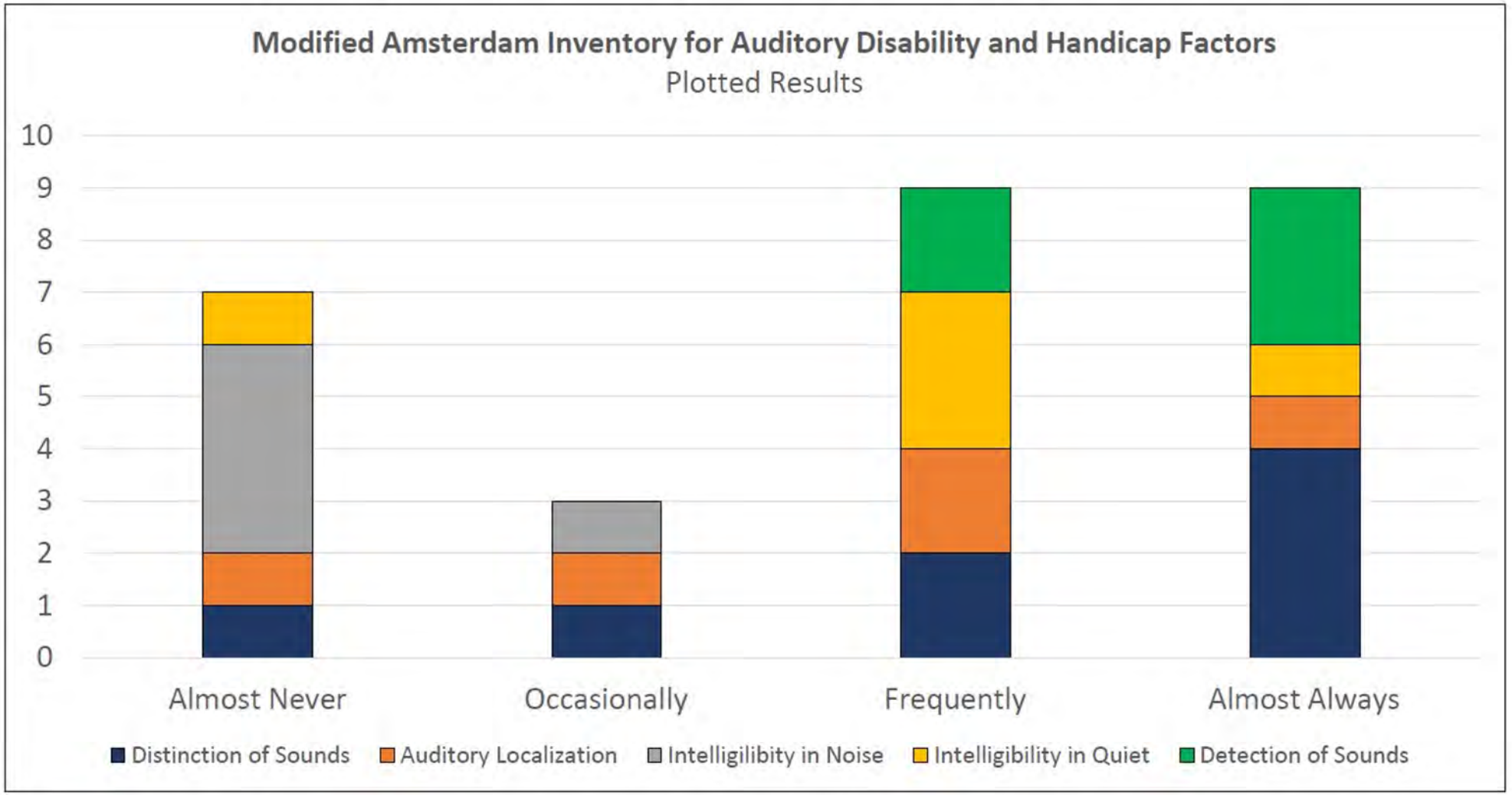
History

- 26 y.o female, right-handed
- Played flute throughout childhood, reportedly excelled at it
- At age 15 underwent surgery to remove large posterior fossa brain tumor (glial neuroma) and treat obstructive hydrocephalus via suboccipital craniotomy, external ventricular drain placement
- “Tumor was in superior vermis, extending down to the region just above the 4th ventricle, and anteriorly extended into the posterior 3rd ventricle. The tectum was very poorly seen on all the films, likely the result of longstanding distortion. The tumor extended superiorly to nearly level of the tentorium.”
- Resulted in CN III, IV, & VI palsies (oculomotor function); now unable to read music
- Graduated with Bachelor’s degree with honors

Case Study

Auditory Complaints

- Difficulty understanding speech in noise
- Unable to follow conversation in groups
- Must turn off radio in car to hear communication partner
- Sound sensitivity, unable to tolerate moderate stimuli such as washing machine, dryer
- When a room is too loud, she is unable to hear for a while after exiting the area
- Can easily become overstimulated from noise
- Experiences brain fatigue often

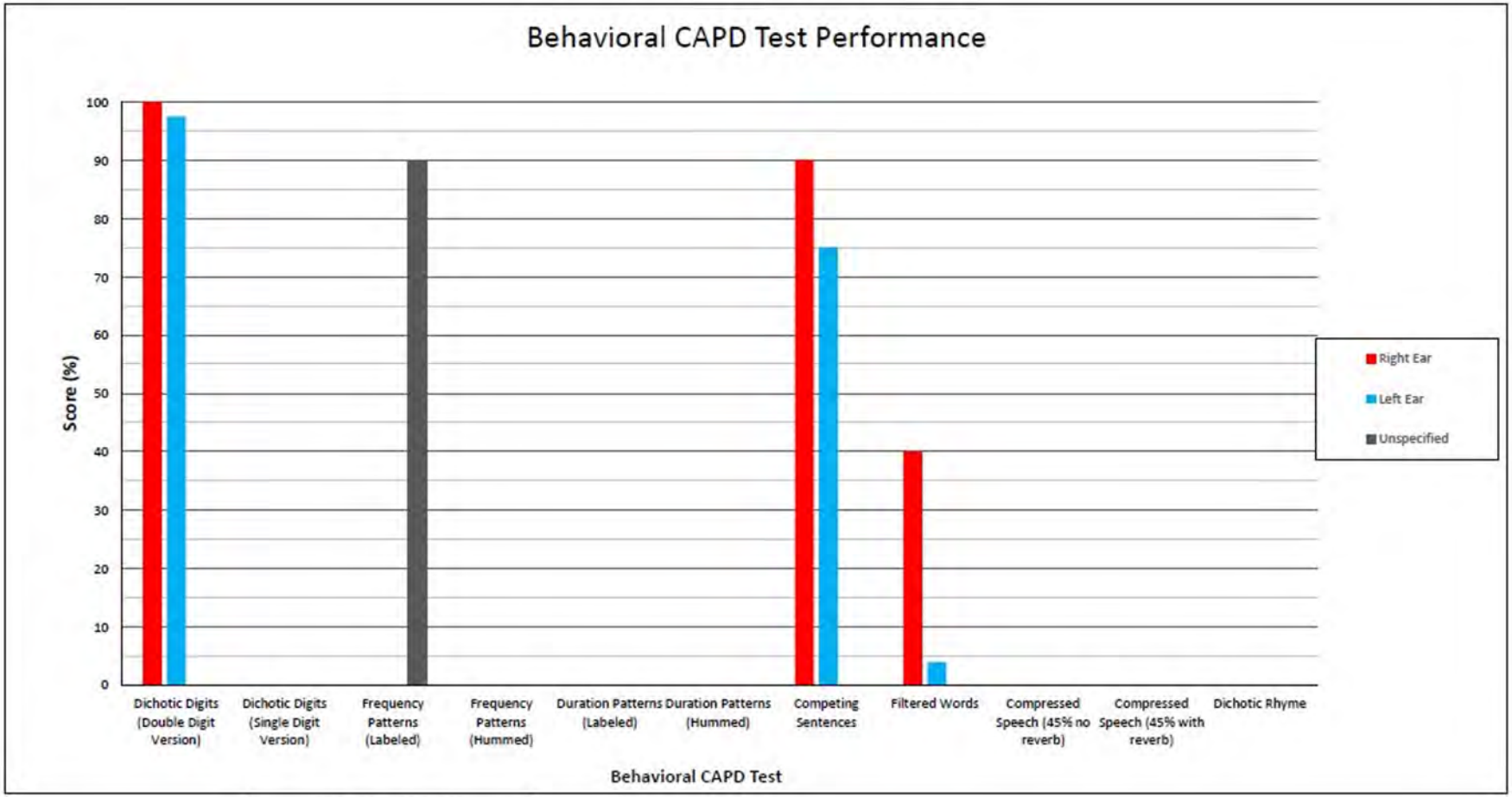

Modified Amsterdam Inventory for Auditory Disability and Handicap Factors
Plotted Results
10
9
8
7
6
5
4
3
2
1
0
Almost Never
Occasionally
Frequently
Almost Always
Distinction of Sounds
Auditory Localization
Intelligilibity in Noise
Intelligibility in Quiet
Detection of Sounds

CAPD Score Summary/Overview

Patient Name:
Age: 26 years

Test	Right Ear	Left Ear	Unspecified
Dichotic Digits (Double Digit Version)	100	97.5	
Dichotic Digits (Single Digit Version)			
Frequency Patterns (Labeled)			90
Frequency Patterns (Hummed)			
Duration Patterns (Labeled)			
Duration Patterns (Hummed)			
Competing Sentences	90	75	
Filtered Words	40	4	
Compressed Speech (45% no reverb)			
Compressed Speech (45% with reverb)			
Dichotic Rhyme			

MLD			CNT
GIN A.Th	CNT	CNT	
GIN Total % Score	CNT	CNT	



OTHER MEASURES			
MLD	CNT		
GIN A.Th RE	CNT		
GIN % RE (Age 12+)	CNT	GIN % RE (Below Age 12)	
GIN A.Th LE	CNT		
GIN % LE (AGE 12+)	CNT	GIN % LE (Below Age 12)	

Results Compared to 11+ Year Norms

Test	Right Ear	Left Ear	Unspecified Ear
Dichotic Digits (Double Digit Version)	WNL	WNL	
Dichotic Digits (Single Digit Version)			
Frequency Patterns (Labeled)			WNL
Frequency Patterns (Hummed)			
Duration Patterns (Labeled)			
Duration Patterns (Hummed)			
Competing Sentences	WNL	Abnormal	
Filtered Words	Abnormal	Abnormal	
Compressed Speech (45% no reverb)			
Compressed Speech (45% with reverb)			
Dichotic Rhyme			

MLD			CNT
GIN A.Th	CNT	CNT	
GIN Total % Score	CNT	CNT	

If Under 12 Years	Right Ear	Left Ear
GIN Total % Score		
Comp. Speech		
Comp. Speech reverb		

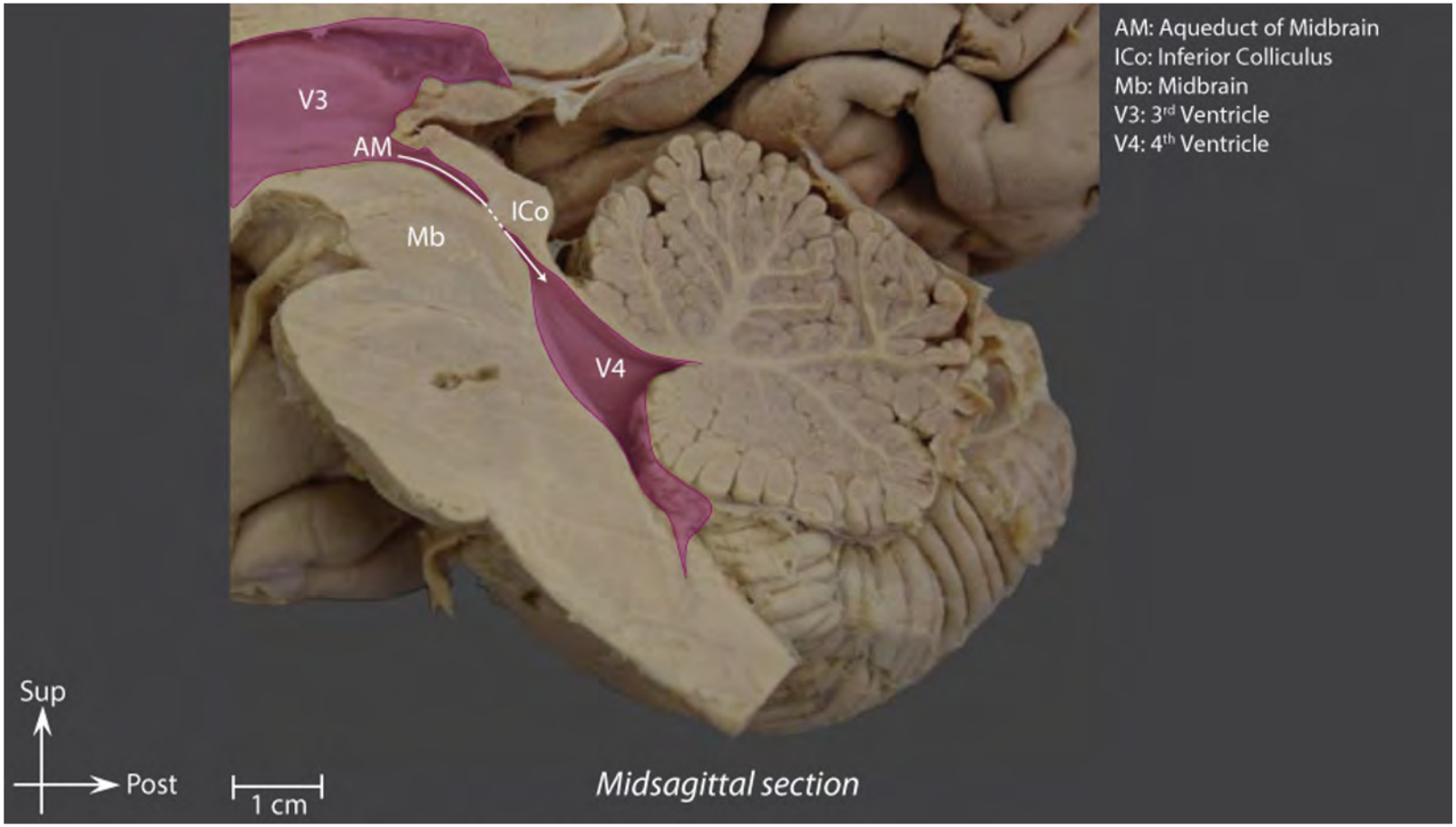
LiSN-S

Condition/Measurement	Client's score (dB SNR)	Standard Error (adj)	Average Score for Age (dB SNR)	Num StdDev from average	Percentile Rank	Normal Limits
Different Voices 90° (High Cue SRT)	0.5	1.3	-14.9	-7.4	0%	Outside
Same voice 0° (Low Cue SRT)	4.1	0.98	-1.6	-6.0	0%	Outside
Talker Advantage	3.2	1.36	9.1	-2.7	0%	Outside
Spatial Advantage	1.4	1.35	12.0	-6.4	0%	Outside
Total Advantage	3.6	1.63	13.3	-5.0	0%	Outside

Pattern of results: This pattern of results is consistent with the presence of a spatial processing disorder (SPD).

ABR Results

- Results with left ear stimulation WNL
- Right ear stimulation
  - Poor morphology
  - Extended Wave IV & V latencies
  - Extended III-V interwave interval
  - Abnormal Wave V interaural latency difference (right delayed)
- Combined with behavioral results



Patient-Centered Interpretation

Abnormal Auditory Spatial Processing

- Difficulty understanding speech in environments with different sound source locations and noise qualities
- Unease in large, complex spatial sound environments
- Spatial disorientation, agitation, and even dizziness in spatial sound environments

Abnormal Binaural Separation

- Difficulty directing/focusing attention to one ear and suppressing/inhibiting extraneous messages/sound/noise in the other ear
- Patient may only be able to use one ear on the phone or have difficulty using the phone monaurally in noisy environments
- Patient may express that they favor one ear over the other despite having symmetrical hearing sensitivity
- Patient may report “muffled” hearing in one ear compared to the other ear despite having symmetrical hearing sensitivity

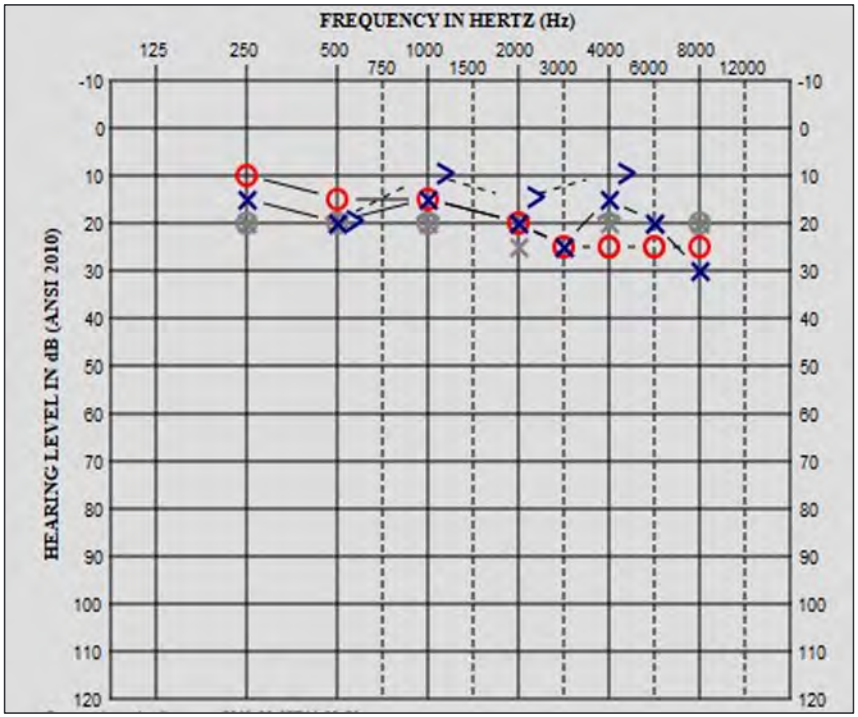
Abnormal Auditory Closure

- Difficulty learning new topics/lessons/skills in a classroom, meeting, or large group setting ***without accommodations***

Likely Abnormal Temporal Resolution (re: ABR findings)

- Patient reports that people talk too fast
- Speech in the patient’s native language sounds like a different language, “jumbled,” or “like Charlie Brown’s teacher”
- Misunderstandings and increased requests for repetition
- Difficulty hearing breaks between words/phrases/sentences
- Difficulty following the rhythm of speech and music
- Difficulty learning a foreign language
- Taking longer to process speech; delayed responses, taking longer to answer questions

All with a normal audiogram



CAPD Management Basics

CAPD Management

The Basics

- Central auditory processing disorder (CAPD; ICD-10: H93.25) is a primarily auditory-driven disorder of the central auditory nervous system (CANS) – evaluation & diagnosis must be made by an audiologist who is trained and knowledgeable re: CAPD
- Challenges with perceptual processing of auditory information not due to peripheral auditory disorder nor higher-order cognitive and/or language disorder
- Hallmark complaint: Difficulty hearing, understanding speech, especially in noise
- Sources of CAPD
  - Neuromaturational lag/delay
  - Neuroanatomical anomalies (not frank)
  - Neurological disorders
  - Acquired
- What about “abnormal auditory perception, bilateral” (ICD-10: H93.293)?

CAPD Management

The Basics

- Central auditory processing skills
  - Dichotic listening (binaural integration, binaural separation)
  - Temporal processing (temporal resolution, temporal ordering/sequencing)
  - Sound localization/lateralization (binaural interaction, auditory spatial processing)
  - Monaural low-redundancy speech (auditory closure)

- It is not enough to apply the diagnosis, when appropriate – **areas of weakness** should be clearly observed in evaluation results and described in the resulting report

- Development of a **successful** treatment plan hinges on proper determination of areas of weakness as well as areas of strength

Why Do We Provide Intervention?

"It is our job as pediatric audiologists to identify and remediate any auditory issues that might interfere with sufficient auditory access for brain development. When we identify a hearing loss, we work to correct acuity to as close to typical hearing as possible. If we can identify an APD, then we should also agree that it is our job to correct that auditory process to as close to typical as possible to give that child the best chance of successfully listening, learning, and communicating."

(Moncrieff, 2017)

Why Do We Provide Intervention?

"…a failure to first improve auditory access may significantly impair outcomes from the cognitive and language interventions, just as a failure to appropriately address amplification requirements in a child with hearing loss would seriously limit speech and language development even with interventions."

(Moncrieff, 2017)

Why Do We Provide Intervention?

*"CAPD may be diagnosed at any point in the life-span; may occur secondary to neurological disease, insult, or injury; or may be of unknown etiology. Although a large focus of CAPD service provision has been on children, it should be recognized that CAPD also occurs in adults. If has been estimated that the prevalence of CAPD in the school-aged population is approximately **2% to 5%,** whereas prevalence in the older adult population may be as high as **76%**."*

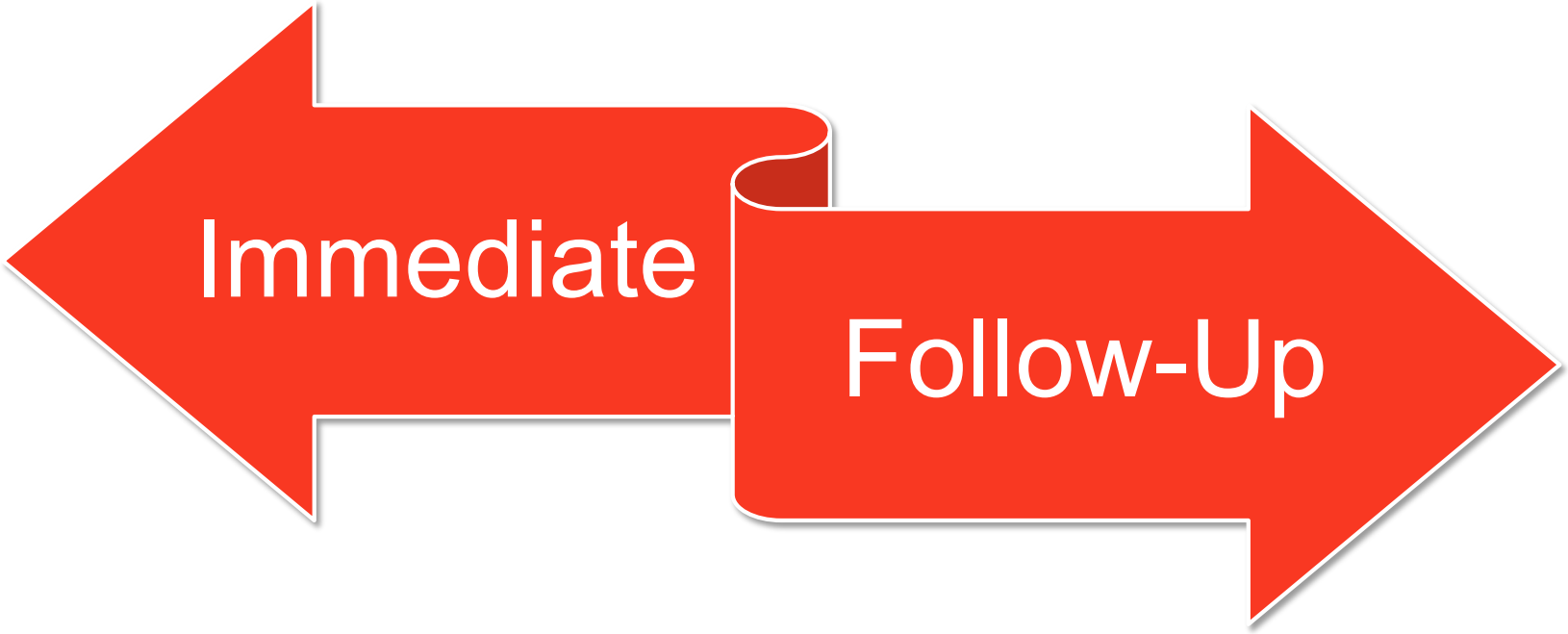
(Bellis & Anzalone, 2008)

Why Do We Provide Intervention?

"In regard to management, Whitelaw exposed the myth that since there is no cure for CAPD in adults, there is no value in assessing their CAP skills or in providing adults with management. Whitelaw further highlights that the auditory system remains plastic for a long period of time and that offering intervention to adults with CAPD is viable. While numerous child-focused management approaches have been developed, only few have been trialed on adults, despite the notion that most people with CAPD will potentially live with these disorders throughout their lives."

[Heine & Sloane, 2019; referring to Whitelaw (2008) article titled, "Auditory processing in adults: Beyond the audiogram."]

Consultation/Counseling Models



Post-Evaluation

Consultation/Counseling

- Go into appointment with at least two (2) copies of report
- Ask parent(s) or patient (if an older child or adult) whether they received the report and if they have any questions about the content
- Review tests performed, what they assess (give “real world” examples), results, & explain your interpretation
- Review recommendations
- Demo devices (if possible)
- Check for understanding throughout!

FOCUSES OF CAPD MANAGEMENT

Patient-Centered Interpretation

Binaural Interaction

- Difficulty telling where sound is coming from
- Difficulty detecting sound in spatial environments
- Patient feels “bombarded” by noise due to reduced binaural squelch
- Lower than expected benefit from binaural amplification due to binaural interference
- Patient may have challenges acclimatizing to hearing aids for managing binaural peripheral hearing loss

Binaural Integration

- Difficulty hearing and understanding multiple verbal messages at once (e.g., in classroom, during meetings/lectures, etc.)
- Patient may express that they favor one ear over the other despite having symmetrical hearing sensitivity
- Patient may report “muffled” hearing in one ear compared to the other ear despite having symmetrical hearing sensitivity

Binaural Separation

- Difficulty directing/focusing attention to one ear and suppressing/inhibiting extraneous messages/sound/noise in the other ear
- Patient may only be able to use one ear on the phone or have difficulty using the phone monaurally in noisy environments
- Patient may express that they favor one ear over the other despite having symmetrical hearing sensitivity
- Patient may report “muffled” hearing in one ear compared to the other ear despite having symmetrical hearing sensitivity

Patient-Centered Interpretation

Temporal Resolution

- Patient reports that people talk too fast
- Speech in the patient's native language sounds like a different language, "jumbled," or "like Charlie Brown's teacher"
- Misunderstandings and increased requests for repetition
- Difficulty hearing breaks between words/phrases/sentences
- Difficulty following the rhythm of speech and music
- Difficulty learning a foreign language
- Taking longer to process speech; delayed responses, taking longer to answer questions

Temporal Ordering/Sequencing

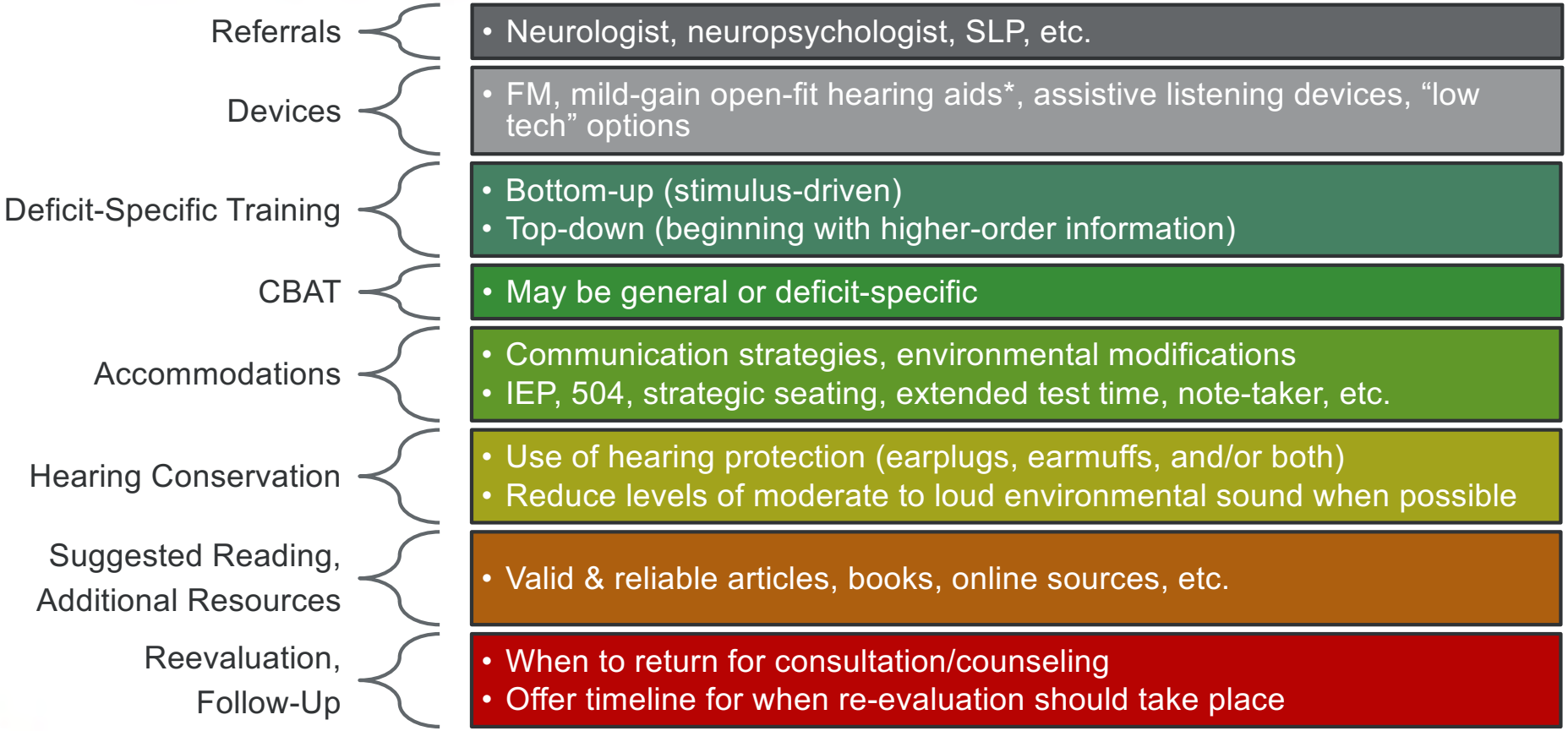
- Difficulties may vary depending on site of involvement
- Right hemisphere: Challenges hearing the difference between 2+ sounds that are similar but different; difficulty "reading between the lines" for interpretation of sarcasm or jokes; lack of interest/enjoyment of music; challenges learning how to play an instrument; "flat" or monotone speech; difficulty perceiving emotion conveyed by voice/rhythm/intonation, suprasegmentals of speech
- Left hemisphere, interhemispheric transfer: Transposition or reversals of phonemes in words; misinterpretations of questions vs. statements; replacement of one phoneme for another that is similar in formant structure

Auditory Spatial Processing

- Difficulty understanding speech in environments with different sound source locations and noise qualities
- Unease in large, complex spatial sound environments
- Spatial disorientation, agitation, and even dizziness in spatial sound environments – does patient have history of head injury?

Auditory Closure

- Difficulty learning new topics/lessons/skills in a classroom, meeting, or large group setting without accommodations
- May also occur in patients with peripheral hearing loss and/or higher-order cognitive and/or language disorder


Referrals
• Neurologist, neuropsychologist, SLP, etc.
Devices
• FM, mild-gain open-fit hearing aids*, assistive listening devices, “low tech” options
Deficit-Specific Training
• Bottom-up (stimulus-driven)
• Top-down (beginning with higher-order information)
CBAT
• May be general or deficit-specific
Accommodations
• Communication strategies, environmental modifications
• IEP, 504, strategic seating, extended test time, note-taker, etc.
Hearing Conservation
• Use of hearing protection (earplugs, earmuffs, and/or both)
• Reduce levels of moderate to loud environmental sound when possible
Suggested Reading, Additional Resources
• Valid & reliable articles, books, online sources, etc.
Reevaluation, Follow-Up
• When to return for consultation/counseling
• Offer timeline for when re-evaluation should take place

CAPD Management

The Basics

- Successful CAPD treatment plans incorporate (AAA, ASHA):
  - Communication strategies & environmental modifications (accommodations)
  - Assistive listening devices (ALDs)
  - **Development of compensatory & metacognitive strategies** ("top-down" approaches)
  - Delivery of necessary services for comorbid conditions
  - **Auditory training** ("bottom-up" approaches)

- If auditory training does not target specific deficits, area of weakness will not be effectively remediated (Cameron, Glyde, & Dillon, 2012) – consequences?

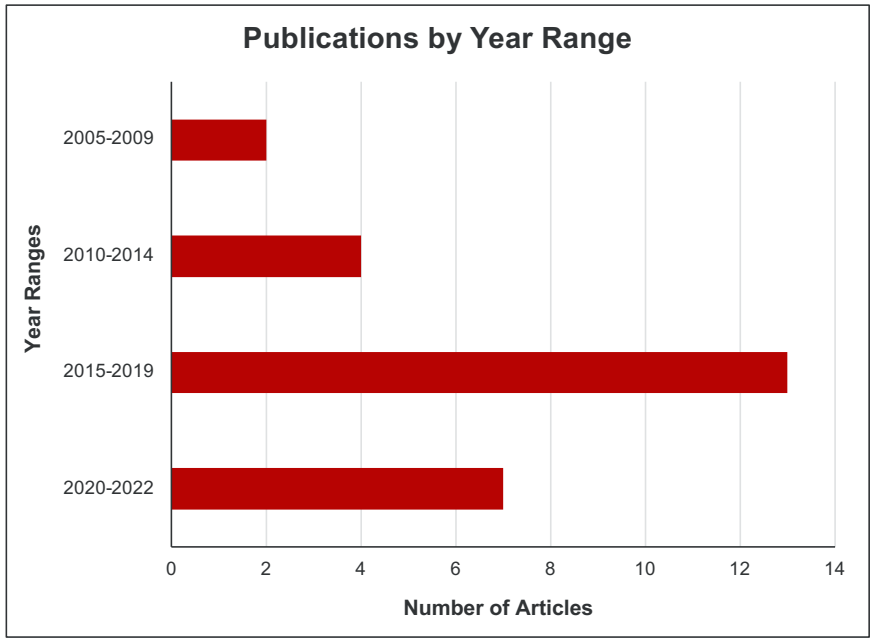
- The case for deficit-specific intervention…

The Literature

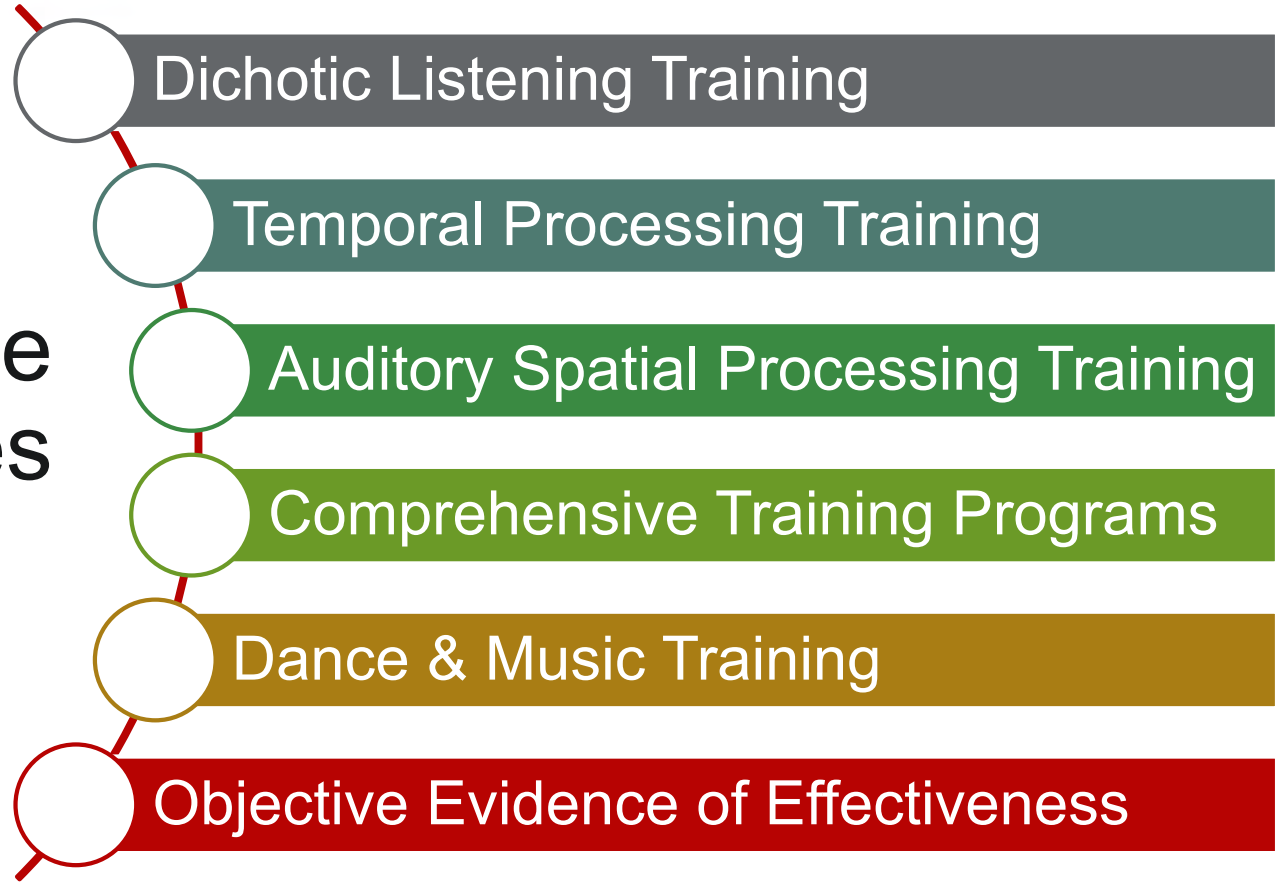
At a Glance

- Search keywords:

  “auditory processing training”
- Excluded articles focused on psychological disorder, peripheral hearing loss, amplification, foreign language acquisition
- Number of peer-reviewed articles: **26**
- Year range of publication: **2006-2022**



Article Themes



Training Approaches

Deficit-Specific (Bottom-Up) & Strategy-Driven (Top-Down)

Top-Down Approaches

Metacognitive Strategies

- Self-instruction & step-by-step reauditorization
- Self-regulation & problem solving (anticipation, problem-solving planning, self-reflection such as journaling)
- Metamemory strategies (mnemonic techniques like chunking & elaboration)
- Recoding the information into a pictorial representation (auditory memory enhancement, or AME)
- Set steps of a task to music or motion

Linguistic & metalinguistic strategies

- Training in the rules of language
- Recognizing & interpreting discourse cohesion devices
- Content (or contextual) schemata

Bottom-Up Strategies

Also known as "deficit-specific training," "direct therapy techniques," or "direct skills remediation"

Effective techniques are those that…

- Are frequent, intense, challenging
- Require active engagement & participation on the part of listeners
- Target the specific auditory deficit(s) present

"Teaching of deficit-specific compensatory skills that focus on the use of these fundamental auditory processes in spoken language comprehension will help to bridge the gap between bottom-up and top-down processing levels and enhance generalization of skills learned to real-world listening environments."

(Bellis, 2011)

Direct Skills Remediation

Direct skills remediation (e.g., auditory training; sometimes referred to as "bottom-up" or "traditional listening treatments") includes procedures to target multiple skills associated with auditory processing (Bellis, 2002, 2003; Chermak & Musiek, 2002; cf. British Society of Audiology [BSA], 2011).

Direct skills remediation may address the following:

- **Auditory discrimination**—training to distinguish the intensity, frequency, and duration of one sound from another
- **Phoneme discrimination**—training to distinguish between speech sounds that make a difference in meaning in a particular language (e.g., /p/ vs. /b/ in English) and phoneme-grapheme skills (written representation of phonemes)
- **Temporal aspects of audition**—training to perceive acoustic signals over time, including
  - temporal integration;
  - temporal gap discrimination; and
  - temporal ordering or sequencing.
- **Auditory pattern recognition**—training to distinguish similarities and differences in sound patterns
- **Sound localization and lateralization**—training to identify the location, origin, direction, and distance of a sound reaching each ear
- **Recognition of auditory information presented within a background of noise or competition (i.e., binaural separation)**—dichotic listening training or speech-in-noise training
- **Recognition of disparate auditory stimuli presented to each ear simultaneously (i.e., binaural integration)**—binaural interaction training (Bamiou, Campbell, & Sirimanna, 2006; Bellis, 2003; Bellis & Anzalone, 2008)

Consideration of formal vs. informal methods

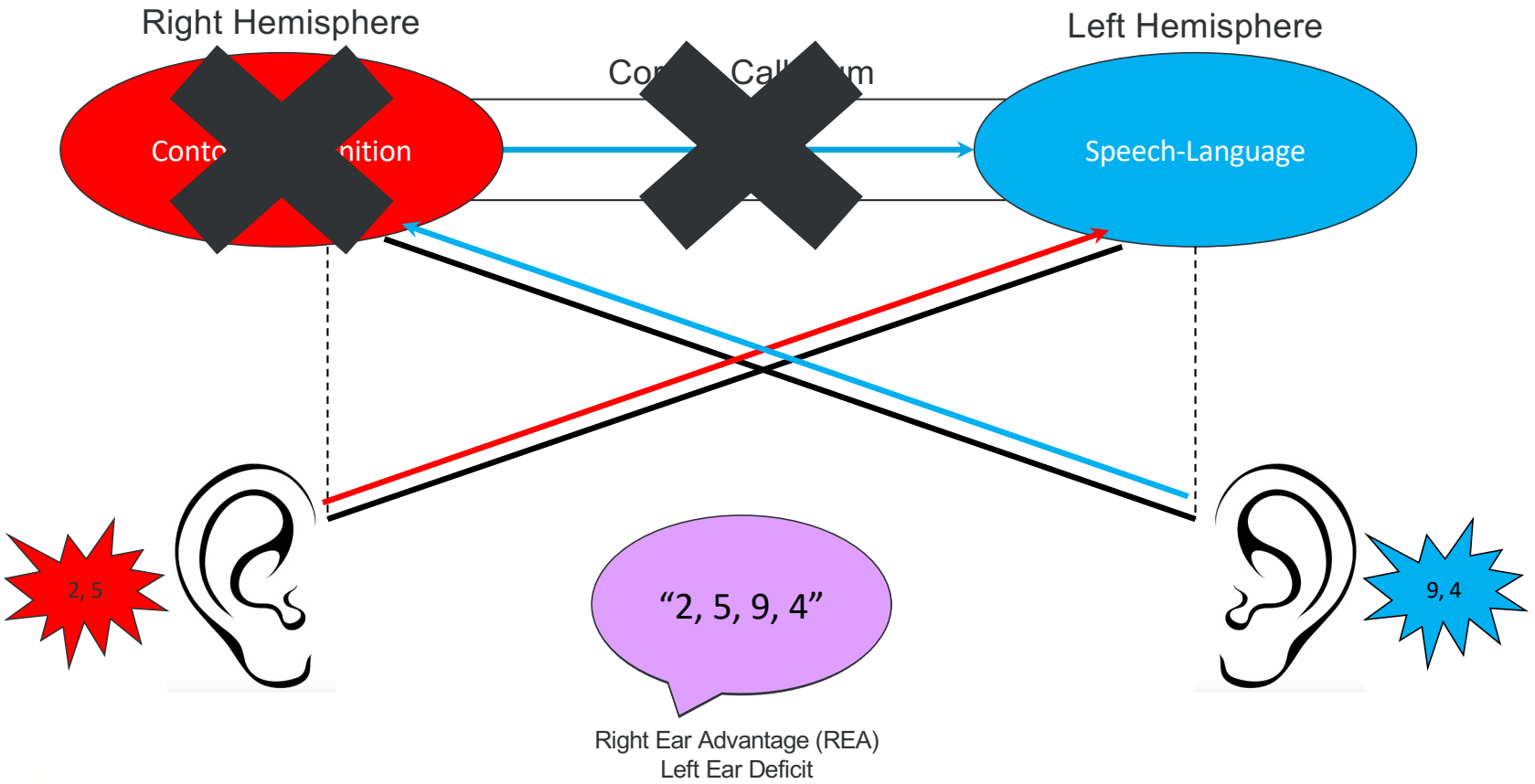
ASHA CAPD Practice Portal

Dichotic Listening Training

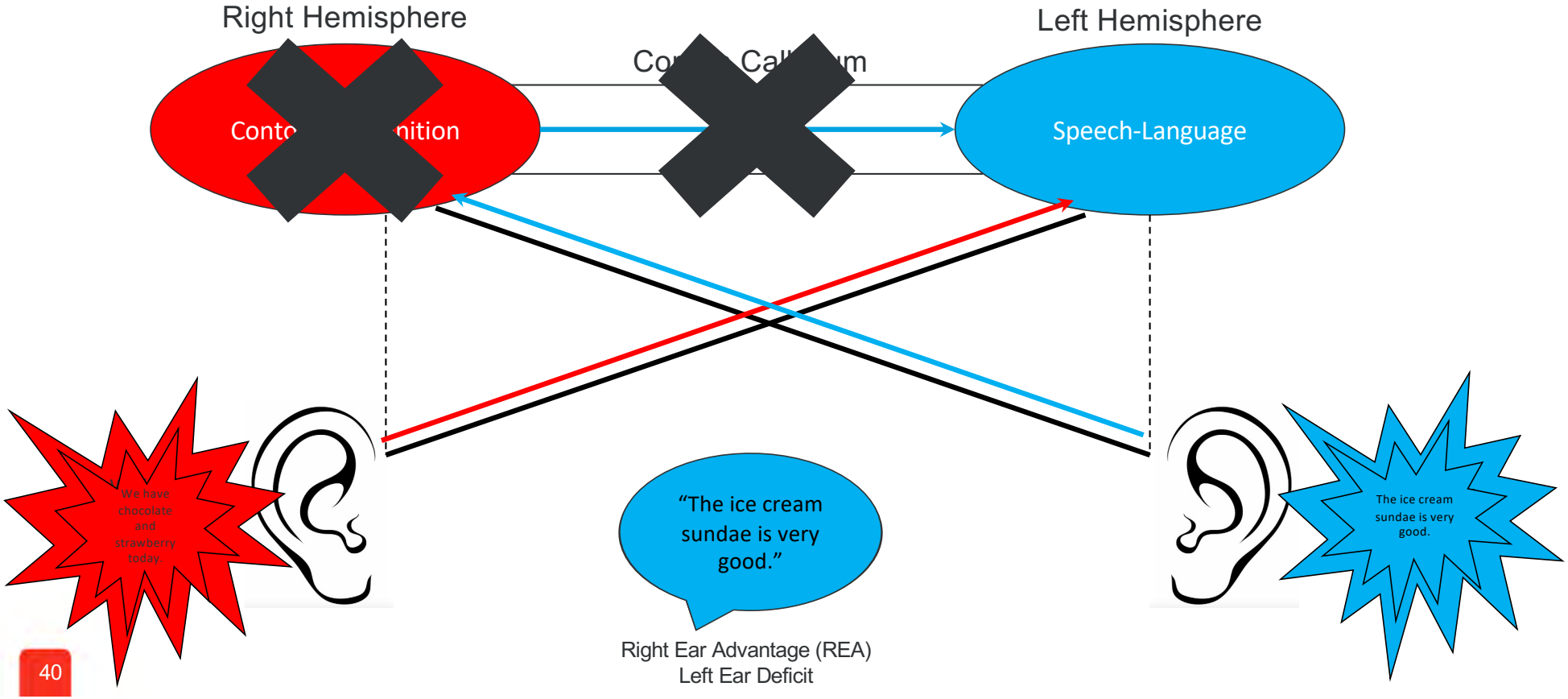
List of Articles

- Baran, Shinn, & Musiek (2006)
- Delphi & Abdollahi (2018)
- McCullagh & Palmer (2017)
- Osisanya & Adewunmi (2018)
- Purdy & McCullagh (2020)
- Tallus, Soveri, Hämäläinen, Tuomainen, & Laine (2015)

Binaural Integration Dichotic Digits Test



Binaural Separation Competing Sentences Test



Dichotic Interaural Intensity Difference (DIID)

Q1

- Training for patients who have deficits in binaural integration and/or binaural separation skills
- Establishment of the DIID Crossover Point – intensity of the stronger ear is decreased until the point at which the weaker ear performs better than the stronger ear
- 2 conditions necessary for DIID use
  1. Performance in poorer ear must be at normal or near normal limits at crossover level
  2. Intensity of stimulus presented to the better ear must not drop below hearing threshold

DIID Crossover & Training

70%	95%		40%	85%
85%	85%		55%	85%
90%	75%		70%	85%
95%	65%	Training Complete!	85%	85%

Delphi & Abdollahi (2018)

DIID Procedure

- Initial training began with interaural intensity difference (IID) of 5 dB greater than crossover point
- Level of weaker ear kept at 50 dB HL presentation level
- Tasks materials used:
  - Dichotic CVs
  - Dichotic sentences
  - Dichotic story in music background
- Response task:
  - Free recall
  - Directed recall

Delphi & Abdollahi (2018)

DIID Training Details

- 4 sessions per week – 30 minutes each session – DDT administered at end of each session
- If performance in weaker ear was ≥80%
  - Training continued at that specific IID for the entire week
- If performance in weaker ear was ≤80%
  - IID was increased in 1 dB increments until performance of weaker ear reached 80% or until IID level returned to starting level
- GOAL = improve performance to normal limits (i.e., only a 10% interaural asymmetry)
- Training stopped; DDT administered 2 weeks later to make sure outcome permanent

Q2

Dichotic Offset Training (DOT)

- Also known as “DIID II”
- Improves weaker ear performance by manipulating interaural timing differences
- Weaker ear stimulus arrives slightly later in time than better ear stimulus
- Weaker ear obtains a dichotic processing advantage – “lag effect”
- As patient improves over time, lag is decreased to make task more challenging

DOT/DIID II Training

90%

Training Complete!

80%

Delphi & Abdollahi (2018)

- 6 cases underwent DIID training
  - REAs of 50-60% at start of training
  - Improvements to scores WNL with 10% REAs in 12-14 sessions
  - 4 sessions per week → weeks of training 3 ½ weeks of training

- 6 cases underwent DOT training
  - REAs of 50-60% at start of training
  - Improvements to scores WNL with 10% REAs in 20-22 sessions
  - 4 sessions per week → 5 ½ weeks of training

Dichotic Listening Training Programs

- Constraint-Induced Auditory Therapy (CIAT®; Auditec)
  - https://auditec.com/2015/08/04/ciat-demonstration/
- Central Auditory Processing Disorder Online Training Software (CAPDOTS)
- Auditory Rehabilitation for Interaural Asymmetry (ARIA)
- Use of dichotic test materials through audiometer in controlled environment

Dichotic Interaural Intensity Difference Training (DIID) app

Frank E. Musiek, Gail D. Chermak, Jeffrey Weihing

Details: Apple App

https://www.pluralpublishing.com/publications/dichotic-interaural-intensity-difference-training-diid

Dichotic Listening Training

Summary of Binaural Separation/Integration Activities
Dichotic Listening Training (Dichotic Interaural Intensity Difference, or DIID, training; Weihing & Musiek, 2013)
Establish beginning target-to-competition ratio (crossover point)
Reduce target-to-competition ratio over time
Readjust target-to-competition ratio as needed
Localization training (including Dichotic Offset Training, or DOT, training; Delphi & Abdollahi, 2018)
Sound room activities with speakers at various horizontal and vertical planes
Children's games like "Blind Man's Bluff" and "Marco Polo"

Formal DIID & DOT administration in-clinic is recommended

Bellis (2011)

Temporal Processing Training

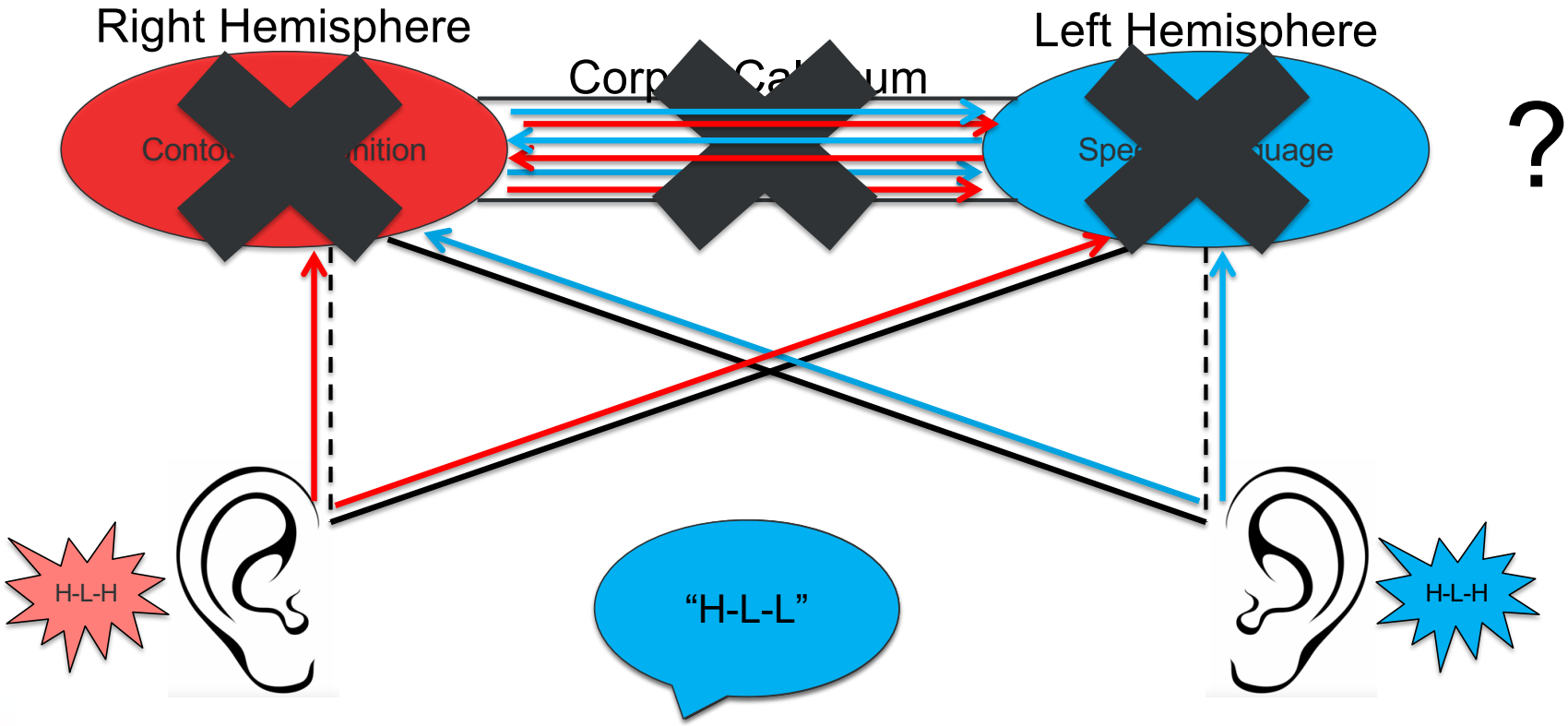
Including Music & Dance

List of Articles

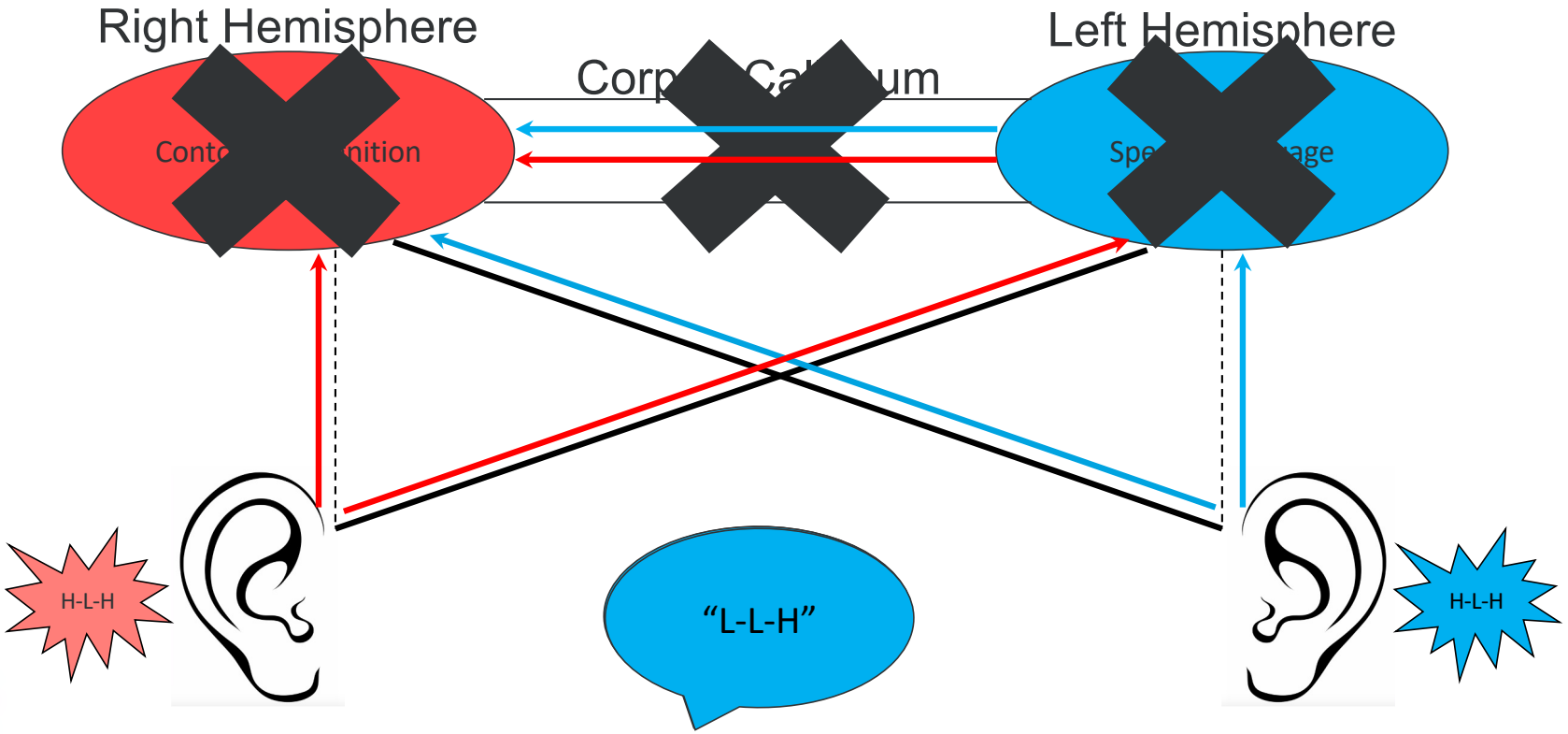
- Elangovan, Payne, Smurzynski, & Fagelson (2016)
- Giacosa, Karpati, Foster, Penhune, & Hyde (2016)
- Jantzen, Howe, & Jantzen (2014)
- Neves, Correia, Castro, Martins, & Lima (2022)
- Schneider et al. (2022)
- Skoe, Scarpati, & McVeety (2021)

Temporal Ordering/Sequencing

Labeling Response Task



Temporal Ordering/Sequencing Humming Response Task



Adapted from Musiek & Chermak (2014)

Article	Main Findings
Elangovan et al. (2016)	Musicians have shorter between-channel gap detection thresholds & sharper phonetic identification functions
Giacosa et al. (2016)	Dance training vs. music training effects on white matter structures in brain (diffusion tensor imaging) Dancers have increased diffusivity & reduced fiber coherence in WM structures (corticospinal tract, superior longitudinal fasciculus, corpus callosum) – musicians had decreased diffusivity & greater coherence **Dance training – which is "whole-body" – may result in greater fanning of fibers connecting different brain regions, an increase in crossing fibers, or larger axon diameter.**
Jantzen et al. (2014)	Musicians demonstrated greater activation of right middle temporal gyrus and superior temporal gyrus compared to non-musician controls when processing speech sounds.
Neves et al. (2022)	Systematic review & meta-analysis of 62 longitudinal studies on music training programs. Provides evidence beyond correlational relationship between music training and temporal processing benefits. **Found that music training produces neurobehavioral enhancements in auditory & linguistic processing.**
Schneider et al. (2022)	Active music listening training produces bilateral, but more pronounced plastic changes in right auditory cortex.
Skoe et al. (2021)	Compared to untrained controls, novice dancers who have trained continuously since childhood had enhanced temporal resolution (gap detection).

Music vs. Dance Training

Temporal processing Benefits dependent upon site of involvement?

- The literature suggests that this *may* be the case
- Dance training/therapy may be most useful for:
  - Left hemisphere, right hemisphere, and/or corpus callosum involvement
- Music training/therapy may be most useful for:
  - Right hemisphere involvement

Temporal Processing Training

Summary of Temporal Ordering/Sequencing Activities
Prosody Training
Words & sentences in which change in stress alters meaning (e.g., con*vict* vs. *con*vict, “he saw the snow drift by the window” vs. “he saw the snowdrift by the window”); reading aloud with exaggerated prosodic features; key word extraction; role playing/charades games focusing on prosodic & nonverbal expression of emotion
Basic Temporal Patterning Training
Same/different judgments of nonspeech or speech patterns differing in pitch, stress, loudness, interstimulus interval
Imitation of nonspeech or speech patterns differing in pitch, stress, loudness, interstimulus interval
Identification of stressed words within sentences (or stressed elements within a nonspeech pattern)

May be delivered in-clinic (formally), by SLP, and/or informally

Bellis (2011)

Temporal Processing Training

Summary of Auditory Discrimination & Temporal Processing Activities
Nonspeech Discrimination Activities
Duration/frequency/intensity difference limens; discrimination of tonal glides; temporal gap detection; flutter fusion; backward masking; two-tone ordering
Phoneme Discrimination & Speech-to-Print Skills
Minimal contrast pairs discrimination – consonants or vowels, live-voice; computer-assisted acoustically modified speech-sound discrimination; phonological awareness activities (sound blending, segmentation, manipulation); sound-symbol association

May be delivered in-clinic (formally) and/or by SLP

Bellis (2011)

Interhemispheric Transfer Training

Selected Interhemispheric Transfer Activities
"Grab bag" verbal-to-motor transfers
"Grab bag" motor-to-verbal transfers
Music Lessons
Listening to Songs & Answering Questions About Lyrics
Video Games Requiring Auditory/Visual Integration & Bimanual Coordination
Sports, Games, Dance Activities Requiring Bipedal and/or Bimanual Coordination

More likely to be delivered informally

Bellis (2011)

Auditory Spatial Processing

List of Articles

- Cameron, Glyde, & Dillon (2012)
- Lofti et al. (2016)
- Lofti et al. (2019)
- Mealings & Harkus (2020)
- Nisha & Kumar (2017)
- Osisanya & Adewunmi (2018)

Article	Main Findings
Cameron, Glyde, & Dillon (2012)	**LiSN & Learn (now Sound Storm) training led to significant improvements in spatial processing and speech-in-noise skills**, while non-deficit-specific training (via Earobics) did not lead to improvements in spatial processing and speech-in-noise skills.
Lofti et al. (2016)	Detection and pointing to sound sources delivered with interaural time differences, under headphones for 12 formal sessions over 6 weeks. **Lateralization training led to improvements on monaural selective auditory attention test (mSAAT) and in spatial word recognition scores in noise.**
Lofti et al. (2019)	12 formal sessions of lateralization training (under headphones using ITDs, performed as a game) led to **latency decreases on MLR binaural interaction component (BIC), significant increases in BIC amplitude, and significant increases in mSAAT score.**
Mealings & Harkus (2020)	Training for spatial processing disorder (SPD) via Sound Storm (formerly LiSN & Learn). 15 Australian Aboriginal & Torres Strait Islander children initiated the study, 8 completed at least 40% of training. Of that group, SPD remediated in 7 children according to LiSN-S.
Nisha & Kumar (2017)	Participants underwent virtual acoustic space (VAS) training – 5-8 sessions, 20 mins each. Changes in spatial performance measured via behavioral spatial acuity measures and electrophysiological measures (P300). **Post-training ITD thresholds significantly better compared to pre-training ITD thresholds.** No changes in ILD thresholds and P300 amplitude and latency.
Osisanya & Adewunmi (2018)	Randomized controlled trial (RCT) of intervention – investigated effectiveness of dichotic listening training (DLT) alone, compensatory strategies (CS) alone, and combined approaches (CT) on the cocktail party effect and sound localization ability. While CT led to greatest benefits in background noise and sound localization, DLT alone led to better sound localization ability compared to CS. **Dichotic listening training can improve sound localization skills.**

Comprehensive Training

List of Articles

- Schochat, Musiek, Alonso, & Ogata (2010)
- Tawfik, Hassan, & Mesallamy (2015)

Schochat, Musiek, Alonso, & Ogata (2010)

Effect of auditory training on the MLR in children with (central) auditory processing disorder

- Experimental (CAPD) group: 30 children aged 8-14 years
- Control group: 22 children aged 8-14 years (without CAPD)
- Pre- and post-intervention MLR measurements
- Intervention
  - 8 weeks
  - 1 formal session per week, 50 minutes each
  - Informal training with parents at home, 15 minutes daily

Schochat et al. (2010)

Training procedures

Formal training

- Temporal training tasks
  - Frequency training (2- and 3-tone pitch discrimination & labeling)
  - Intensity training (2- and 3-tone intensity discrimination & labeling)
  - Temporal training (2- and 3-tone duration discrimination & labeling; gap detection training)
- DIID training
- Localization & speech perception

Schochat et al. (2010)

Training procedures

Informal training

- Storytime – subject listened to a story and raised hand every time one target word was heard (*auditory attention*)
- Listen to a story and sketch the paragraph; recount the story based on drawings after completing 4-5 sketches (*auditory memory enhancement*)
- Select a topic (e.g., fruit, clothes, animals, etc.) and subject was asked to add a word; take turns while adding more words (*auditory memory span*)
- Listen to songs and repeat lyrics

Schochat et al. (2010)

- Training significantly improved behavioral test scores in the CAPD experimental group
  - PSI (70.8% → 82.2%)
  - Speech-in-noise (72.9% → 86%)
  - Non-verbal dichotic (71.9% → 93.2%)
  - SSW/Digits (63.5% → 78%)

- Training significantly changed MLR amplitudes measured at C3 electrode site

Tawfik, Hassan, & Mesallamy (2015)

Evaluation of long-term outcome of auditory training programs in children with auditory processing disorders

Training program:

- Bottom-up approach
  - Temporal processing
  - Selective auditory attention
  - Dichotic listening
  - Inter-hemispheric transfer of information
  - Auditory closure
- Top-down approach
  - Auditory vigilance
  - Auditory memory
  - Phonological awareness
  - Language comprehension

Tawfik, Hassan, & Mesallamy (2015)

- Behavioral testing after 7-42 months post-training demonstrated significant improvements
  - DDT (single digits) – right and left ears
  - DDT (double digits) – right and left ears
  - PPS
  - GIN (A.Th)

- Also demonstrated improvements in strategy-driven skills
  - Recognition memory
  - Memory for content
  - Memory for sequence

Auditory Closure Training

Summary of Auditory Closure Activities
Missing Word Exercises
Familiar songs/rhymes; prediction of rhyming words; new, unfamiliar messages in which context is used to fill in the missing word
Missing Syllable Exercises
Sentences with embedded target word; single words
Missing Phoneme Exercises
Sentences with embedded target word; single words
Repeating Above Activities in Noisy/Distracting Situations
Vocabulary Building
Reauditorization; contextual derivation of word meaning; immediate provision of definition; reinforcement of definition

More likely to be delivered by SLP and/or informally

Bellis (2011)

Possibilities for in-booth (formal) training

Focuses on bottom-up (stimulus-driven) strategies

- Dichotic Interaural Intensity Difference (DIID) Training – Various materials available, including **Constraint-Induced Auditory Training** (CIAT), **CAPD Online Therapy System** (CAPDOTS), & **Auditory Rehabilitation for Interaural Asymmetry** (ARIA) (Weihing & Musiek, 2013)

  https://auditec.com/2015/08/04/ciat-demonstration/

  https://capdots.com/about-capdots/the-system/

  https://www.dichoticsinc.com/

- Gap detection training (Kishon-Rabin, Avivi-Reich, & Roth, 2013) – ***Unilateral or bilateral***
- Lateralization training (Lofti et al., 2019) – ***Binaural***
- Dichotic Offset Training (DOT) – Stimuli available on CIAT ("interaural time delay") & may benefit individuals who have both binaural interaction (MLD) *and* dichotic listening deficits (Delphi & Abdollahi, 2018)
- Frequency/intensity/duration difference limens, tonal glides, 2+ tone discrimination & ordering/sequencing – ***Unilateral or bilateral***

Key Takeaways

- Central auditory training is effective and efficient when training task is matched appropriately with the deficient skill (i.e., when it is deficit-specific!)
- Improvements in performance can occur within weeks (as early as 3.5 weeks of targeted intervention)
- Improvements in performance are long-lasting (current evidence suggests at least 3+ years)
- Improvements in skills are observed on behavioral and electrophysiological measures
- While deficit-specific (“bottom-up”) training is effective and efficient, it is made even more so when it is part of a multidimensional treatment plan (including strategy-driven, or “top-down” approaches)

Device-Based Intervention

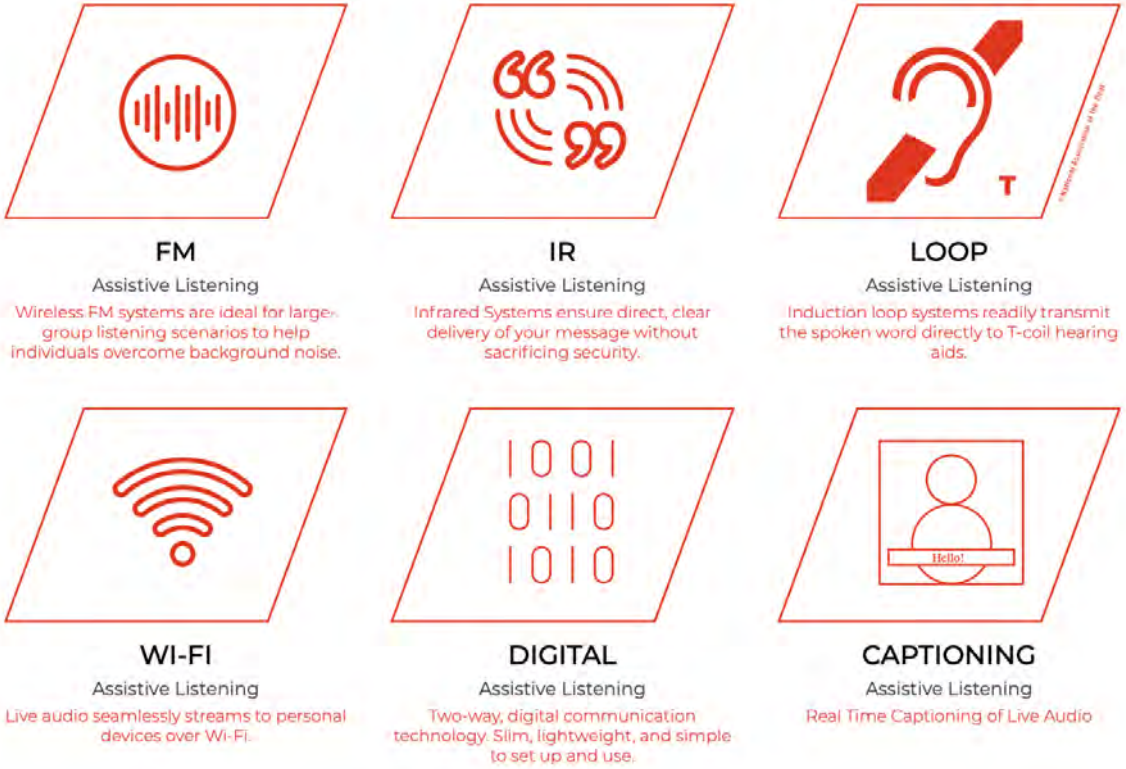
Effectiveness of Assistive Listening Devices & Mild Gain Hearing Aids

- **FM systems**
  - Hornickel, J., Zecker, S.G., Bradlow, A.R., & Kraus, N. (2012). Assistive listening devices drive neuroplasticity in children with dyslexia. *Proceedings of the National Academy of Sciences, 109*(41), 16731-16736.
  - Schafer, E.C., Mathews, L., Mehta, S., Hill, M., Munoz, A, Bishop, R., & Moloney, M. (2013). Personal FM systems for children with autism spectrum disorders (ASD) and/or attention-deficit hyperactivity disorder (ADHD): An initial investigation. *Journal of Communication Disorders, 46*(1), 30-52.

- **Mild gain hearing aids**
  - Kuk, F., Jackson, A., Keenan, D., & Lau, C-C. (2008). Personal amplification for school-age children with auditory processing disorders. *Journal of the American Academy of Audiology, 19,* 465-480.
  - Roup, C.M., Post, E., & Lewis, J. (2018). Mild-gain hearing aids as a treatment for adults with self-reported hearing difficulties. *Journal of the American Academy of Audiology, 29*(6), 477-494.

Types of Device-Based Strategies

- Ear-level frequency modulation (FM) systems (digital vs. “true” FM)
- Hearing aids
- Hearing aids + “FM”
- Hearing aids + remote microphone
- Soundfield systems
- “Live Listen” technology



https://williamsav.com/product-category/professional-listening-products/assistive-listening/

Device-Based Intervention
Some Overall Considerations

- Goal is to boost SNR – just for CAPD?
- Temporary fix or permanent CANS changes?
  - Hornickel et al. (2012)
- Associated cost
  - Insurance coverage
  - Private pay
  - School system via IEP/504

Device-Based Intervention

Hearing Assistive Technology Systems (HATS)

HATS: Devices that can help people hear in loud or busy places

- When sound comes from a distance
- When there is a lot of noise in the room
- When sound bounces around the room (reverberation)
- When in situations with low context

Device-Based Intervention

What is an FM System?

- FM: Frequency Modulation
- Operates like a tiny radio station with its own frequency
- Two parts
  1. Microphone (speaker wears)
  2. Receiver (dedicated receiver on ears, in hearing aids, in soundfield, etc.)

Device-Based Intervention

"FM" Systems

Ear-level devices are the preferred recommendation

Also body-worn devices and sound field systems

Devices manufactured by hearing aid companies

Phonak (Roger Focus II; "FM")

Devices manufactured by non-hearing aid companies

Williams AV FM Systems

Device-Based Intervention
Ear-Level FM Systems

Phonak (Roger Focus II, “FM”):

- https://www.phonak.com/us/en/hearing-aids/accessories/roger-focus.html
- https://www.phonakpro.com/us/en/products/wireless-accessories/roger-focus/overview-roger-focus.html

Roger Focus II boasts an array of features, including rechargeability, lockable volume control, SlimTube and tamperproof battery door. It comes in two models: rechargeable (Roger Focus II) and a Zinc Air battery version (Roger Focus II-312). Roger Focus II-312 has a tamperproof battery door; keeping batteries away from curious fingers and mouths. The rechargeable model comes in a wide range of pediatric colors.

Colors to match any personality

Hearing aid color

Caribbean Pirate

https://www.phonak.com/en-us/hearing-devices/microphones/roger-focus-ii

Ear-Level "FM" Systems

Transmitter Microphone Examples

Roger microphone option necessary

Roger Select™

Wireless microphone that offers Roger technology which improves speech understanding in loud noise. Placed on a table, it allows patients to fully engage and feel at the heart of the conversation

Learn More ›

Roger On™

Roger On is a microphone dedicated for all conversations that occur in background noise and over distance.

Learn More ›

Roger™ Clip-On Mic

Small microphone designed for one-to-one conversations. Featuring a directional microphone, the user can focus on a conversation with their partner.

Learn More ›

Roger™ Touchscreen Mic

With a large mute and unmute button, and other icons on screen to control the microphone function it is very simple to use. It is the premier microphone in the Roger for Education portfolio, and is a popular choice for families who get a Roger mic for home.

Learn More ›

Ear-Level FM Systems

Non-Hearing Aid Manufacturer Example

Rechargeable Personal FM System

FM SYSTEMS
PFM PRO RCH

The Rechargeable Personal FM System PFM PRO RCH kit delivers superior audio directly to the ear, enhancing sound at home, work, or school – anywhere background noise or distance from the source makes listening difficult. This system uses rechargeable batteries.

The T46 transmitter can broadcast on 17 selectable channels on the 72-76 MHz band, and has an operating range of up to 150 feet. The listener uses a PPA R37 receiver that works with a variety of earphones and headphone options. The receiver is also compatible with neckloops (not included with system) for connecting to Telecoil-equipped hearing aids. The transmitter, receiver, microphone, earphones and headphones are provided in a convenient carrying case.

https://williamsav.com/product/pfm-pro-rch/

Ear-Level FM Systems

Multiple Receiver Systems

12-pack FM R37 Receiver Rechargeable Bundle

FM RECEIVERS, FM SYSTEMS
PPA R37-12 PRO

The 12-pack FM R37 Receiver Rechargeable Bundle comes with 12 FM R37 receivers and a CHG 3512 PRO Twelve Bay Charger. Also includes earphones and a carrying case.

The FM R37 features seek-button channel selection with access to 17 pre-set, wideband frequencies on reserved for hearing assistance by the ADA. The receiver is compatible with all Williams Sound 72-76 MHz wide-band transmitters.

The FM R37's audio is digitally synthesized for exceptional audio clarity and stability. Versatile 3.5mm stereo/mono jack allows for a variety of earphone/headphone options, and is neckloop/telecoil-equipped hearing aid compatible. The FM R37 offers sleep mode, low-battery indicator and stereo headphone jack.

NOTE: The Receiver requires a transmitter operating on 72-76 MHz. TheReceiveris approved by the FCC for operation in U.S. Markets. The receiver cannot be used in all countries. Check with your government 's radio regulations for 72-76 MHz operation.

https://williamsav.com/product-category/professional-listening-products/assistive-listening/fm/fm-systems-fm/

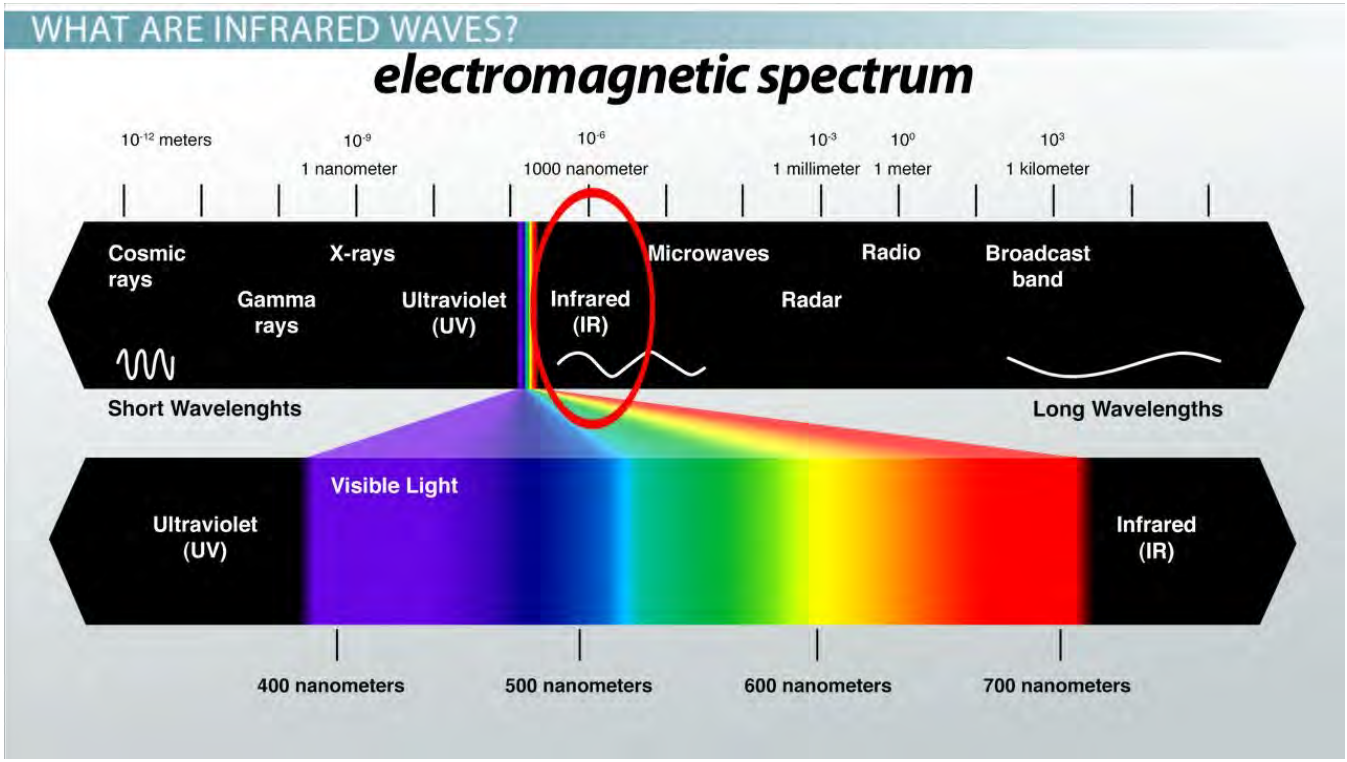
Device-Based Intervention

What is an Infrared System?

- Uses light waves to send sounds across a room
- Changes sounds into light and sends them to a receiver
- Receiver turns the light waves back into sound, by a dedicated infrared receiver or one in the hearing aid

Device-Based Intervention

What is an Infrared System?



Device-Based Intervention

What is an Infrared System?

- Home use is often with the TV
  - Allows for individual using the system to hear the TV without turning the volume up too high
  - Others can watch the TV at a volume that is comfortable for them

- Can be used in larger places, like theaters

https://williamsav.com/product-category/professional-listening-products/assistive-listening/ir/ir-systems/

Device-Based Intervention

What is an Induction Loop System?

- Also known as telecoil!
- Loop wire goes under carpet or in ceiling
- Wire connects to microphone
- Electrical current moves through the wire when someone talks into the microphone – this creates an electromagnetic field in the room

https://williamsav.com/product-category/professional-listening-products/assistive-listening/loop/loop-systems-loop/

Device-Based Intervention
Soundfield Systems

The right speaker for every room

Roger™ Touchscreen Mic

This exciting and easy to use wireless teacher microphone is the core component of the Roger for Education portfolio.

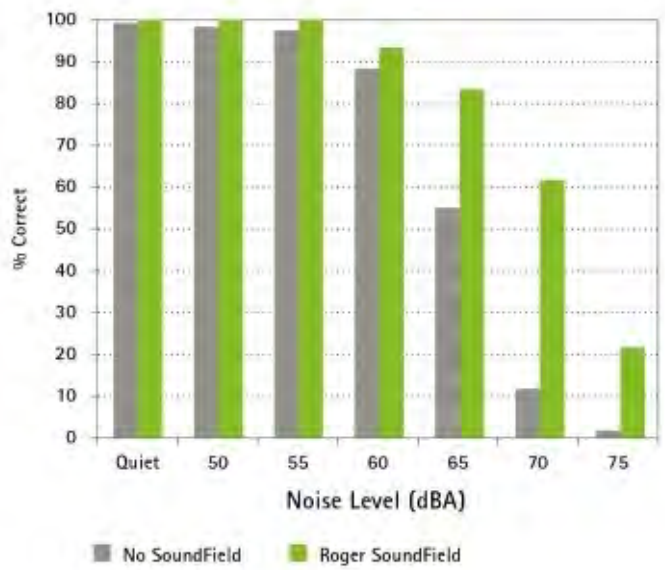
Learn More ›

Roger™ SF Touchscreen Mic

An intuitive new user interface, this simple-to-use microphone can be combined with one or more Roger Pass-around microphones and transmits exclusively to Roger DigiMaster loudspeakers for the entire class.

Learn More ›

Device-Based Intervention
Soundfield Systems

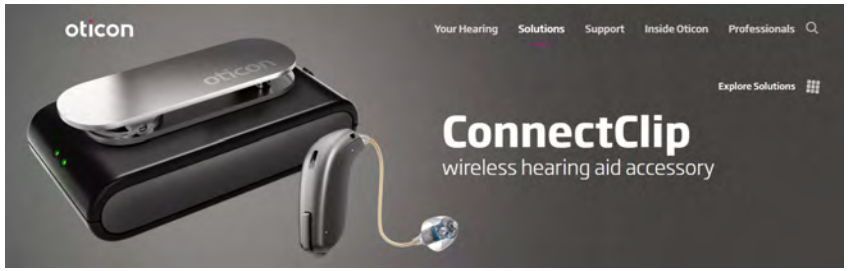


- What are some pros to using a soundfield system?
- What are some cons to using a soundfield system?

https://www.phonakpro.com/us/en/products/wireless-accessories/roger-dynamic-soundfield/overview-roger-dynamic-soundfield.html

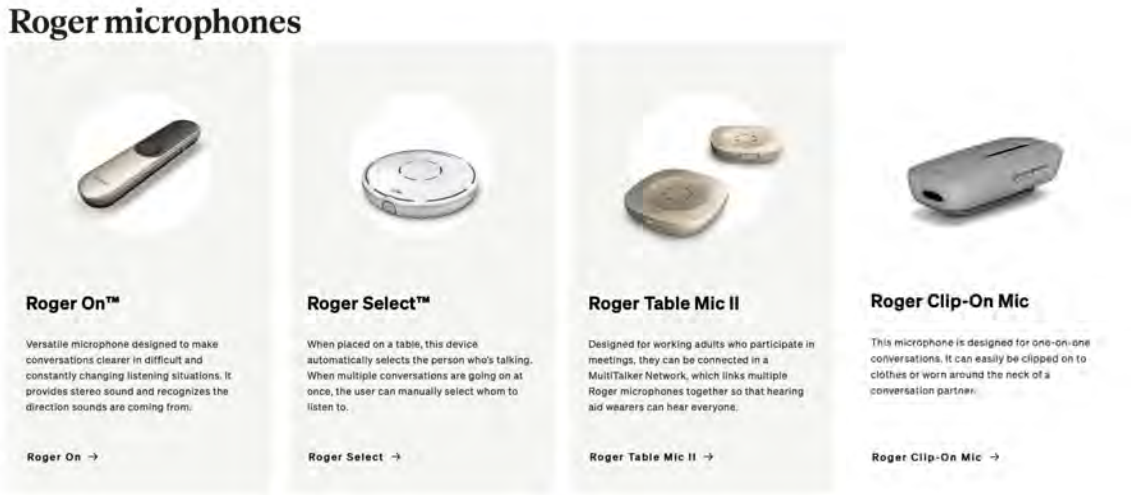
Device-Based Intervention

Hearing Aids + Remote Mic



Hearing Aids + FM

Recent Developments in Technology



“Live Listen” Technology
Without Hearing Aids (Apple)

Use Live Listen with AirPods, AirPods Pro, AirPods Max, or Powerbeats Pro

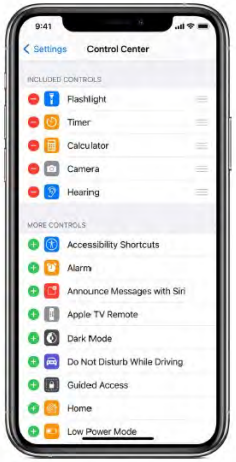
With Live Listen, your iPhone, iPad, or iPod touch can act like a microphone that sends sound to your AirPods, AirPods Pro, AirPods Max, or Powerbeats Pro. Live Listen can help you hear a conversation in a noisy area or even hear someone speaking across the room.

To use Live Listen with your AirPods, AirPods Pro, AirPods Max, or Powerbeats Pro, your iOS or iPadOS device needs iOS or iPadOS 14.3 or later. You also need to connect your AirPods, AirPods Pro, AirPods Max, or Powerbeats Pro to your device.

Add Live Listen to Control Center

To use Live Listen, you need to add it to Control Center:

1. Go to Settings > Control Center.
2. Scroll down and tap the Add button next to the Hearing button.
3. Tap Settings to save the changes.



4. Place your device in front of the person that you want to hear. Make su your device if you can't hear well enough.

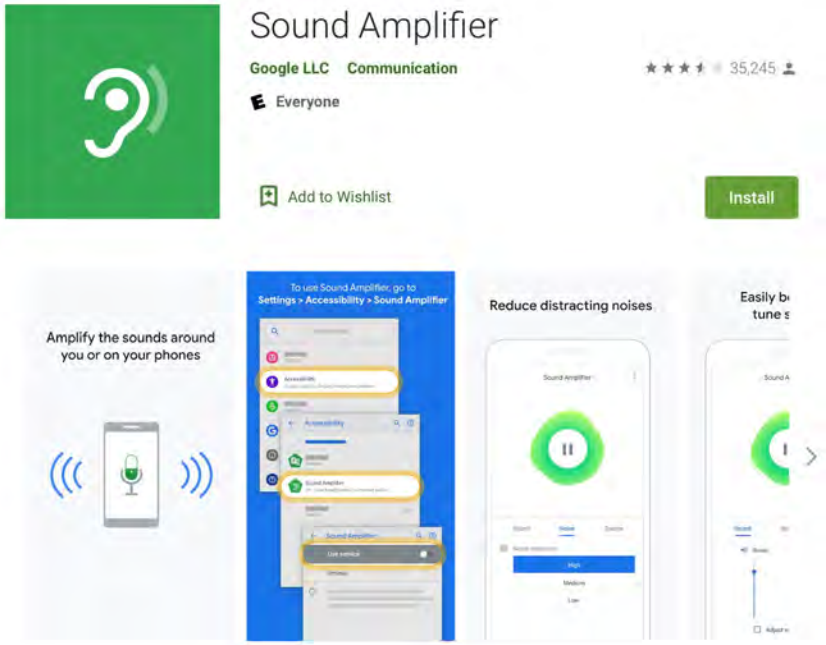
You can also see your headphone audio levels in real time as you're listening to content. You can quickly glance to see detailed decibel-level information.

If you can’t connect to your AirPods, AirPods Pro, AirPods Max, or Powerbeats Pro, or if Live Listen won’t turn on, make sure that Bluetooth is on and that your headphones are charged.

Learn about Live Listen with Made for iPhone hearing aids.

Published Date: January 05, 2021

“Sound Amplifier” Technology
Without Hearing Aids (Google)



- Amplify the sounds around you or on your phones
- Reduce distracting noises
- Boost and tune sounds
- Apply settings to each ear independently

https://play.google.com/store/apps/details?id=com.google.android.accessibility.soundamplifier&hl=en_US&gl=US

Accommodations

Accommodations: Questions to Consider

- What limitations is the individual experiencing?
- How do the limitations affect the individual and the individual's job/classroom performance?
- What specific job/classroom tasks are problematic because of the limitations?
- What accommodations are available to reduce or eliminate these problems? Are all possible resources being used to determine possible accommodations?
- Has the individual been counseled re: possible accommodations?
- Once accommodations are in place, would it be useful to meet with the individual to determine effectiveness and whether adjustments are needed?
- Do supervisory personnel/teachers and employees/classmates need training?

Accommodations: ADA, IEP, 504

In meetings/trainings/classroom activities

- Consider environment and what is going on re: background noise/voices
- Minimize auditory distractions
- Provide assistive listening devices (ALDs)
- Preferential/strategic seating
- Provide written agendas/lesson plans in advance
- Provide materials in multiple formats
- Provide printed minutes/notes
- Provide instructions, communications, etc., in writing as much as possible; check for understanding
- Follow-up verbal communications in writing
- Allow use of audio and/or video recording
- Allow time for responses to oral communications/questions, extra time for tests and assignments
- Demonstrate and explain new info and tasks

Accommodations: ADA, IEP, 504

In overall communication

- Consider the environment and background noise
- Minimize distractions
- Slow rate of speech (CLEAR speech)
- Simplify or minimize verbal communication/instructions and follow-up in writing
- Allow written communication such as emails, texts, etc.
- Allow ample time to respond to verbal communications/questions
- Encourage employee/student to question/repeat back information received
- Be patient

CAPD & IEP Eligibility

- Qualifies CAPD – on its own – as eligible for services through IEP under *Other Health Impairment* (OHI)

FOR PUBLICATION

UNITED STATES COURT OF APPEALS
FOR THE NINTH CIRCUIT

E.M., a minor, by and through his parents, E.M. and E.M., *Plaintiff-Appellant*, v. PAJARO VALLEY UNIFIED SCHOOL DISTRICT OFFICE OF ADMINISTRATIVE HEARINGS, *Defendant-Appellee.*	No. 12-15743 D.C. No. 3:06-cv-04694-MMC OPINION

Appeal from the United States District Court
for the Northern District of California
Maxine M. Chesney, Senior District Judge, Presiding

Argued and Submitted
April 7, 2014—San Francisco, California

Filed July 15, 2014

Before: Mary M. Schroeder, Kermit V. Lipez*, and Consuelo M. Callahan, Circuit Judges.

Opinion by Judge Callahan

* The Honorable Kermit V. Lipez, Senior Circuit Judge for the First Circuit, sitting by designation.

Questions?

References:

Thank you!

Email: gonzalez.jennifer@mayo.edu