MAXIMIZING AUDITORY ACCESS FOR CHILDREN WITH HEARING LOSS

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Why is Auditory Access / Listening Magic?

- Language is learned by listening
- If children do not hear, they will not learn spoken language
- If they do not hear language, they will not learn phonics
- If they do not learn phonics, they will not develop good literacy skills
- Learning language requires hearing speech
- Language is magic

Audiology as the Foundation

- Hearing is the ***foundation*** of listening and spoken language development
- Audiology is the foundation for understanding hearing and listening
- Children need to use listening to learn spoken language
- Appropriately fit technology is the only way to assure that children with HL can use audition to learn
- Without appropriately fit technology
  - *Brain development will be compromised*
  - *Development and use of spoken language will be compromised*
  - *Academics, literacy, and social skills will be compromised*
- Understanding speech acoustics is critical for fitting technology appropriately and for planning therapy

Hearing = Auditory Access to the Brain

- Hearing is a first-order event for the development of spoken communication and literacy skills
- Anytime the word "hearing" is used, think "**auditory brain development**"!!
- Auditory accessibility of *intelligible* speech is essential for brain growth
- Signal-to-Noise Ratio is the key to hearing intelligible speech

Impact of Untreated HL on Children by Degree of Loss

	Slight / Minimal	Mild	Moderate	Moderately-severe	Severe to Profound
Hear soft sounds?	NO	NO	NO	NO	NO
Vowel articulation?	Most likely unaffected	Most likely unaffected	Most likely affected	Affected	Limited or no development
Consonant articulation?	May be affected	Most likely affected	Affected	Limited or no development	No development
Receptive language?	May be affected	Delayed for age	Significantly delayed	Minimal development	No development
Expressive language?	May be affected	Delayed for age	Significantly delayed	Minimal development	No development
Processing time?	Slightly increased	Noticeably longer	Awkwardly long	Longer may not help	Long with visual input

Audiologists' Role in Building the Foundation

- Audiologists are primarily responsible for evaluation, fitting and adjusting, and monitoring technology
- All clinicians working with children and families need to understand audiology and speech acoustics so they can monitor children's performance

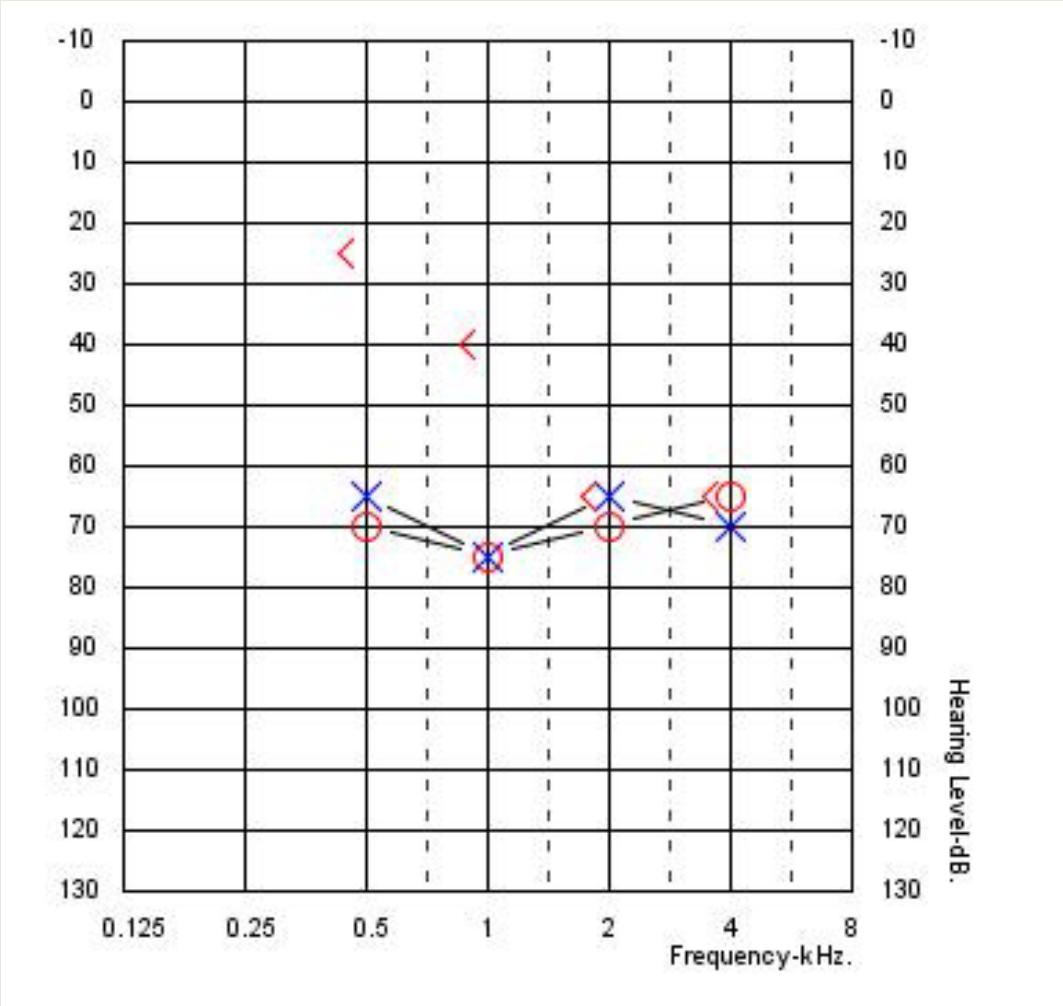
AUDITORY ACCESS TO THE BRAIN #1:

Audiological Testing Must Be Thorough and Accurate

Auditory Access to the Brain #1: Audiological Testing Must Be Thorough and Accurate

- Auditory access is the biggest problem worldwide--for all degrees of hearing loss!
- Audiological testing must be accurate and complete
- If audiological testing is not accurate or not complete, we cannot ensure that any intervention will be successful

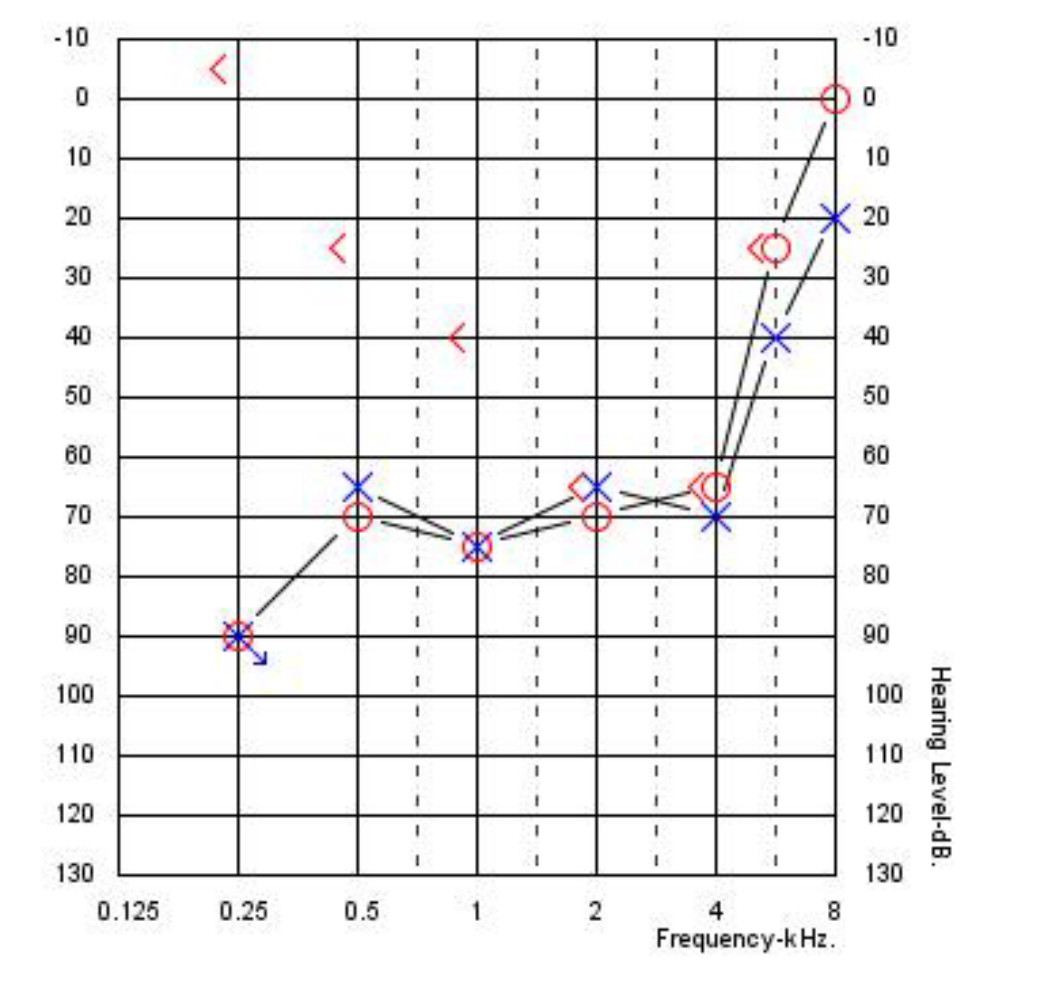
Meet Child A



SAT Right = 10dBHL / SAT Left = 25dBHL

- Failed OAE NBHS in one ear
- Failed follow-up ABR screen
- "Inconsistent" diagnostic results
  - *Sometimes present OAEs*
  - *Inconsistent ABRs*
  - *"Fatigued" to VRA*
- At age 1, determined to have otitis media
- Bilateral PE tubes placed
  - *Parents reported child responded to sound*
- Not talking at age 2
  - *Obtained this audiogram*
  - *Diagnosed with ANSD*
  - *Fitted with HAs with mild amplification because of tolerance issues from ANSD*

Meet Child A



- Age 4, child mainstreamed in community preschool
- Poor voice quality, articulation, and spoken language development despite “hearing”
- “Not developing to potential” because of ANSD
- RX: Enroll in TC program and discontinue amplification??
- Family sought 4th opinion
- Audiogram obtained

Meet Child A

- Speech perception testing completed

	Unaided SRT	Aided SRT	Unaided NU-Chips @ 95dB (open set)	Aided NU-Chips @ 50dB (open set)
Right ear	55dB	50dB	36%	20%
Left ear	60dB	60dB	28%	0%

- Imaging completed
  - *Bilateral cochlear malformations*
- Child does NOT have ANSD
- Bilateral cochlear implantation recommended ASAP

When Early Intervention is Not Easy . . .

- We must *aggressively* manage these patients!!
- Audiologists must continue to test and reconcile inconsistent findings
- ENTs must consider genetic testing and imaging
- AVTs, SLPs, and TODs must carefully monitor and communicate auditory, speech, and language progress or lack of progress
- All professionals must listen to parent input
- If results are inconsistent and the child is not progressing as expected – and everyone has very high expectations – then the results are not adequate or sufficient

AUDITORY ACCESS TO THE BRAIN #2:

All Day, Every Day

Auditory Access to the Brain #2: All Day, Every Day

- Auditory access is the biggest problem worldwide--for all degrees of hearing loss!
- ***Technology must be worn all waking hours to be effective***
- Eyes open; ears on!

The Developing Brain

- At birth, a child's brain has about 100 billion neurons.
  - *In addition, they have multiple synapses*
  - *Synapses are not developed at birth*
  - *With appropriate stimulation, a child's brain develops 700-1000 new connections or synapses every second*
    - Every time we talk to a child, make them laugh, make eye contact, we grow their brain
  - *Early years are most critical for this development*
- As children grow, the brain starts pruning unused synapses

How Much Practice is Needed to Develop the Necessary Complex Neural Structure?

- Malcolm Gladwell: 10,000 hours of practice
- Hart and Risley: 46 million words heard by age 4
- Dehaene: 20,000 hours of listening as a basis for reading
- Pittman: Children with hearing loss require three times the exposure to learn new words and concepts due to the reduced acoustic bandwidth caused by the hearing loss
- Children with cochlear implants can develop speech and language skills similar to their typical hearing peers

The Benefits of Full-time Technology Use

- Ryan McCreery, Bruce Tomblin, Melody Harrison, et al (2015)
  - *Children fit with HAs before 6 months of age had better language abilities than children fit over 12 months*
  - *Children who had more than 10 hrs/day HA use had more positive language trajectory*
- Jordan Holder, Renee Gifford (2021)
  - *Adults experienced an average of 7% increase in speech perception scores for every hour of additional wear*

Appropriate Technology plus acoustic accessibility

+

Enriched Auditory Exposure

=

AUDITORY BRAIN DEVELOPMENT

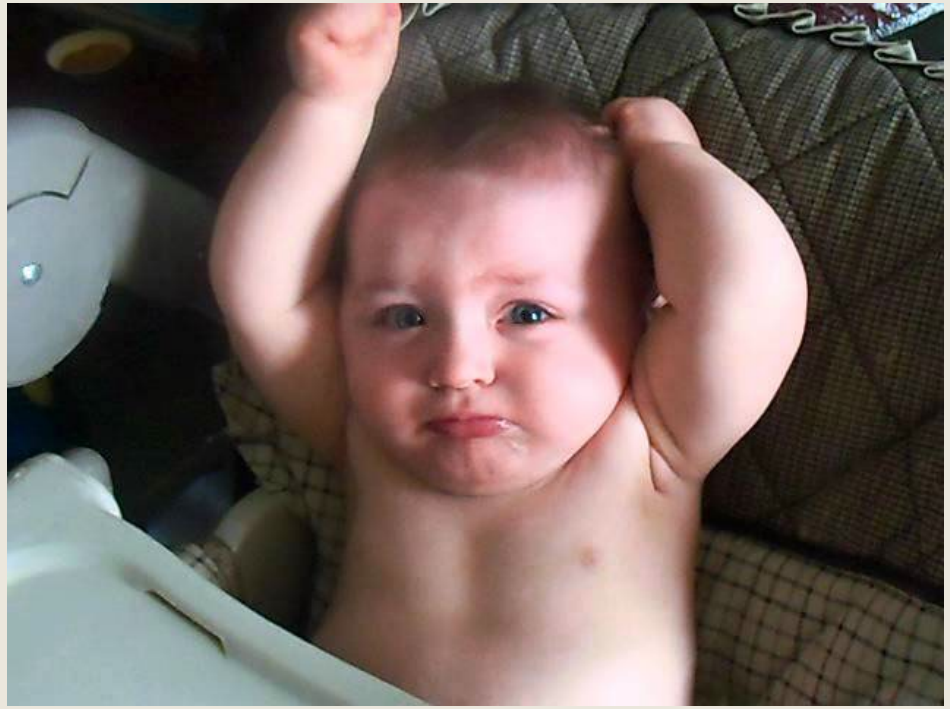
Madell and Hewitt

But . . .

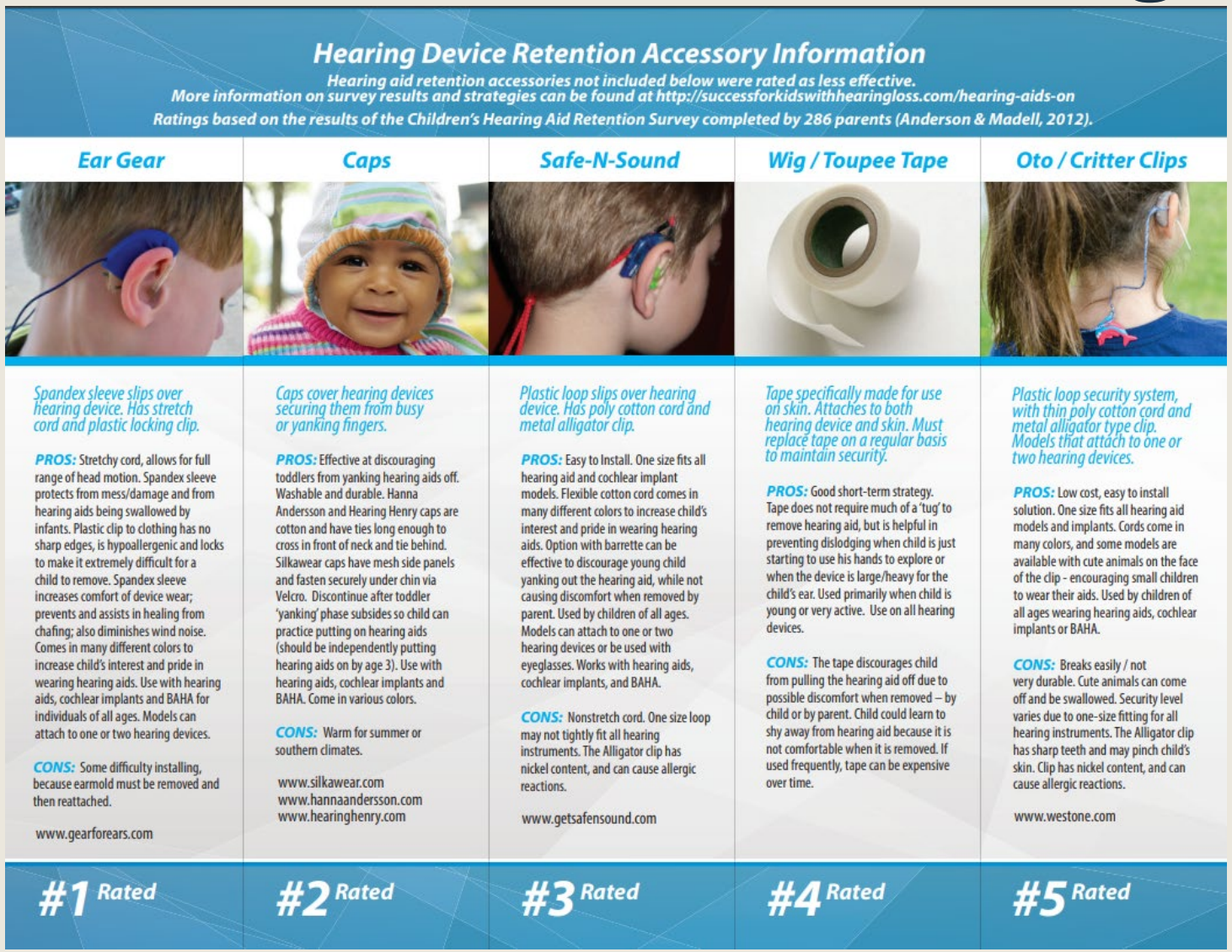
- Typically hearing children have access to sound 24 hours/day
- If a child wears technology 4 hours/day, it will take 6 years for that child to hear what it take a typically hearing child to hear in 1 year
- As early interventionists, we must assist families with technology retention plans

Understand Typical Development and Assist Parents with Technology Retention Plans

- Professional and caregiver understanding typical development is essential:
  - *Accidental exploration (4 – 7 months):*
    - Explores body and objects with hands and mouth
  - *Thorough investigation (6 – 12 months):*
    - Thorough investigation of objects by mouthing, shaking, banging, transferring from hand to hand
- Review data logging regularly with caregivers



Anderson and Madell, 2013
Available at SuccessforKidswithHearingLoss.com



Hearing Device Retention Accessory Information

Hearing aid retention accessories not included below were rated as less effective.
More information on survey results and strategies can be found at http://successforkidswithhearingloss.com/hearing-aids-on
Ratings based on the results of the Children's Hearing Aid Retention Survey completed by 286 parents (Anderson & Madell, 2012).

Ear Gear

Spandex sleeve slips over hearing device. Has stretch cord and plastic locking clip.

PROS: Stretchy cord, allows for full range of head motion. Spandex sleeve protects from mess/damage and from hearing aids being swallowed by infants. Plastic clip to clothing has no sharp edges, is hypoallergenic and locks to make it extremely difficult for a child to remove. Spandex sleeve increases comfort of device wear; prevents and assists in healing from chafing; also diminishes wind noise. Comes in many different colors to increase child's interest and pride in wearing hearing aids. Use with hearing aids, cochlear implants and BAHA for individuals of all ages. Models can attach to one or two hearing devices.

CONS: Some difficulty installing, because earmold must be removed and then reattached.

www.gearforears.com

#1 Rated

Caps

Caps cover hearing devices securing them from busy or yanking fingers.

PROS: Effective at discouraging toddlers from yanking hearing aids off. Washable and durable. Hanna Andersson and Hearing Henry caps are cotton and have ties long enough to cross in front of neck and tie behind. Silkawear caps have mesh side panels and fasten securely under chin via Velcro. Discontinue after toddler 'yanking' phase subsides so child can practice putting on hearing aids (should be independently putting hearing aids on by age 3). Use with hearing aids, cochlear implants and BAHA. Come in various colors.

CONS: Warm for summer or southern climates.

www.silkawear.com
www.hannaandersson.com
www.hearinghenry.com

#2 Rated

Safe-N-Sound

Plastic loop slips over hearing device. Has poly cotton cord and metal alligator clip.

PROS: Easy to Install. One size fits all hearing aid and cochlear implant models. Flexible cotton cord comes in many different colors to increase child's interest and pride in wearing hearing aids. Option with barrette can be effective to discourage young child yanking out the hearing aid, while not causing discomfort when removed by parent. Used by children of all ages. Models can attach to one or two hearing devices or be used with eyeglasses. Works with hearing aids, cochlear implants, and BAHA.

CONS: Nonstretch cord. One size loop may not tightly fit all hearing instruments. The Alligator clip has nickel content, and can cause allergic reactions.

www.getsafensound.com

#3 Rated

Wig / Toupee Tape

Tape specifically made for use on skin. Attaches to both hearing device and skin. Must replace tape on a regular basis to maintain security.

PROS: Good short-term strategy. Tape does not require much of a 'tug' to remove hearing aid, but is helpful in preventing dislodging when child is just starting to use his hands to explore or when the device is large/heavy for the child's ear. Used primarily when child is young or very active. Use on all hearing devices.

CONS: The tape discourages child from pulling the hearing aid off due to possible discomfort when removed – by child or by parent. Child could learn to shy away from hearing aid because it is not comfortable when it is removed. If used frequently, tape can be expensive over time.

#4 Rated

Oto / Critter Clips

Plastic loop security system, with thin poly cotton cord and metal alligator type clip. Models that attach to one or two hearing devices.

PROS: Low cost, easy to install solution. One size fits all hearing aid models and implants. Cords come in many colors, and some models are available with cute animals on the face of the clip - encouraging small children to wear their aids. Used by children of all ages wearing hearing aids, cochlear implants or BAHA.

CONS: Breaks easily / not very durable. Cute animals can come off and be swallowed. Security level varies due to one-size fitting for all hearing instruments. The Alligator clip has sharp teeth and may pinch child's skin. Clip has nickel content, and can cause allergic reactions.

www.westone.com

#5 Rated

Available Hours of Listening by Age

Age	Hours per day
Under 3 months	9.4 hours
3 months	10.4 hours
6 months	11.1 hours
9 months	11.4 hours
12 months	11.1 hours
2 years	12 hours
3 years	12.5 hours

Meet Child B

- 26-month-old male
  - *Comes for audiological evaluation*
  - *Not wearing technology*
  - *Audiologist asks mom where technology is*
  - *Mom removes HAs from purse*
  - *Audiologist asks mom to put HAs on*
    - Mom tries, but is clearly uncomfortable doing it
    - Child resists, cries, swings arms
    - Mom stops and reaches into purse for a very large chocolate covered donut

Auditory Access to the Brain

- Auditory access is the biggest problem worldwide--for all degrees of hearing loss!
- ***Technology often is not programmed to today's possibilities***
- If a technology is not appropriately programmed, the child cannot use hearing to develop speech perception skills
- Technology must be checked **daily** to be sure it is functioning optimally
  - *Close enough is not good enough here.*
- If the child is not progressing as expected – and everyone has very high expectations – suspect the technology/acoustic accessibility first

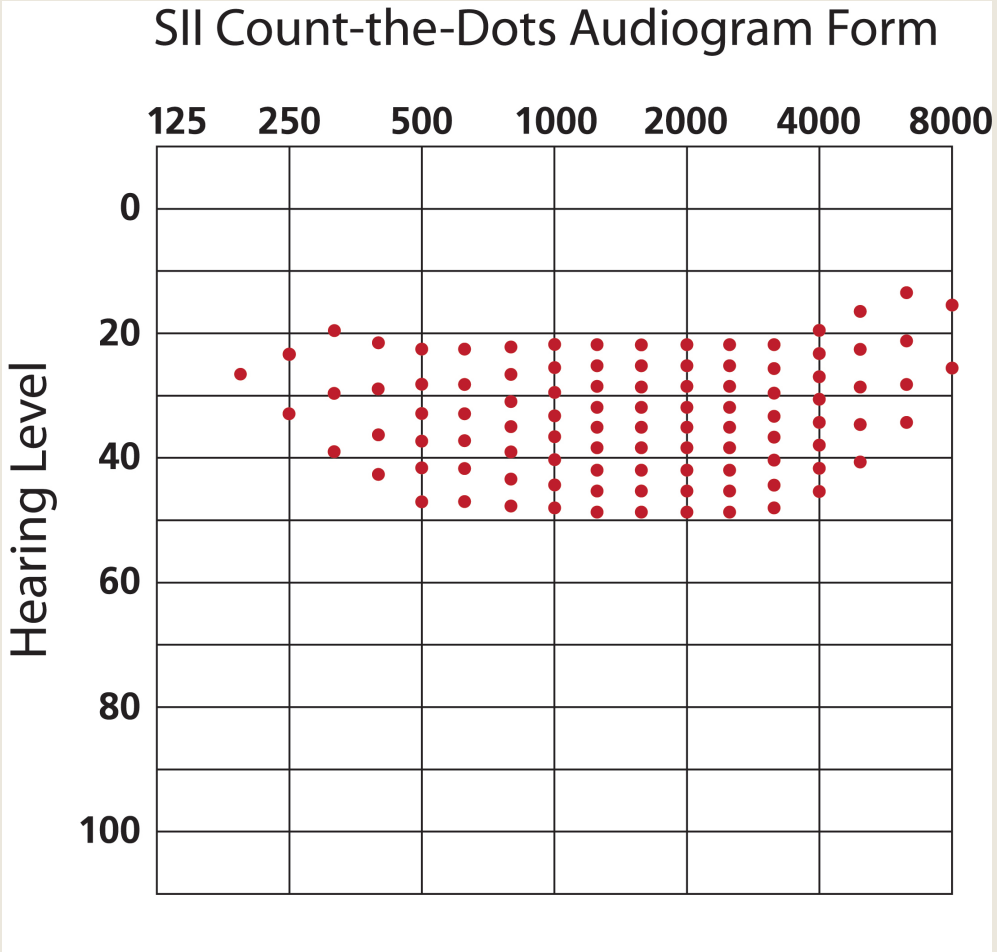
AUDITORY ACCESS TO THE BRAIN #3:

Access to the Entire Speech Spectrum

Auditory Access to the Brain: Access to the Entire Speech Spectrum

- The child needs to hear throughout the frequency range
  - *Low frequencies contain 90% of the power of speech, but only 10% of the intelligibility*
  - *High frequencies contain only 10% of the power of speech, but 90% of the intelligibility*
  - *6000 and 8000 Hz really do matter*
  - *Missing high frequencies results in missing grammatical markers for pluralization, possessives, and missing non-salient morphemes (eg: morphemes that are not stressed during conversation like prepositions)*

Madell and Hewitt



Mueller and Killion, 2010

Auditory Access to the Brain: Access to the Entire Speech Spectrum

- Ryan McCreery, Bruce Tomblin, Melody Harrison, et al
  - *Children with poorer 4K thresholds had poorer LNT and CASPA scores*
- Consider technology carefully:
  - *Type and level of hearing aid can affect speech spectrum access*
  - *One pediatric hearing aid has a high frequency cutoff at 5000Hz to 8000Hz depending upon the model purchased*
- How can we evaluate access to the speech spectrum?
  - *Real ear measurements to ensure appropriate frequency range reaches the TM*
  - *Sound field thresholds to warble tones or narrow band noise*
  - *LMH Testing*

Brief Pitstop:

The LMH Test
(Ling-Madell- Hewitt

or

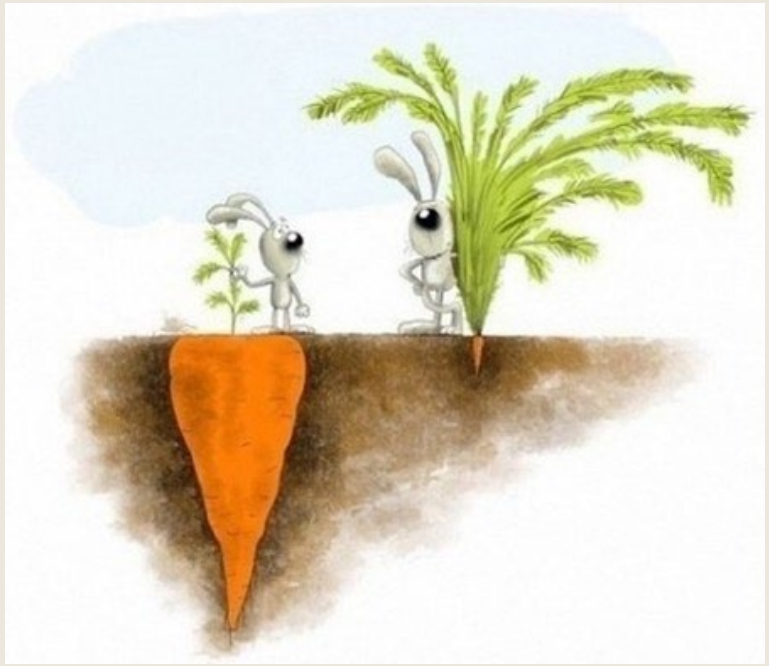
Low-Mid-High)

Madell and Hewitt, 2021

What led us to the LMH?

- As number of CI patients increased, trends became apparent
  - *Some patients were superstars; some were not*
  - *Blame was placed on:*
    - CI: “CIs just don’t work for everyone.”
    - Child: Circumstances surrounding implantation, oral motor issues, apraxia, other issues
    - Parents: “You just need to do more.”
- One common thread was evident in many, many cases:
  - *Children who did not do well could not hear well.*

What led us to the LMH?



- We began to see distinct patterns emerging from Ling reports
  - *Have all the Lings*
    - Superstar patients
    - Struggling patients
  - *Have some of the Lings*
    - Struggling patients
    - Patients with little to no progress
  - *Don't have any Lings; can't move forward*
    - Patients with little to no progress
- Clearly, responses to Lings were not sufficient to see what was happening "below the surface"

What led us to the LMH?

- We began a retrospective study of 230+ subjects' phoneme perception errors before and after programming
- What we already knew:
  - *Lings appeared to be overused*
    - Used as a "curriculum"
    - Used well beyond applicable ages
    - Memorized by children
    - Seen as boring by children

What led us to the LMH?

- We began a retrospective study of 230+ subjects' phoneme perception errors before and after programming
- What we already found:
  - *Finding #1: Responses to Lings did NOT predict speech perception of all phonemes*
  - *Finding #2: Multiple errors on Lings indicated SIGNIFICANT, global speech perception errors*
  - *Finding #3: Lings did NOT identify most common perception errors*

Most common speech perception errors with CI

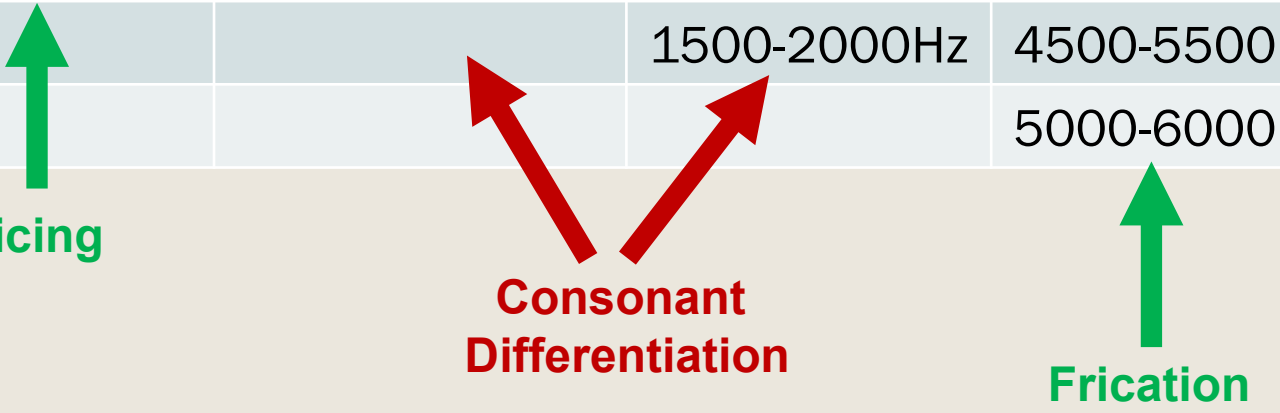
Lochner L , Hewitt, J, Madell, J. “Analysis of Common Speech Perception Errors Prior to Cochlear Implant MAPping and Successful, Remedial Programming Changes.”

Specific Articulation Error	% of Occurrence	% of Correction
/z/ heard as /m/	69%	84%
/ch/ heard as /sh/ or /t/	67%	87%
/s/ omitted, distorted, or heard as /sh/	42%	95%
m/n confusion	41%	85%
Omission of /b/	36%	98%
/p/ heard as /h/ or omitted	29%	96%
/sh/ heard as /s/	21%	91%

What specifically was missing from the LING test??

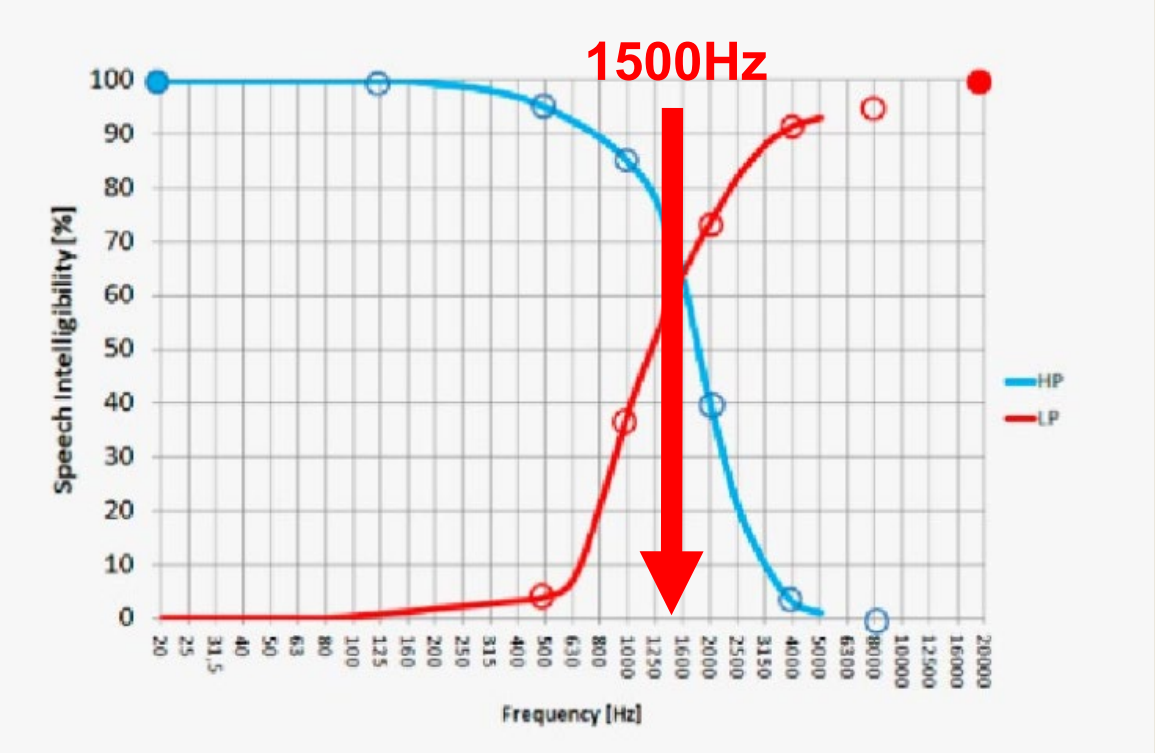
Formant / Frequency Bands of Lings Compared with Consonant Bands

Ling Sound	Band 1 200 – 1000Hz	Band 2 1000 – 1500Hz	Band 3 1500 – 3500Hz	Band 4 3500Hz +
/oo/	F1: 300Hz F2: 870Hz		F3: 2240Hz	
/a/	F1: 730Hz	F2: 1090Hz	F3: 2440Hz	
/ee/	F1: 270Hz		F2: 2290Hz F3: 3010Hz	
/m/	250-350Hz	1000-1500Hz	2500-3500Hz	
/sh/			1500-2000Hz	4500-5500Hz
/s/				5000-6000Hz



Why Mid-Frequencies are Crucial to Speech Perception

- Low freqs = 90% of power / 10% of intelligibility
- High freqs = 90% of intelligibility / 10% of power
- Mid freqs = differentiation of voicing, manner, place



Madell and Hewitt

Lings provide limited info about perception of consonant differences

Consonant Energy Bands						
Bands			1	2	3	4
Manner	Voiced	Voiceless	200-800	1000-1500	1500-3500	3500 +
Plosives	b		300-400		2000-2500	
	d		300-400		2500-3000	
	g		200-300		1500-2500	
		p			1500-2000	
		t			2500-3500	
		k			2000-2500	
Nasals	m		250-350	1000-1500	2500-3500	
	n		250-350	1000-1500	2000-3000	
	ŋ		250-400	1000-1500	2000-3000	
Fricatives	v		300-400			3500-4500
	z		200-300			4000-5000
	ʒ		200-300			4000-4500
	ð		250-350			4000-6000
		h			1500-2000	
		f				4000-5000
		s				5000-6000
		ʃ			1500-2000	4500-5500
		θ				~6000
Affricates		tʃ			1500-2000	4000-5000
	dʒ		200-300		2000-3000	
Liquids	r		600-800	1000-1500	1800-2400	
	l		250-400		2000-3000	

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Our LMH Additions: Phoneme #1 /n/

Consonant Energy Bands						
Bands			1	2	3	4
Manner	Voiced	Voiceless	200-800	1000-1500	1500-3500	3500 +
Plosives	b		300-400		2000-2500	
	d		300-400		2500-3000	
	g		200-300		1500-2500	
		p			1500-2000	
		t			2500-3500	
		k			2000-2500	
Nasals	m		250-350	1000-1500	2000-3000	
	n		250-350	1000-1500	2000-3000	
	ŋ		250-400	1000-1500	2000-3000	
Fricatives	v		300-400			3500-4500
	z		200-300			4000-5000
	ʒ		200-300			4000-4500
	ð		250-350			4500-6000
		h			1500-2000	
		f				4000-5000
		s				5000-6000
		ʃ			1500-2000	4500-5500
		θ				~6000
Affricates		tʃ			1500-2000	4000-5000
	dʒ		200-300		2000-3000	
Liquids	r		600-800	1000-1500	1800-2400	
	l		250-400		2000-3000	

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Our LMH Additions: Phoneme #2 /h/

Consonant Energy Bands						
Bands			1	2	3	4
Manner	Voiced	Voiceless	200-800	1000-1500	1500-3500	3500 +
Plosives	b		300-400		2000-2500	
	d		300-400		2500-3000	
	g		200-300		1500-2500	
		p			1500-2000	
		t			2500-3500	
		k			2000-2500	
Nasals	m		250-350	1000-1500	2500-3500	
	n		250-350	1000-1500	2000-3000	
	ŋ		250-400	1000-1500	2000-3000	
Fricatives	v		300-400			3500-4500
	z		200-300			4000-5000
	ʒ		200-300			4000-4500
	ð					4500-6000
		h			1500-2000	
		f				
		s				5000-6000
		ʃ			1500-2000	4500-5500
		θ				~6000
Affricates		tʃ			1500-2000	4000-5000
	dʒ		200-300		2000-3000	
Liquids	r		600-800	1000-1500	1800-2400	
	l		250-400		2000-3000	

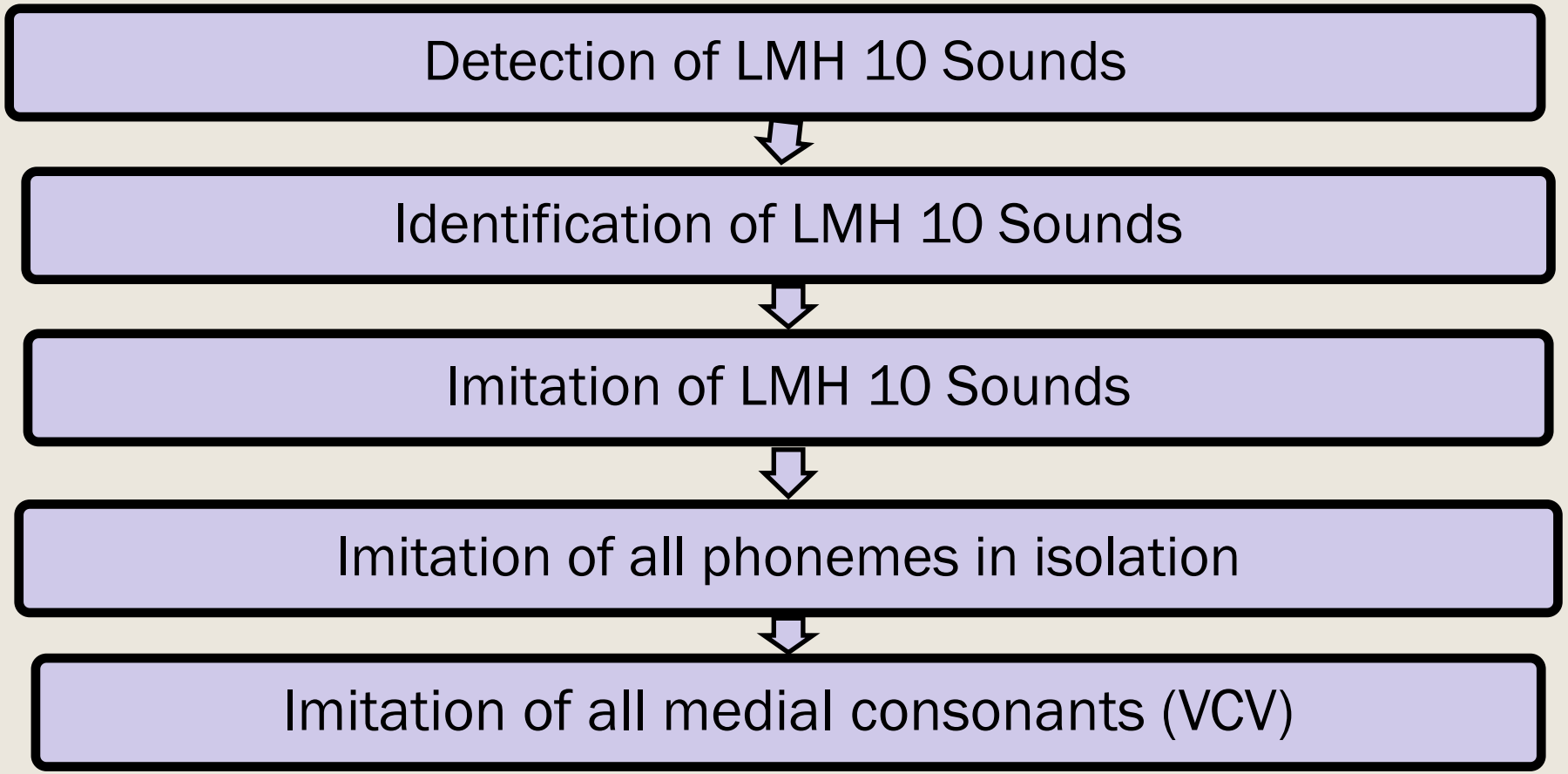
Our LMH Additions: Heavy Weight Phoneme #3 /ʤ/

Consonant Energy Bands						
Bands			1	2	3	4
Manner	Voiced	Voiceless	200-800	1000-1500	1500-3500	3500 +
Plosives	b		300-400		2000-2500	
	d		300-400		2500-3000	
	g		200-300		1500-2500	
		p			1500-2000	
		t			2500-3500	
		k			2000-2500	
Nasals	m		250-350	1000-1500	2500-3500	
	n		250-350	1000-1500	2000-3000	
	ŋ		250-400	1000-1500	2000-3000	
Fricatives	v		300-400			3500-4500
	z		200-300			4000-5000
	ʒ		200-300			4000-4500
	ð		250-350			4500-6000
		h			1500-2000	
		f				4000-5000
		s				5000-6000
		ʃ			1500-2000	4500-5500
		θ				~6000
Affricates		ʧ			1500-2000	4000-5000
	ʤ		200-300		2000-3000	
Liquids	r		600-800	1000-1500	1800-2400	
	l		250-400		2000-3000	

Our LMH Additions: Heavy Weight Phoneme #4 /z/

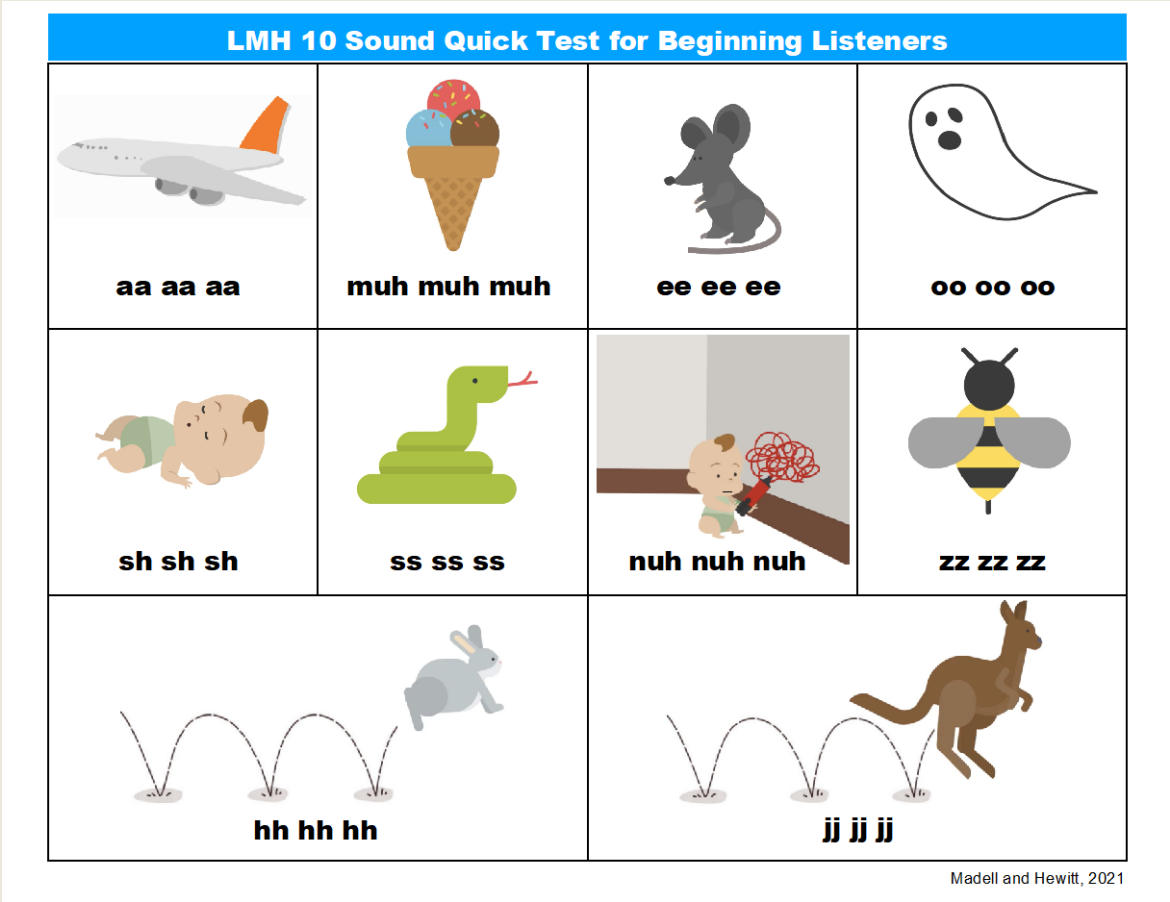
Consonant Energy Bands						
Bands			1	2	3	4
Manner	Voiced	Voiceless	200-800	1000-1500	1500-3500	3500 +
Plosives	b		300-400		2000-2500	
	d		300-400		2500-3000	
	g		200-300		1500-2500	
		p			1500-2000	
		t			2500-3500	
		k			2000-2500	
Nasals	m		250-350	1000-1500	2500-3500	
	n		250-350	1000-1500	2000-3000	
	ŋ		250-400	1000-1500	2000-3000	
Fricatives	v		300-400			2500-4500
	z		200-300			4000-5000
	ʒ		200-300			4000-4500
	ð		250-350			4500-6000
		h			1500-2000	
		f				4000-5000
		s				5000-6000
		ʃ			1500-2000	4500-5500
		θ				~6000
Affricates		tʃ			1500-2000	4000-5000
	dʒ		200-300		2000-3000	
Liquids	r		600-800	1000-1500	1800-2400	
	l		250-400		2000-3000	

Moreover, the LMH is a test battery!!

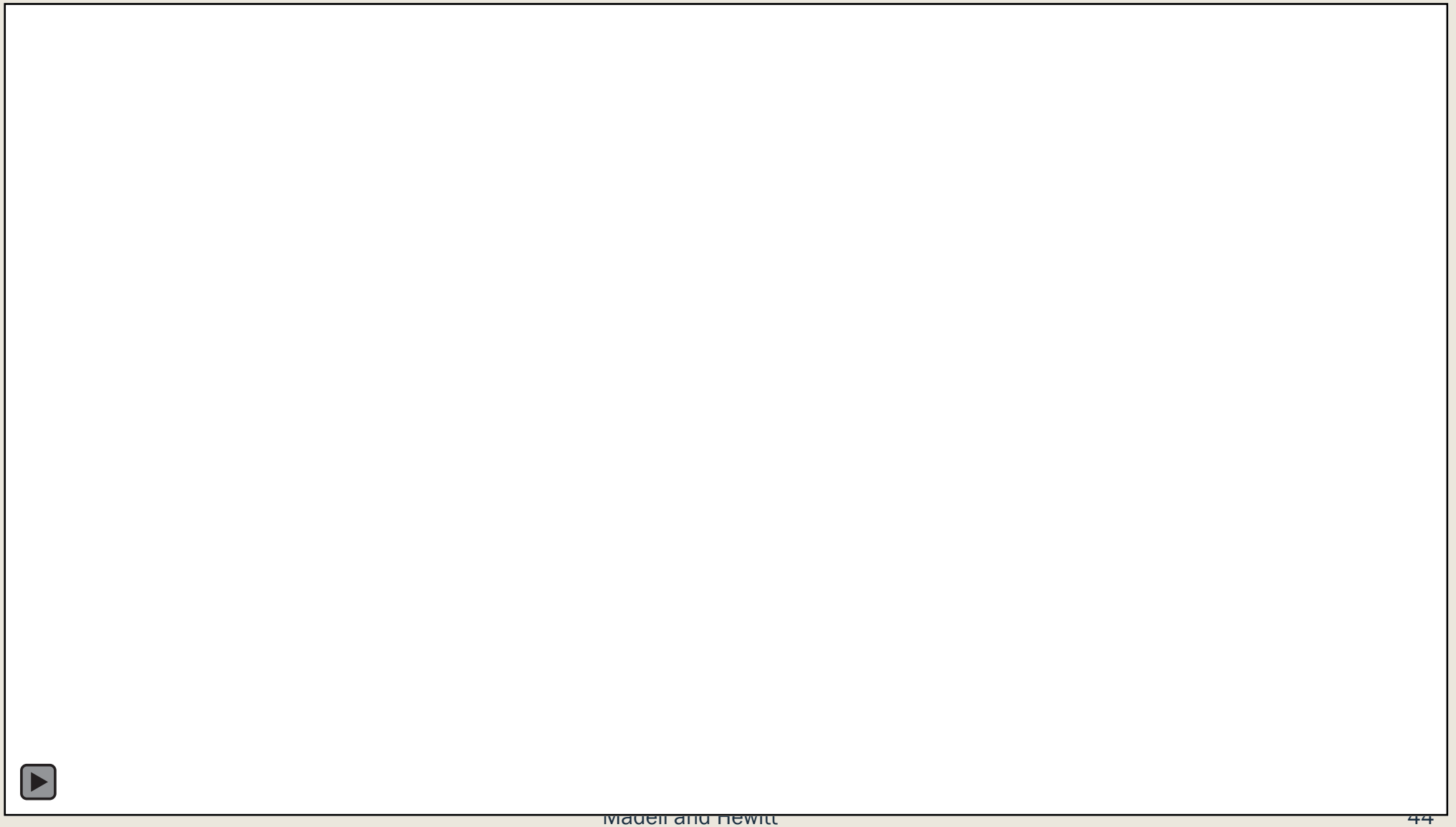


Presentation of LMH Test Battery

- Detection:
  - *Sound repeated 3 times to minimize cues as noted on 10 Sound Quick Test*
  - *Except: m m m / n n n*
- Identification and Imitation:
  - *Sound repeated 3 times as noted on 10 Sound Quick Test*
- All phonemes
  - *Sound repeated 3 times to minimize cues*
  - *Voiced consonants have natural vowel*
  - *Voiceless consonants have no vowel*
- Medial consonants
  - *VCV combinations*
- All are random presentation

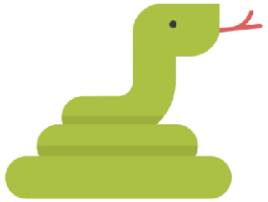
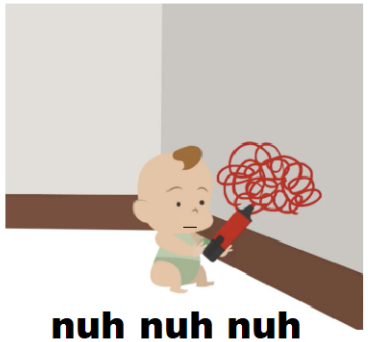
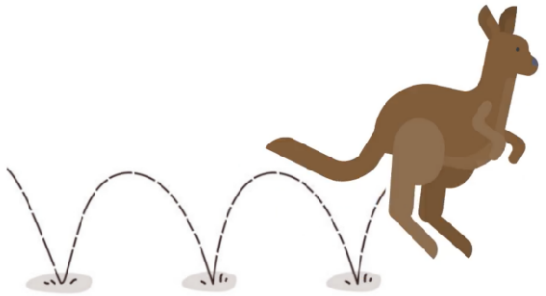


Detection:
12-month-old / 5 months post CIs



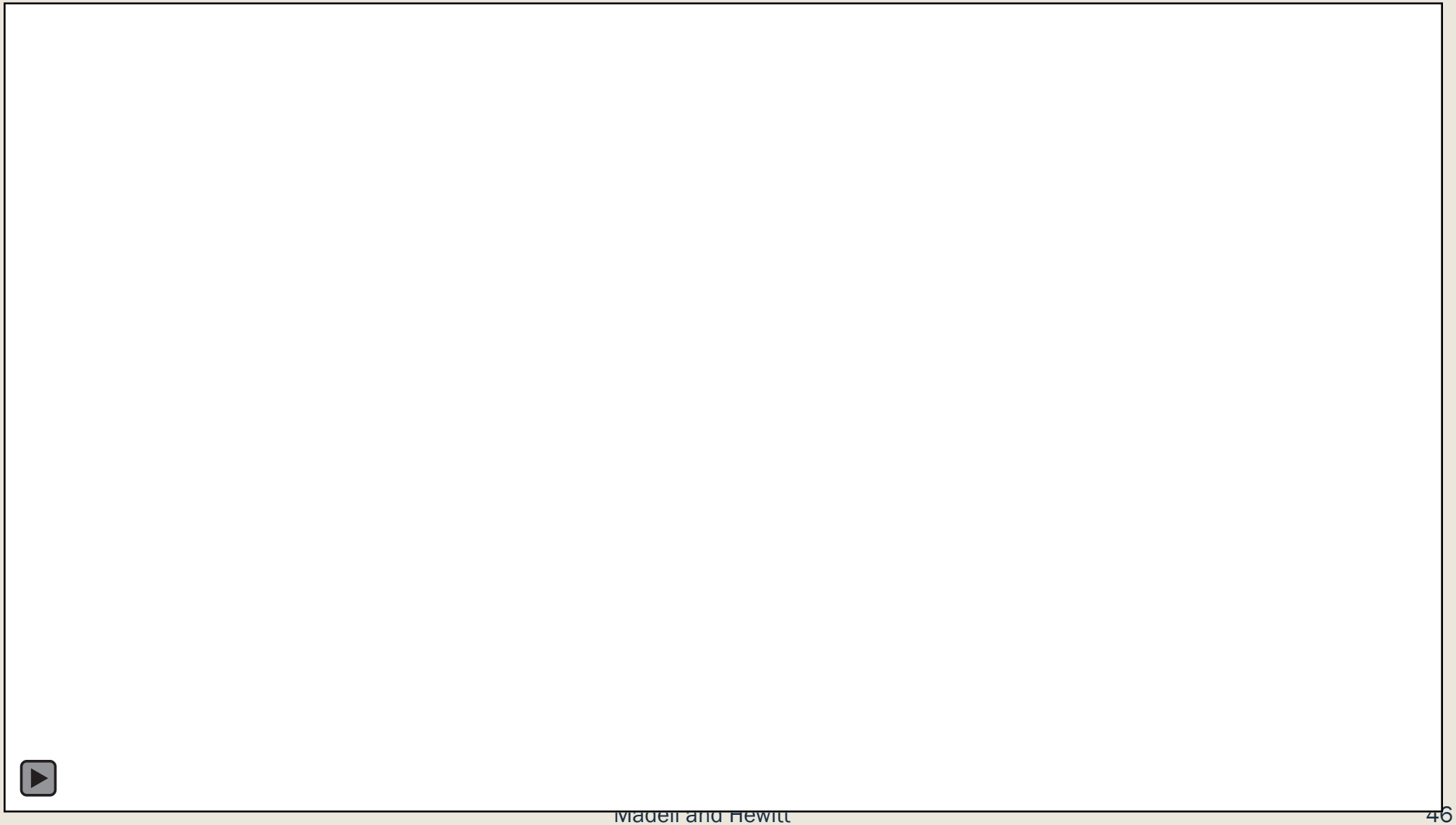
Identification

LMH 10 Sound Quick Test for Beginning Listeners

 aa aa aa	 muh muh muh	 ee ee ee	 oo oo oo
 sh sh sh	 ss ss ss	 nuh nuh nuh	 zz zz zz
 hh hh hh	 jj jj jj		

Madell and Hewitt, 2021

Detection to Imitation:
11-month-old / 2 months post CIs



Imitation of Phonemes: 3-year-old with CND / 2 years post CIs, 4 months post new MAP

Medial Consonant Test – English

NAME														
Date														
Technology														
Distance														
T							**CH**							
V							**N**							
N							**F**							
P							**Z**							
M							**D**							
G							**V**							
K							**K**							
Z							**SH**							
V							**S**							
F							**N**							
N							**B**							
G							**Z**							
J							**G**							
SH							**SH**							
K							**J**							
P							**D**							
SH							**M**							
J							**D**							
SH							**G**							
G							**P**							
M							**F**							
SH							**T**							
P							**B**							
F							**J**							
B							**K**							
Z							**P**							
T							**T**							
B														
K														

M

Prueba de Consonantes Intermedias
Hoja de Puntuación

Nombre:														
Tecnología:														
#	AFI	Palabra clave	1 metro a___a			1 metro i___i			3 metros a___a			3 metros i___i		
			D	I	A	D	I	A	D	I	A	D	I	A
1	b	***b****ien*												
2	p	***p****or*												
3	m	***m****e*												
4	w	a***gu****a*												
5	x	***j****uego*												
6	f	***f****oco*												
7	d	***d****os*												
8	t	***t****en*												
9	n	***n****o*												
10	ʝ	***y****o**												
11	ʎ	ca***y****ó**												
12	ʃ	llorar**												
13	s	***s****ol*												
14	θ	***c****ebra****												
15	k	***c****asa*												
16	g	***g****ato*												
17	ŋ	cha***ng****o*												
18	tʃ	***ch****upón*												
19	l	***l****upa*												
20	ɲ	A***ñ****o*												
21	ɾ	Ho***r****a*												
22	r	***r****ata*												
# Correctas de 21/20****														
% Puntuación de 21/20****														

Revisado por Mary D. McGinnis, 2020; Adaptado por Hinojosa, F. y Hernández, A., 2020

*En países yeístas será la misma pronunciación para las palabras escritas con grafía "y" y "ll". Algunas zonas de Bolivia, Ecuador, Paraguay, Argentina, Chile, entre otros, deberán hacer la diferenciación entre los sonidos /ʝ/ y /ʎ/ (fila 10 y 11).

**Pronunciación de "ll" para Argentina y Uruguay

*** En países que realizan diferente pronunciación de palabras escritas con las grafías "s" de aquellas escritas con "c" y "z" (Guinea Ecuatorial, gran parte de España)

****La cantidad de respuestas correctas posibles dependerá de los sonidos producidos en la región de desarrollo del evaluado.

Medial Consonants - Short List

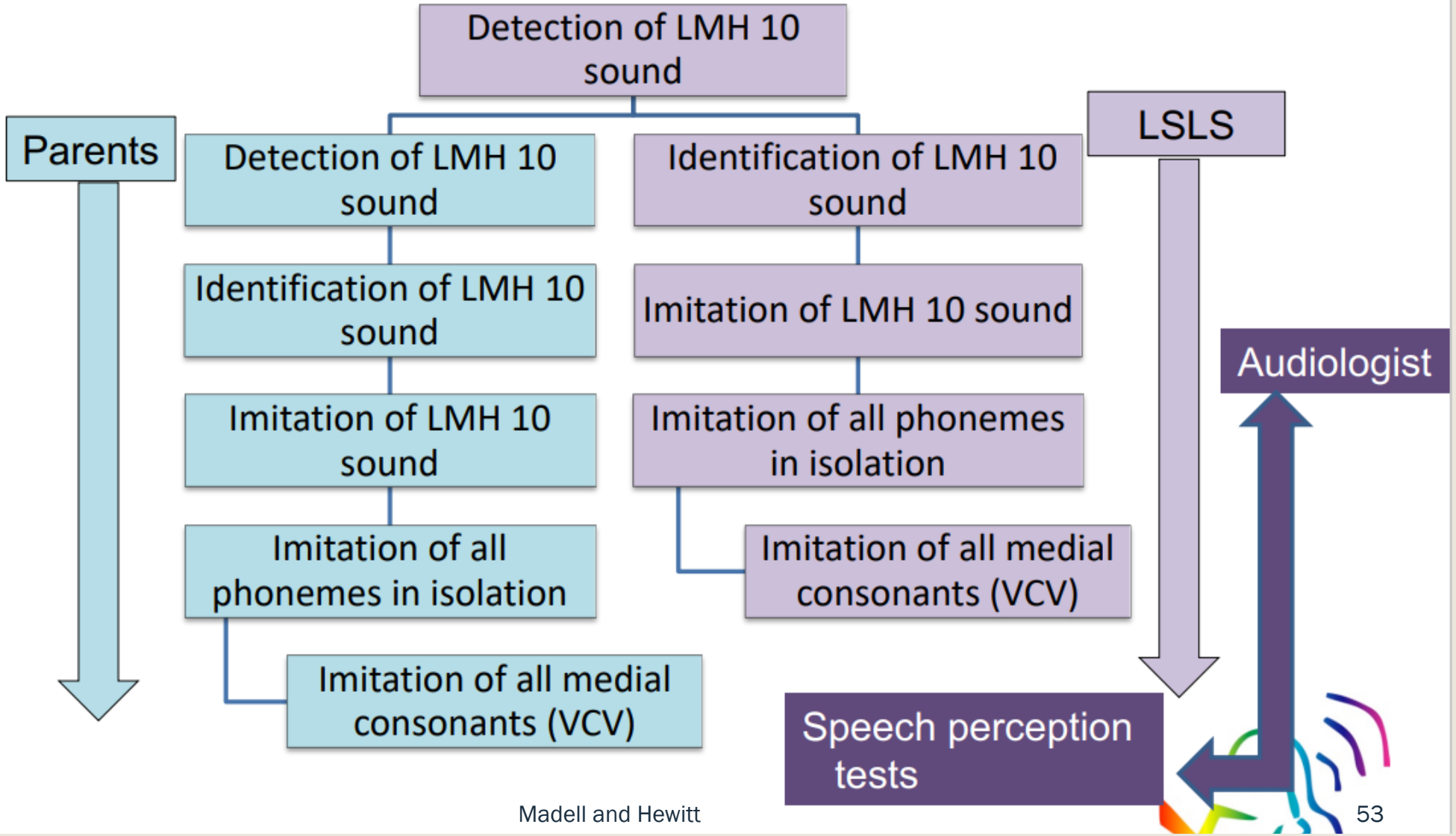
- English consonants from low to high (presented randomly)
- Joan Hewitt's Short list
  - /w/ ___
  - /n/ ___
  - /l/ ___
  - /m/ ___
  - /r/ ___
  - /g/ ___
  - /b/ ___
  - /d/ ___
  - /j/ ___
  - /v/ ____
  - /z/ ___
  - /h/ ___
  - /p/ ___
  - /k/ ___
  - /t/ ___
  - /ch/ ___
  - /sh/ ___
  - /f/ ___
  - /s/ ___
  - /th/ ___
- Spanish consonants from low to high (presented randomly)
  - /w/ ___
  - /n/ ___
  - /l/ ___
  - /m/ ___
  - /r/ ___
  - /g/ ___
  - /b/ ___
  - /d/ ___
  - /j/ ___
  - /z/ ___
  - /h/ ___
  - /p/ ___
  - /k/ ___
  - /t/ ___
  - /ch/ ___
  - /sh/ ___
  - /f/ ___
  - /s/ ___

Imitation of Medial Consonants: 4-year-old / 1 year post CIs

LMH Notes

- Always test a variety of vowels AND consonants with beginning listeners
  - *Developmental progression varies!!*
  - *Once differentiation of vowels is noted, focus on consonants*
  - *Continued problems with vowels indicate global perception issues*
- Time to test:
  - *ALL individual phonemes: 3-year-old with CHARGE and cochlear nerve deficiency repeating using toy*
    - Better ear: 1 min, 17 secs
    - Poorer ear: 2 mins, 12 secs
  - *ALL medial consonants:*
    - 3 elementary-aged children: Average of 30 seconds per ear

LMH (Low-Mid-High or Ling-Madell-Hewitt) Test Battery



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AUDITORY ACCESS TO THE BRAIN #4:

Access to Soft Speech

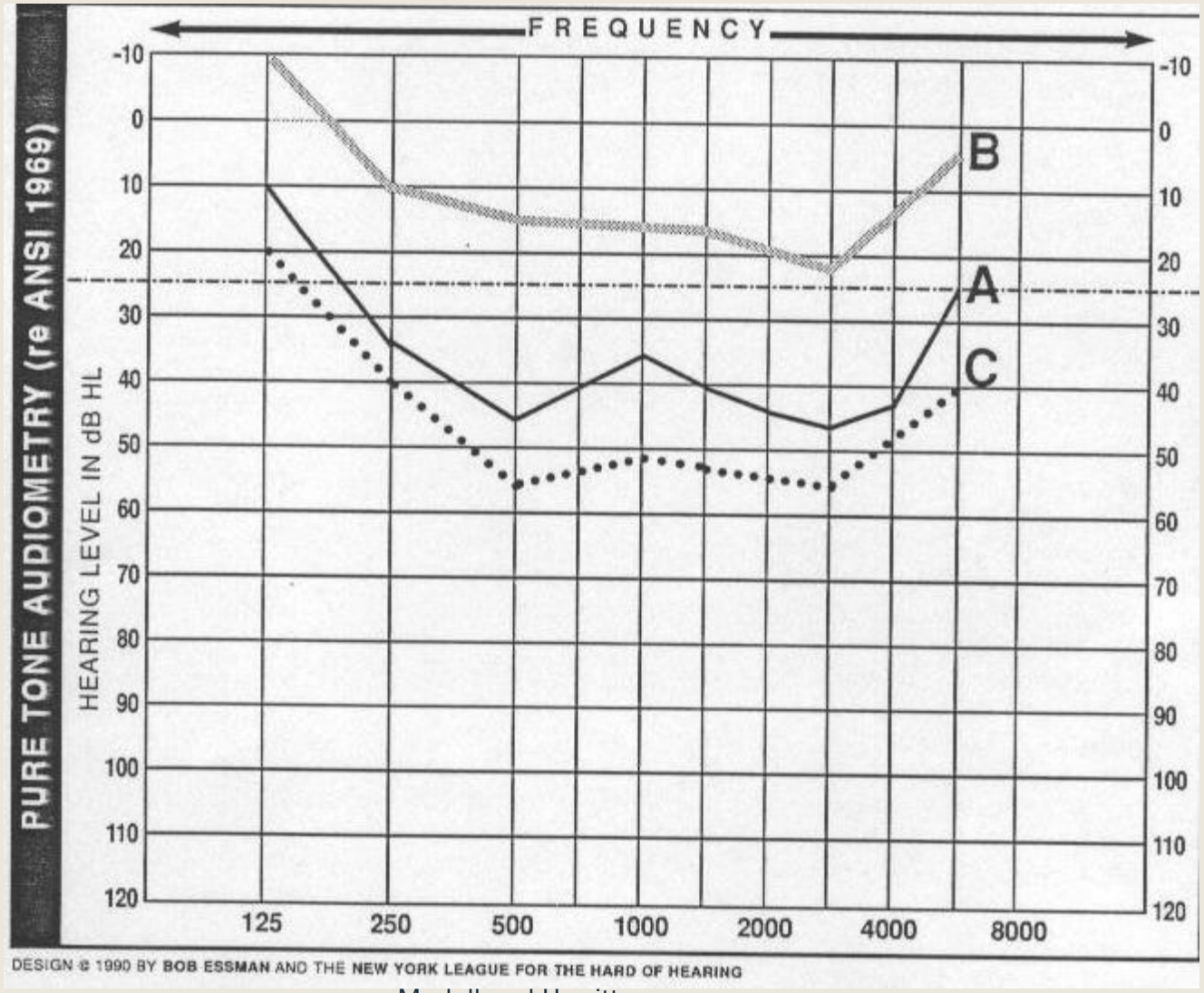
Auditory Access to the Brain: Access to Soft Speech

- Auditory access is the biggest problem worldwide--for all degrees of hearing loss!
- ***Technology often is not programmed to today's possibilities***
- Children need to hear at normal and soft conversational levels, but soft is often overlooked and not assessed
- Soft speech is about 30-35 dBHL
- Soft speech = Speech at distances or quiet speech up close
  - *"Overhearing/incidental" is critical*
  - *Over 80% of what infants and young children know about the world they learn incidentally*

Auditory Access to the Brain: Access to Soft Speech

- If a child cannot hear soft speech, they will:
  - *Not hear peers in the classroom or on playground*
  - *Not "overhear" conversation and will have limited incidental learning*
  - *Have reduced language and literacy skills*
- Tomblin's (2011) research reported 40% of children fit with HAs were underfit
- But aided hearing at 0dBHL is not the goal as it causes distortion
- With CIs and HAs, soft speech can be adjusted independently

The Audiology Fruit



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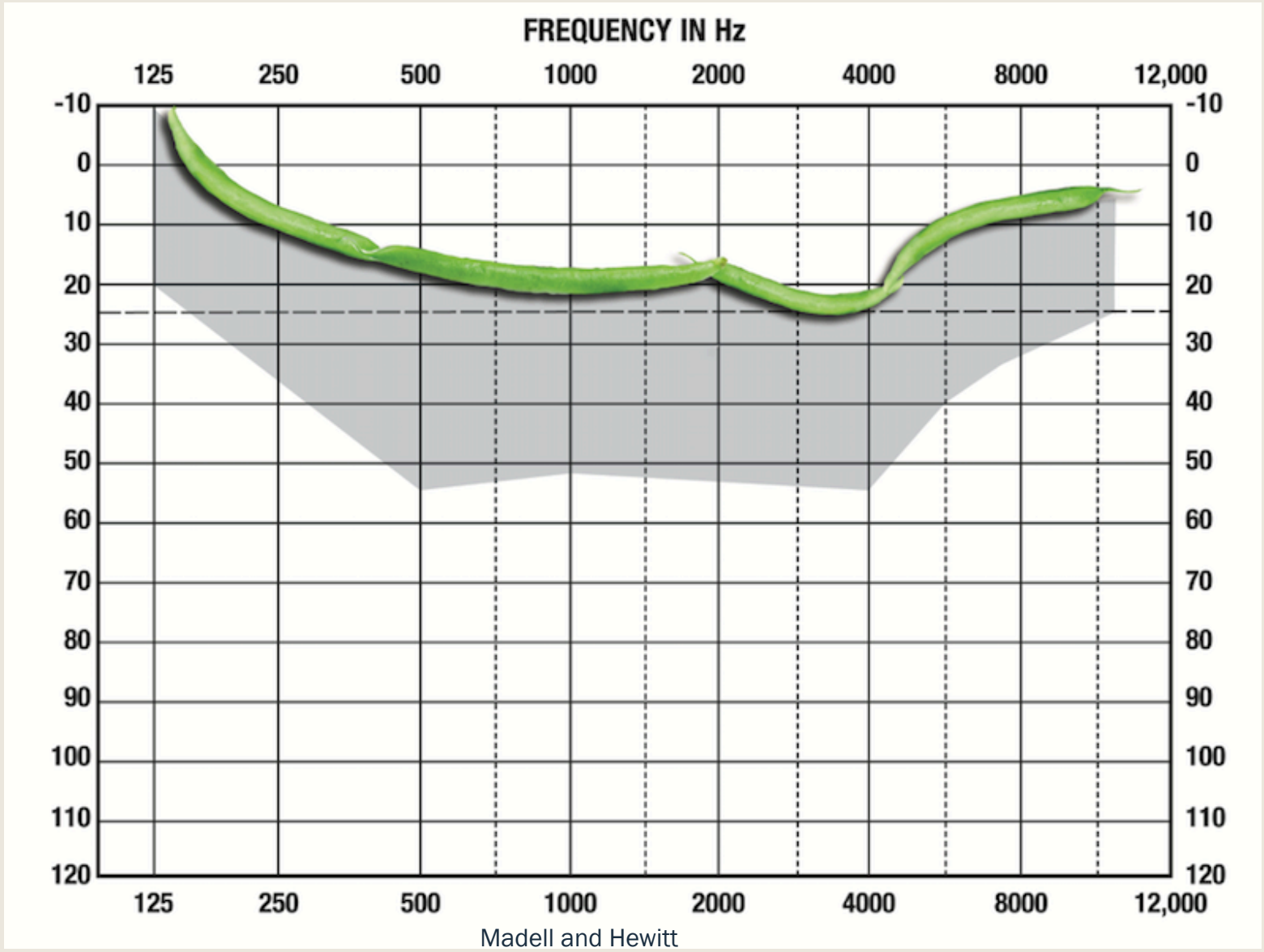
Can We Call It the Speech String Bean?



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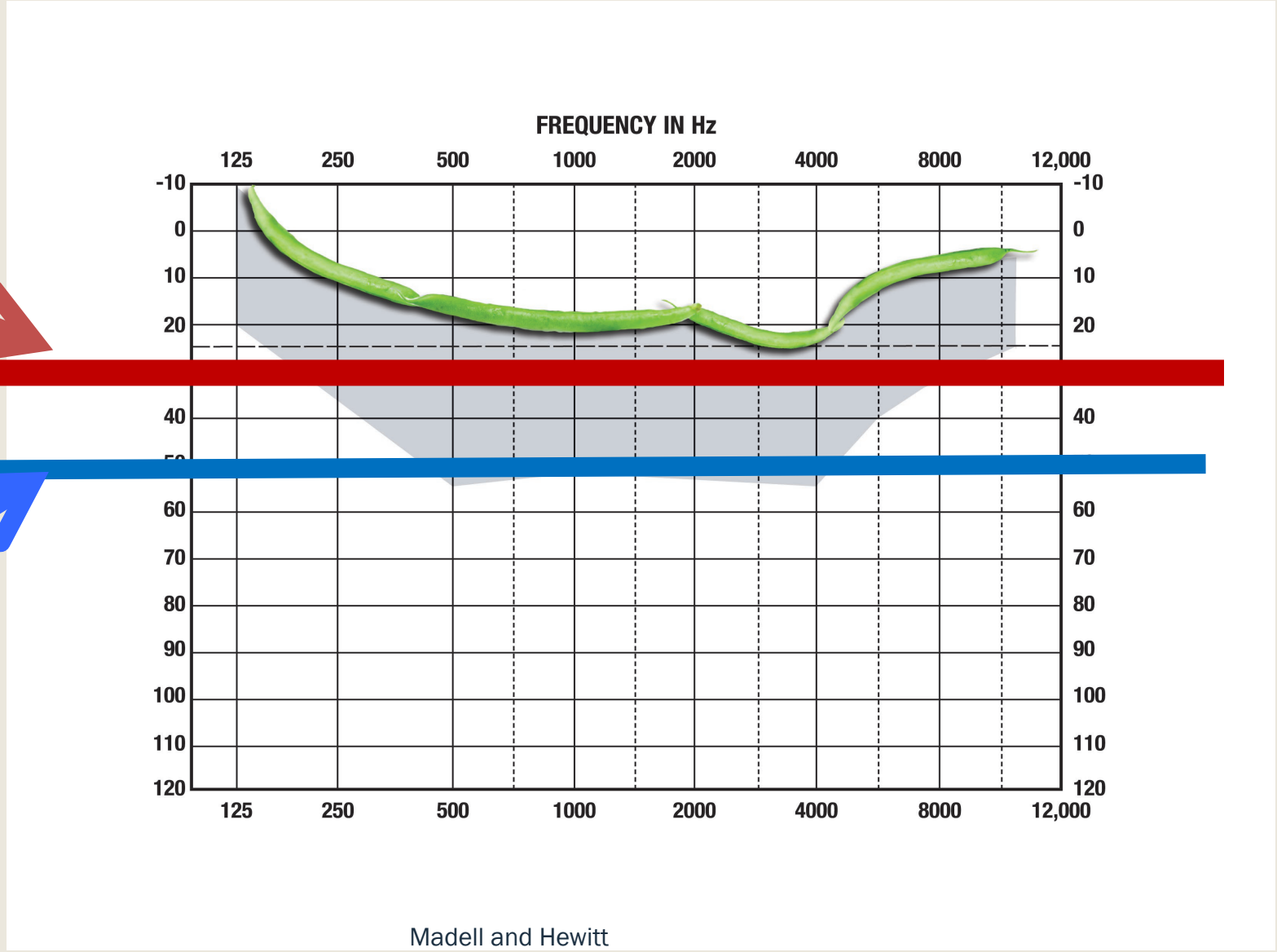
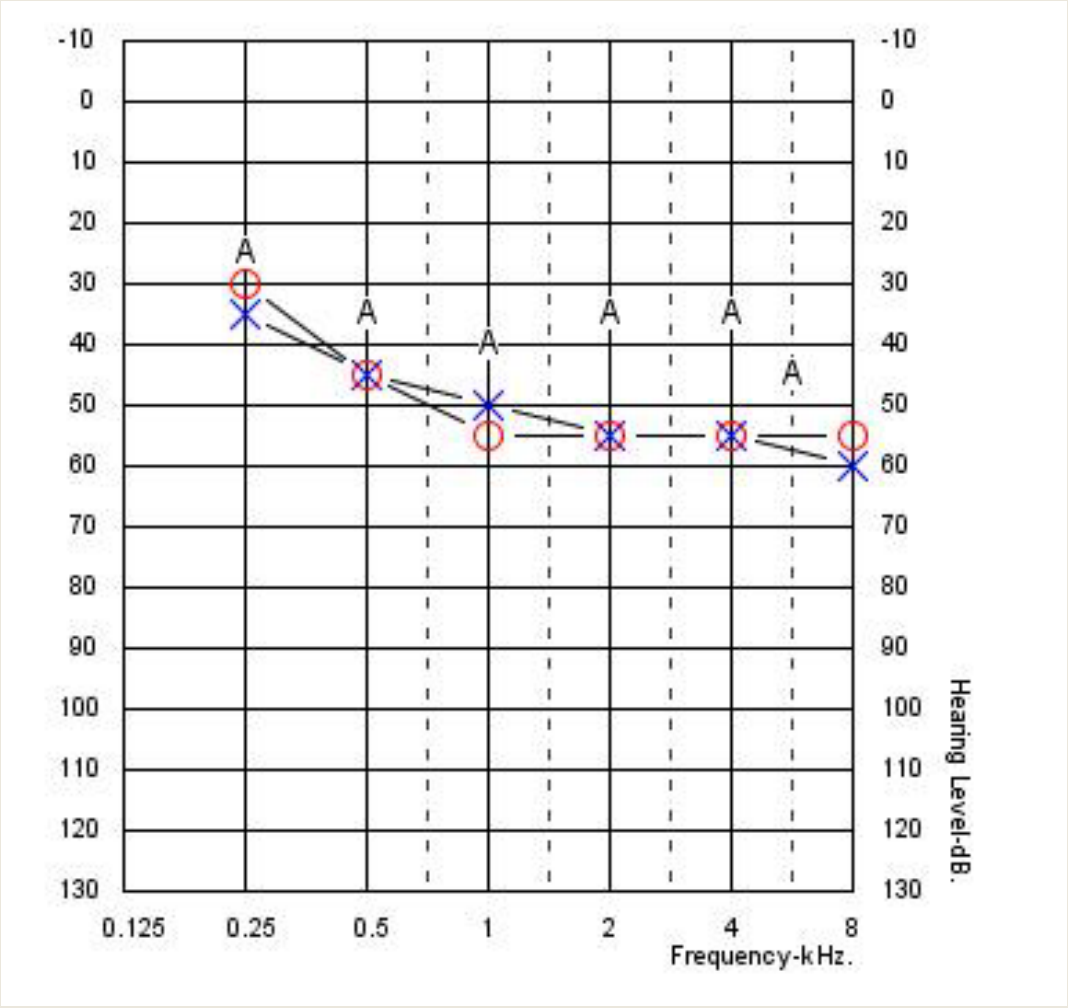
Normal and Soft Conversation

Soft Conversation

Normal conversation





Meet Child C

- 2-year-old whose language was developing slowly
- Parenting / compliance issues?
  - *"We just don't see much difference with the HAs on."*
  - *"He only listens when he wants to."*
- After increasing access to soft speech:
  - *"He's saying so many things we didn't teach him!"*

	Right Ear	Left Ear
Unaided SRT	50dB	45dB
Aided SRT	40dB	35dB
Aided WR @ 50dB	72%	80%
Aided WR @ 35dB	0%	8%

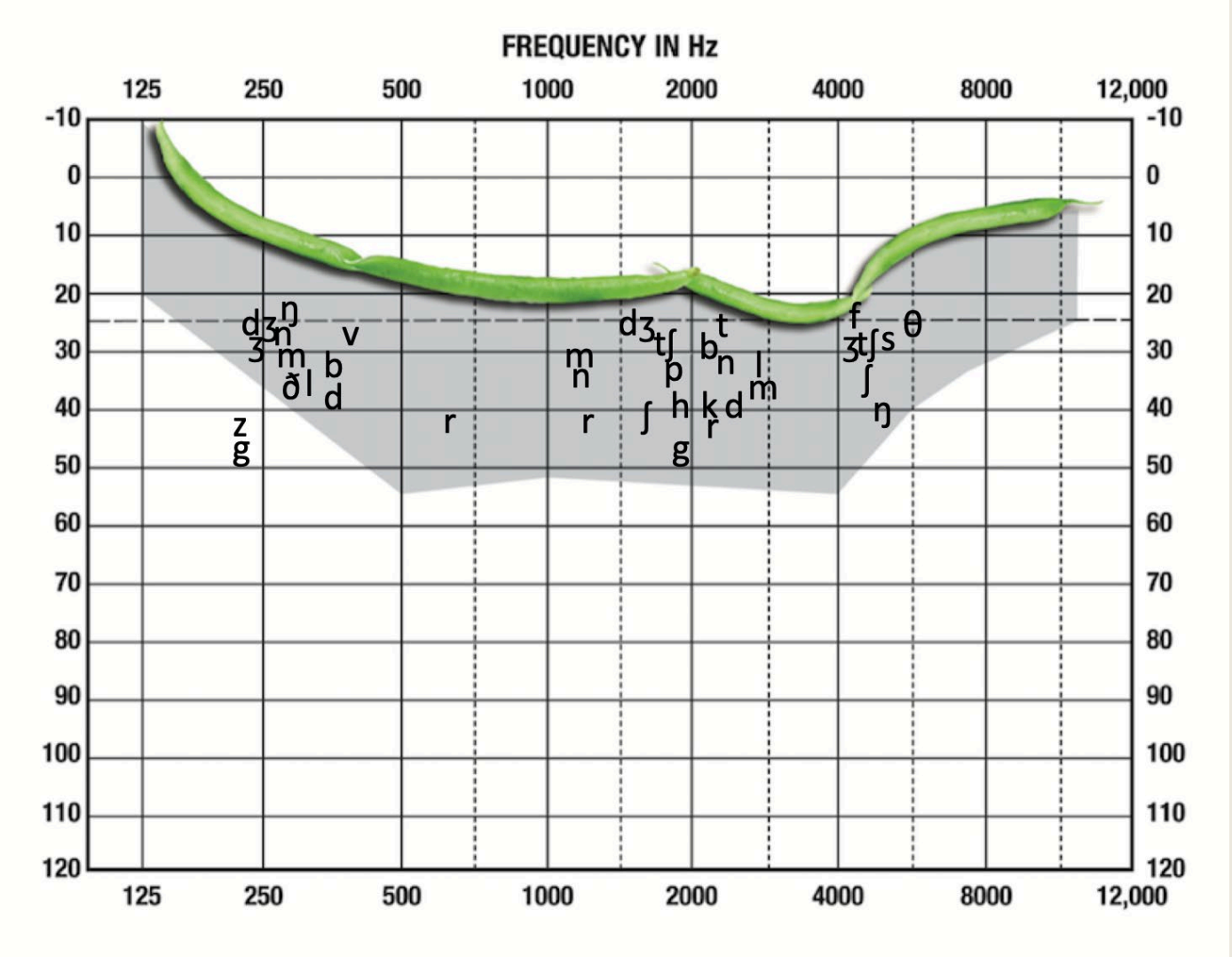
AUDITORY ACCESS TO THE BRAIN #5:

Access to Intelligible Speech in All Environments

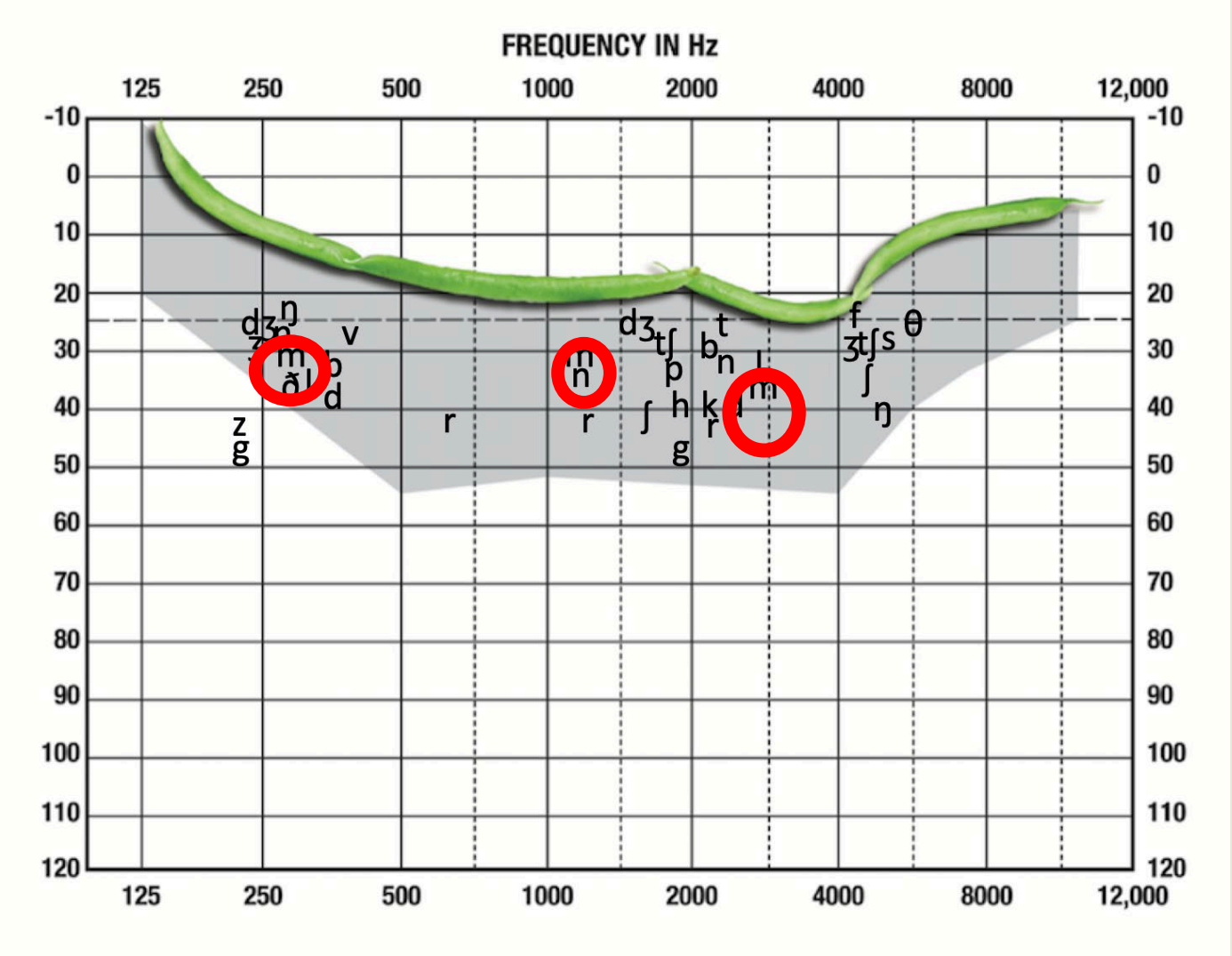
Auditory Access to the Brain: Access to Intelligible Speech in All Environments

- Auditory access is the biggest problem worldwide--for all degrees of hearing loss!
- ***Technology often is not programmed to today's possibilities***
- Children learn language by hearing it
- For this to happen, ***every*** sound must be audible
- The goal of technology is to provide access to ***intelligible*** speech and language information in quiet, in noise, up close, at a distance

Speech String Bean with Consonants



Speech String Bean with Consonants



Audiograms

- What does the audiogram tell us?
  - *Degree and type of HL*
  - *Quantity of loss, but not quality of loss*
  - *Suggestions of type of technology needed*
  - *Estimates of speech perception expectations*
- What the audiogram does NOT tell us
  - *Speech perception skills*
  - *Speech production*
  - *Language development*
  - *Non-auditory concerns*

Degree of Hearing Loss *Does NOT Predict* Level of Auditory Function

- *NEVER ASSUME*
- Evaluation of auditory perception is critical
  - *For words*
  - *For phonemes*
  - *For sentences*
  - *In quiet and in noise*

What Do Speech Acoustics Tell Us?

- Speech acoustics can help
  - *Understand how children are receiving sounds of speech*
  - *Understand a child's auditory perception*
  - *Understand speech production*
  - *Evaluate missing or distorted phonemes*
  - *Ability to hear at different distances*

Audibility vs Intelligibility

- Speech may be audible but not intelligible
  - *You can detect it, but not understand*
- Intelligibility – you can tell the difference among words which can be very subtle
  - *A child may be able to hear the difference between sleep and sleeping (1 vs 2 syllables) but not discriminate between sleep and sleeps*

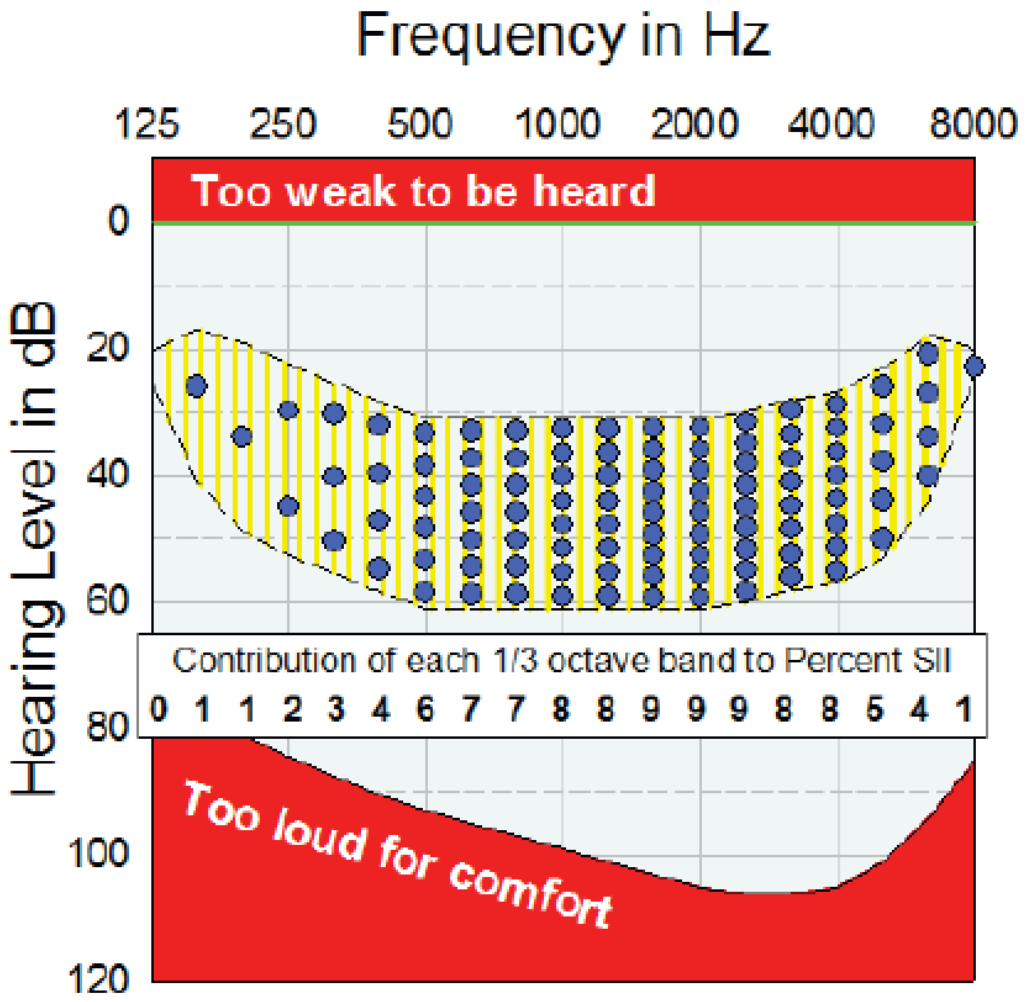


Fig. 19.5 The contribution of frequency to Speech Intelligibility Index (SII), represented by dots within the speech banana.

Boothroyd, in Madell et al 2019

Contribution of frequency to Speech Intelligibility Index (SII)

Technology Testing Recommendations

	0-6 months	6-12 months	12-24 months	24-36 months	>36 months
RECD	✓	✓	✓	✓	✓
Cortical Responses	✓	✓	✓	✓	✓
Aided thresholds 500-8K	✓	✓	✓	✓	✓
SAT – Ling Sounds	✓	✓	✓		
SRT			✓	✓	✓
Speech Perception 50 dBHL Quiet			✓ (R, L, B)	✓ (R, L, B)	✓ (R, L, B)
Speech Perception 35 dBHL Quiet				✓ (R, L, B)	✓ (R, L, B)
Speech Perception 50 dBHL +5SNR				✓ (R, L, B)	✓ (R, L, B)

SPEECH PERCEPTION TESTING RECOMMENDATIONS

Selecting Test Materials

- What is the goal of the evaluation?
  - *To obtain the highest possible score?*
  - *To compare child to peers?*
  - *To monitor technology benefit?*
  - *To monitor treatment?*
  - *To identify specific speech perception errors?*
- We believe it is to obtain the most realistic picture possible of how the child functions in everyday life

Selecting Test Materials

- Linguistically appropriate
  - *Not too easy or too hard*
- Appropriate level of complexity
  - *Sentences*
    - Makes use of person's top-down skills - ability to "fill in the blanks"
    - Not necessarily providing accurate measure of what the person hears
    - For potential patients with more hearing, sentences may not be the appropriate test of choice for determining candidacy for CI
    - BUT for young children, may provide data about what is being processed in connected language
  - *Monosyllabic words*
    - More accurate measure of auditory perception
  - *Phoneme testing or phoneme scoring*
    - Most accurate measure of auditory perception
  - *Nonsense syllables*
    - Excellent measure of auditory perception

Open Set vs Closed Set

- Closed set measures
  - *Limited set of response possibilities*
  - *Useful for young children with limited vocabulary because they reduce the confounding variable of linguistic knowledge*
  - *Useful for patients with articulation which is difficult to access*
  - *May inflate performance or overestimate speech perception skills compared to real life*
  - *Inappropriate use*
- Open set measures
  - *More challenging test condition*
  - *Stimulus possibilities are unlimited*
  - *More representative of what the listener might encounter in everyday situation*
  - *Very little kids can do this!*

Speech Test Protocols by Age

	0-6 months	6-12 months	12-18 months	18-24 months	24-36 months	3-5 years	6-8 years	8+ years
SAT/LMH	✓	✓	✓	✓				
SRT			✓	✓	✓	✓	✓	✓
ESP	✓	✓	✓	✓				
LMH	✓	✓	✓	✓	✓	✓	✓	✓
NU Chips				✓	✓	✓		
WIPI						✓	✓	
PBK						✓	✓	
NU-6 / CNC							✓	✓
HINT-C							✓	✓
Ped AZ Bio						Age 5	✓	✓
BKB-SIN						Age 5	✓	✓
AZ Bio								✓

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Evaluating Test Scores

- Word scoring vs phoneme scoring
  - *Word scoring is a small part of the picture*
  - *What exactly is the person misperceiving?*
    - High frequencies? – Which frequencies?
    - Vowels – Is technology providing enough lows?
    - What is the confusion?
      - *Bed/bet*
      - *Shoe/sue*
    - What can be done to change the response of the technology?
- Technology programming and then therapy should work on improving perception of the difficult to hear sounds

Bodkin, Madell, and Wegman

				Male				Female		
Condition	**CA**	**List**	**N**	**WR%**	**SD**	**95% CI**	**N**	**WR%**	**SD**	**95% CI**
Quiet 50 dB	3-5	NU-C	14	98	3.7	96-100	12	98	3.2	96-100
Quiet 50 dB	6-8	PBK	13	98	3.1	97-100	12	98	3.2	96-100
Quiet 50 dB	9+	W-22	13	99	1.9	98-100	6	96	5.1	92-100
Quiet 35 dB	3-5	NU-C	19	95	5.2	92-97	13	96	4.8	93-98
Quiet 35 dB	6-8	PBK	23	97	3.7	95-98	24	98	3.1	97-99
Quiet 35 dB	9+	W-22	17	98	2.8	97-100	9	96	4.2	93-98
50 @ +5 SNR	3-5	NU-C	28	93	4.6	91-95	16	94	4.1	92-96
50 @ +5 SNR	6-8	PBK	13	94	4.5	92-96	25	95	5.1	93-97
50 @ +5 SNR	9+	W-22	17	97	4.1	95-99	7	93	3.8	90-96
50 @ 0 SNR	3-5	NU-C	23	91	6.9	88-94	17	92	6.5	89-95
50 @ 0 SNR	6-8	PBK	18	91	5.4	89-93	28	93	6.0	90-95
50 @ 0 SNR	9+	W-22	19	95	4.7	93-97	11	93	4.8	91-96
35 @ 0 SNR	3-5	NU-C	23	90	6.1	87-93	16	92	6.0	89-94
35 @ 0 SNR	6-8	PBK	28	91	6.2	88-93	28	90	6.1	87-92
35 @ 0 SNR	9+	W-22	18	91	6.2	88-94	11	90	7.0	86-94

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SUGGESTED SCORING

- Excellent 90-100%
- Good 80-89%
- Fair 70-79%
- Poor < 70%

Meet Child D

- 5-year-old fully mainstreamed kindergartener
  - *Bilateral EVA*
  - *HAs at 2 years; Right CI at 2.6 years*
- Moved and reprogrammed at new center
  - *When time leave, he started to cry and said he couldn't hear*
  - *SAT = 15dB - NU-Chips @ 50dBHL = 96%*

	250Hz	500H	1000Hz	2000Hz	4000Hz
Right CI	15dB	20dB	15dB	20dB	25dB

Detection	/m/	/a/	/oo/	/ee/	/sh/	/s/
Right CI	15dB	20dB	20dB	25dB	20dB	25dB

- RX: Wait 3 weeks until he adapts

Meet Child D

- 3 weeks later:
  - *Child continued to report he could not hear*
  - *Reports of overly sensitive, disruptive, and chewing clothing and pencils*
- Returned to previous center
  - *SRT = 40dB - PBK @ 50dBHL = 40% - PBK @ 35dBHL = 0%*

Imitation	/m/	/a/	/oo/	/ee/	/sh/	/s/
Right CI	35dB	40dB	40dB	45dB	45dB	55dB

- Reprogrammed
  - *SRT = 25dB - PBK @ 50dBHL = 80% - PBK @ 35dBHL = 68%*
- Audibility does NOT ensure intelligibility!

LET'S REVIEW

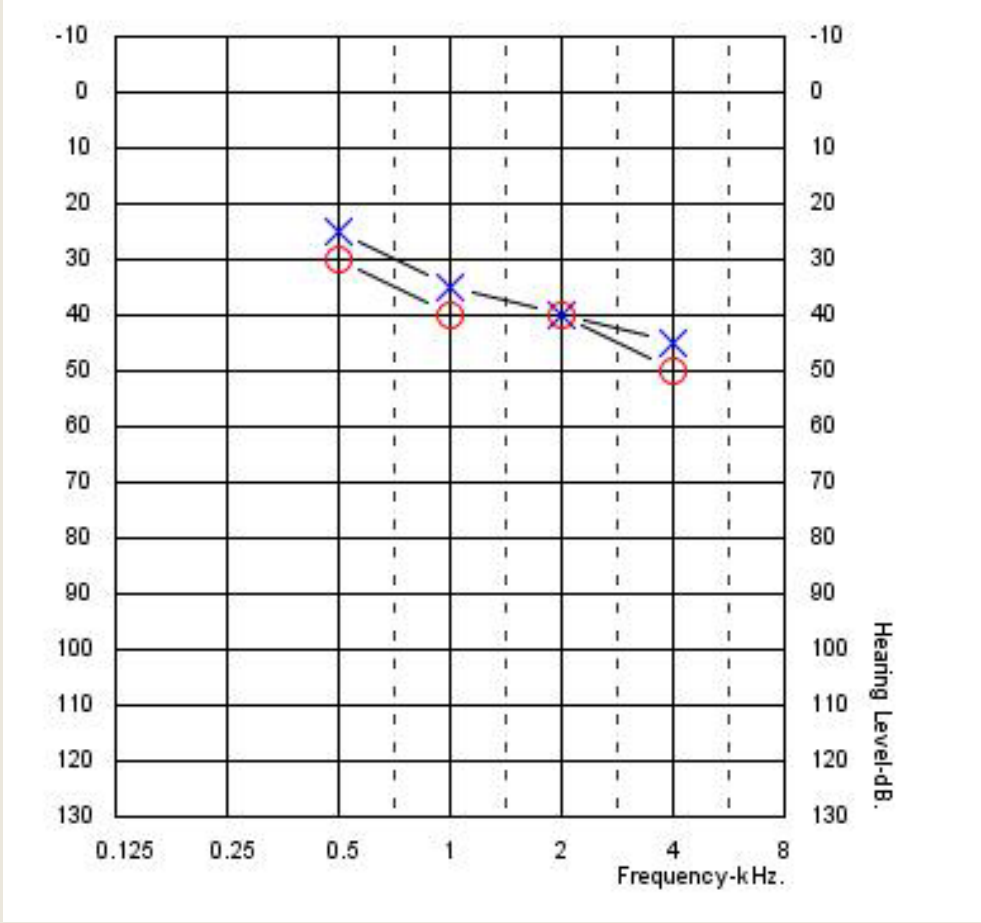
Meet Child E

- Unremarkable birth history, except for failing NBHS
- Subsequent testing revealed:
  - *Absent OAEs*
  - *ABR thresholds*
    - Minimal / mild to moderate thresholds
- Referral to ENT for review and medical clearance for HAs

	500Hz	1000Hz	2000Hz	4000Hz
Right	30dBnHL	40dBnHL	40dBnHL	50dBnHL
Left	25dBnHL	35dBnHL	40dBnHL	45dBnHL

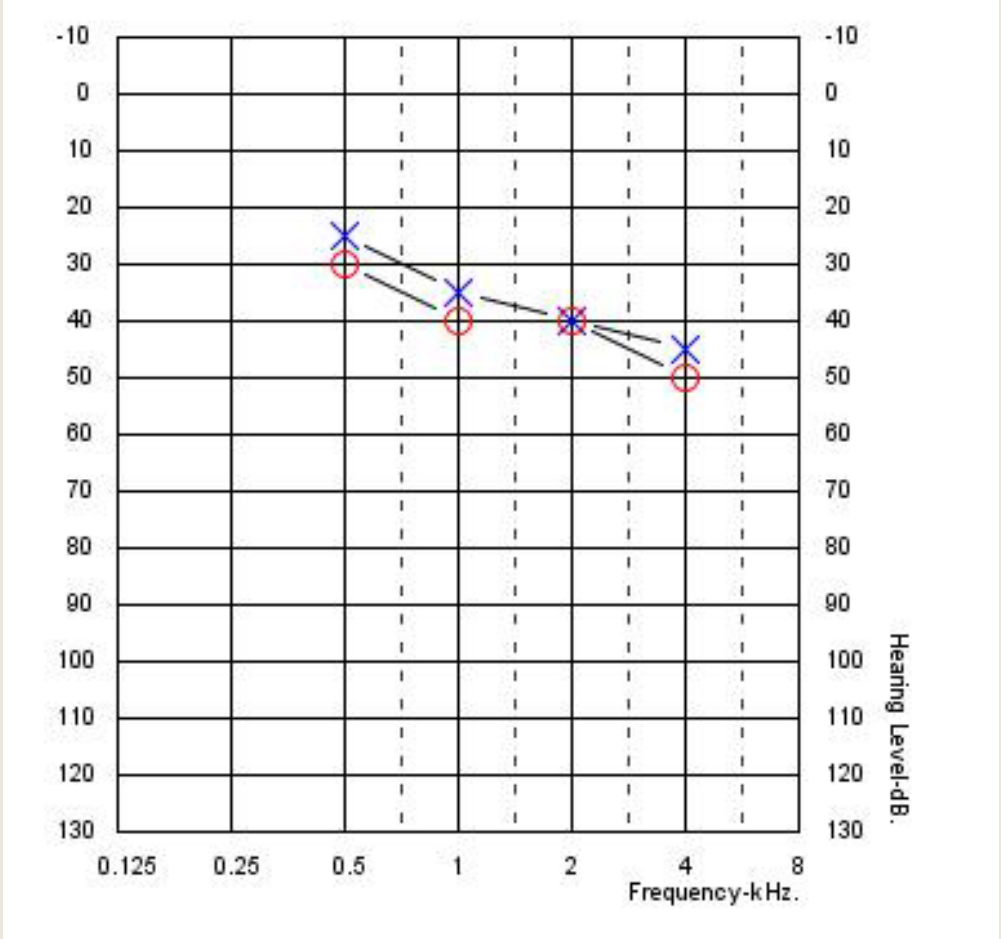
Meet Child E

- ENT:
  - *Saw no otitis media or middle ear abnormalities*
  - *Cleared patient for bilateral hearing aids*
  - *Recommended no need for additional follow up with mild / moderate hearing loss*
- Audiologist:
  - *Fit hearing aids at 3 months of age*
  - *RX: Follow-up testing at 12, 18, and 24 months*
- DHH Auditory/verbal specialist:
  - *Saw child 2 hours per month in home*



Meet Child E

- At 24 months, parents concerned about:
  - *Lack of attachment to HAs*
  - *Lack of a difference with HAs on*
  - *Lack of progress in SL development*
- Audiologist: “child fatigues” and “difficult to test”
- DHH specialist: “rate of progress is concerning” and “center not the best”

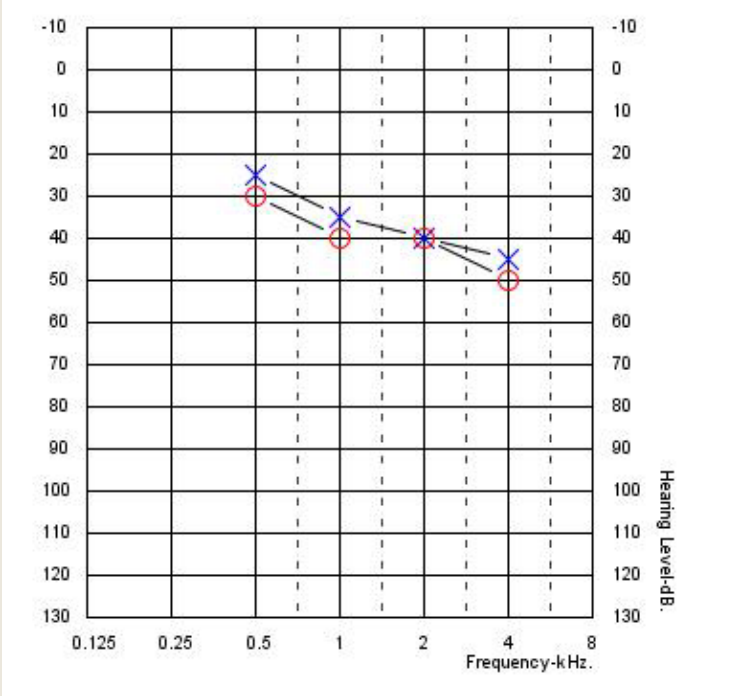


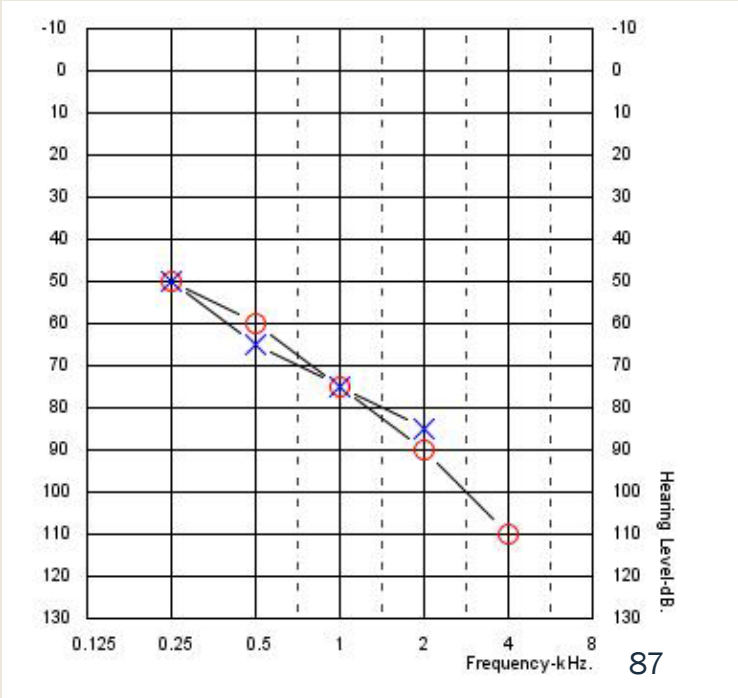
LESSON #1: WE ALL MUST BE THOROUGH AND ACCURATE!

LESSON #2: BRAINS SHOULD WANT TECHNOLOGY ALL DAY, EVERYDAY

Meet Child E

- 2nd opinion center suggests:
  - *CPA: DHH, SLP, AVT, **please teach this!!!!***
  - *Testing every 6 months*
  - *One ear at a time*
- Compilation audiogram (3 tests) completed at 3 years, 2 months of age
- 2nd opinion center recommends increasing gain on hearing aids and using FM / DM
  - *Child begins combining words and using some familiar simple sentences*
  - *Articulation is poor so "can't assess speech perception"*

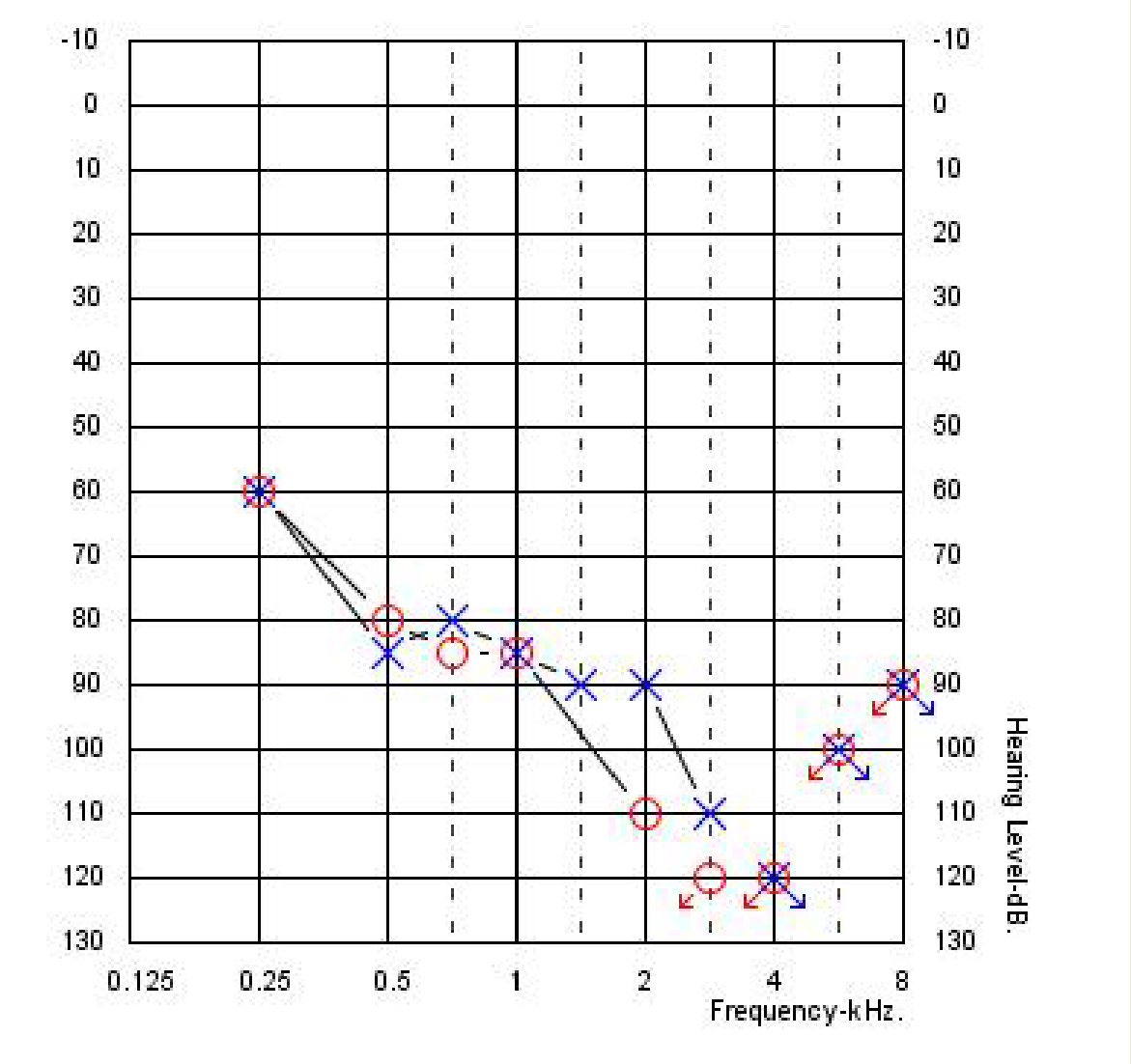




LESSON #3: FOUR FREQUENCIES IS NOT THE ENTIRE SPEECH SPECTRUM

Child E:

3rd opinion



	Unaided SRT (open set)	Unaided NU-Chips at 105dBHL (open set)	Aided SRT (open set)	Aided NU-Chips at 50dBHL (open set)
Right	105dB	24%	CNT at 65dB	CNT
Left	105dB	48%	50dB	0%

Mom received call on way to 3rd center that EVA was present bilaterally

Meet Child E

- 3rd opinion center:
  - *Recommended bilateral CIs*
- Decision:
  - *Sequential CIs vs Simultaneous CIs*
  - *Parents chose simultaneous*
- At 3.9 years, patient simultaneously bilaterally implanted
  - *1st 6 weeks were very difficult*

Meet Child E

6 months post CI

	Right HA	Right CI	Left HA	Left CI	Bilateral CIs
Aided SRT (open set)	CNT at 65dB	30dB	50dB	35dB	
Aided NU-Chips @ 50dB (open set)	CNT	64%	0%	76%	
Aided NU-Chips @ 35dB (open set)					48%
HINT-C (in quiet)					51%

Meet Child E

- Language progress:
  - *By 3 months post implant, child had made 6 months' language growth from preimplant levels*
  - *By 6 months post implant, child had made 1 year's language growth*
  - *By 12 months post implant, child had made 2 years' language growth*
- Parents delayed Kindergarten entrance for 1 year; child is fully mainstreamed

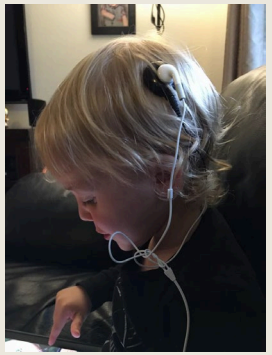
LESSON #4: ACCESS TO SOFT SPEECH FOSTERS INCIDENTAL LEARNING

LESSON #5: ACCESS TO INTELLIGIBLE SPEECH GROWS LANGUAGE AND BRAINS

Summary

- Everyone with a hearing loss has the right to hear optimally
- Perception is much, much, much more than 6 Ling sounds or LMH 10
- Assessment of perception should grow with the child
- There is no such thing as “good enough”
- If a child is not hearing wonderfully, something is wrong. Do not just accept it. Technology is the most likely problem
- Perception can be improved with programming changes
- Only after you rule out technology as the problem can you start to direct the concern to therapy or family
- **Everyone** on the team (including family) needs to work together to achieve success.







Thanks for Listening



IT'S HERE!!!

A unique resource for helping children and adults with hearing loss develop listening and spoken language as the foundation for cognition, literacy, and educational advancement

Substantial neurobiological evidence indicates hearing is the most effective sensory modality for developing spoken language and cognition. *From Listening to Language: Comprehensive Intervention to Maximize Learning for Children and Adults with Hearing Loss*, edited by renowned clinicians Jane R. Madell and Joan G. Hewitt, features contributions from a distinguished group of experts. The text focuses on evidence-based practice to maximize the learning potential of children with hearing loss by nurturing the auditory brain development necessary to help them learn to listen and talk, as well as helping adults build stronger listening skills.

Six sections and 22 chapters cover the spectrum of comprehensive listening and spoken language intervention for all age groups (including adults) and for the professionals working with them. Topics include literacy, executive function, bilingualism, dual diagnoses, educational support, changes in auditory access, red flags for auditory development, music therapy, telepractice, and intervention with adults. In-depth discussions of the stages of speech and language development for the diverse population of children with hearing loss assist new and experienced clinicians develop effective therapeutic and educational plans and encourage caregivers to become effective partners in their children's progress.

Key Features

- Reader-friendly chapters with summaries, key points, pearls, and pitfalls facilitate learning
- Case studies assist clinicians in applying chapter information
- A wealth of LSL resources, assessments, charts, suggested readings, websites, and more provide the opportunity to expand knowledge
- Videos offer examples of hearing evaluation of infants and young children and speech perception testing, including demonstrations of the LMH (Ling-Madell-Hewitt) Test Battery.

This is an essential textbook for graduate courses in audiology, speech-language pathology, early intervention, and deaf education, and an invaluable resource for new and experienced professionals and the caregivers with whom they work.

Jane R. Madell, PhD, CCC A/SLP, FAAA, LSLS Cert AVT is a Pediatric Audiologist and Retired Director, Hearing and Learning and Cochlear Implant Centers, NYEE-Beth Israel Medical Center, New York, New York, USA.

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Madell/Hewitt

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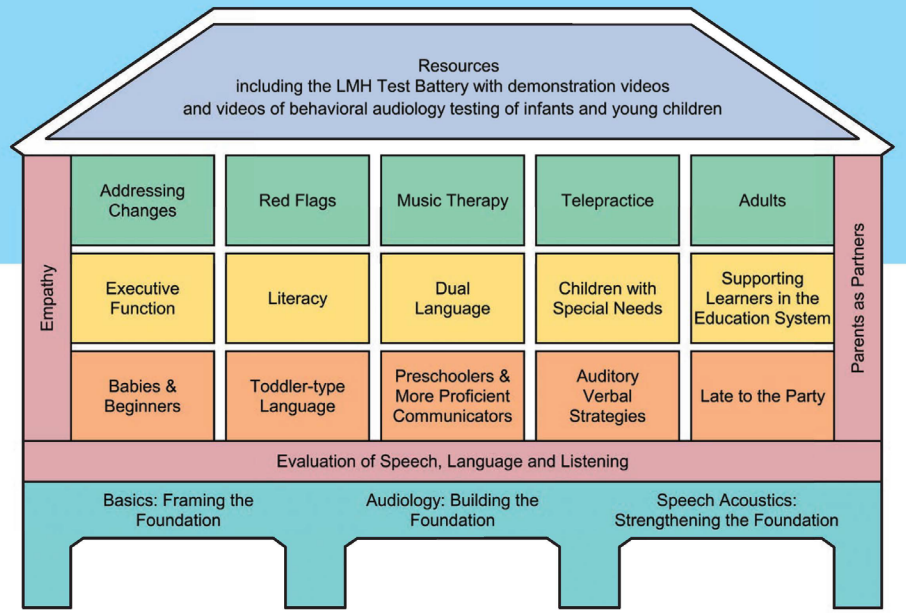

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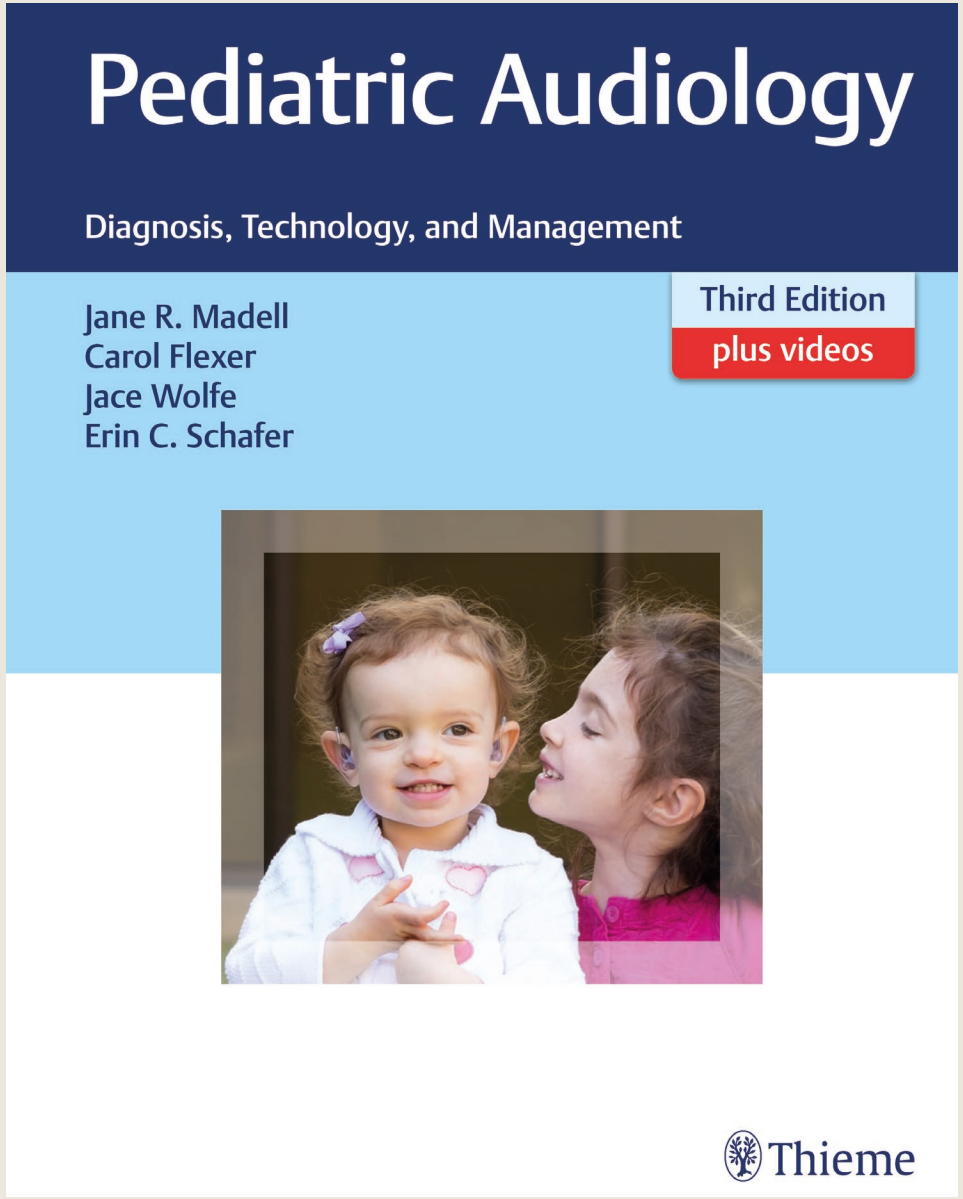

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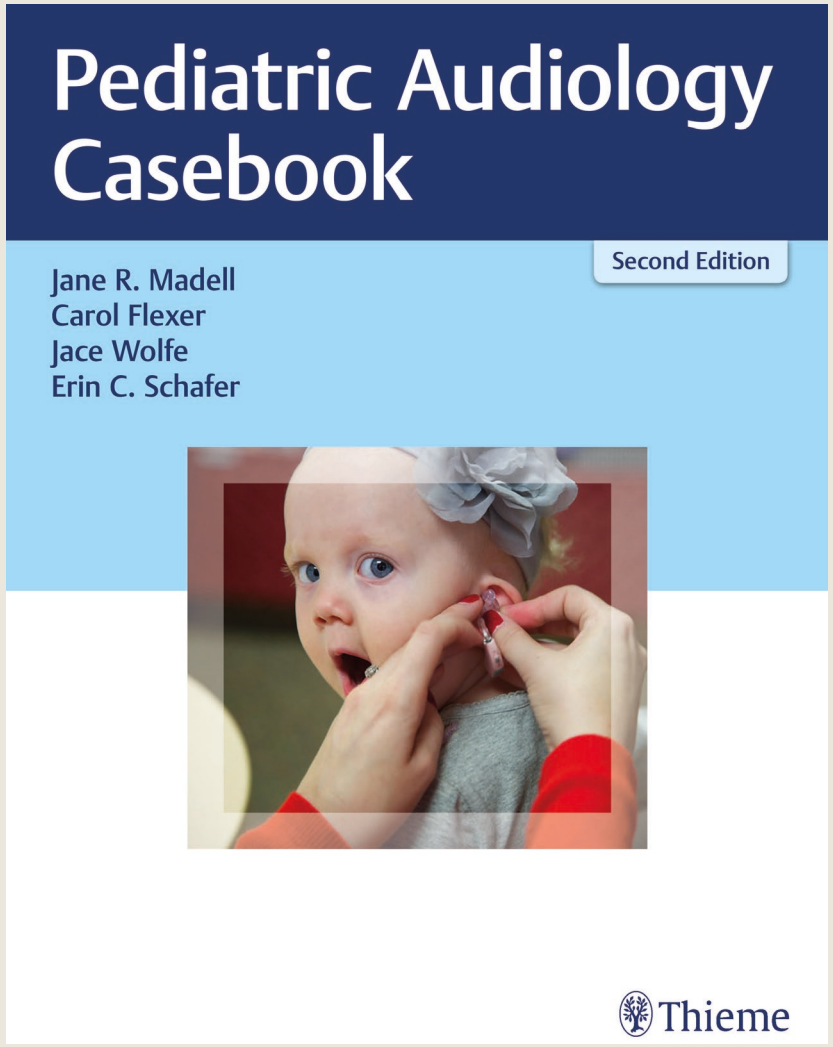

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Questions??

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