Optimizing Audibility: Practical Tools for Families and Providers Supporting Spoken Language Development

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Disclosures

Blaiser:

- Salaried at Idaho State University
- URLEND Faculty
- OSEP Awards
- AAP Faculty

Sapp:

- Salaried at UNC Medical Center & UNC School of Medicine
- Consultant for Akouos/Eli Lilly
- Research support from ASHA, NIH/NIDCD

Goals

- Review the WHY in caring about audibility
- Review family, SLP lens in considering
- Apply audiology tools to case studies
- Support infrastructure for communication/collaboration

Leveling the playing field with a common language.

Audibility expresses how much a child's hearing loss limits access to speech sounds on a % scale.

Audibility can also express how much a child's hearing aids help.

Audibility is not just for audiologists

While audiologists are the primary providers who are responsible for addressing audibility in the fit of the hearing technology, it's really *a team effort* to understand how it is impacting communication access and development

Considering this...

Lens 1: Audiologist: Pretty Map

Lens 2: SLP: LSLS- increased productions

Lens 3: Family: Increased productions, more responsiveness

Case study 2

- 2 year old boy
- Mild-to-moderate hearing loss
- Speech sample – omission of all high frequency sounds
- Mom- "We have high frequency hearing loss, /s/ is hard for us"

Mommy going drive in mommy car and daddy going to drive in dad car
Mommy gonna ride in the boat, and daddy gonna ride in the boat.
Where the water?
That daddy boat!
Stay in the boat. Don’t fall down in the ocean! That the ocean.
Don’t fall down
They got wet!
Don’t fall in the ocean again!
That a captain and that a captain
There two captain
That mommy boat and that daddy boat
I think he going ni-night
I think he not going ni-night. I think he going to bite!
Now mommy going to eat the apple

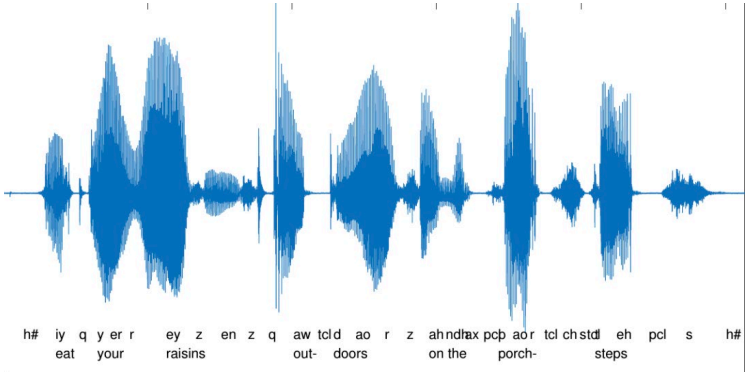
Mommy IS going to drive in mommy'S car and daddy IS going to drive in dad'S car
Mommy IS gonna ride in the boat, and daddy IS gonna ride in the boat.
Where'S the water?
That'S daddy'S boat!
Stay in the boat. Don’t fall down in the ocean! That IS the ocean.
Don’t fall down
They got wet!
Don’t fall in the ocean again!
That'S a captain and that'S a captain
There'S two captainS
That'S mommy'S boat and that'S daddy'S boat
I think he IS going ni-night
I think he IS not going ni-night. I think he IS going to bite!
Now mommy'S going to eat the apple

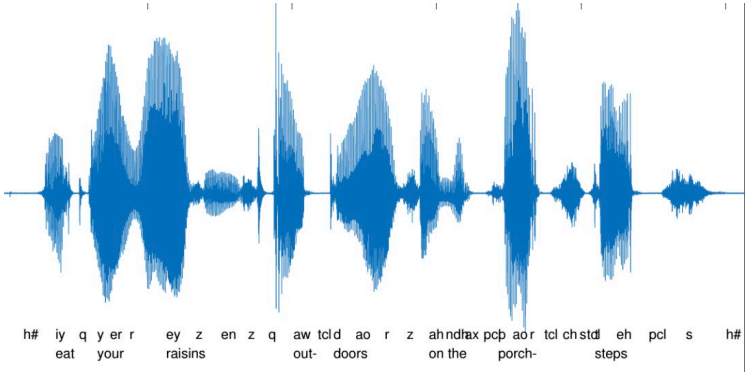
From Cole & Flexer, 2020

Table 2–1. Speech Information Carried by the Key Speech Frequencies of 250–4000 Hz (± one half octave)

250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
• First formant of vowels /u/ and /i/ • Fundamental frequency of females' and children's voices • Nasal murmur associated with the phonemes /m/, /n/, and /ng/ • Prosody • Suprasegmental patterns (stress, rate, inflection, intonation) • Male voice harmonics	• First formants of most vowels • Harmonics of all voices (male, female, child) • Voicing cues • Nasality cues • Suprasegmentals • Some plosive bursts associated with /b/ and /d/	• The important acoustic cues for manner of articulation • Second formants of back and central vowels • Consonant-vowel and vowel-consonant transition information • Some plosive bursts • Voicing cues • Suprasegmentals • Unstressed morphemes	• The important acoustic cues for place of articulation • The key frequency for speech intelligibility • Second and third formant information for front vowels • Consonant-vowel and vowel-consonant transition information • Acoustic information for the liquids /r/ and /l/ • Plosive bursts • Affricate bursts • Fricative turbulence	• The key frequency for /s/ and /z/ audibility that is critical for language learning: – plurals – idioms – possessives – auxiliaries – third person singular verb forms – questions – copulas – past perfect • Consonant quality

Helping families understand “They turn their head so I know they can hear me”


h# iy q y er r ey z en z q aw tcl d ao r z ah ndh ax pcl p ao r tcl ch stcl d eh pcl s h#
eat your raisins out- doors on the porch- steps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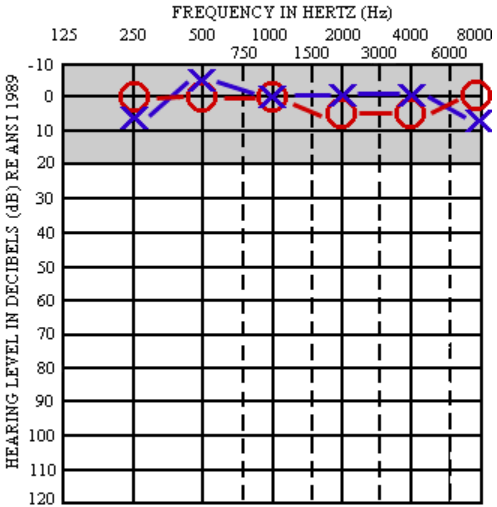
Measuring audibility for spoken language requires that we know two components:

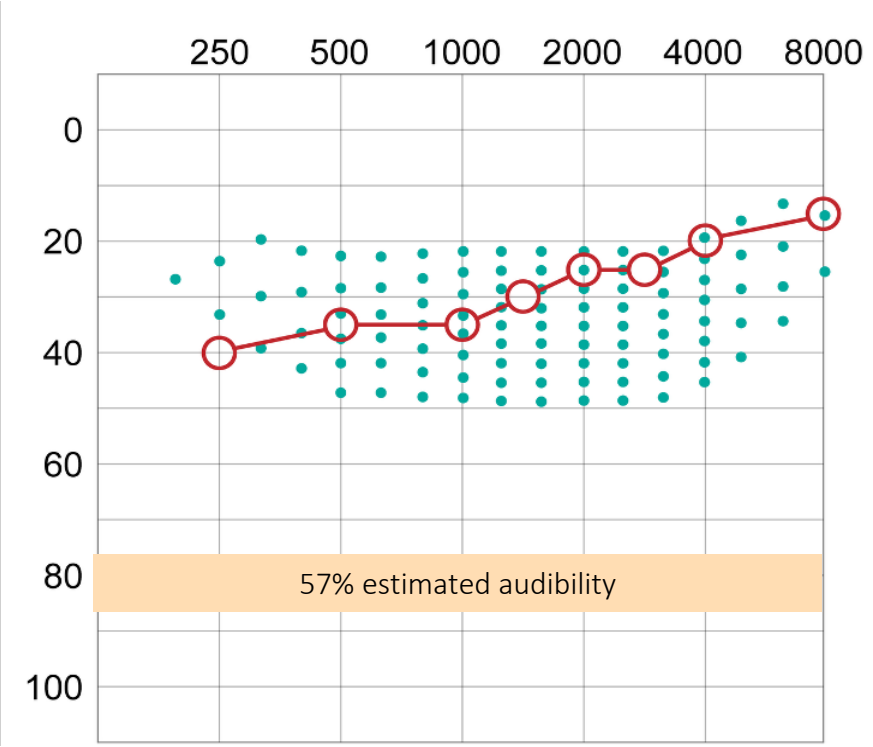
How much of a given pitch range falls above a patient's thresholds?



How important is that pitch range to understanding spoken language?

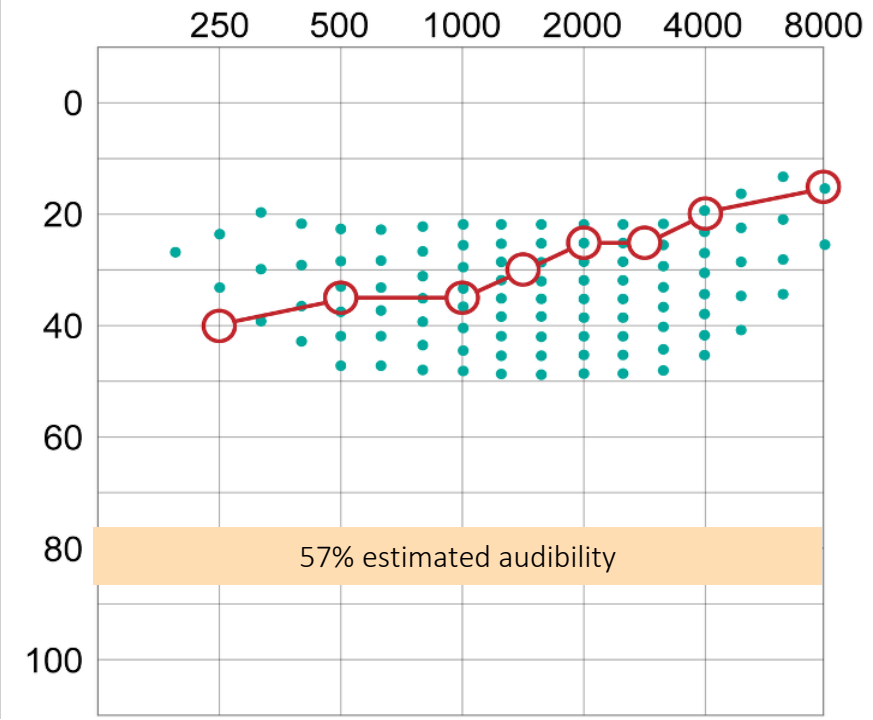
Visualizing Audibility on the Audiogram

- Right ear, “mild hearing loss rising to hearing within normal limits”
- Teal dots represent the distribution of speech sounds.
- Audibility captures **how much of this speech information is accessible based on the underlying hearing loss**.
- The value is more precise when we account for a child’s ear canal shape and size.



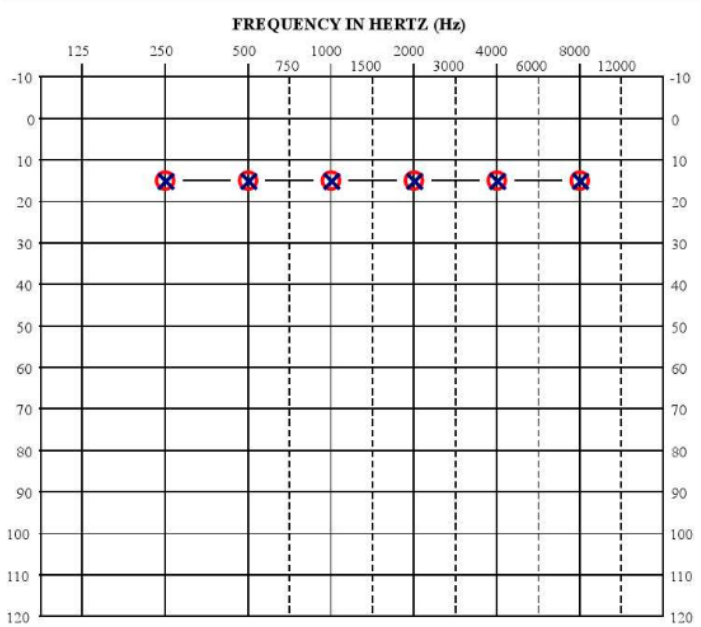
Visualizing Audibility on the Audiogram

- Right ear, “mild hearing loss rising to hearing within normal limits”
- Teal dots represent the distribution of speech sounds.
- Audibility captures **how much of this speech AND LANGUAGE information is accessible based on the underlying hearing loss**.
- The value is more precise when we account for a child’s ear canal shape and size.

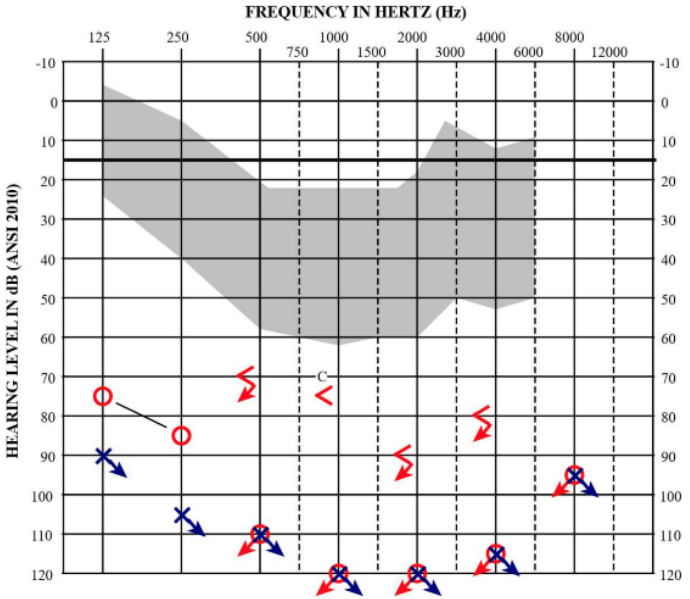


Audibility centers our clinical decision making on observable, repeatable measures and serves both our major populations:

Children with typical or normal hearing



Children with hearing loss



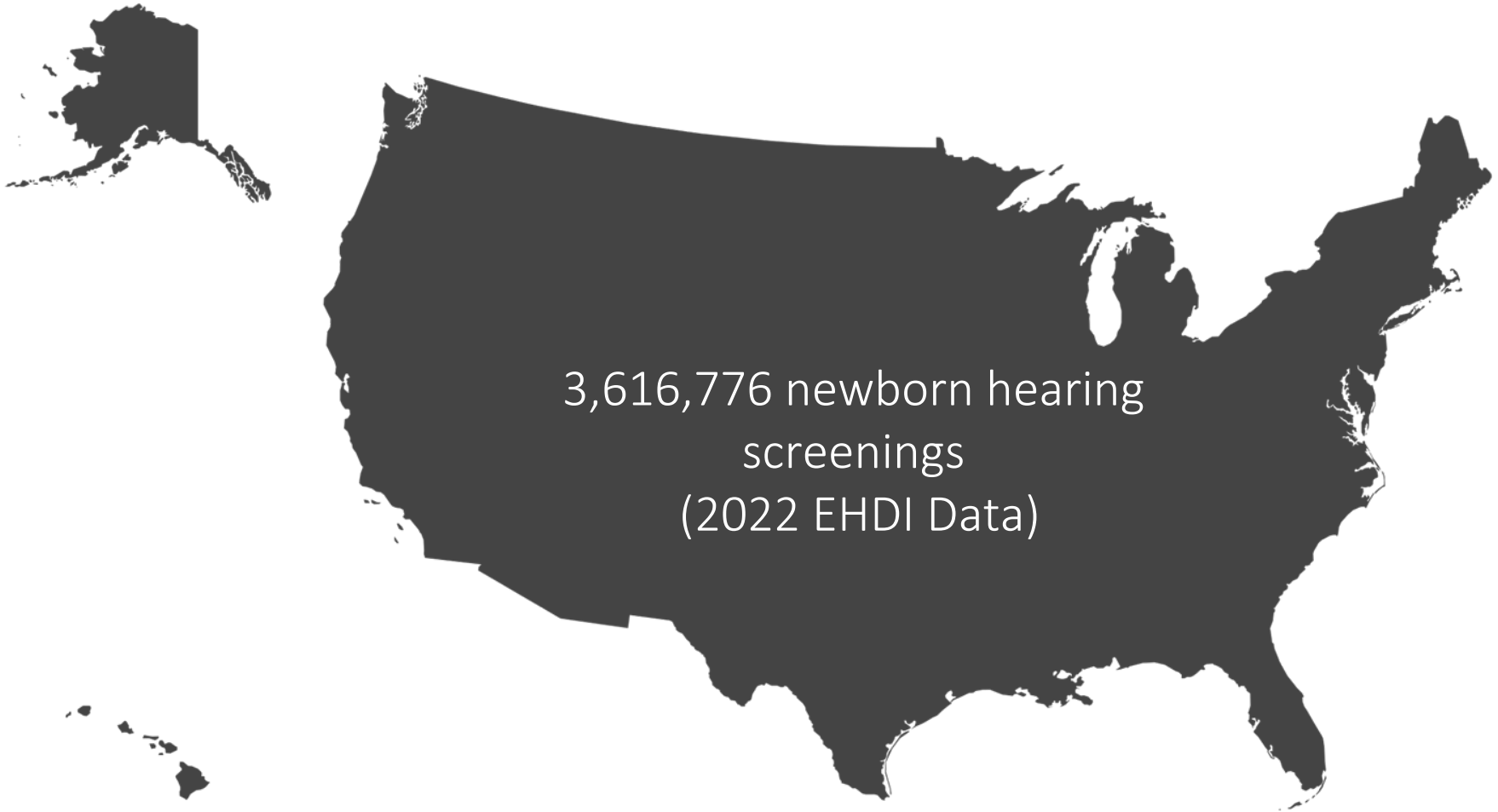
There are clinical applications for audibility-based counseling any time we talk to families about hearing loss.

- Hearing Loss Diagnosis
- Hearing Technology Candidacy
- Verifying Hearing Aids
- Supporting Device Use
- Monitoring Schedule
- Transitions

Why is follow up after the newborn hearing screening so urgent?

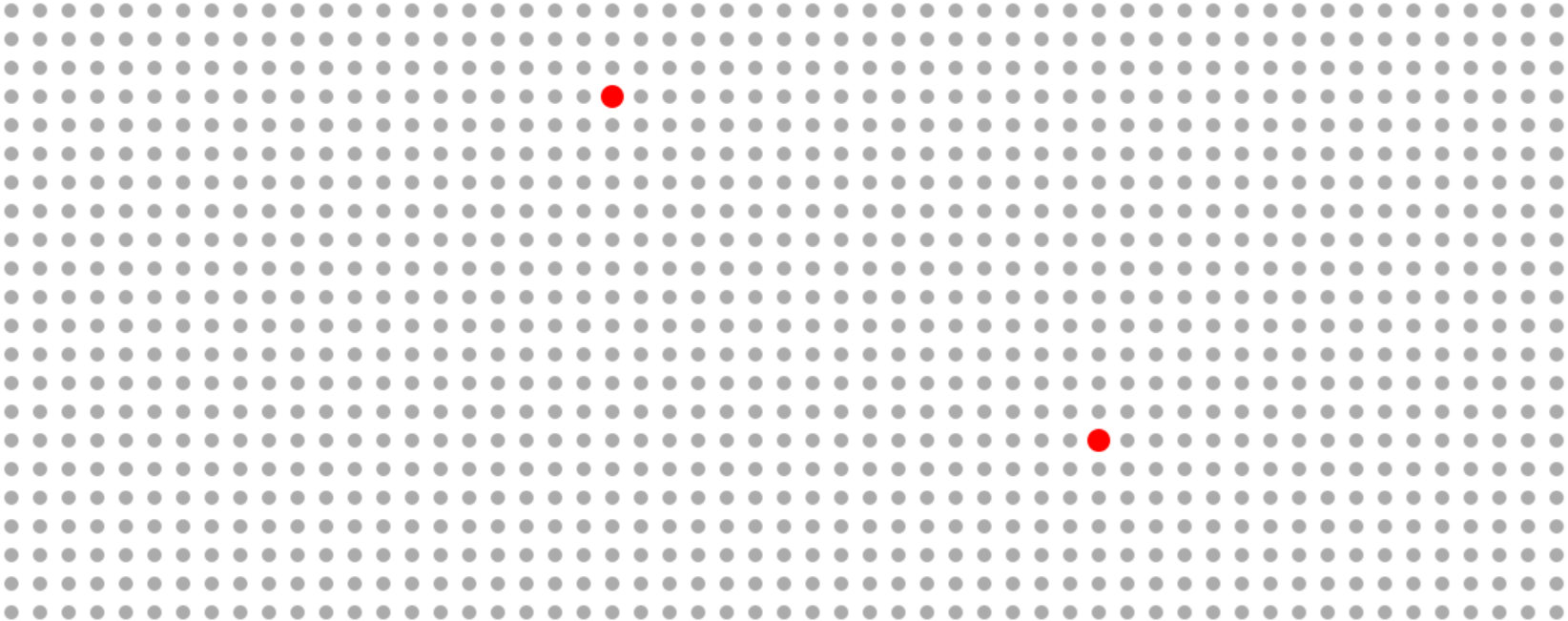
How did you picture teaching your baby language?

How did **you** learn language when you were young?

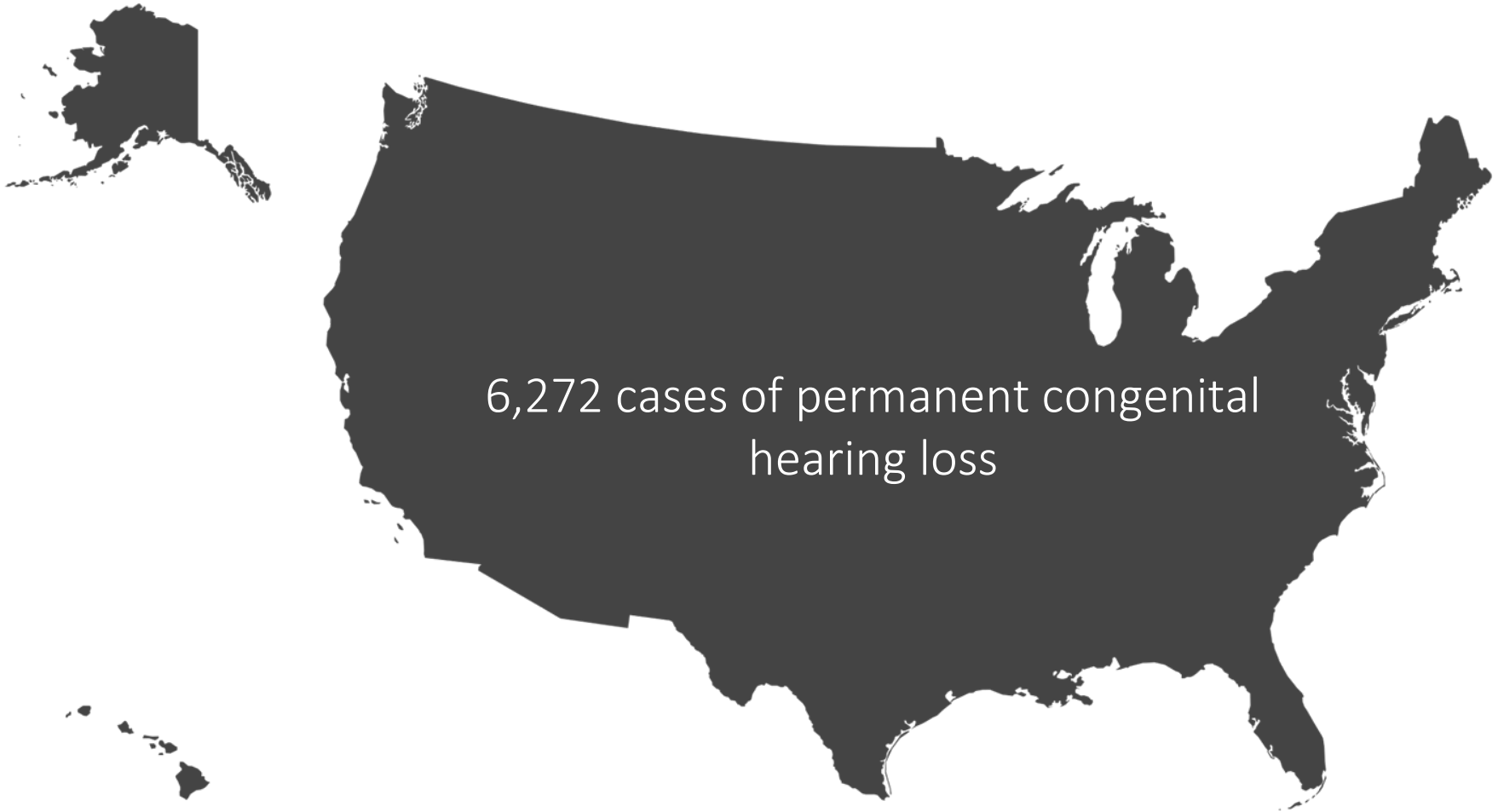

3,616,776 newborn hearing
screenings
(2022 EHDI Data)


Why do we do it?

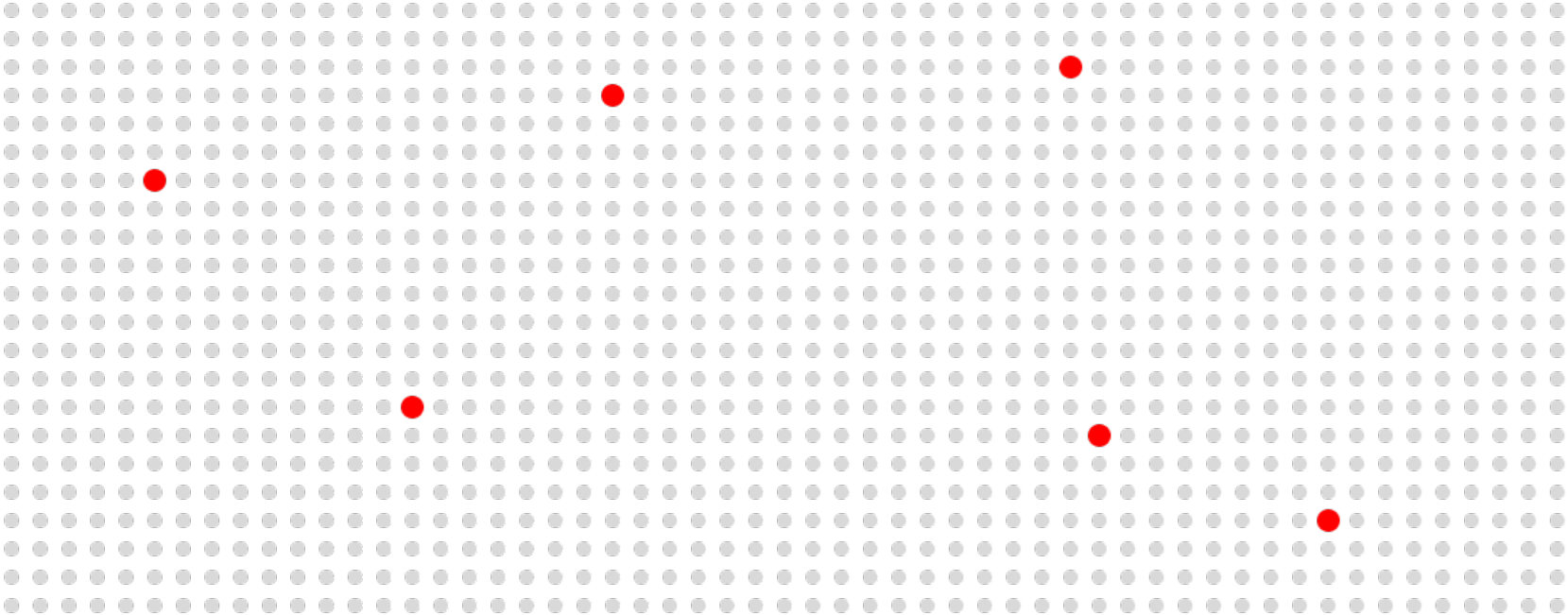
Making language accessible for those children is what makes it worth screening them all!



(CDC, 2022)

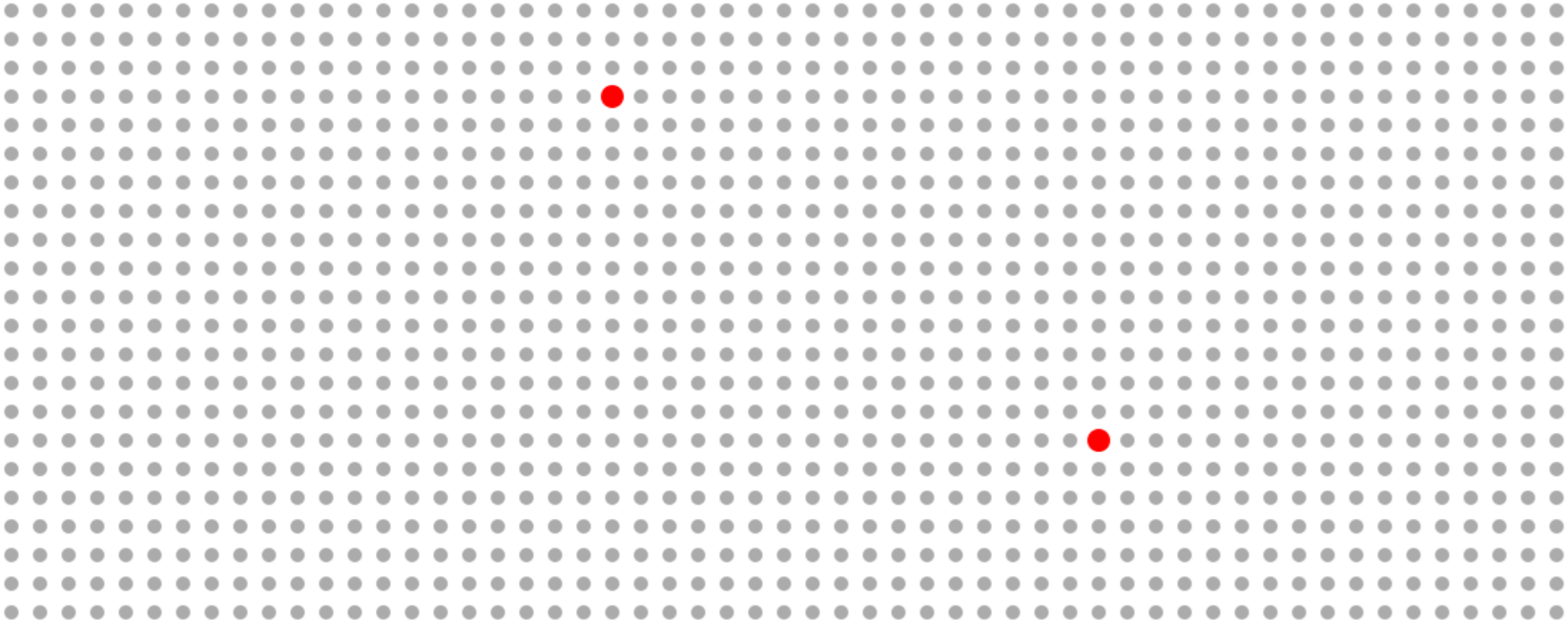

6,272 cases of permanent congenital hearing loss

By the school-age years, this number goes up to about six children per 1,000.[1]



[1]CDC, 2024; 1.8/1000 births, collapsed across states and territories.

One aspect of the EHDI system that we don't spend a lot of time with is the BIGGEST group we serve:



(CDC, 2022)

Why do I need to go into the audiologist so often with my baby?

Auditory experience happens over time, our task is to **proactively** stay ahead of changes to sustain that experience.

Auditory Experience

Spoken language is an experience-dependent phenomenon: we learn language by experiencing language.

Hearing loss changes that experience- important cues are less audible and children with hearing loss have fewer opportunities for language learning.

This is where EHDI comes in.

Kuhl, 2004; Tomasello, 1992; Moeller & Tomblin, 2015; McCreery & Walker, 2021; Nicholas & Geers, 2006

The drive to ensure effective audibility metrics is the common thread of our big clinical challenges:

High quality hearing assessments

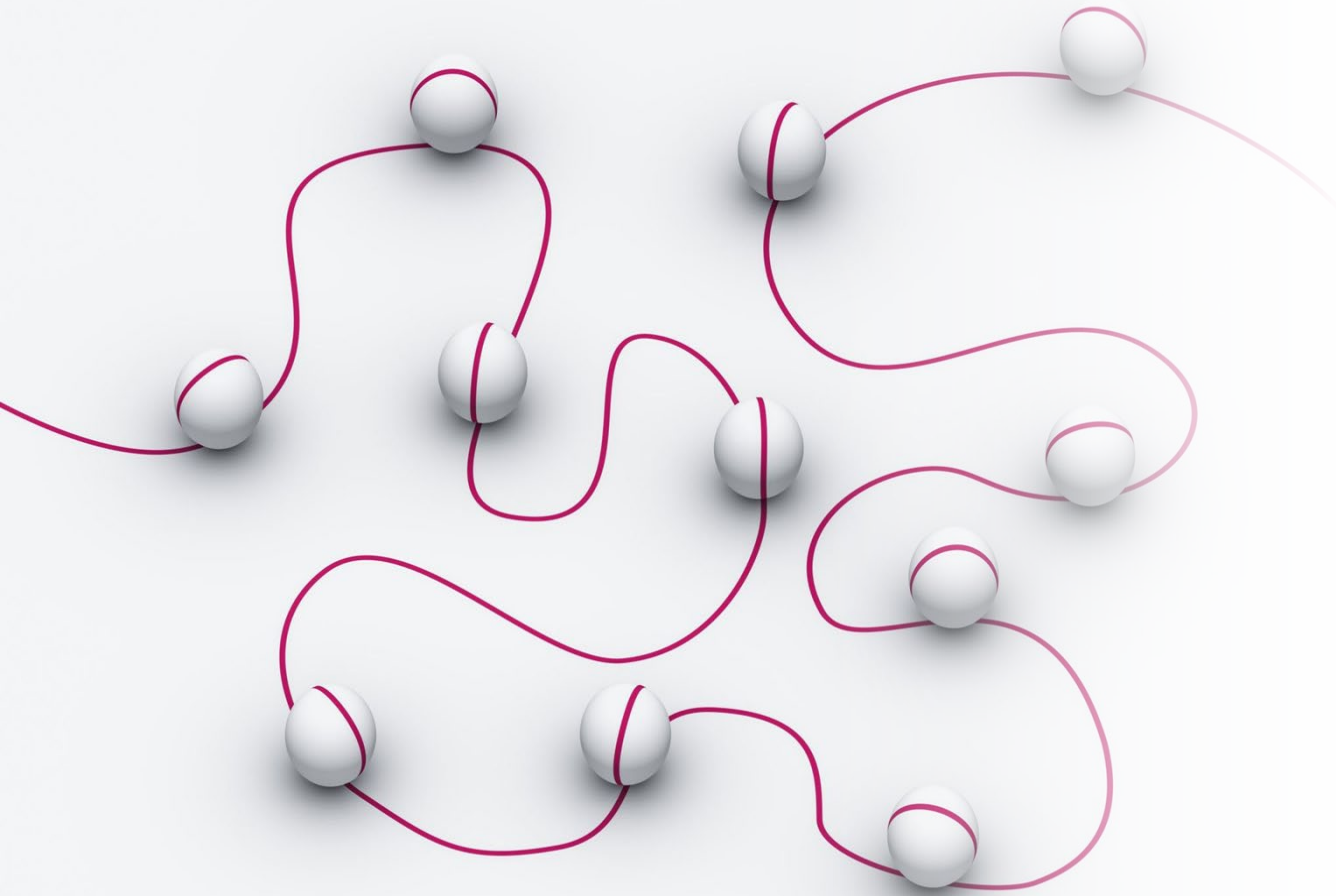
- Up to date, recent tests
- Valid, age-appropriate test methods
- Using multiple types of test methods and formal parent observations

High quality hearing technology fittings

- Best practices with hearing aid fittings (probe microphone verification)
- Child appropriate hearing aid targets
- Low error in hearing aid fittings
- Recent ear measurements (RECD)
- Full time device use

As an EI provider, why do I care about audibility?

You want to ensure the auditory tasks you've targeted are *fair* tasks, given a child's auditory access.



Auditory access should be the common thread that ties diagnostic findings, intervention selection, surveillance timelines, and device use recommendations.

Mild hearing loss

Focus on unaided audibility and the decrease it has on auditory access.

Profound hearing loss

Focus on aided audibility and the limitations of traditional amplification to boost access.

What do the Ling sounds tell us about audibility?

From an EI/Family standpoint

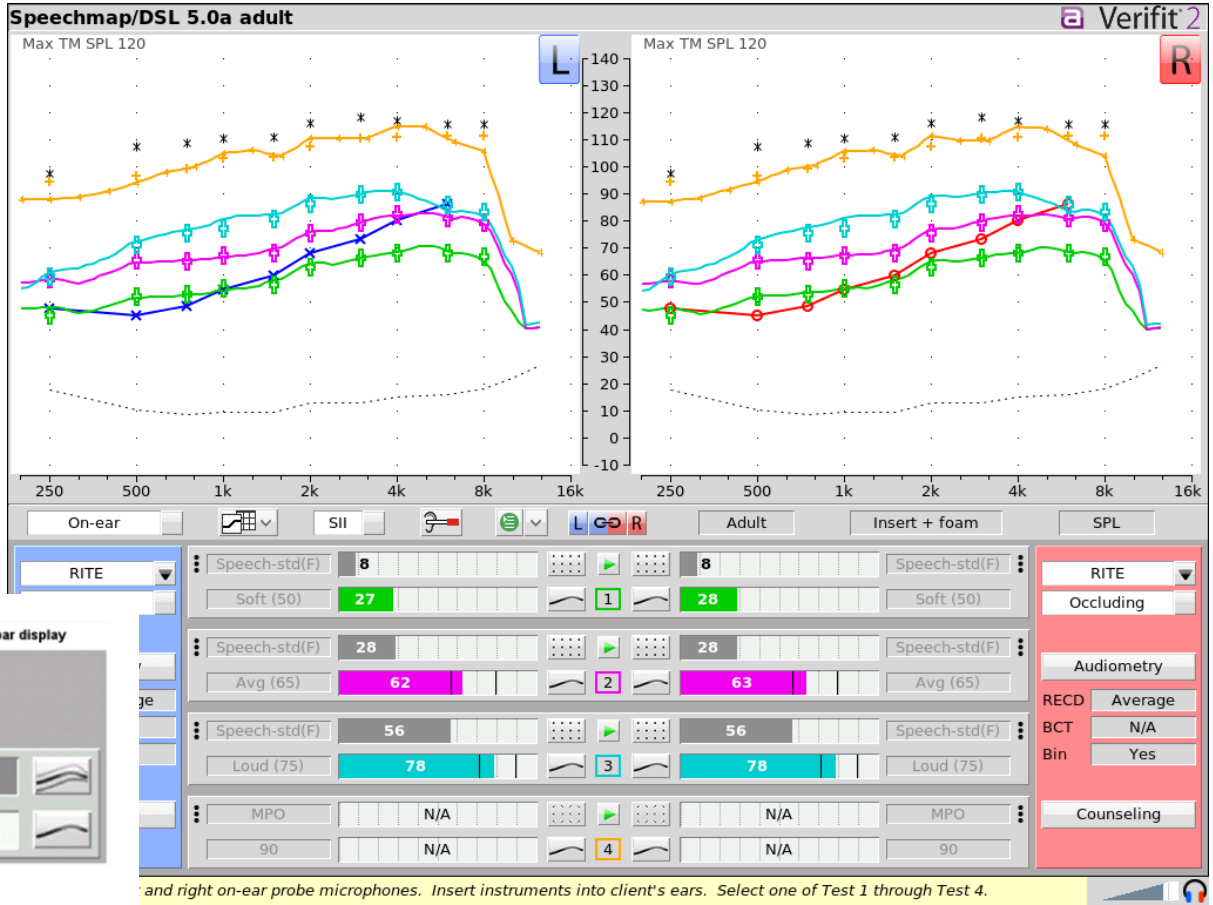
- Hearing across frequencies is part of it
- Understanding and eliciting responses
- Understanding *change* in responses

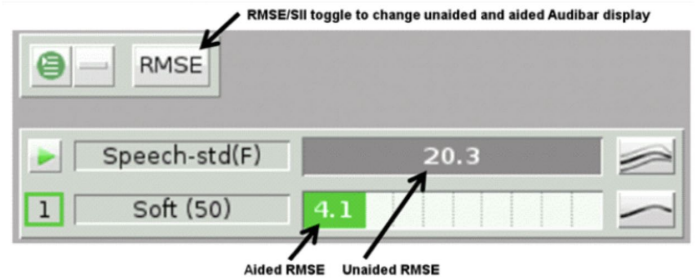
How does the audiologist know that they have effectively programmed the HA?

Plug and play hearing aids are not good enough when you're using your ears for the first time to learn spoken language!

Considerations

1. Visual match to targets for important speech sounds.
2. Aided audibility for speech samples played at different levels.
3. Low error in the fitting from prescriptive targets.





Is there something like a checklist that I could/should use with my audiologist to ensure audibility?

Quality hearing aid fittings are everyone’s business!

The audiologist should welcome your questions!

Unaided audibility

- What does my child hear without their hearing aids? (unaided SII)
- How has their auditory access changed over time?
- Can I hear a simulation of his/her hearing loss?

Aided audibility

- What kind of boost does my child get from wearing their hearing aids?
- Are hearing aids still the right choice?
- Is their aided audibility in the range we expect for their level of hearing loss, and if not why?

What is RECD? Why does it matter?

Every ear is unique, and quality hearing aid fittings account for individual differences!

Real ear to coupler difference (RECD)

“We are going to measure how sound behaves in your baby’s ears.”

“It’s important we account for the unique size and shape of your baby’s ear when we program her hearing aids.”

“As she grows, we will repeat this measurement frequently to be as accurate as we can when we check her hearing aid programming.”

What is the difference between Deaf/Hard-of-Hearing?

Many families share that when they received their child's diagnosis, to them any level of hearing loss = d/Deaf.

"What I thought on day one was that it was zero to one hundred percent. So, I thought it was like putting on a pair of glasses. It knew nothing about hearing aids."

"When they tell you that it's moderate moderate to severe, I literally think she can't hear a thing....Now that I know more about hearing loss, I know that moderate to severe really isn't as severe as it sounds."

"I immediately jumped to the conclusion that she was profoundly deaf because hearing loss to me, at the time, equaled she was deaf. It was black and white."

Sapp et al. (in press) Audibility-based informational counseling in pediatric audiolog
using the speech intelligibility index: A qualitative study

How do I decode the audiologists report?

Degree-based and functional descriptions of pediatric hearing loss: A retrospective chart review

Sapp et al., (in review)

- Most reports provide limited information outside of degree of hearing loss
  - Degree can be misleading
  - Nothing mild about mild!
  - Misses important individual differences based on configuration
- Children's hospital reports were more likely to include a more functional description of ***what does this hearing loss mean?***
- Several reports contained no details about the ***level of hearing loss, permanency of hearing loss, or what happens next.***

"On retest we are showing “decreased hearing in the failed right ear”

"…results of today's evaluation are largely inconclusive." **[click thresholds at 50 dBnHL and No Response in the right and left ear]**

"Conductive hearing loss in at least one ear"

“…newly identified hearing loss”

“Hearing sensitivity is outside the normal range.”

“No clear responses in right ear and some responses in left ear….”

"…maximum conductive hearing loss" **[bilateral atresia, Treacher Collins syndrome]**

“Abnormal ABR response for each ear.”

"…assume there is some level of permanent conductive hearing loss for the right ear."

“…permanent conductive”

"…normal bone conduction" **[unilateral atresia]**

“…35 click and 75 clicks”

"…on retest is found to have reduced hearing and abnormal middle ear results"

"…reduced hearing and abnormal middle ear results…child will require medical evaluation and retest."

"Results suggest sensorineural hearing loss for both ears"

Example language
for reporting and discussing audibility concepts

Reporting and discussing how hearing loss impacts auditory access to important speech sounds and environmental cues can help reinforce the counseling audiologists do in person with families. Here are some ways to incorporate audibility concepts into written audiology records.

Hearing Evaluation

"These results show that [patient] has reduced access to the sounds of spoken language. Based on today's hearing test, her audibility for average speech is xx% in the right ear and xx% in the left ear."

Hearing Technology Candidacy

"Based on [patient]'s unaided audibility for average conversational speech, she is likely to experience significant aided audibility benefit from wearing bilateral hearing aids. When children have access to <80% of speech information, hearing aids are able to amplify sounds which would otherwise be too soft."

"[Patient]'s family was counseled on today's results. He has an educationally and developmentally significant hearing loss which will limit his auditory access to the cues of spoken language. Hearing aids restore auditory access by amplifying sounds which would otherwise be too soft, and facilitate language and academic achievement. Amplification is recommended both ears and his family was ready to proceed with a hearing aid consult."

"Due to the level of this hearing loss, hearing aids alone may not support language development. We see limited aided audibility benefit with her hearing aids (estimated xx% and xx% in the right and left ears) compared to her unaided audibility (xx% and xx%)."

Hearing Technology Fitting

"During [patient]'s fitting today, we measured the output of his hearing aids to verify this his amplification was fit appropriately. Our results show that [patient] is receiving significant aided audibility benefit with her hearing aids (estimated xx% and xx% in the right and left ears) compared to her unaided audibility (xx% and xx%). Overall, our fitting shows a strong match to recommended targets (RMSE < 5dB)."

Supporting Device Use

"During our discussion, we reviewed how each hour that [patient] is able to use his hearing aids is an hour spent with greater auditory access to speech sounds that are critical for learning spoken language. We also reviewed his most recent hearing evaluation results and how much his hearing loss limits his unaided access to sound (estimated at xx% and xx% from his last hearing evaluation)."

"Due to the level of this hearing loss, hearing aids alone may not support language development. We see limited aided audibility benefit with her hearing aids (estimated xx% and xx% in the right and left ears) compared to her unaided audibility (xx% and xx%)."

Audibility centers our clinical decision making on objective measures and serves both our major populations:

Children with typical or normal hearing

- All speech sounds are audible and available for listening and language.

Children with hearing loss

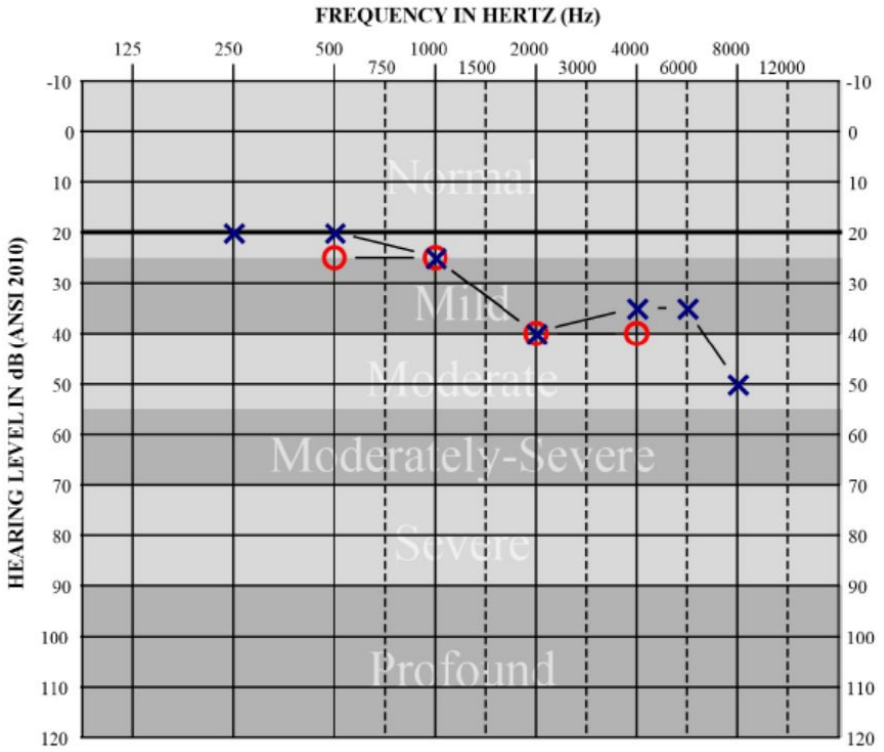
- Diminished audibility for speech sounds is what drives the decision to recommend hearing aids.
- Poor aided audibility is what drives the decision to recommend a CI.

(Wiseman et al., 2023)

Using audibility: The decision to fit a Hearing Aid

HA Candidacy Case:

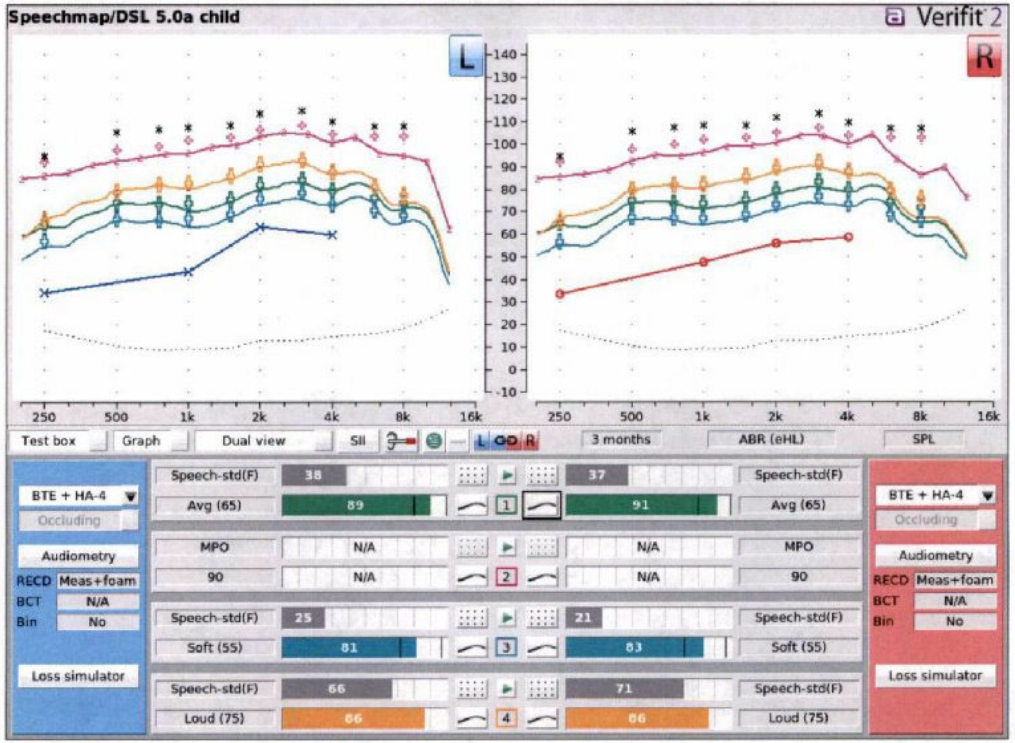
- 8-month-old female (born March 2020)
- Failed bilaterally @ birth
  - 24-hour discharge requested
  - No second screen
- Lost to follow up until age 8 months



Huge aided audibility benefit in both ears from offering hearing aids!

Right: 37%→91%
Left: 38%→89%

This is a child who is ready to make progress in spoken language skills working with her SLP and early interventionists.

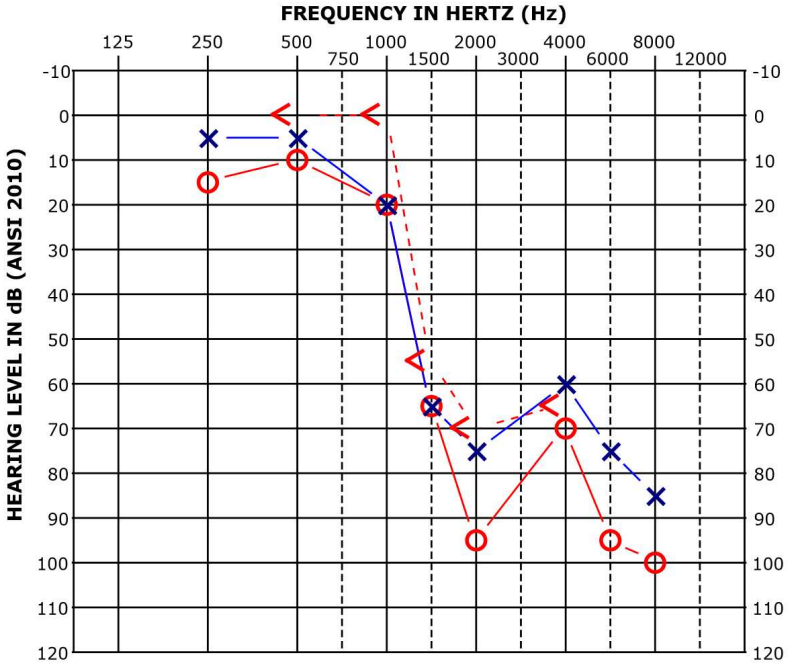


Using audibility: The decision to use frequency lowering

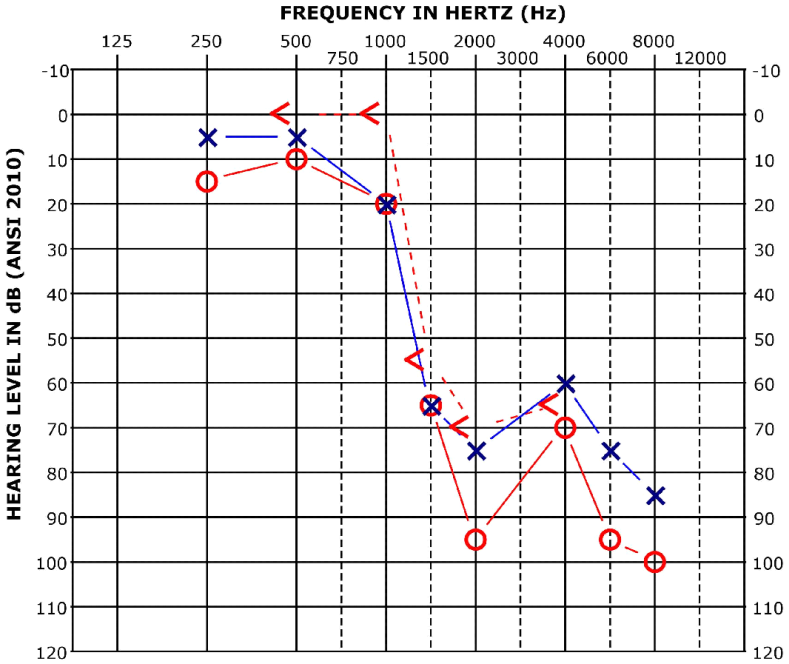
Candidacy for frequency lowering

- 4 year old who failed hearing screening at the PCP office
- Recently asking for repetitions
- Passed OP re-screen AABR after having initially failed bilaterally as a newborn in well-baby nursery

- No family hx, no risk factors



Candidacy for frequency lowering



- Right ear PTA: 42
- Left ear PTA: 33

- Referral 1/12
- Eval 1/22
- HAF 2/11
- MRI 2/13- unremarkable


Speechmap/DSL 5.0a child
Verifit 2
L
R
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1k
2k
4k
8k
16k
Test box
SII
L
R
50 months
Insert + foam
Non tonal
dB SPL
BTE + HA-4
Mold/Custom
S (0.5-1.5mm)
Audiometry
RECD
Meas+foam
BCT
N/A
Bin
No
Counseling
Speech-std(F)
42
41
Avg (65)
78
1
67
MPO
N/A
N/A
90
2
Speech-std(F)
39
37
Soft (55)
70
3
57
Speech-std(F)
51
44
Loud (75)
80
4
71
Connect instruments to silver .4cc couplers and to coupler microphone. Select test 1 through 4.

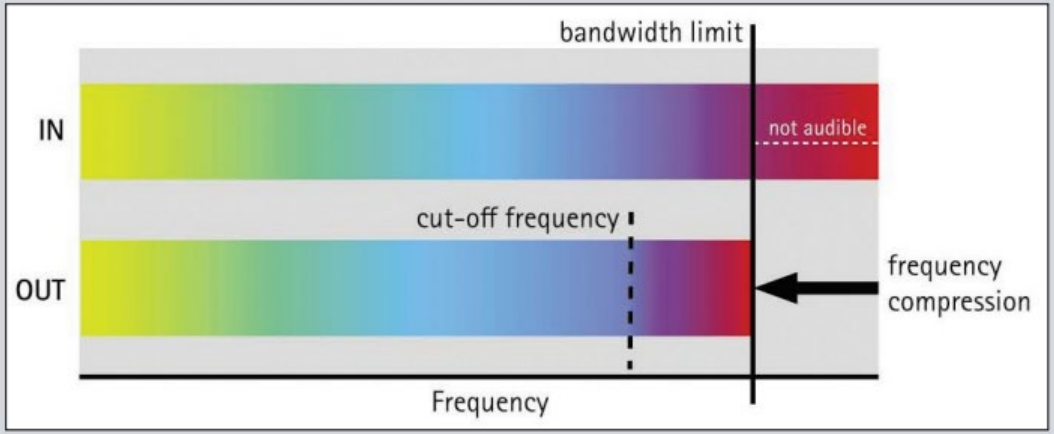
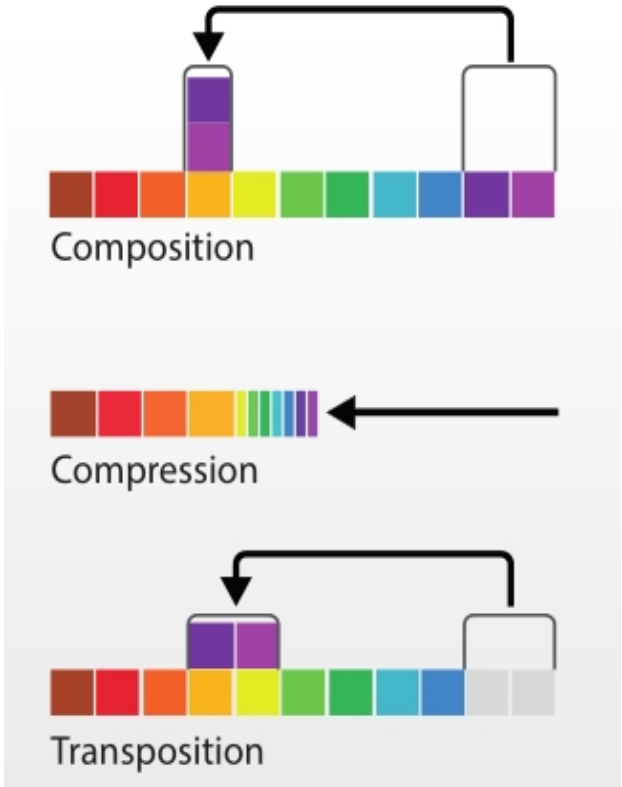


Figure 5. *How SoundRecover can extend the perceptual bandwidth. The upper bar shows the full frequency spectrum of sounds at the input of a hearing instrument. Signals with frequencies above the bandwidth limit, shown to the right of the solid vertical line, are not audible to the HI user. With SoundRecover enabled, however, signals above the cut-off frequency (vertical dashed line) are compressed in frequency so that they fall within the available bandwidth (lower bar).*

Credit: Phonak, 2010



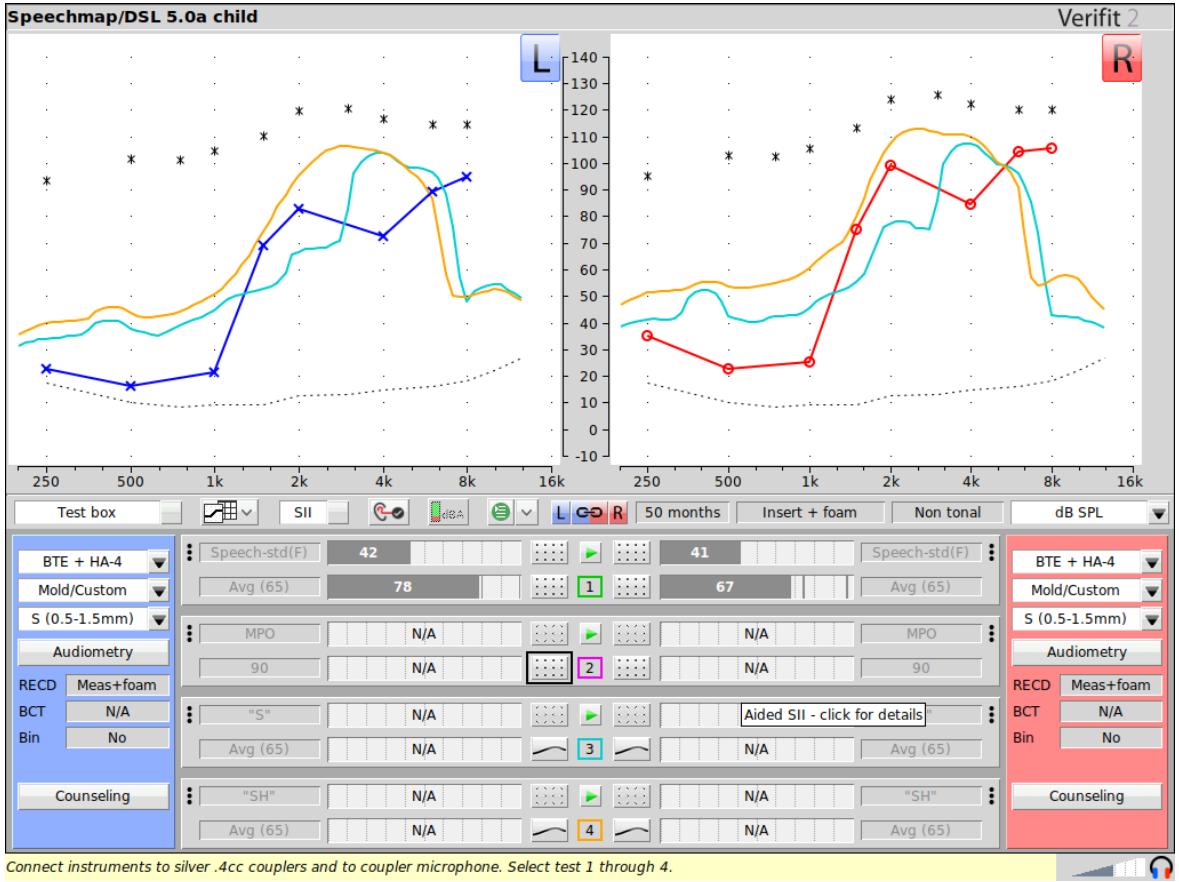
Credit: Oticon (undated)

High frequency Audibility for speech sounds using frequency lowering

Trading the risk of a speech sound omission for the risk of a speech sound error?

“Show me ‘Mesh’”

- Mɛʃ
- Mɛ_
- Mɛʒə


Speechmap/DSL 5.0a child
Verifit 2
L
R
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
250
500
1k
2k
4k
8k
16k
Test box
SII
50 months
Insert + foam
Non tonal
dB SPL
BTE + HA-4
Mold/Custom
S (0.5-1.5mm)
Audiometry
RECD
Meas+foam
BCT
N/A
Bin
No
Counseling
Speech-std(F)
42
41
Avg (65)
78
67
MPO
N/A
90
"S"
Aided SII - click for details
"SH"
1
2
3
4
Connect instruments to silver .4cc couplers and to coupler microphone. Select test 1 through 4.

Using audibility: The decision to refer for a CI

Candidacy for CI referral

History

19-year-old young man

Multiple diagnoses, including autism spectrum disorder with cognitive involvement

Not a verbal communicator

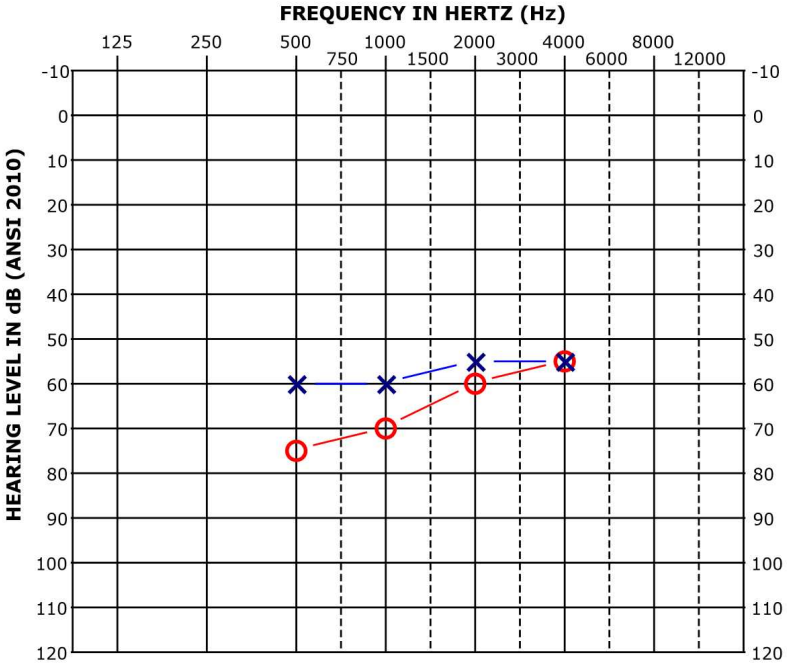
Enrolled in his local SD until age 21

Family has hearing concerns

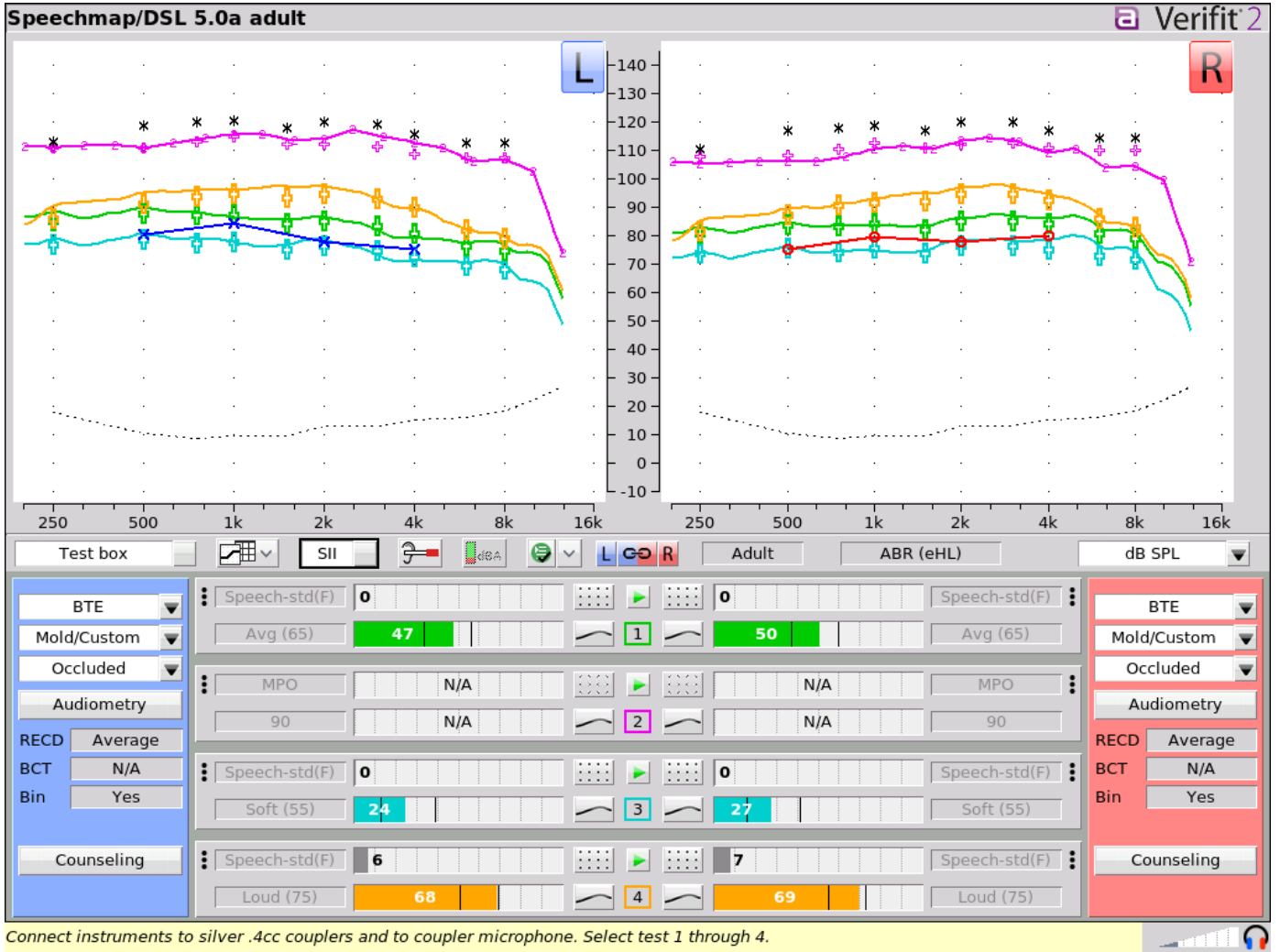
Follow up behavioral assessment was re-attempted, beginning with an SRT task.

Identification Pathway

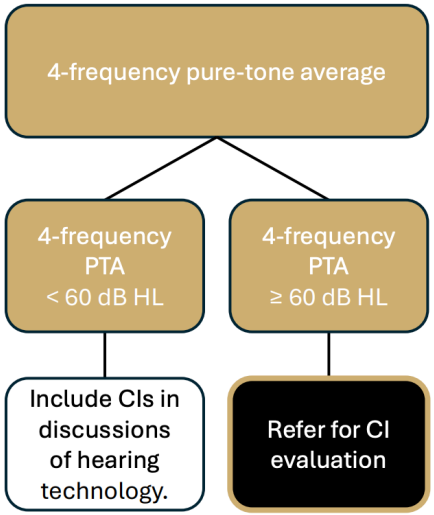
- Extremely limited previous hearing history, with new lack of responsiveness per his mom.
- History of otitis media early teens managed in the medical home.
- @age 7, “HEARING SCREENING, unable to follow instructions for testing”

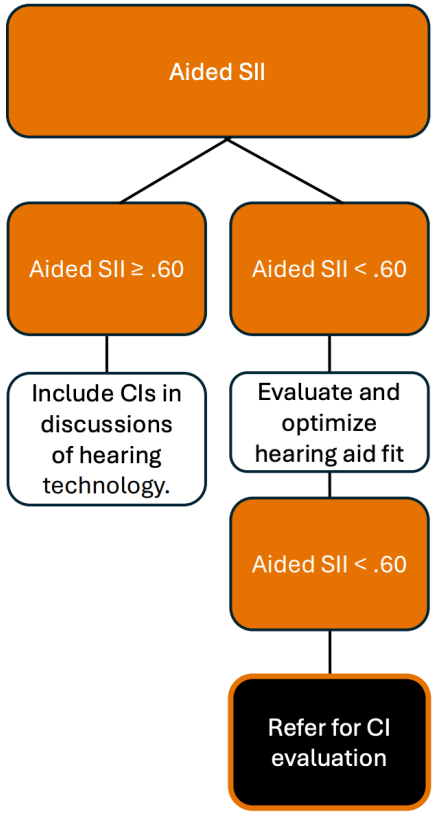


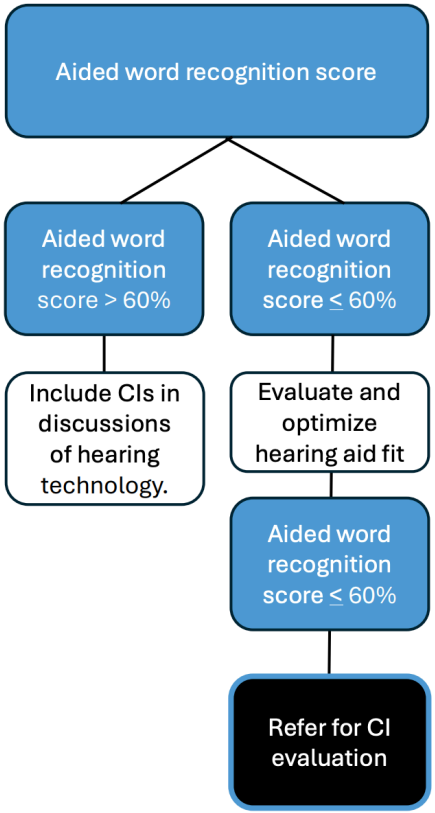
DSL 5 Adult Hearing Aid Prescriptive Targets




CI 3-60
4-frequency PTA ≥ 60 dB HL • Aided word recognition <60% • Aided SII <.60


4-frequency pure-tone average
4-frequency PTA < 60 dB HL
4-frequency PTA ≥ 60 dB HL
Include CIs in discussions of hearing technology.
Refer for CI evaluation


Aided SII
Aided SII ≥ .60
Aided SII < .60
Include CIs in discussions of hearing technology.
Evaluate and optimize hearing aid fit
Aided SII < .60
Refer for CI evaluation


Aided word recognition score
Aided word recognition score > 60%
Aided word recognition score ≤ 60%
Include CIs in discussions of hearing technology.
Evaluate and optimize hearing aid fit
Aided word recognition score ≤ 60%
Refer for CI evaluation

Summary

- Understanding audibility depends on a team
- Decoding the terms
- Looking for the evidence
- Supporting families and EI providers in navigating these discussions as empowered supporters of audibility

Questions? Thoughts?

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Thank you!