

Navigating CAPD: From Symptoms to Solutions

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Disclosure

- Trey Cline, AuD, PhD:
 - Salary paid by the University of Kentucky
 - No other disclosures



Outline

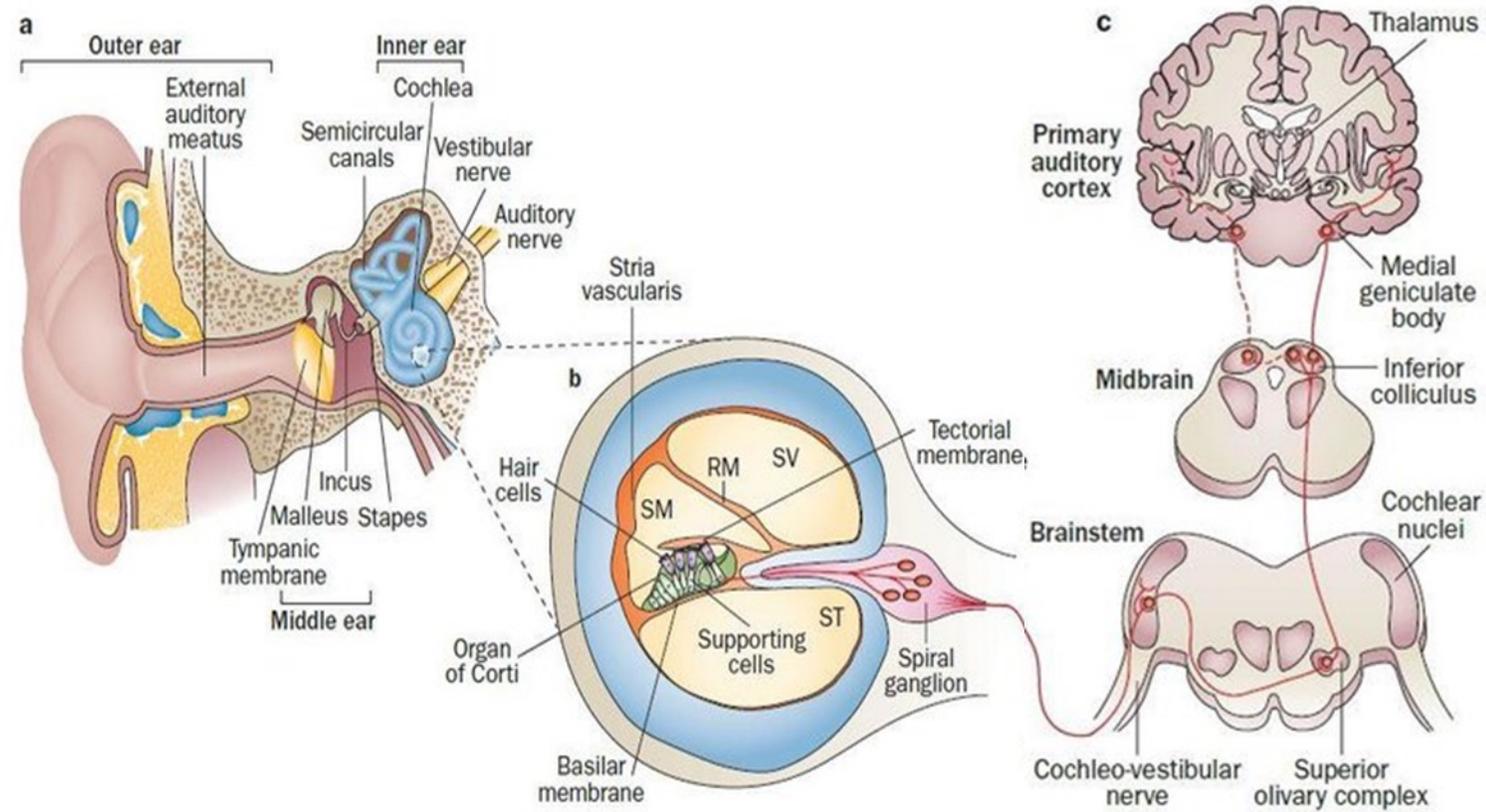
Central Auditory Processing Overview

Diagnosis

Management Strategies

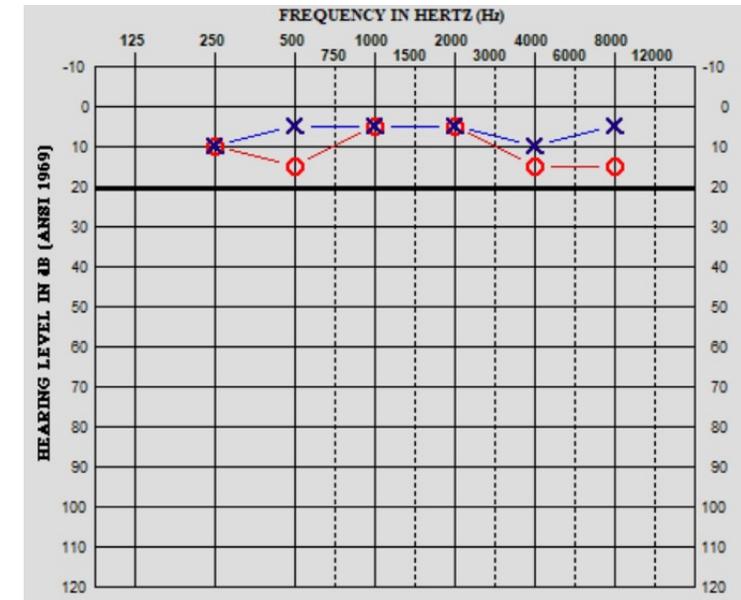
Case Studies

The Auditory System



The Auditory System

- The largest focus is on the peripheral auditory system.
- But what if we get this....
- We have to consider central auditory function and look into a central auditory processing evaluation.



What is CAPD?

- Central auditory processing disorder (CAPD) can be defined as dysfunction within the central auditory nervous system leading to deficits on behavioral and electrophysiologic central auditory measures
(AAA, 2010).

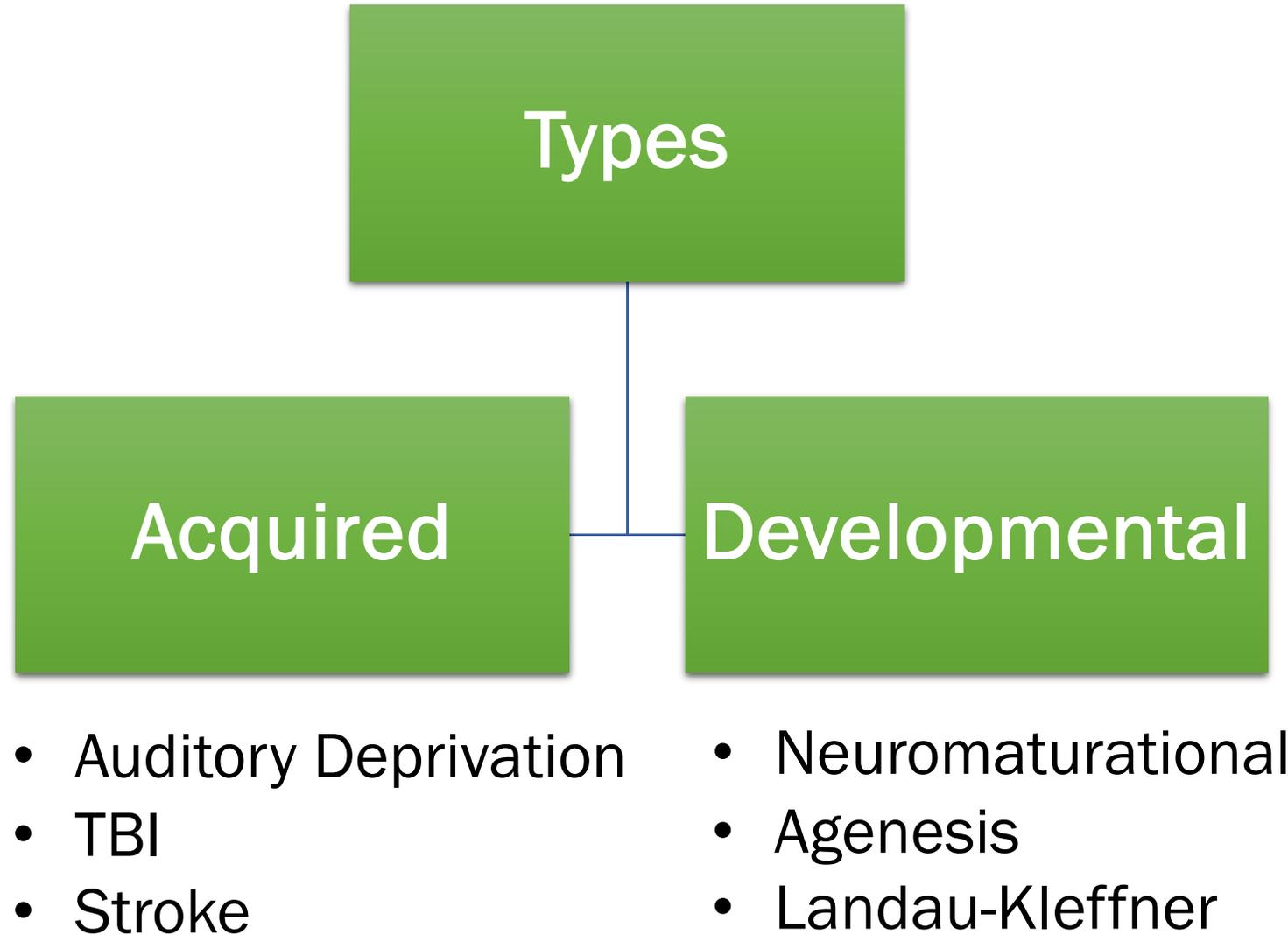
OR...

It's what we do with what we hear.

CAPD Symptoms

- Understanding speech in background noise
- Following complex directions
- Comprehending rapid speech
- Frequently asks for repetition
- Inconsistent or inappropriate responses
- Paying attention/Easily Distracted
- Localizing sound
- Learning songs or nursery rhymes
- Learning new languages
- Poor musical/singing skills
- Understanding prosody/sarcasm
- Reading, spelling, learning

Possible Causes of CAPD



Etiology of CAPD

Pediatrics

- CMV
- Hyperbilirubinemia
- Prematurity
- Prenatal Drug Exposure
- Neuromaturational Delay
 - Auditory deprivation

General

- Otologic disease
 - Auditory deprivation
- Neurological Disorders
 - Meningitis/MS/Seizures
- Head Trauma
- Stroke
- Age-related CNS changes



Behavioral CAP

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Central Auditory Processes

Dichotic Listening

Auditory Closure

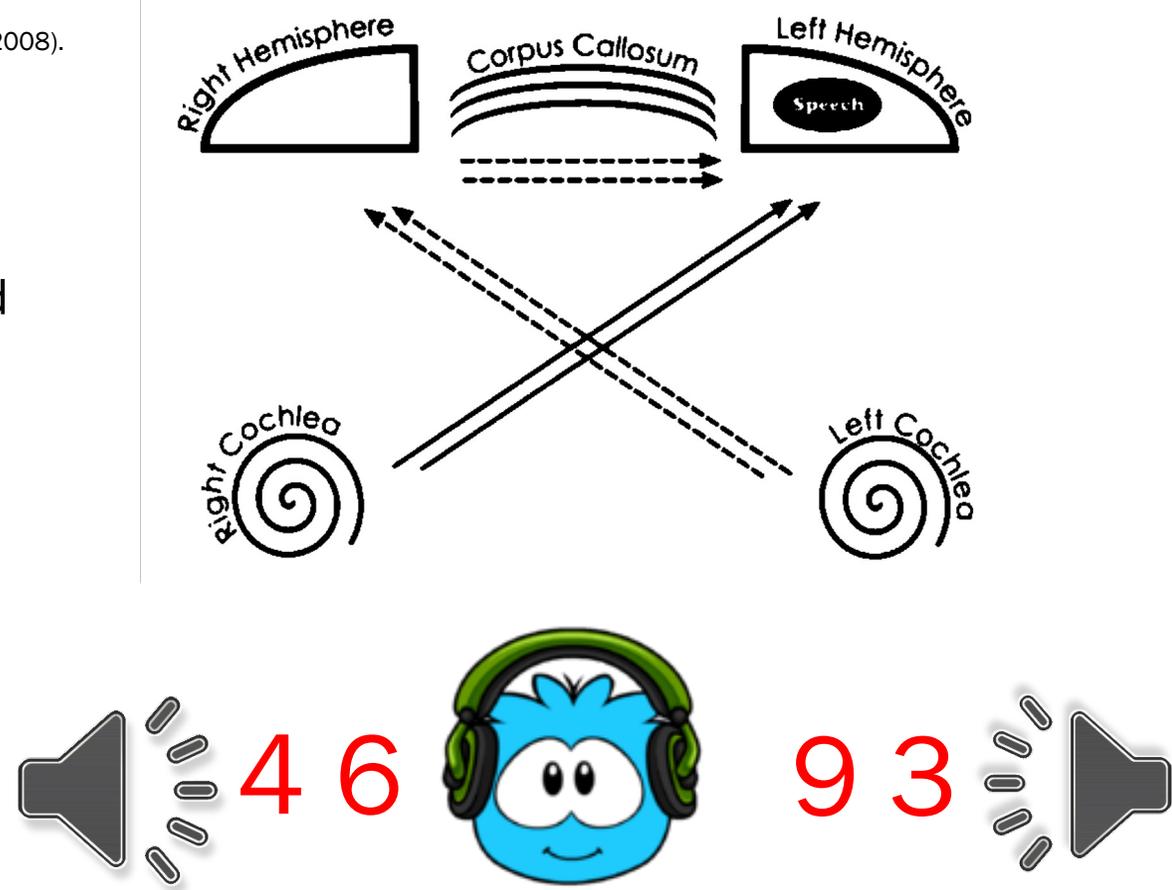
Temporal Processing

Spatial Processing



Dichotic Listening

- Dichotic Listening** (Kimura, 1961; Keith and Anderson, 2007; Musiek, Weihing, Lau, 2008).
 - A different stimulus is presented to each ear simultaneously.
 - Utilizes contralateral auditory pathways and suppresses ipsilateral connections.
 - Monotic or diotically presented stimuli use ipsi- and contralateral pathways.
- Binaural Integration** (Bellis, 2003)
 - “Divided Attention or Free Recall”
 - Recalling everything that is heard from both ears.
 - i.e. Dichotic Digits, SSW
- Binaural Separation**
 - “Directed or Focused Attention”
 - Focus only on one ear and repeat what is heard in that ear only.
 - i.e. Competing Sentences



Auditory Closure

- The ability to make auditory discriminations when a portion of the auditory signal is missing or distorted and recognize the whole message.
- Individuals utilize quality and knowledge of the auditory signal and efficient processing throughout the CANS to perform auditory closure.
- **Assessed by Monaural Low-Redundancy Speech tests**
 - i.e. Low-Pass Filtered Speech, Speech-in-Noise Tests
 - Commonly used because they are easy to administer and score.
 - Sensitivity and specificity are not great, but provides good ecological validity.
 - Offers insight into intervention



(Bellis, 2003)

(Krishnamurti, 2007)

Temporal Processing

- Defined as the perception of sound or the alteration of sound within a restricted or defined time domain (Musiek, Shinn, Jirsa, Bamiou, Baran, & Zaiden, 2005).
- Temporal processing subdivisions (Shinn, 2007):
 - Temporal Integration (summation)
 - Temporal Masking
 - **Temporal Ordering (sequencing)** – processing of 2 or more auditory stimuli in their order of occurrence in time.
 - Duration Patterns Test, Frequency Patterns Test
 - DPT is relatively resistant to cochlear lesions.
 - **Temporal Resolution (discrimination)** – the shortest duration of time one can discriminate between 2 auditory stimuli.
 - Gap Detection Test



Spatial processing

- Successful processing of speech in noise often utilizes spatial cues.
- Utilize interaural timing and intensity differences for sound localization.
- Other factors contributing to speech discrimination:
 - The ability to spatially separate the intended speech signal from competing speech signals.
 - Speaker differences (pitch, rate, gender)
 - Utilizing relevant linguistic information that differs from other speech signals.
 - Utilization of visual cues
- Assessed by the **Listening in Spatialized Noise Test**.





Electrophysiology

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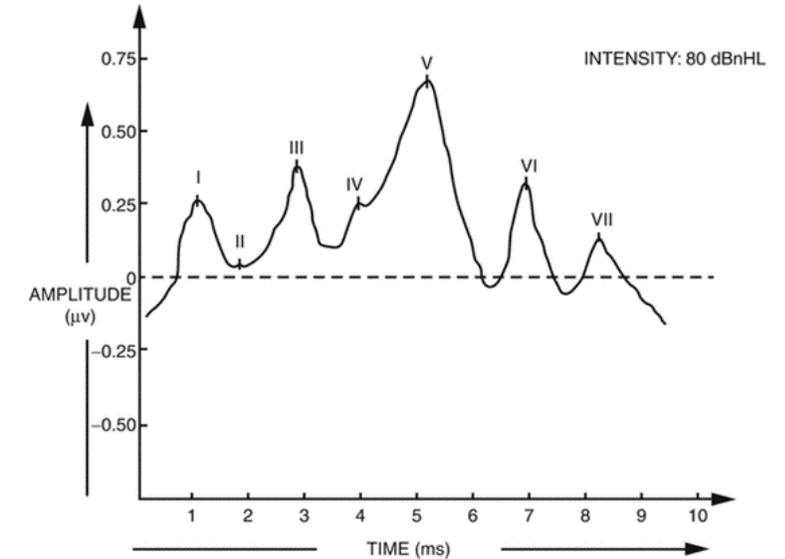
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Electrophysiological Measures

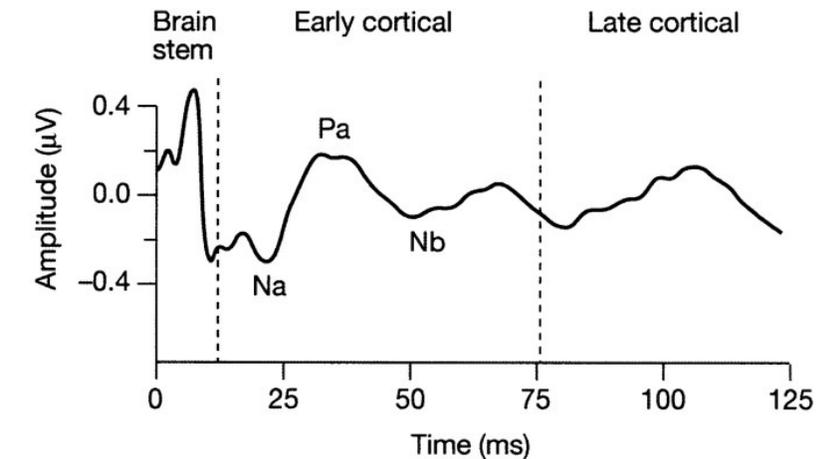
- Auditory Brainstem Response (ABR)

- Reflects auditory function from auditory nerve through the inferior colliculus.
- Focused on absolute and interpeak latencies (I-III, III-V, I-V).
- Assesses rate effects on latency shift.



- Middle Latency Response (MLR)

- Thalamocortical projections through Primary Auditory Cortex
- Focused on amplitudes
- Usually occurs in the 15 – 60ms range





Diagnosis

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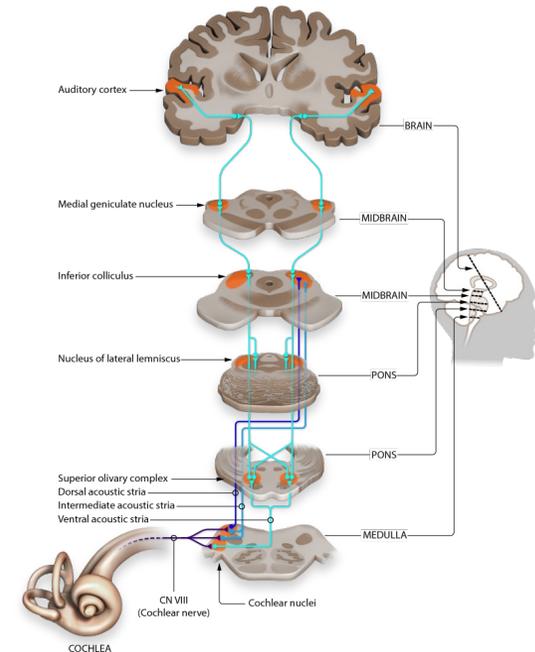
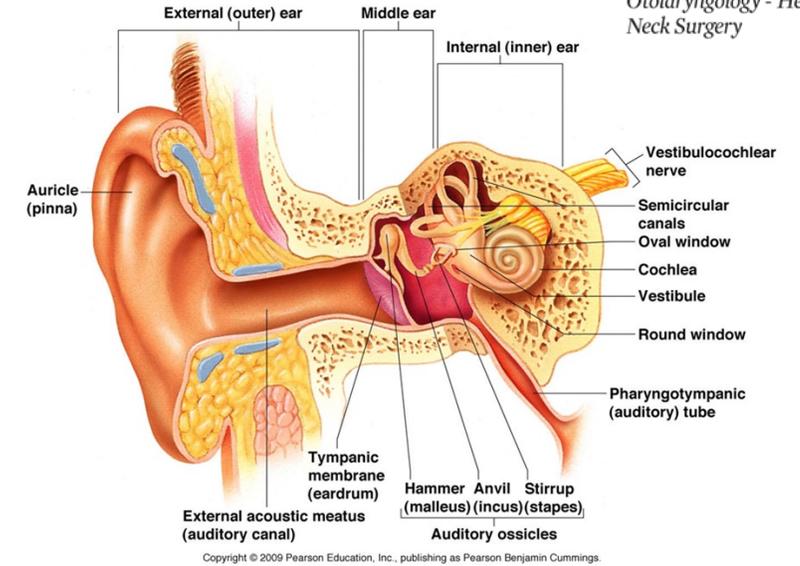
Evaluation

- Peripheral Assessment

- Sensitivity

- Central Battery

- Behavioral = Functional
- Electrophysiological = Neural Integrity



Types of Tests

Integration & Separation

Hearing in Noise

Temporal Processing
(Timing)

Low-Redundancy

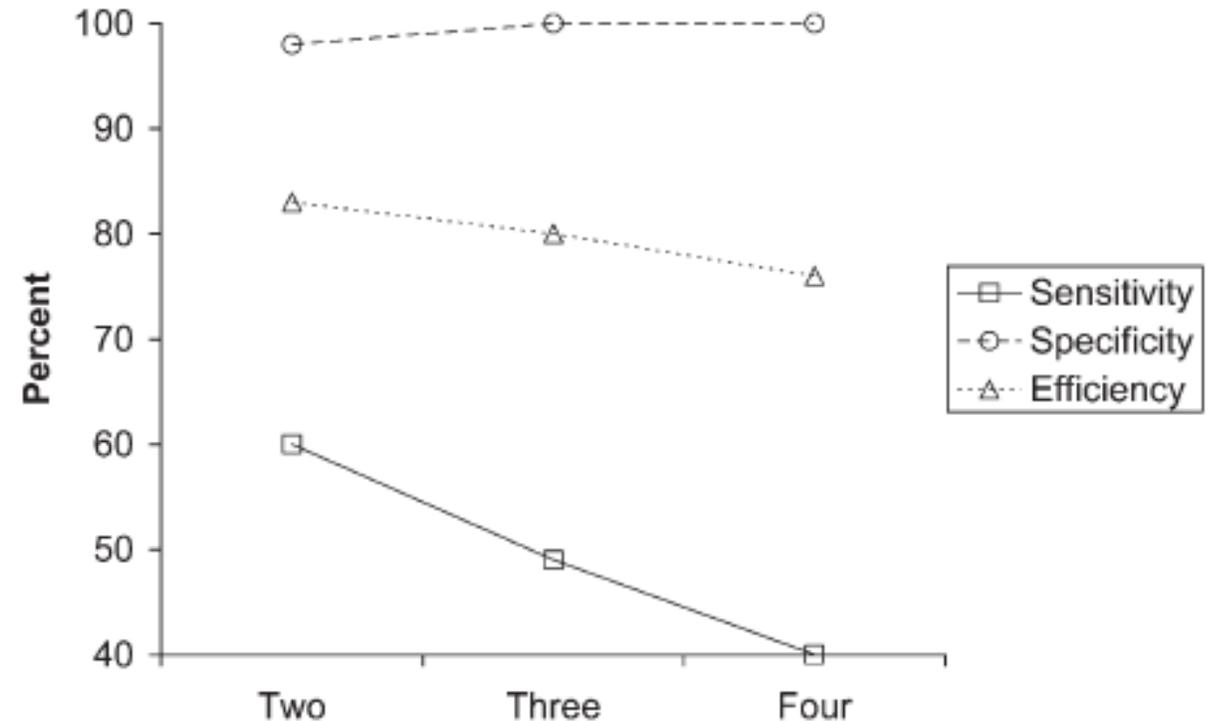
Spatial Processing

Abnormalities on Test Battery

Diagnostic Criteria

- Fail 2+ Test or...
- Fail 1 test by 3+ SD

- Failing two tests in a battery to satisfy positive CAPD diagnosis provides best sensitivity, specificity, and efficiency.



The background features a dark blue 'UW' logo on the left and the text 'College of Medicine' in a light blue serif font on the right. The main title 'Management Strategies' is centered in white.

Management Strategies

*Otolaryngology - Head
Neck Surgery*

Management Strategies

Therapy

- Direct vs Indirect
- Home/Online Programs

Amplification

FM System/Remote Microphone Technology

Environmental Modifications

DIID Training

- Dichotic Interaural Intensity Difference (DIID) Training
 - Training paradigm that addresses central auditory processing deficits in dichotic processing.
 - Usually, a deficit in dichotic listening will manifest as a unilateral deficit.
 - Asymmetry on tests of dichotic listening (DD, DR, CS).
- It is a form of Constraint-Induced Therapy
 - Based on work in stroke patients by Edward Taub.
 - Forced use of paretic limbs by restraining the stronger limbs (Taub et al, 1993).
 - In DIID training, there is forced use of the poorer ear.
- The goal of DIID training is to bring the poorer ear performance up to normal while also ensuring the stronger ear maintains performance.

DIID Training

Administration

- Establish the crossover point (~20-30 dB IID)
- Initial training session at a slightly larger IID than needed for crossover (extra 3-5 dB to IID)
 - Use binaural integration and separation with a variety of stimuli (words, digits, sentences)
 - Utilize a log to track progress
- Schedule sessions 2-3x per week, 30 minutes each (12 sessions)
- With time, you should be able to reduce the IID (increasing the better ear).
- Ultimate goal is to have both ears performing normally at 0 dB IID (equal SL).

RE (Better)

LE (Poorer)

Hot Dog (50 dB SL)



Pancake (50 dB SL)

100%

“Pancake and ??”

60%

Hot Dog (50 dB SL)



Pancake (35 dB SL)

85%

“Pancake and ??”

75%

Hot Dog (50 dB SL)



Pancake (25 dB SL)

75%

“Hot Dog and Pancake”

90%

Indirect therapy

- **Keyboard Exercises**

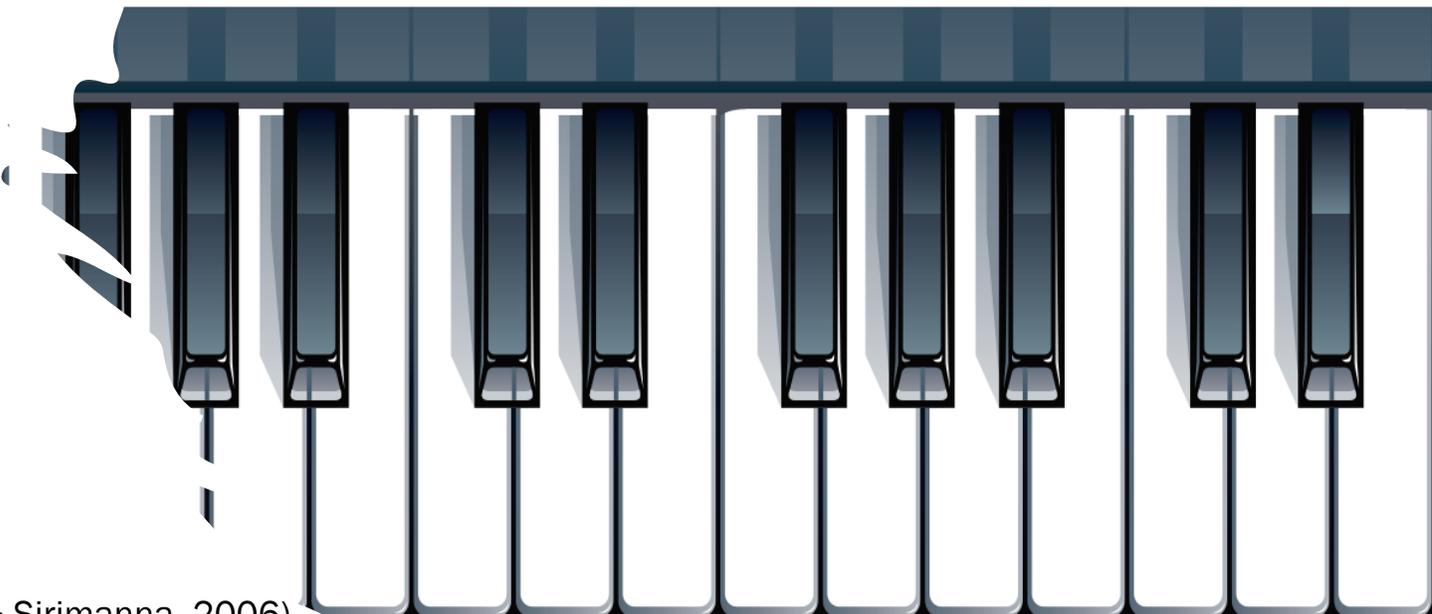
- Start at the extremes of the keyboard and work towards the middle
- Temporal Ordering

- **Simon Game**

- Play the game without visual cues.
- Temporal Ordering

- Usually 3-4x per week
- 20 minutes per session

(Bamiou, Campbell, & Sirimanna, 2006)



Home Therapy Programs



Amplification

- Trial mild-gain, fixed-directional, open-fit binaural amplification and a remote microphone.
- Kuk et al (2008)
 - 17 age-matched children with CAPD fit with binaural amplification
 - Omnidirectional only – no change in speech in noise scores
 - Omni with NR – 6% better than omni only and unaided
 - Directional with NR – 10% better than omni only and unaided
- Rec: Open-fit HAs with directional microphones and NR may be beneficial on some children with APD as a trial-basis.



Amplification and CAPD

- Mild Gain Amplification has demonstrated improvement in self-perceived hearing difficulties.
 - HHIA and APHAB
- Improvement in Speech-in-Noise Testing
 - QuickSIN
 - R-SPIN
- May also need FM/Remote Microphone technology.





Case Studies

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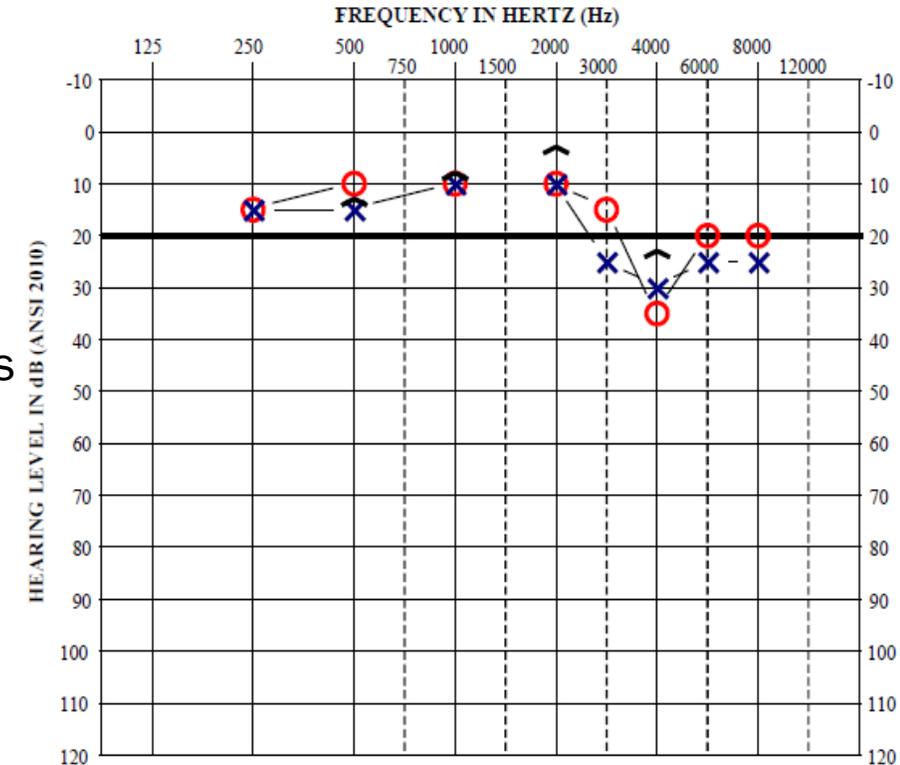
Neck Surgery



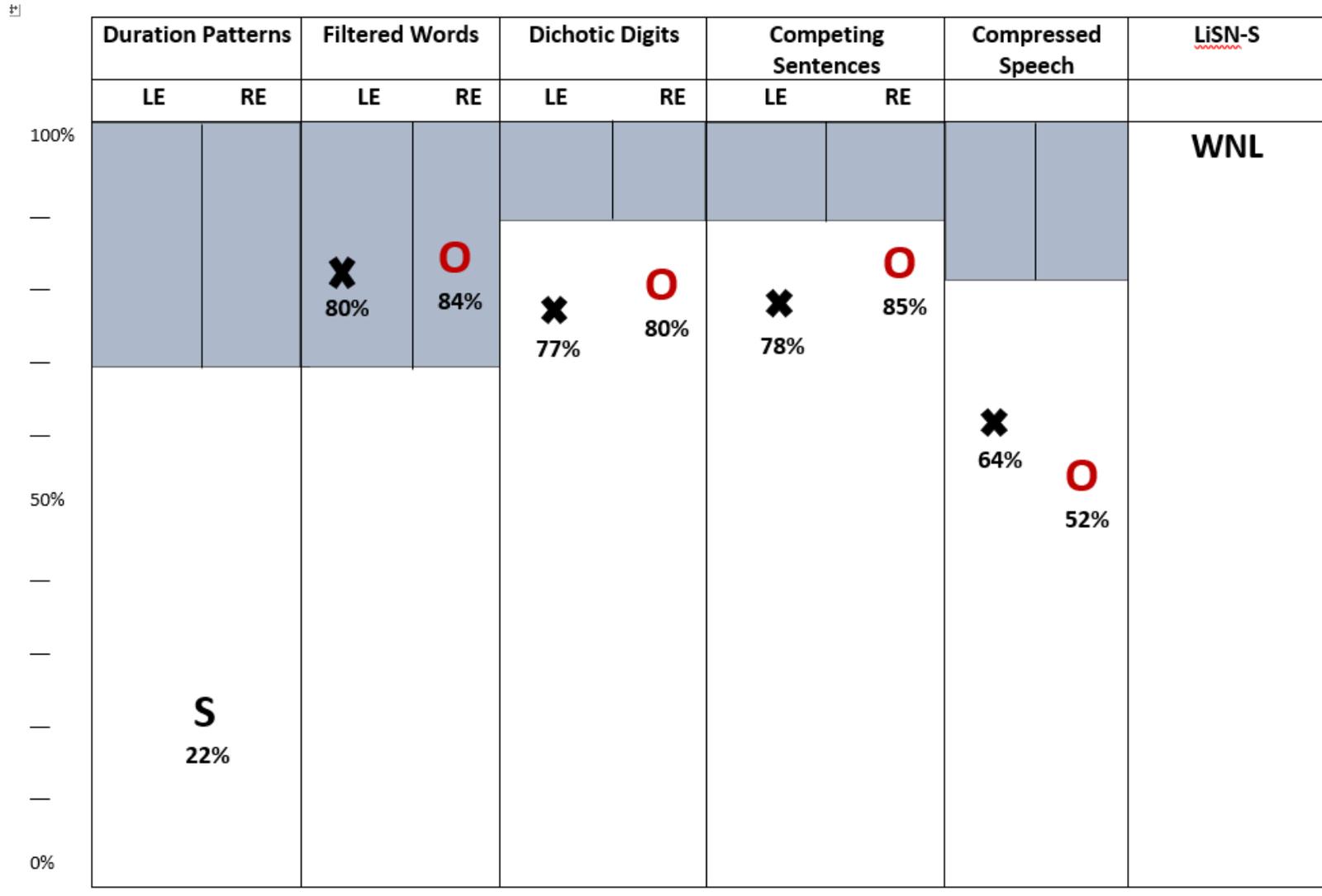
Case Study: RH

Case study: RH

- 39 y.o. male
- UK Audiology Clinic – September 2021
 - No difficulty with hearing difficulty per se. Feels as if he processes slowly.
 - Reports difficulty with people who speak very quickly
 - Difficulty in background noise
 - Difficulty following multistep directions
 - Increased difficulty with pandemic due to masks and lack of visual cues
 - Recreational pilot who has difficulty understanding ATC
- As a child....
 - Received SLP services for articulation disorder
 - Difficulty with reading comprehension and relied heavily on extra tutoring
 - Struggled with music and foreign language
 - Dx of ADHD



CAPD Results: RH



Speech, Spatial and Qualities of Hearing Scale

Speech = 7.64

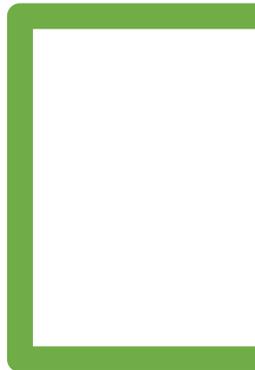
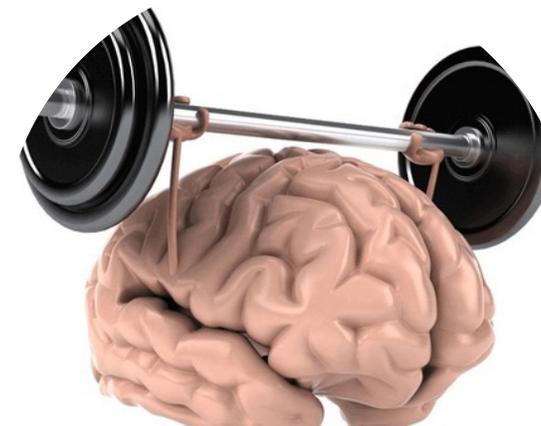
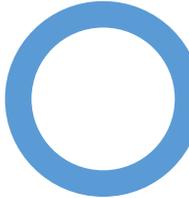
Spatial = 8.25

QoH = 7.67

Total = 7.85

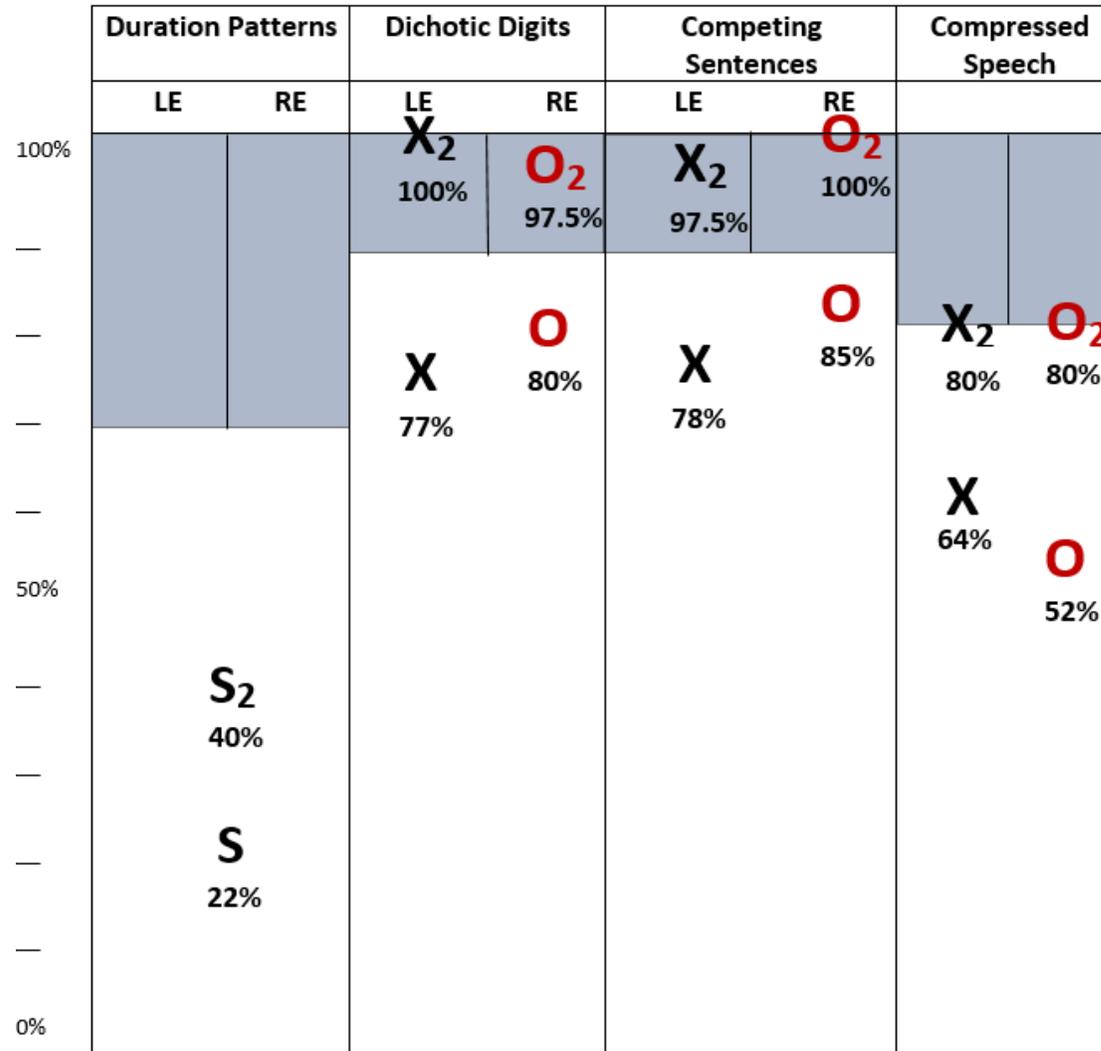
How did we manage?

- Patient showed deficits in:
 - Binaural Integration and Separation (dichotic listening)
 - Temporal Processing
 - Rapidly Presented Speech
- Dichotic Interaural Intensity Difference (DIID) Training
- Mild-gain amplification with remote microphone



Follow-up CAPD Results: RH

- Following DIID training:
 - Dichotic Digits and Competing Sentences improved dramatically



Speech, Spatial and Qualities of Hearing Scale

Speech =	7.64	8.57
Spatial =	8.25	9.13
QoH =	7.67	9.22
Total =	7.85	9.06

The Update: RH

Results improved on post-DIID APD assessment.

Subjective results improved on the SSQ assessment.

Patient also reports in general that his conversations flow much easier.

- Asks for less repetition and doesn't take as much time to process
- Also responds appropriately to the questions asked/conversation
- Wife also notices tremendous improvement in communication ability.

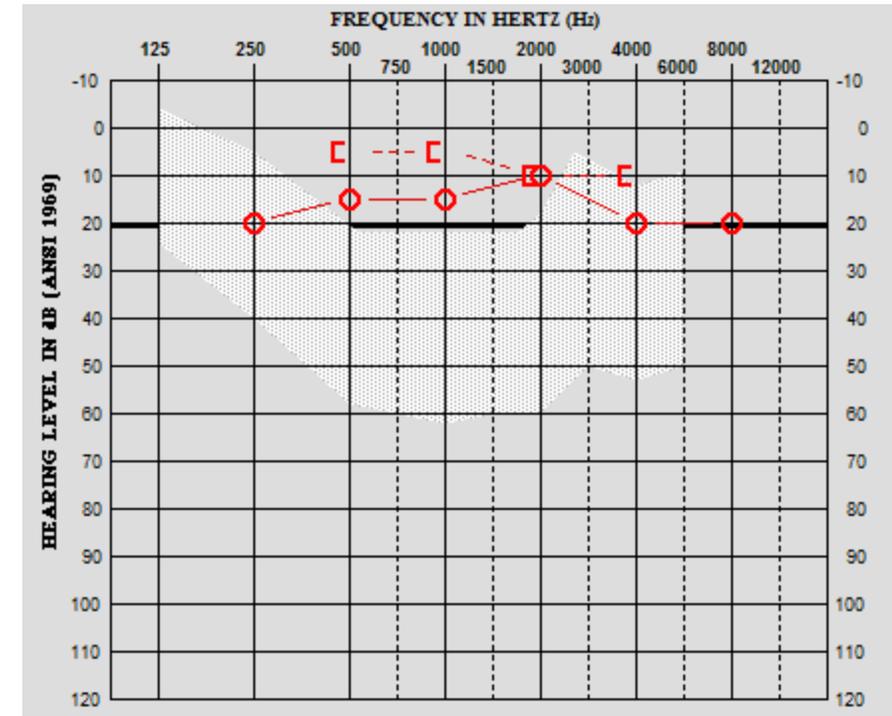
Most importantly (to him)...he obtained his instrument certification.



CASE STUDY: NH

Case study: NH

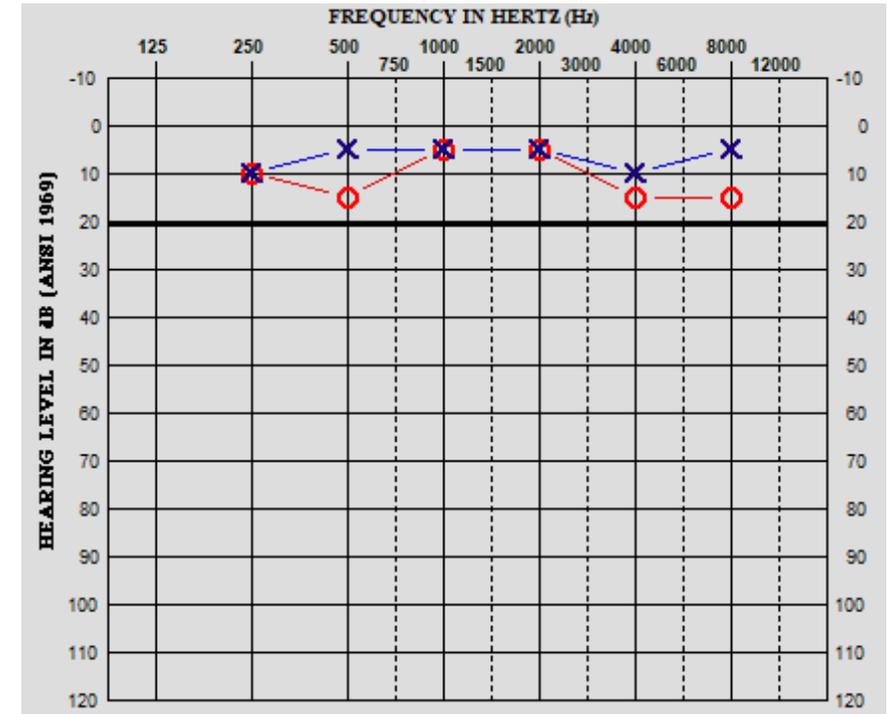
- 18 y.o. female
 - Senior in high school, competitive swimmer (college scholarship), high academic performance
- UK Audiology Clinic - March 2015
 - Followed at outside ENT prior
 - Fairly chronic otitis media throughout childhood and teenage years
 - History of PE tubes
 - Right TM perforation with a mild conductive hearing loss
- April 2015- successful right tympanoplasty
 - Hearing improved in right ear
- September 2015
 - Patient reports no concerns regarding hearing and no otologic concerns
 - Discharged at this point, follow-up PRN.



March 2015

Fast Forward...

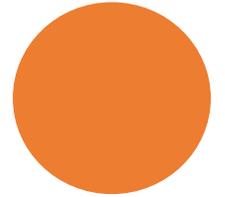
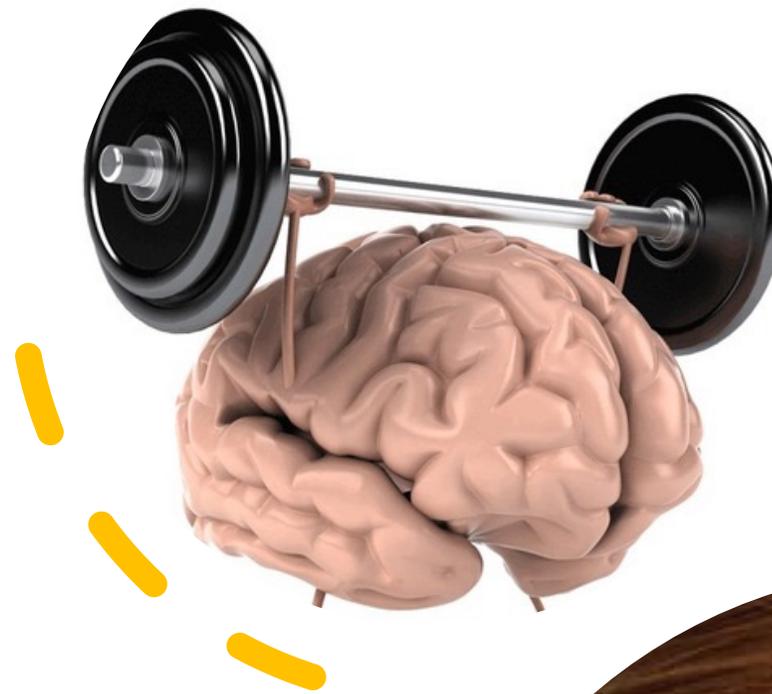
- May 2018
 - Even after tympanoplasty and no further middle ear issues, she still reports *difficulty hearing in noise*.
- Difficulty hearing over the previous 2 years
 - Fell off treadmill and hit her head on bookcase resulting in LOC
 - Since then she has had 4 other concussions (No LOC) (most recent Dec. 2017)
 - Followed by neurology due to concussion and multiple migraines per week.
 - Imaging work-up was unremarkable.
 - Still doing well in school and achieving at high academic levels, but *subjectively has to work much harder now than before.*
- Additionally...
 - Visual therapy for central visual deficits (reading)
 - Required vestibular rehabilitation (balance issues)



May 2018

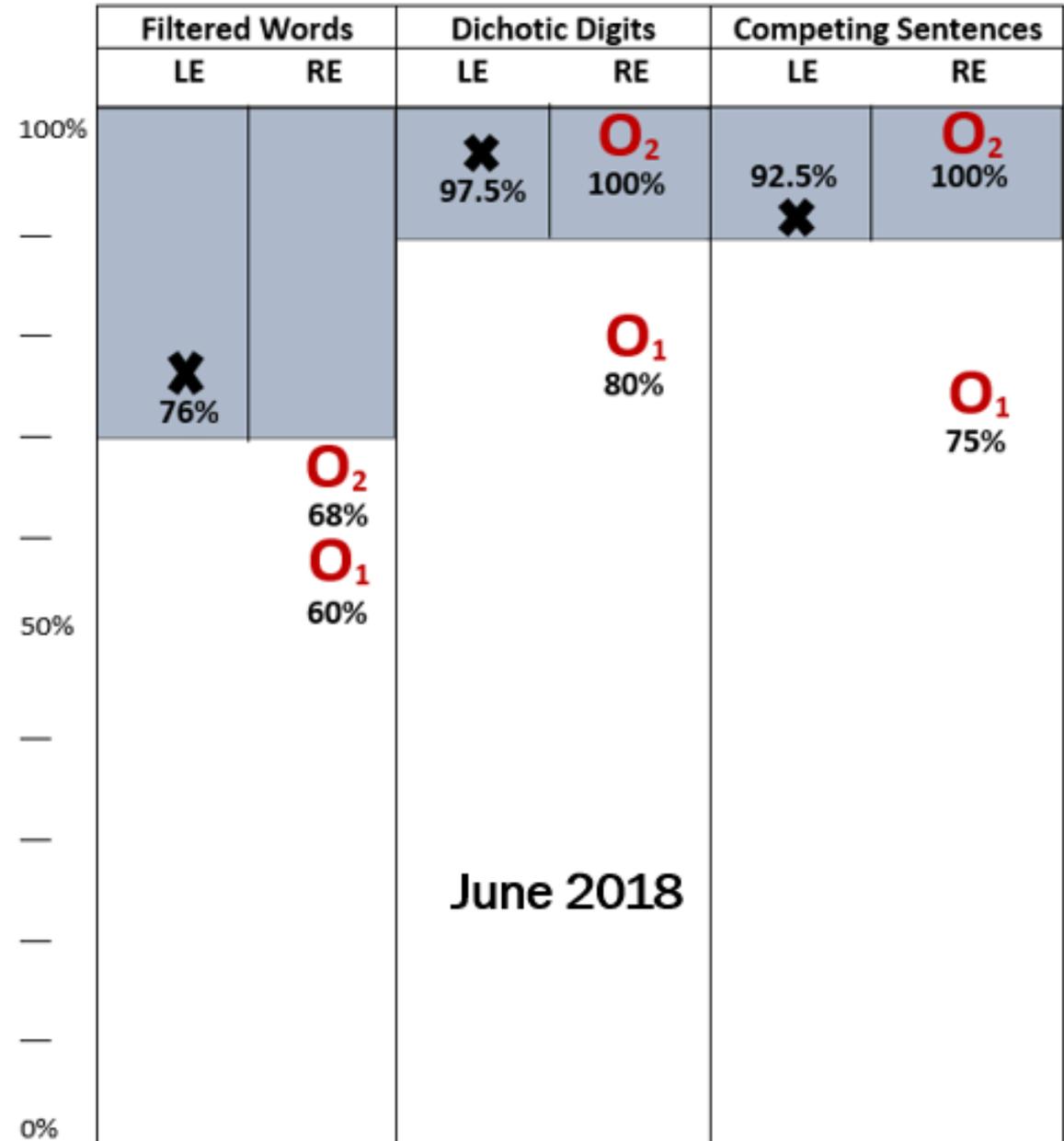
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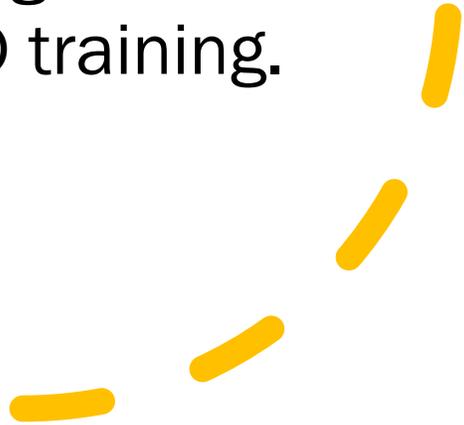
Follow-up CAPD Results

- Following DIID training:
 - Dichotic Digits and Competing Sentences improved dramatically
 - LPFS test still shows auditory closure deficit.



Following DIID training and amplification...

The UPDATE

- No more migraine headaches. Improved fatigue.
 - Doing well in college.
 - “Loves the hearing aids.” Appreciates tremendous difference in listening abilities with and without them even after DIID training.
- 

Contributing Factors to CAPD

- Auditory deprivation due to chronic otitis media and TM perforation in right ear

(Maruthy and Mannarukrishnaiah, 2008; Hall and Grose, 1993)

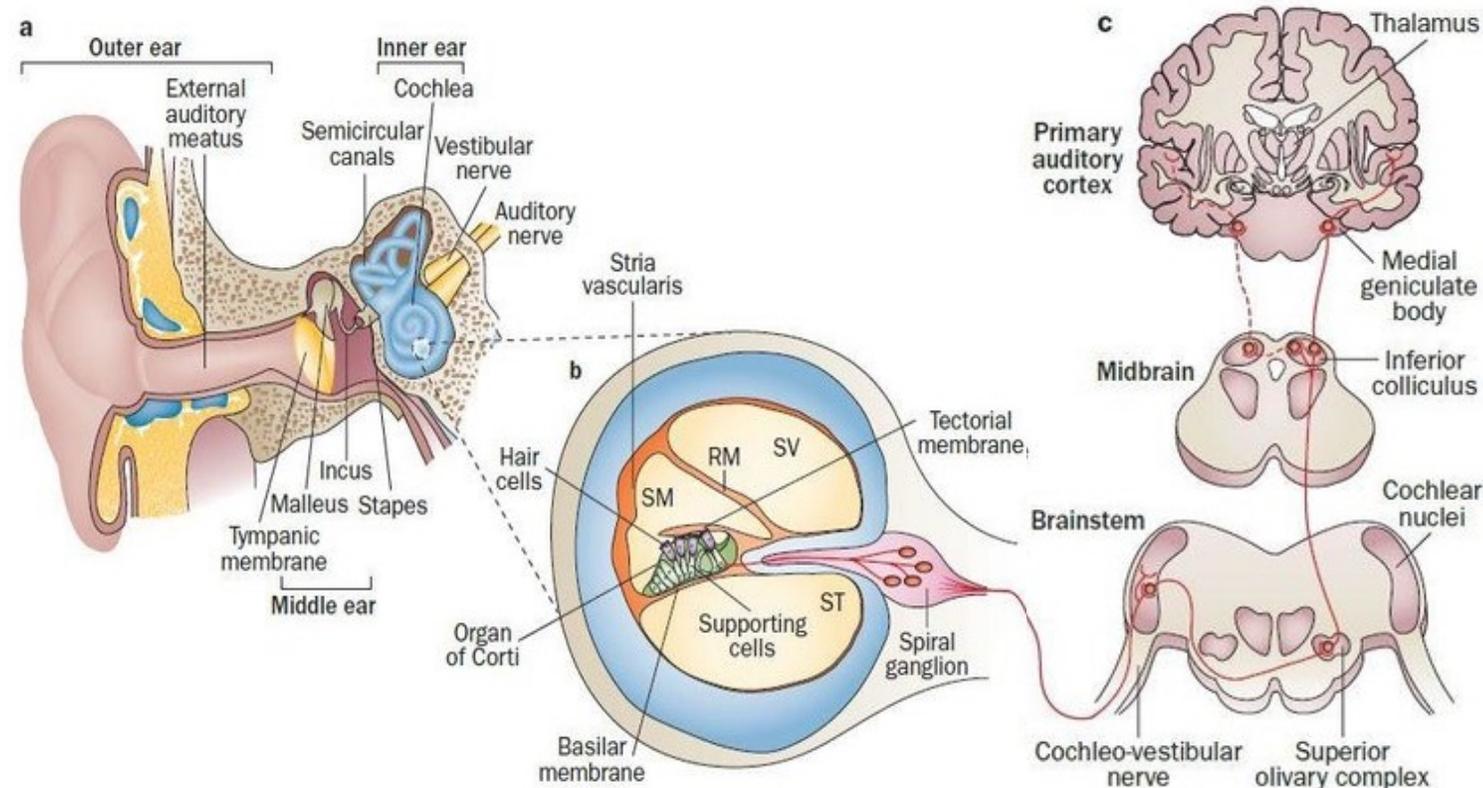
- Problematic for neural development of the central auditory systems.
- The ABR matures around 2 years of age. MLR/LLR do not mature until 10-12 years of age.
(Bamiou, Musiek, and Luxon, 2001).
- Studies have shown interaural asymmetries on EP testing with prolonged wave III and V absolute latencies.
- If there are processing difficulties at the brainstem, then this likely is creating processing difficulties at the level of the cortex.
 - Poor input from the bottom-up processing.

- Multiple concussions/TBI (Turgeon et al, 2011; Taylor et al, 2017; Agarwal & Than, 2024)

- ~ 2.8 million TBI-related emergency department visits occurred in the U.S. in 2013.
 - Estimated to be as many as 3.8 million TBIs per year.
- ~ 454,000 sports-related TBIs hospital visits annually in the U.S in 2018.
- One study compared 8 athletes with 1 or more sports-related concussions to 8 athletes with no prior concussions.
 - All 8 non-concussed athletes had normal CAPD evaluations, while more than 50% of concussed athletes showed central auditory processing deficits.

Dig Deeper...

- Central auditory deficits can be a result of peripheral auditory involvement.
- As clinicians, we have to look beyond the peripheral auditory system.



Acknowledgement

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Thank You.

Questions



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