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Disclaimers

- Hollea Ryan is employed by Samford University and receives financial compensation for her work. No conflict of interest exists for this presentation.

- Bethany Wenger is employed by Vanderbilt University Medical Center and receives financial compensation for her work. She has previously worked as a consultant for a hearing protection device company and was financially compensated. No conflict of interest exists for this presentation.

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Hearing Loss and Auditory Disorders: Outside the Clinic

AGENDA

- Unilateral Hearing Loss
- Minimal (Bilateral) Hearing Loss
- Auditory Disorders
- Non-clinical Settings
- Noise-Induced Hearing Loss

Learning Objectives

At the completion of this presentation, the participant will be able to:

1) Detail current research findings regarding children with minimal hearing loss and/or noise-induced hearing loss.

2) Identify non-academic settings in which children with hearing loss struggle.

3) Summarize various treatment options for children with hearing loss that improve communication, academic performance, and/or quality of life.

What the Literature is Indicating about Minimal/Unilateral Hearing Loss

Hearing Care Practices Before and After UNHS

(Fitzpatrick, Whittingham, & Durieux-Smith, 2013; Fitzpatrick, Durieux-Smith, & Whittingham, 2010)

- Retrospectively evaluated 20 years of history related to diagnosis time period of HL and amplification interventions (1990-2010)
- 381/823 (~46%) Canadian children were identified with MBUHL
  - proportion similar pre- and post-UNHS.
  - Median age of 5.0 pre-UNHS
  - Median age of 0.8 years post-UNHS
  - 22% experienced progressive HL
- Roughly 90% of children with MBUHL dx receive a recommendation of amplification by 2010
  - 50% experienced significant delays in amplification after identification
  - less than ⅔ of children consistently wear their amplification devices

Auditory and Language Outcomes and UNHS

(Fitzpatrick et al., 2019)

- Evaluated auditory and spoken language outcomes for children with UHL to determine outcomes for these children at 48 months when identified early through universal newborn hearing screening programs.
- When compared to mild BHL peers and NH peers, children with UHL at ~48 months performed poorer than did either the BHL or NH peer groups, particularly in functional auditory listening and in receptive and expressive language skills.
  - receptive vocabulary and speech production had no significant difference
- Children with UHL demonstrate deficits in receptive and expressive language development as well as functional auditory listening abilities, even when identified early (~3.4 months; HA fit ~12.2)

Communication Development in Early Identified Children with MHL and UHL

(Fitzpatrick et al., 2015)

- 55 children w/HL and their families from Ontario participated
  - 45 children with NH
- 80% of children with HL received recommendations that included amplification
- No difference b/t groups on auditory development measures
  - exception CHILD at ages 3 and 4 years
- No differences for any language outcome measure
- Thus, children with MHL or UHL demonstrate equivalent language skills through age 4 years
  - HA usage not evaluated and might be a contributing factor

Common Areas of Delay or Difficulty in Children with MBHL or UHL (McKay, 2008)

- Academic Delays
  - 10 times more likely to repeat a grade OR
  - Receive special services
  - spelling, language, and math
- Language Delays
- Poorer attention and behavioral per teacher reports
  - fatigue, frustration, withdrawal, irritability and low self-esteem
- Impact of HL is present in some children, absent in others

Listening is Exhausting

Bess & Hornsby (2014); Ohlenforst et al. (2017)

- Emerging studies indicate that children with hearing loss experience significant fatigue as a results of listening effort during speech perception
  - to the point that it can impede classroom performance
- 'Cognitive fatigue' includes the following characteristics: reduced alertness, attentiveness, mental efficiency; increased distractibility and anxiety levels.
  - fatigue is highly related to/correlated to stress
- Fatigue can be noted in the behavioral changes of children with hearing loss: moodiness, inattentiveness, tiredness (even in morning), and lack of physical activity/play.
- Evidence that amplification, and the use of ALDs, can help to reduce listening fatigue in school age children.

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QOL in Children with Hearing Loss

(Roland et al., 2016)

- Systematic Review: Out of 979 abstracts, 40 selected for review
- 4 articles had detailed studies with the PedsQL Inventory
  - provides physical health and psychosocial health summary scores
- Children with HL reported significant issues in areas of social and school
- However, they also indicated improvement in QoL after intervention
- Scores were statistically significant, but not clinically meaningful, for children with/UHL

Associated Condition: Tinnitus

- Children can describe when asked, but often do not spontaneously report tinnitus to parents/healthcare providers
- Although 13-47% of children with HL will report tinnitus, it is most common in children with moderate to profound HL (23-56%)
- Pitrowska and colleagues (2015) found 6% of school-aged children reported tinnitus.
  - 20% of children with tinnitus reported that it was permanent
  - significantly related to age and HL
  - children with HF UHL reported tinnitus less often that other children with UHL
  - Children with moderate, bilateral HL reported significantly more tinnitus than other peers with BHL.
  - No differences between sexes or UHL vs BHL conditions.

Unilateral Hearing Loss

The Implications of UHL (Krishnan & Hyfte, 2016)

- between 32-67% of those with UHL have abnormal anatomy of the inner ear
  - Abnormalities of the normal ear have also been identified, suggesting possible future bilateral HL
- JCIH recommended that all children identified with UHL receive imaging of the cochlea and associated structures
- JCIH also recommends that all children identified with UHL receive an ophthalmic evaluation.

The Implications of UHL (Krishnan & Hyfte, 2016)

Literature review specifically looked at the impact of UHL on the following abilities:

- localization
- social and behavioral development
- speech recognition
- speech and language competence
- cognitive functions
- academic achievement

The Implications of UHL (Krishnan & Hyfte, 2016)

Localization

- Children with UHL have poorer localization abilities than NH peers
- Greater the degree of HL, the poorer the ability to localize
- Contributing factors to poor performance: age, degree of HL, age at onset of HL, and duration of HL
- Training in localization can improve performance

Overall conclusion based on current evidence: Poor localization abilities are present in children with UHL, which continues into adulthood. However, most individuals are aware of their deficits in localization.

The Implications of UHL (Krishnan & Hyfte, 2016)

Social and Behavioral Development

- Includes factors such as distractibility, aggression, withdrawal, inattentiveness, and decreased cooperation.
- Teacher report of behavioral issues in children with UHL ranges from 20-33%.
- Embarrassment and the feeling of inferiorness is reported by children with HL at nearly 33%.
- Greater report of behavioral issues in children with UHL that have repeated a grade.
- Quality of Life is reportedly lower for children with UHL; these issues persist into adulthood, often with complaints of loneliness, frustration and embarrassment.

The Implications of UHL (Krishnan & Hyfte, 2016)

Speech Recognition

- Varying results in the literature, as there is some evidence to support no difference in performance in speech recognition abilities in quiet when compared to hearing peers, while other evidence suggests poorer performance by children with UHL, regardless if it is a closed-set task or open-set task and even in 'favorable' conditions
- Even on questionnaires about listening effort, children with UHL report (at rate of 66%) more difficulty in noisy environments
  - ⅓ report difficulty hearing teacher
- Difficulty continues into adulthood
  - requiring a greater SNR advantage to perform similarly to NH peers.

The Implications of UHL (Krishnan & Hyfte, 2016)

Speech and Language Competence

- Against traditional thought, children with UHL demonstrate difficulties in language competencies, including: oral ability/speech, spelling, reading, auditory comprehension, and word recognition and language scores.
- Can see delays in “early auditory behaviors” as young as 9 months, with 41% demonstrating delays in pre-verbal vocalizations.
- 41% of children with UHL are also enrolled in speech-language services.

The Implications of UHL (Krishnan & Hyfte, 2016)

Cognitive Function

Not as widely investigated, available evidence provided mixed conclusions.

- Normal to poorer verbal IQ scores have been found; consistent lower verbal IQ scores for children that have repeated a grade
- Some evidence to support lower complex verbal working memory
- Some evidence to support lower verbal and performance IQ scores for adolescents with UHL
- More research is needed

The Implications of UHL (Krishnan & Hyfte, 2016)

Academic Achievement

- 22-40% of children with UHL have repeated a grade
  - UHL due to atresia appears to be an exception for need to repeat
  - nearly 60% of children with 'any' degrees of UHL demonstrate academic difficulties
- 41-54% of children with UHL have IEPs
  - 48% of children with atresia also had a IEP
- Although children with UHL overall demonstrate equivalent academic success rates as well as post-school employment, they often continue to demonstrate academic struggles and behavioral difficulties while in the school setting.

Quality of Life in Children with UHL

(Borton, Mauze, & Lieu, 2010)

- Pilot study included a focus group of children 6-17 years of age from an academic otolaryngology department
- Evaluated the health-related quality of life of children with UHL
- Children reported experiencing issues due to their hearing loss but also report learning to adapt to their difficulties
- Social functioning scores demonstrated significantly larger variance than peers (both NH and bilateral HL)
- Important conclusion: Parents should be counseled on potential negative influences of UHL on children's overall quality of life
  - various environments

Progression of Hearing Loss in Children

(Barreira-Nielsen, et al. 2016)

- Canadian population-based study of children identified with HL through UNHS.
- Progressive HL seen in 158/330 (~48%) children followed
- Of those with progressive HL, ~57% had a unilateral decrease
- 73/330 had UHL
- 27 children with UHL had progressive HL (46 had stable UHL)
  - 25 had a decrease in the impaired ear within a 4-year timeframe
  - 5 eventually experienced BHL

There was no significant relationship between any risk factors and progressive HL.

- Exception: craniofacial anomalies were more likely to have stable hearing thresholds over the duration of the study.

Threshold Shifts in Young Adults

(Carter & Black, 2017)

- Cross-sectional cohort study of young Australians with pre-adult onset HI [11 to 35 yr olds]
- Median observation period was 10 years (3 months - 29.5 years)
- Hearing threshold shifts were noted in 50% of individuals without risk factors
- Authors specifically recognize that doesn’t include any potential changes in thresholds for younger children

Threshold Shifts & Progressive HL

(Carter & Black, 2017)

- Cross-sectional cohort Australian study
  - 268 adolescents and young adults with preadult HL onset
  - most dx with HL prior to school-aged; almost all by adolescence
- HTL equal to or greater than 70 dB at 2k or 4k Hz at initial evaluation was a risk factor for high frequency threshold shifts.
  - Thus, threshold shifts were seen in ~50% of study participants
- Also found that for the participants, threshold shifts were resulting from ‘whole-of-life’ noise exposure
  - very few participants reported high levels of noise exposure

The Implications of UHL: (Krishnan & Hyfte, 2016) Intervention Options

Conventional Hearing Aids

- Roughly 1 out of every 4 children with UHL receive an initial recommendation of amplification
  - various studies indicate 9-48% of children with UHL receive a HA
  - Surprisingly, a parental survey indicated that 42% of patients were informed that amplification would not be beneficial, despite that only 8% of the children had complete loss in the affected ear.
- Both patient and parent report indicates that the use of amplification improves listening effort, academic and behavioral performance, localization and improved quality of life.
- Roughly 1 quarter of children with UHL wear the HA full-time; contributed to late fittings

Conventional Amplification in UHL

(Briggs, Davidson, & Lieu, 2011)

- Eight children between the ages of 7 and 12
- Evaluated speech perception in quiet and noise
- Subjective assessments from children, parents and teachers
- Measurements made prior to HA fitting and 3 months post
- Results showed no significant differences in any of the speech perception tests
- However, a large significant aided benefit was reported at home and at school per parents and children.
- Additionally, children reported an overall improvement in QoL.

The Implications of UHL: (Krishnan & Hyfte, 2016) Intervention Options

CROS and BAH Options

- CROS HAs do not offer notable improvement in speech recognition in the classroom
  - Therefore, they are NOT recommended for young children who do not have the ability to manipulate themselves within an environment to ensure that the NH ear is not directed towards the environmental noise.
- Research on bone-anchored Hearing systems in children with UHL is relatively new; however, results suggest improvement in ability to listen in noisy situations and in quality of life.
  - Better speech recognition scores for BAH use vs CROS use
  - Subjective reports indicate patient satisfaction as well as a preference over traditional bone conduction hearing aids
  - However, some studies indicate that early implantation is not beneficial for individual into adulthood.
  - Better outcomes for CHL vs SNHL

BAHA Use in Profound UHL

(Christensen, Richter, & Dornhoffer, 2010)

- Retro-spective review of 23 children with BAHA to determine benefit of BAHAs in children with SSD
  - average age 12.6; range 6-19 yrs
- Two-stage BAHA surgery w/ 6-month osseointegration
  - minimum age at implantation was 5 years
- BAHA provided significant benefit to all patients in both overall (parental) report [CHILD] and in hearing in noise [HINT], regardless of age group (young children and teenagers)
  - complication rate was 17%

The Implications of UHL: (Krishnan & Hyfte, 2016) Intervention Options

FM Systems

- Multiple studies demonstrate the benefit of FM systems on speech recognition, both in quiet and in noise, in children with UHL
  - beneficial even when noise is presented on the NH ear
  - benefit increased as the severity of the HL increases
- Noted benefit for FM systems when compared to CROS and conventional HAs
- Ear-level FM fittings, with either tube fittings or non-occluding headphones, are recommended to ensure optimum SNR, environmental awareness, and natural ear resonance.
-

Rehabilitation Outcomes in Children w/UHL

(Appachi et al., 2017)

- Systematic review analyzing rehabilitation outcome studies
  - Of the 249 articles initially identified, only 12 were selected for analysis
- 5 studies focused on FM systems, conventional HAs and/or CROS HAs.
  - HA result in improved speech perception
  - FMs provided most benefit, specifically for speech recognition in noise
  - CROS results were mixed
  - More research is needed, particularly for benefit of conventional HAs
- 7 studies focused on bone conduction hearing devices.
  - improvement in PTAs, localization, and speech recognition thresholds

The Implications of UHL: (Krishnan & Hyfte, 2016) Intervention Options

Cochlear Implants

- As cochlear implantation of children with UHL is rare, only two articles were reviewed by Krishnan & Hyfte.
  - Benefits were noted in the areas of speech recognition in noise, localization abilities, and overall self-reported benefits.
- Literature is too limited to make recommendation/summary of benefit, although benefit is noted for adults with UHL who receive a CI.
- Revised clinical evaluations and development of implantation criteria for children with UHL have been recommended (First, Reeder, & Holden, 2017; Krishnan & Hyfte, 2016).

The Implications of UHL: Intervention Options (Park et al., 2018a; Park et al., 2018b)

- Ongoing study evaluating quality of life in children with UHL who receive a cochlear implant
- Overall findings:
  - child reports greater fatigue than parents perceive
  - improvements in localization/spatial hearing, auditory skills and listening effort occur
    - benefit of CI can be seen as early as 3 months post implantation
- Greater focus in UHL, particularly as it relates to cochlear implants as a treatment option (Cushing et al., 2018).
  - Specific references were presentations at 15th International Conference on Cochlear Implants.

Use of Cochlear Implants in Childhood UHL

(van Wieringen et al., 2019)

- Of 237 neonates with UHL, ~22% of neonates had microtia.
  - Unilateral aural atresia was present in ~70% of microtia patients.
  - Not traditionally candidates for CI unless additional inner ear abnormalities are present.

- 60% of neonates had profound SNHL in affected ear
  - Cochlear nerve deficiency (CND) was most common cause identified
    - CND has been associated with poor outcomes after cochlear implantation (Walton et al., 2008)
    - Patients with CND are not good candidates for CIs

Use of Cochlear Implants in Childhood UHL

(van Wieringen et al., 2019)

- Conducted a review and provided recommendations for management of childhood UHL
- Infants/young children with SSD show an average delay of 5 months to produce two-word phrases as well as delays in preschool language development (Borg et al., 2002)
- Lower scores on expressive and receptive language tests (Lieu et al., 2010) that continue into adolescents (Fischer & Lieu, 2014)
- Authors argue that “neural consequences of congenital SSD should not be underestimated” (p. 33).

Use of Cochlear Implants in Childhood UHL

(van Wieringen et al., 2019)

Causes of SSD/UHL Cont.

- congenital cytomegalovirus (cCMV)
  - 2nd most common cause of congenital SSD
  - CI should be considered for SSD cCMV cases; however b/c likelihood of condition to become bilateral HL, recommendations should also include auditory rehabilitation and speech therapy
- Bacterial and viral meningitis (30% of cases result in UHL)
  - not contra-indication for CI; however, expediency is necessary due to ossification of the cochlea
- Congenital inner ear malformation
  - current study demonstrated had a low percentage but literature indicates rates as high as ~35%
    - Benefits of CI have been documented

Minimal Hearing Loss

Slight-Mild SNHL in Children

(Cone et al., 2010)

- Out of 6581 Australian elementary school-aged children, 55 were identified with SMHL
  - 39 had slight HL (16 - 25 dB HL)
  - 16 had mild HL (26 - 40 dB HL)
  - majority had bilateral and symmetrical
  - prevalence of SMHL in the ‘year 5’ group was twice that of ‘year 1’, suggesting possibility of acquired HL (e.g., headphone use)
- Most prevalent risk factor was “neonatal intensive care unit/special care nursery admission”
- Personal stereo use was also a significant risk factor
- 36/55 kids also had parents evaluated
  - 33% of mothers and 58% of fathers also had at least a mild HL

Risk Factors for Slight-Mild Hearing Loss

(Cone[-Wesson] et al., 2010)

- Cross sectional analysis of Australian school-aged children revealed that:
  - Most prevalent risk factor was “NICU/SCN admission”
  - Other common (but none significant) factors included congenital infection, APGAR score of <4 @ 5 mins, discharged on oxygen
- Study was the first to indicate possible relationship b/t noise exposure in children is a possible risk factor for acquired HL.
  - Use of a “personal stereo” was the only statistically significant risk factor associated with slight-mild SNHL

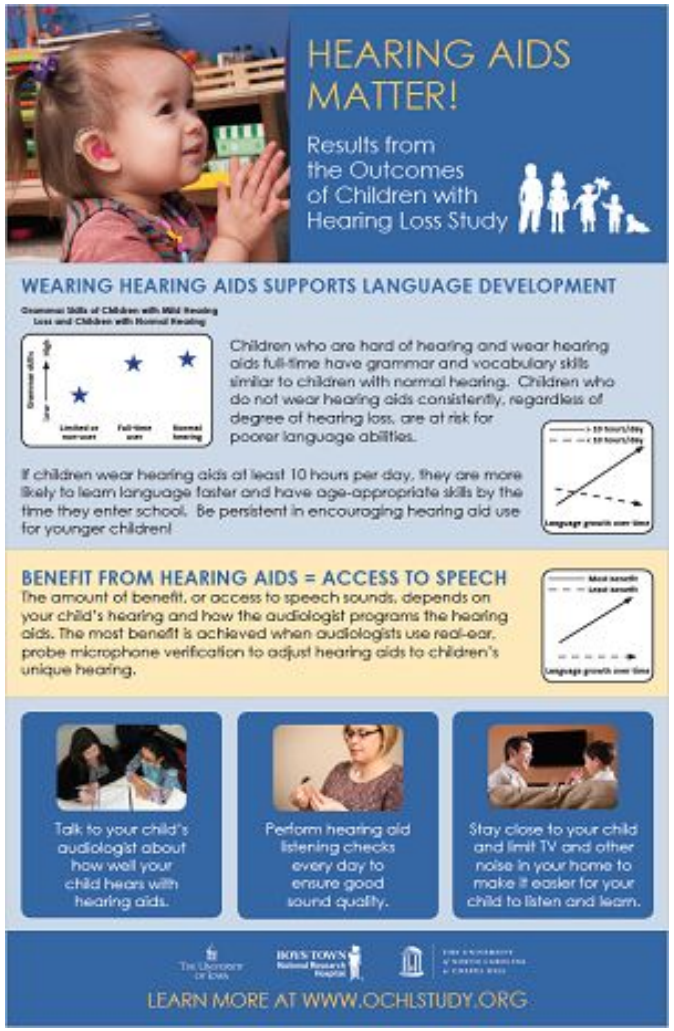
Language Development in Mild Hearing Loss

(Halliday et al., 2017)

- Ninety children with mild to moderate hearing loss were assessed on a variety of standardized language assessments

- Findings:
  - no difference to controls on receptive vocabulary and word reading
  - were WNL (but significantly different than controls) on expressive vocabulary and receptive and expressive grammar
  - worse than norms and controls on phonological processing and communication skills (per parental report)
  - Risk factors included lower maternal education and family history of language problems

Language Development in Mild Hearing Loss (Walker et al., 2015)



https://ochlstudy.org/

- (MHL)Full-time HA wearers had significantly higher vocabulary and grammar scores than their non-wearer counterparts.
- No difference for speech perception or articulation when evaluating FT usewearers, PT wearers, and non-wearers.
- Walker et al. (2015) and Halliday et al.(2017)'s findings suggest that consistent hearing aid use should be recommended to patients to facilitate language development

Practice Patterns for MHL in children

(Walker, et al., 2017)

- Data collected as part of a longitudinal, multisite Outcomes of Children with Hearing Loss study.
  - age: 6 months - 7 years @ enrollment
  - permanent bilateral HL (mild to ~severe) or mild HFHL
  - oral communication
  - 113 children w/MHL for current study
- 74% of children with MHL were identified via NBHS
- 94% of children with MHL were fit with HAs
  - significantly later than those with moderate-to-severe HL
  - 96% of children with MHL received early intervention services
- 93% of parents indicated “yes”, HAs helped their child to hear better
  - however, some parents had difficulty indicating specific examples of benefit

Hearing Aid Use in Mild Bilateral Hearing Loss

(Walker, 2015)

- Young children (5 or 7 y/o) divided into 3 groups
  - full-time, part-time, non-users
- No significant difference between all 3 groups on articulation and speech perception measures
- Significant difference in vocabulary and grammar performance for FT users vs Nonusers.
  - Daily hearing aid use only predictor of grammar and vocabulary.

Current Practice Patterns for treating Children with Mild HL (Walker, et al., 2017; Fitzpatrick et al., 2010)

- Unpublished data from Boystown: if SII < 80, child is a candidate for amplification

Minimal Hearing Loss: Evidence-Based Practice (Winiger et al., 2016)

- Literature review related to pediatric outcomes and/or intervention for minimal hearing loss
  - MBHL, UHL, and HFHL
- Areas that historically are affected by MHL:
  - localization
  - language development
  - academic performance
  - speech recognition
  - emotional wellbeing/psychosocial

Minimal Hearing Loss: Evidence-Based Practice (Winiger et al., 2016)

Intervention Options for Minimal Hearing Loss

Special Services

- Minimal research, but evidence suggest children w/MHL benefit
- Includes IEPs, referrals for both medical, psychosocial and emotional issues

Monitoring

- Both for hearing status (every 3-6 months for infants/toddlers and annually for school-aged children) and developmental and academic performance
- Includes parental education on monitoring of signs/symptoms

Minimal Hearing Loss: Evidence-Based Practice (Winiger et al., 2016)

Intervention Options for Minimal Hearing Loss

Bone anchored implants (BAI)

- benefits in quality of life and overall satisfaction in conditions including unilateral atresia and CHLs

CROS Hearing Aids

- Not recommended for children with MHL as they have yet to develop ability to use the system successfully

Minimal Hearing Loss: Evidence-Based Practice (Winiger et al., 2016)

Intervention Options for Minimal Hearing Loss

FM systems

- Various studies documenting benefit of FM systems in children with MHL, particularly as it relates to speech recognition
- Particularly beneficial when accompanying HAs for children with HF HL
- Beneficial for all children with MHL in regards to speech recognition

Frequency Modulated Considerations

(McKay, 2008 - *Perspectives on Hearing and Hearing Disorders in Childhood*)

- Due to difficulty with increased distances and background noise, children with MBHL/UHL can benefit from FM in various listening environment
- When fitting to an aided poorer ear, consider that ear's speech recognition ability
- If placing FM on good ear, McKay recommends always using an open fit earmold to allow access to environmental sounds
- Even when classroom soundfield system is available, consider offering a trial period of an ear-level FM system
- Parental reports of desktop FM use in strollers, cars, dinner tables, and preschools (educational time)
- Decisions made on individual basis

Minimal Hearing Loss: Evidence-Based Practice (Winiger et al., 2016)

Intervention Options for Minimal Hearing Loss

Hearing Aids

- Improvement in speech recognition abilities
  - although some children receive minimal to no benefit, especially those with severe-to-profound UHL
- Less beneficial in noise
  - some proven directional microphone benefits
- Most beneficial when fit prior to age 6 years

Children with MHL: Hearing Aids Options

(Tharpe, 2016; McKay, Gravel, & Tharpe, 2008)

Consistent with published findings:

1) Hearing aids - for UHL if aideable; can offer improved localization
2) FM systems - known to be beneficial, especially in classroom settings
   a) monaural fit with skeleton earmold demonstrates significant listening benefit; allows for speech input from environment or classmates in the 'open' ear
3) cochlear implants - limited research; potential to offer benefit
4) CROS hearing aids - not recommended for children that are unable to manipulate their environment to ensure optimal signal; potential benefit for older children

Considerations for Hearing Aid Use in Children with MBHL (Bagatto et al., 2016)

- CASE-BY-CASE REASONING
  - Child Considerations
  - Family Considerations
  - Hearing Aid Output
  - Earmold and Ear Canal Acoustics
  - Hearing Loss Degree and Configuration

Parental Perceptions of Hearing Loss Classification (Haggard & Primus, 1999)

- Terminology is confusing for parents, often resulting in under-estimating the impact of the hearing loss has on the child in everyday life
- Suggests that parents will less acceptance towards amplification as a treatment option
  - which can delay intervention
- Recommendations include the use of simulations of HL

Auditory Disorders

Management of ANSD

(Nguyen, 2017; Walker et al., 2016)

For mild to moderate ANSD cases, evidence suggests that conventional amplification/hearing aids can be an effective intervention

- individual monitoring needed

For severe ANSD cases, cochlear implants might be an appropriate intervention

- dependent on overlying causes of ANSD, as supported by findings by Madden et al., 2002

Early CI findings (Buss et al., 2002) indicated no significant differences in performance by ANSD patients compared to the 'typical' CI patients .

Intervention with Auditory Processing Disorders (Sharma, Purdy & Kelly, 2012)

Randomized control trial

- 3 groups: Training group, personal FM and no intervention
- both treatment groups demonstrated improvement …….

Auditory Processing Disorders (Chermak, 2018)

- Positive results have been obtained in regards to auditory training as an effective treatment option for those with auditory processing disorders
  - supported by behavioral and electrophysiological studies
  - (Alonso & Schochat, 2009; Bellis et al., 2012; Cameron & Dillon, 2011; Loo et al., 2016; Moncrieff & Wertz, 2008; Sharma et al., 2012; Schochat et al., 2010; Weihing et al., 2015)
  - importance of deficit-specific intervention (Cameron et al., 2012)

Considerations when Fitting children with APD (Childress, 2018) : Human Activity Assistive Technology Model

Social Contexts	Setting	Physical Contexts
Alone	School	Sound
Peers/Friends	Group Home	Light
Familiar adults or individuals of other ages	Employment	Heat
Strangers	Community	
	Home	

Considerations when Fitting children with APD (Childress, 2018)

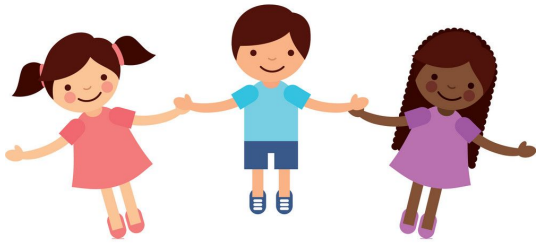
- Low gain or no-gain hearing aids
- FM systems [remote microphone hearing assistive technology]
- Classroom speaker systems [classroom auditory distribution systems]
- Noise cancelling headphones
  - **Only appropriate for those that are affected by competing background noise
  - www.amazon.com/Reduction-Headphone-Auditory-Processing-Sensitivity/dp/B01MPZMKV2
- Strategic seating in classroom and community locations
- Listening therapy
- Speech therapy

Non-Clinical Settings that Children with Hearing Loss Struggle

Family (Home) and Communities

- Canadian focus group of patients, parents and teachers indicated that:
  - the number of facilitators were reduced for social/community contexts than for family contexts.
    - often resulted in feelings of exclusion, isolation, and discrimination
    - contributed to apathetic attitudes toward hearing loss as well as ignorance
  - Participation in sports/extracurricular activities was noted to be important as it ‘equalized’ the participants and promoted positive self-esteem and proper social behaviors.
  - Preferred use of communication strategies over the use of intermediaries .

Family (Home) and Communities



- The importance of having a few close friends (who could serve as interpreters when necessary) is more valuable than many friends
  - quality of friendship more important than quantity
- Students expressed need to meet other students with hearing loss, as often the only student with hearing loss at school
- Eriks-Brophy et al.'s (2007) study indicated that there was a need for advocacy, encouragement, and instructional strategies to improve the inclusion of children with hearing loss in academic settings as well as social settings, even within the child's family.

Home Setting: Phone Use

- Children with hearing loss can experience difficulty using the telephone
- Phonak DuoPhone feature (and other wireless binaural streaming features) allow for binaural hearing of the phone's signal.
- When compared to monaural telephone conditions, children with hearing loss had significantly better speech recognition in both quiet and noise conditions (Wolfe et al., 2015).
- https://www.youtube.com/watch?v=bpB13BUq4RI

Academic Settings

Ample evidence to indicate that children with hearing loss, even mild hearing loss or unilateral hearing loss, can struggle in school (Bess & Tharpe, 1986; Kuppler, Lewis & Evans, 2013; Oyler, Oyler, & Matkin, 1987).

Difficult Listening Environments

- Movie Theater / theater
  - Suggestions on how to use closed captioning at live theaters events @ https://tinachildress.wordpress.com/category/information-and-resources/accessibility/captioning/
- Sporting Events
- Restaurants
- Theme Parks
- Home
- Car
  - All above have potential for FM benefit

Sport Environments

- Participation in sports promotes self-esteem and positive social interactions (Eriks-Brophy, et al., 2007).
- However, for individuals with either UHL or BHL that play team sports, the inability to hear teammates or coaches without visuals cues could impact performance as well as teammate interactions (Patel & Greydanus, 2002).
- Participation in recreational activities (specifically ice skating) results in significant improvements in both behavioral and emotional domains.
  - improved quality of sleep
  - improved psychological well-being
- https://successforkidswithhearingloss.com/for-professionals/helmets/
  - (link to suggested helmet considerations)

What the Literature is Indicating about Noise-Induced Hearing Loss

Noise-induced hearing loss (NIHL) topics

- Prevalence
- Sources of noise
- Effects on kids beyond hearing loss
- Gaps in research
- Gaps in legislation
- Clinical tips

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NIHL - prevalence

- Landmark population studies: NHANES surveys
  - Niskar et al, 2001
    - Overall, 12.5% incidence rate
      - ages 6-12 yrs: 8.5% with NIHL
      - ages 12-19 yrs: 15.5%
  - Henderson, Testa, & Hartnick, 2011
    - ages 12-19 yrs: 16.8%
      - no significant increase over 1988-1994 data

PEDIATRICS

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Estimated Prevalence of Noise-Induced Hearing Threshold Shifts Among Children 6 to 19 Years of Age: The Third National Health and Nutrition Examination Survey, 1988–1994, United States

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American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN

NIHL - prevalence

- Study critiques/considerations
  - Many just air-conduction
    - Tymps? Medical eval? History of noise exposure?
  - Many via headphones, no soundbooth
  - Suggested high false-positive rates
    - Schlauch & Carney, 2012: Unpublished NHANES data show poor test-retest agreement

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Sources of NIHL: prenatal

- Several animal studies have demonstrated post-natal hearing loss following maternal noise exposure
- High frequencies more attenuated than lows in-utero

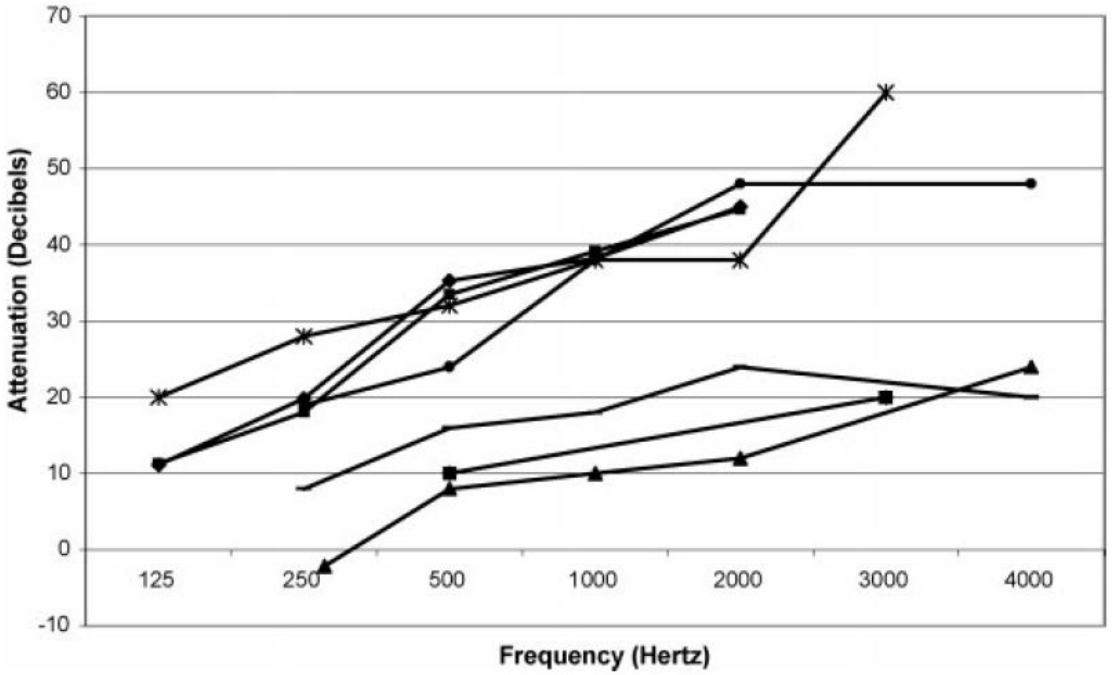

Figure 1 Attenuation summaries: ◆ Gerhardt et al[20]; × Walker et al[36]; ▪ Gerhardt and Abrams[21]; • Bench[35]; ▲ Vince and Armitage[31]; ▪ Peters et al[27]; – Querleu et al.[10]

Thurston, F. E. (2008,

Sources of NIHL: prenatal

- Selander et al, 2015
  - Swedish population study comparing prenatal maternal interview data re: occupation and later childhood diagnoses of SNHL and/or tinnitus
  - Prenatal occupational noise exposure >85 dBA (FT work) associated with hearing dysfunction

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Sources of NIHL: NICU

- NICUs are generally quiet, but these are medically fragile infants with 24/7 exposure
  - Even if not a risk of NIHL--how much is needed for restful sleep?
    - AAP: <35 dBA (Committee on Environmental Health, 1997)
  - Abujarir et al, 2012: adhesive earmuffs correlated with improved heart rate, blood pressure, respiratory rate, oxygen saturation and days of oxygen requirement
- MEE could have preventative effect (~35%-67%) (Bess, Peek & Chapman, 1979)
- Transport helicopters 90-110 dB (Johnson, 2011)

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Sources of NIHL: Toys

- American Society of Testing and Materials (ASTM)
  - Max volume: 85 dB as measured 50 cm from toy
    - … do all kids play with toys 20” from their ears?
  - Excludes impulse noises
    - 3-yr-old with 30 dB hearing loss from bike horn (143 dB SPL) (McMillan & Kileny, 1994)
- Even if a toy advertises safe levels… not necessarily!

Sources of NIHL: Toys

- Bittel, Freeman & Kemker, 2008
  - Most handheld / tabletop / crib toys and ALL ear-level toys exceeded safety levels

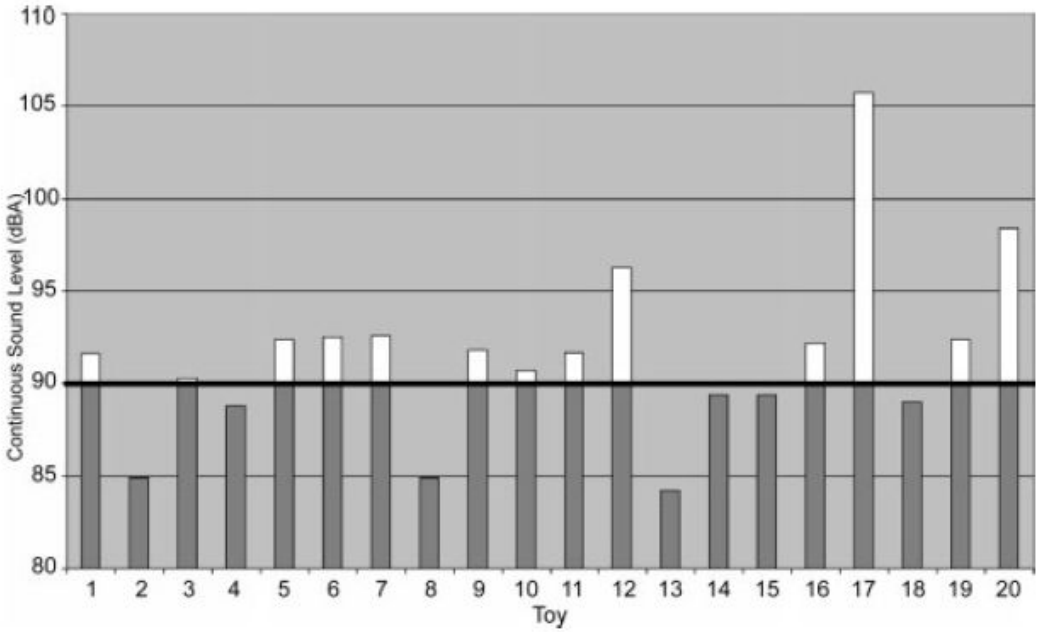

Figure 1 Continuous sound levels (dBA) for all toys included within the handheld, tabletop, and crib group. Areas in gray represent intensity levels below the ASTM International toy-noise standard, and areas in white represent intensity levels in excess of that recommended by ASTM International. Toys assessed and noted in the illustration: 1, laser gun; 2, magnetic alphabet learning toy; 3, cartoon character car; 4, alphabet-singing cartoon character; 5, cartoon character karaoke; 6, toy bazooka; 7, toy fire truck; 8, magnetic animals learning toy; 9, cartoon character boombox; 10, toy phone (sound from base); 11, music sing-along platform; 12, controllable race car driver; 13, musical book; 14, electronic guitar; 15, cement truck; 16, sword; 17, lightning and thunder staff; 18, laser gun; 19, toy tool (weed trimmer); 20, toy tool (air wrench).

Sources of NIHL: Farms

- Renick, Crawford & Wilkins, 2009
  - Longitudinal study: baseline ages 4-21 yrs, follow-up 6-10 yrs later
  - Significantly higher rates of HL and NITS, but unable to conclude significant change over time in NITS
    - HL: baseline 22.5%, follow-up 33.1%
    - NITS: baseline 22.5%, follow-up 19.6%

Possible exposure to ototoxic solvents (Perry 2003)

Any hearing loss = safety issue

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Sources of NIHL: Sports

- Hockey (Hodgetts & Liu, 2006)
  - Wore dosimeter during Stanley Cup finals
  - Fans w/o HPD received 8100% of their daily allowable noise dose
- Soccer (Swanepoel & Hall, 2010)
  - Average 100.5 dBA
  - Decrease in behavioral thresholds and DPOAE amplitudes

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Sources of NIHL: Music

- iPods (and others) contribute… but it's complicated (Fligor, 2007)
  - ~5-15% of listeners demonstrate risky volume/duration, but actual damage will depend on many individualized factors
  - They are *capable* of damaging hearing, but difficult to prove in large population studies

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Sources of NIHL: Recreational activities

- Fireworks
  - Gupta & Vishwakarma, 1989: ~2.5% of children/young adults had NIHL persisting 3 months after Deepawali fireworks festival

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Effects *beyond* NIHL

- Munich Airport study (Hygge, Evans, & Bullinger, 2002)
  - Old airport closed, new airport opened
  - After new airport: poorer long-term memory and reading
- Heathrow Airport study (Haines et al, 2001)
  - Matched schools (4 near airport, 4 away), children ages 8-11 yrs
  - Airport noise: higher levels of annoyance and stress, poorer reading comprehension and sustained attention
- Also studies of railroad noise, road noise, etc.

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Effects *beyond* NIHL

Children and noise

IMPAIRED COGNITION

STRENGTH OF EVIDENCE FOR EFFECTS OF AIRCRAFT NOISE ON CHILDREN

HEALTH OUTCOME	STRENGTH OF EVIDENCE
Annoyance	Sufficient
Hearing loss	Sufficient
Cognitive performance - **reading**	Sufficient
Cognitive performance - **memory**	Sufficient
Cognitive performance - **auditory discrimination**	Sufficient
Cognitive performance - **speech perception**	Sufficient
Cognitive performance - **academic performance**	Sufficient
Cognitive performance - **attention**	Inconclusive
Motivation	Sufficient / limited
Wellbeing/perceived stress	Sufficient / limited
Catecholamine secretion	Limited / inconclusive
Hypertension	Limited (weak associations)
Psychiatric disorder	Inconclusive / no effect
Sleep disturbance	Inadequate / no effect
Birth weight	Inadequate
Immune effects	Inadequate

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World Health Organization presentation: “Children and Noise”

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Gaps in research

- Standards and recommendations based on *adults* (ANSI, etc.)
  - Adult auditory systems
  - Sources of noise
  - Safe listening levels

    Animal studies suggest increased susceptibility for pediatrics (e.g., Humes, 1984)
- Population studies' critiques

  Headphones vs. inserts, training level of tester, high-false positive rates, poor test-retest reliability, etc.

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Gaps in legislation

- OSHA HPD requirements don't apply to small companies
  - … what about employees who are children? (e.g., family farms, landscaping)

Honey, I Shrunk the Kids, 1989

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Clinical tips

- Talk to ALL families about sources of noise and potential for NIHL
  - Earbuds/headphones: “If mom/dad can hear it, it’s too loud. If you can’t hear mom/dad talking to you, it’s too loud.”
  - Speakers: “If you can’t talk to someone without raising your voice, it’s too loud.”
  - “I know it might not seem that loud, but it’s dangerous because of how *long* you’re listening to it, and can change your hearing little by little over time.”
- Websites for families (e.g., www.noisyplanet.nidcd.nih.gov)
- Pediatric hearing protection
  - e.g., Baby Banz, Ems 4 Bubs/Kids, Peltor)

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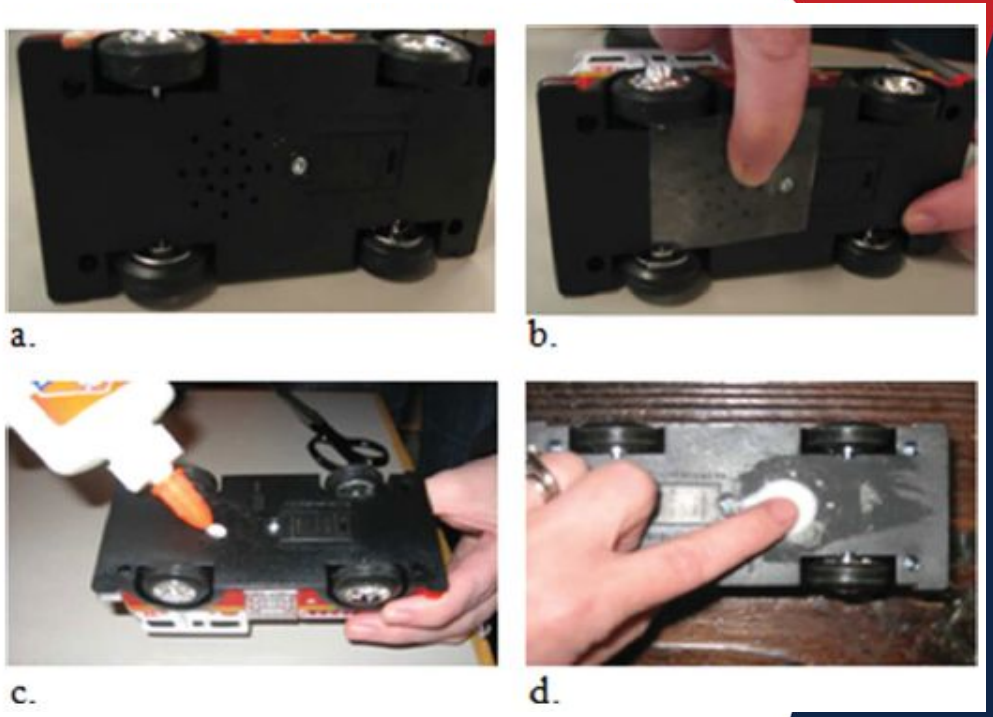
Clinical tips

- Toys: tape/glue over the speakers (Weinreich et al, 2013)
- Annual list of noisy toys (Sight and Hearing Association)



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HEAR-QL Survey

- HEAR-QL (Hearing Environments and Reflection on Quality of Life)
  - 26-28 questions, ages 7-12 and 13-18 yrs
  - Environments, activities, and feelings

HEAR-QL Survey

- Specific environments (other than academics)
  - playing outside/recess/sports
  - restaurants/cafeteria
  - ball games
  - field trips
  - parties
  - pool/beach
  - phone
  - movies/tv

Sports: *Time Out! I Didn't Hear You*

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Table 6: Identifying communication within an activity

Student's Name: _____

Coach's Name: _____

Activity: _____

Communication Situation	Tryouts indoor	Tryouts outdoor	Practice indoor	Practice outdoor	Pre-game indoor	Pre-game outdoor	Competition indoor	Competition outdoor	Telephone	During travel	Award ceremonies	Related events	Over night stays
Coach-to-player													
Member-to-member													
Team/group instruction													
Official-to-player													
TV/film viewing													
Guest speaker													
Alerting signals													
Emergency Alerting Plan*													

*Anytime an athlete might be alone when an emergency alert (e.g., tornado alert during Cross Country) could be delivered, there needs to be a plan to communicate with the athlete who might not hear this alert.

Sports: *Time Out! I Didn't Hear You*

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- **Table 7.** Solutions to previously identified difficult communication situations

Student's Name: _____

Coach's Name: _____

Activity: _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Current Hearing Aids																				
Different Hearing Aids																				
HAD *																				
HA & HAD *																				
Captioning																				
Writing																				
Hand Signal																				
Sign Language																				
Auditory Alerting																				
Visual Alerting																				
Tactile Alerting																				
Comm. Strategies																				

* Indicate type of coupling: T=telecoil, Bt=Bluetooth (delivered through Gateway device communicating with hearing aid), BtL=Bluetooth Light, DAI=direct audio input, FM=built-in FM receiver
Note if this type of system is being used in the student's academic activities.

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Considerations for Management of Hearing Loss in Children who are Hispanic (Caballero, et al., 2017)

- [Bethany – I know you speak Spanish – do you have any general or specific comments that would be useful?]
  - I do!
  - Make sure you have a qualified interpreter, not family member
    - If phone interpreter & you have to demo something, maybe rely on visual rather than having the interpreter explain a physical process they're not seeing
  - Hearing testing
    - Even if you have an interpreter all the time, some test battery items are time-sensitive (e.g., CPA coaching, tasking during vestibular testing) or easier if you can do it in Spanish (e.g., spondee board). (attach Bethany's cheat sheet for non-Spanish speakers)

Helpful Resources

- https://www.cdc.gov/ncbddd/hearingloss/conference.html
- https://www.understood.org/en/school-learning/special-services/504-plan/the-difference-between-ieps-and-504-plans (differences b/t 504 and IEPs)
- https://www.aussiedeafkids.org.au/creating-a-good-listening-environment.html (has details specific for UHL and MBHL)
- https://ochlstudy.org/ (OUtcomes of Childhood HL brochures/posters)
- https://successforkidswithhearingloss.com/for-professionals/hearing-aids-on-2/ (resources)

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