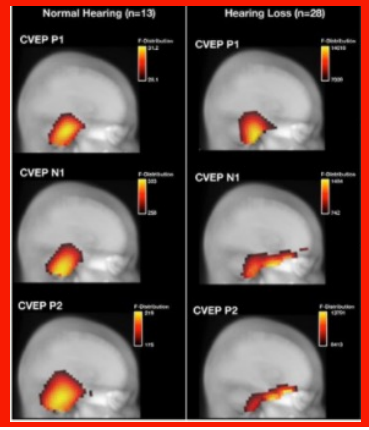
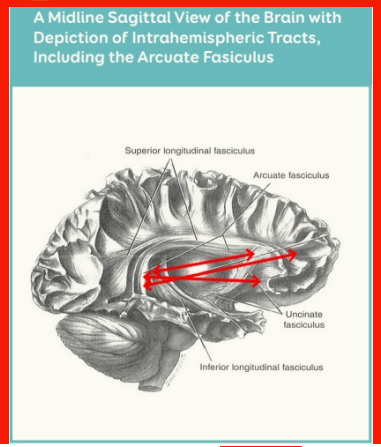
Audibility is important, but more is needed

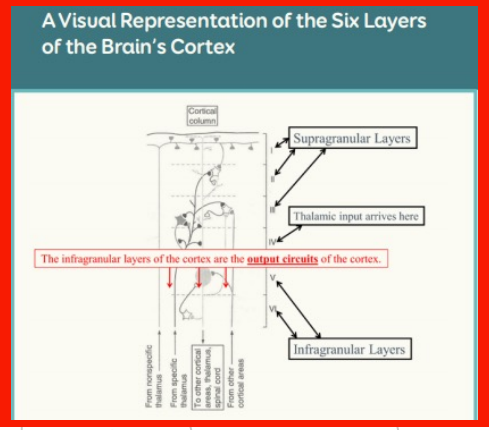
Ron Leavitt, Carol Flexer, Nikki Clark, ColetteWelch

C Underlying Premises

Patients of all ages who receive cochlear implants and/or hearing aids require brain reorganization at both superficial and deeper levels

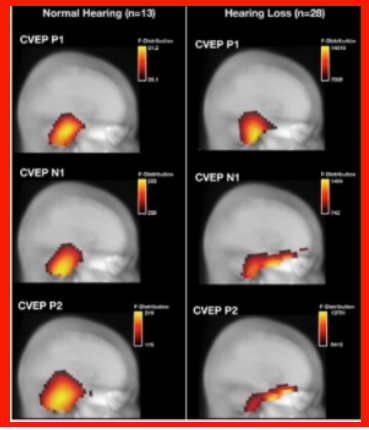


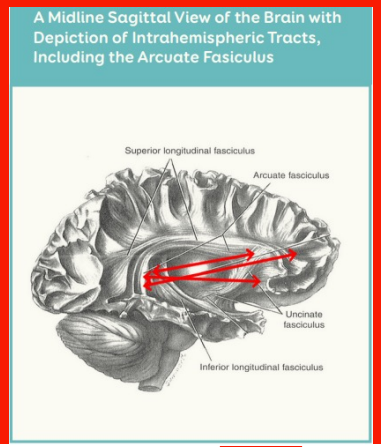


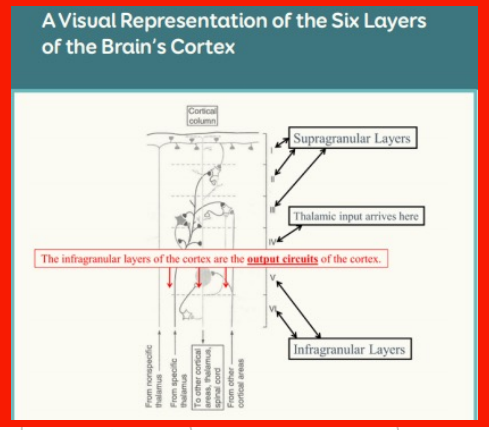


Underlying Premises

Without such brain reorganization the patient is prone to unfavorable changes in brain anatomy & physiology.

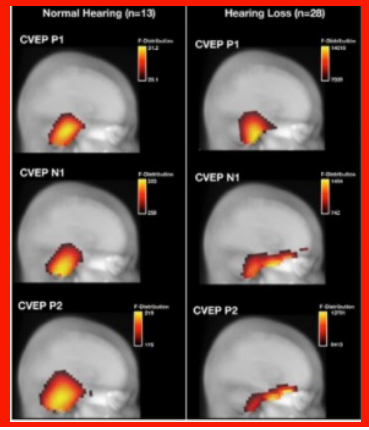


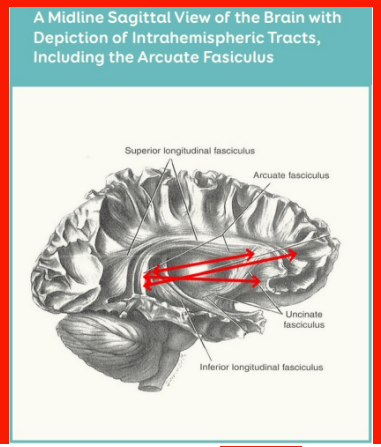


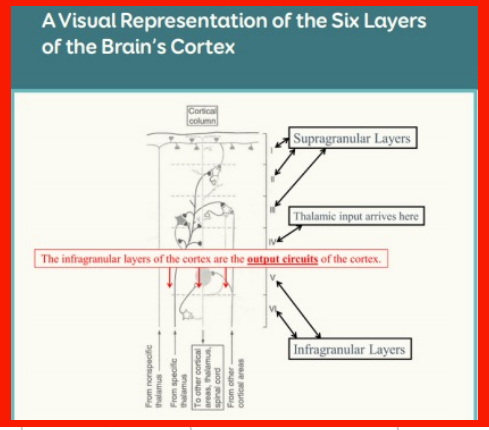


Underlying Premises

As such, we are in the cognitive optimization business not hearing aid/cochlear implant sales.







Underlying Premises

For this brain reorganization to occur optimum audibility is the first essential goal as the deeper (primary auditory) brain layers require optimum audibility and are the gateway to the higher areas

Audibility is the foundation upon which we build brain reorganization

Underlying Premises

Unfortunately, appropriate audibility for people with hearing loss is a frequent area of foundational failure in our profession

Underlying Premises

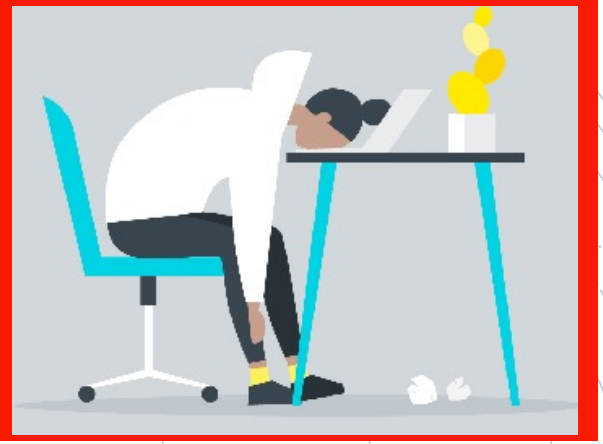
…and cognitive decline and brain resource reallocation have been linked to poor scores on speech in noise tests….

Underlying Premises

..and these poor scores on speech in noise tests are often due to insufficient audibility

Underlying Premises

…but even after achieving proper audibility, many patients still are at risk for social/academic/vocational failure and dementia



Underlying Premises

So we must first optimize audibility in all cochlear implant and hearing aid fittings

Underlying Premises

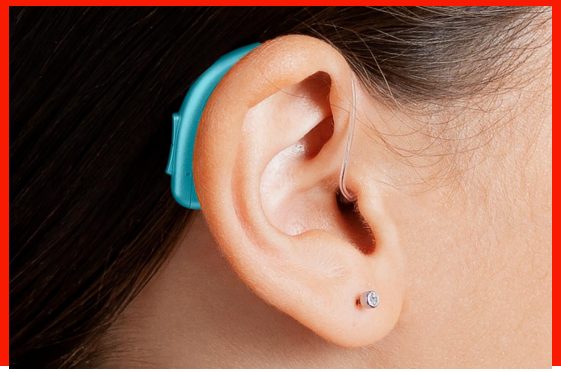
…and there are things we must do after assuring appropriate audibility to decrease the likelihood of poor outcomes.

Underlying Premises

Now let's look at the evidence supporting these premises

Co/R

1. Aided audbility of speech is important to cognitive/linguistic and social function in adults and children with hearing loss [1-14]



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2. Desjardins JL. Analysis of Performance on Cognitive Test Measures Before, During, and After 6 Months of Hearing Aid Use: A Single-Subject Experimental Design. Am J Audiol. 2016 Jun 1;25(2):127-41.

3.McCreery RW, Walker EA, Spratford M, Lewis D, Brennan M. Auditory, Cognitive, and Linguistic Factors Predict Speech Recognition in Adverse Listening Conditions for Children With Hearing Loss. Front Neurosci. 2019 Oct 15;13:1093.

4. Shen J, Sherman M, Souza PE. Test Administration Methods and Cognitive Test Scores in Older Adults with Hearing Loss. Gerontology. 2020;66(1):24-32. doi: 10.1159/000500777. Epub 2019 Jun 26.

5. McCreery RW, Brennan M, Walker EA, Spratford M. Perceptual Implications of Level- and Frequency-Specific Deviations from Hearing Aid Prescription in Children. J Am Acad Audiol. 2017 Oct;28(9):861-875.

6.Megha, Maruthy S. Consequences of hearing aid acclimatization on ALLRs and its relationship with perceived benefit and speech perception abilities. Eur Arch Otorhinolaryngol. 2019 Apr;276(4):1001-1010.

7. Habicht J, Behler O, Kollmeier B, Neher T. Exploring Differences in Speech Processing Among Older Hearing-Impaired Listeners With or Without Hearing Aid Experience: Eye-Tracking and fMRI Measurements. Front Neurosci. 2019 May 3;13:420.

8. Rudner M. Cognitive Spare Capacity as an Index of Listening Effort. Ear Hear. 2016 Jul-Aug;37 Suppl 1:69S-76S

9. McClannahan KS, Backer KC, Tremblay KL. Auditory Evoked Responses in Older Adults With Normal Hearing, Untreated, and Treated Age-Related Hearing Loss. Ear Hear. 2019 Sep/Oct;40(5):1106-1116.

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10. Jenkins KA, Fodor C, Presacco A, Anderson S. Effects of Amplification on Neural Phase Locking, Amplitude, and Latency to a Speech Syllable. Ear Hear. 2018 Jul/Aug;39(4):810-824.

11. Jenkins KA, Fodor C, Presacco A, Anderson S. Effects of Amplification on Neural Phase Locking, Amplitude, and Latency to a Speech Syllable. Ear Hear. 2018 Jul/Aug;39(4):810-824.

12. Spratford M, McLean HH, McCreery R. Relationship of Grammatical Context on Children's Recognition of s/z-Inflected Words. J Am Acad Audiol. 2017 Oct;28(9):799-809.

13. Glick H, Sharma A. Cross-modal plasticity in developmental and age-related hearing loss: Clinical implications. Hear Res. 2017 Jan;343:191-201.

14. Glick HA, Sharma A. Cortical Neuroplasticity and Cognitive Function in Early-Stage, Mild-Moderate Hearing Loss: Evidence of Neurocognitive Benefit From Hearing Aid Use. Front Neurosci. 2020 Feb 18;14:93.

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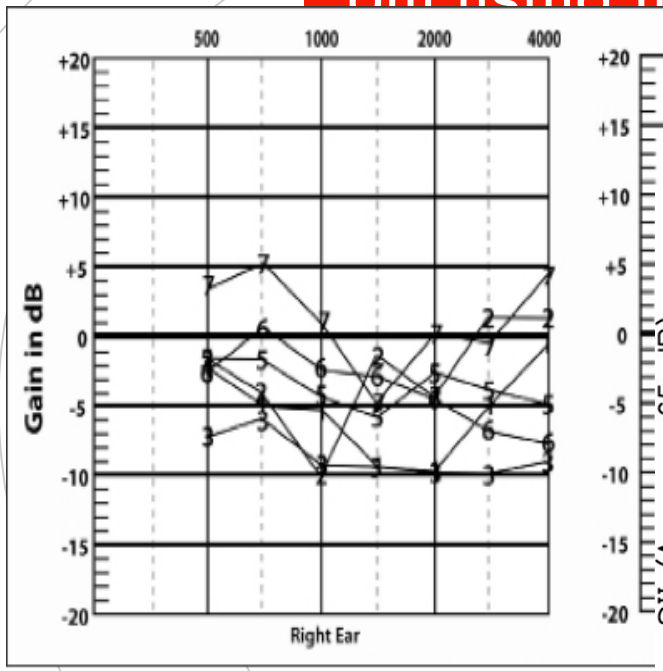
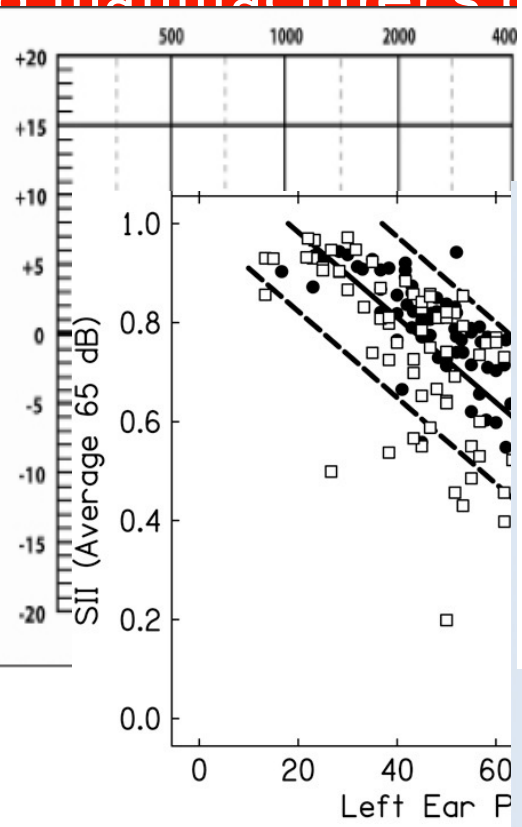




The Total Number of
DSL v5 Prescribed Tar
and

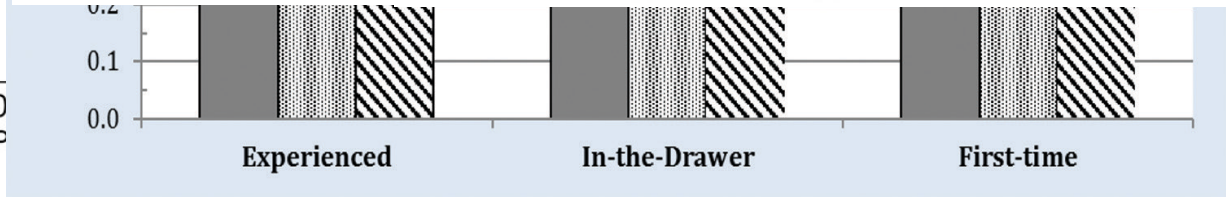
		250 H
50 input	Fit-to-target (+)	4 (3)
	Fit-to-target (–)	0 (0)
65 input	Fit-to-target (+)	0 (0)
	Fit-to-target (–)	5(3)
75 input	Fit-to-target (+)	0 (0)
	Fit-to-target (–)	14(9)

Numbers without brackets represen
numbers in bracket represents the
prescribed targets. Fit-to-target (+)
target (–) means the output was lo

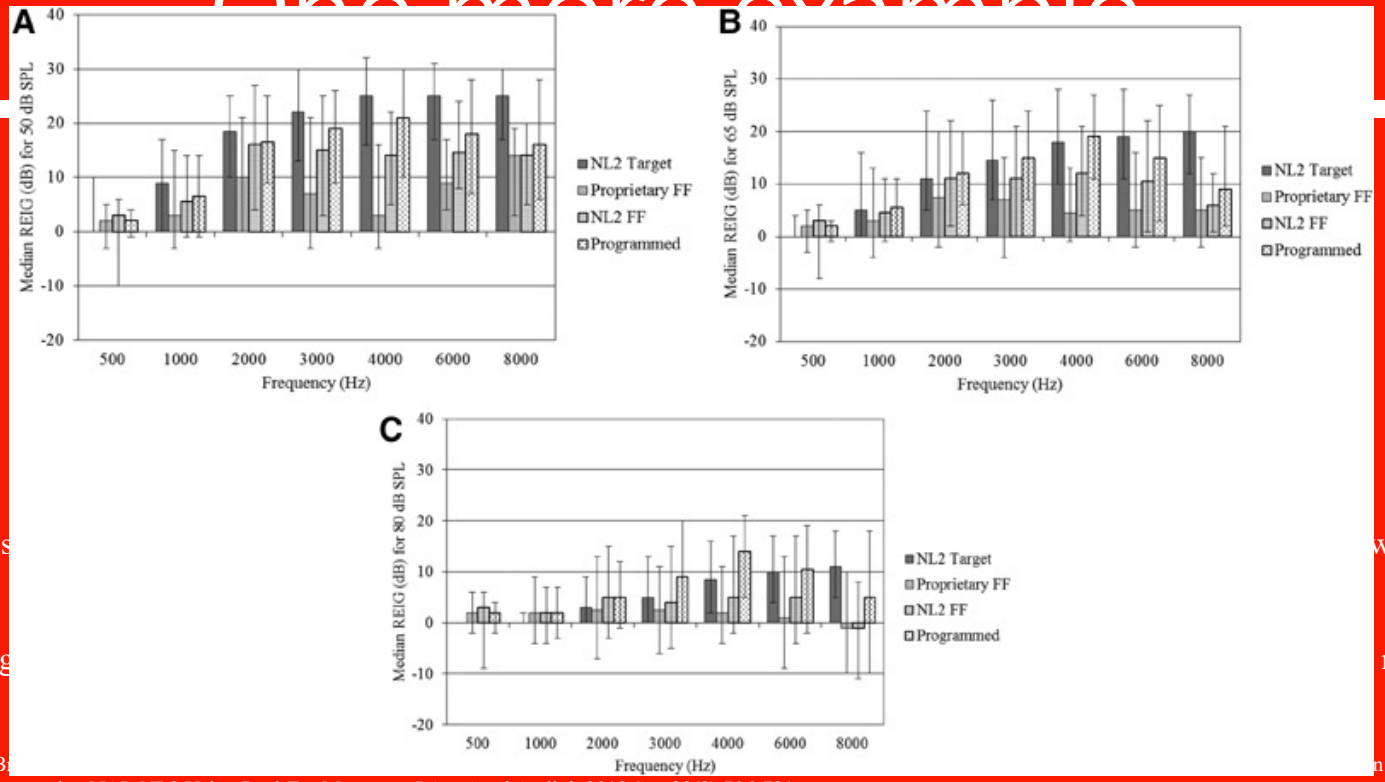
Table 4

Percentage of Fittings with an RMSE of ≤5 dB with (maximum RMSE if >5) Per Level

dB SPL	N1–N5	N6–N7
55	88 (6)	8(11)
65	84 (6)	8(11)
75	88 (7)	8(11)
90—MPO	92 (6)	58 (10)



One more example



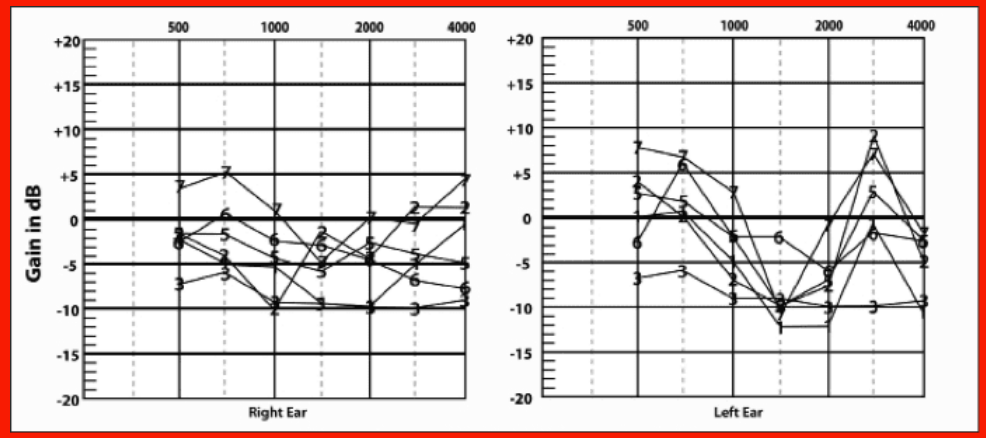
A s with

A sig noise

Valente M, Oeding K, B n Manufacturer First-Fit and Hearing Aids Programmed to NAL-NL2 Using Real-Ear Measures. J Am Acad Audiol. 2018 Sep;29(8):706-721.

Because…

Real-ear programming gives more audibility.



Leavitt R, Flexer C. The importance of audibility in successful amplification of hearing loss. *Hearing Review*. 2012; 19(13):20-23.

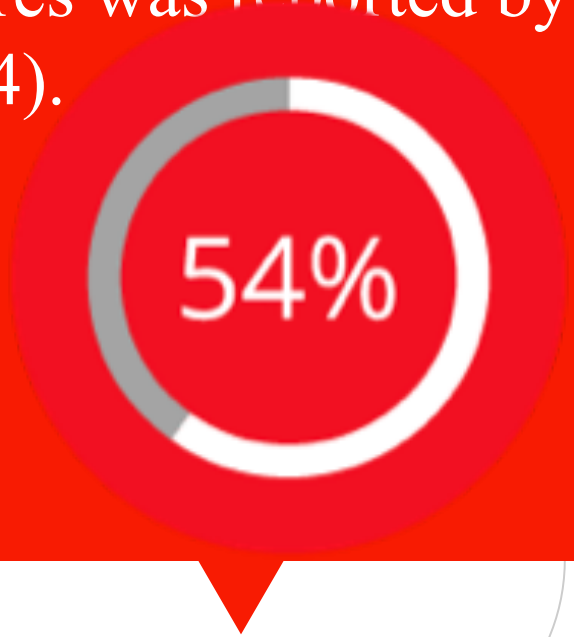
2 So hopefully we can agree real-ear validated speech audibility is important for speech perception in q & noise.

N

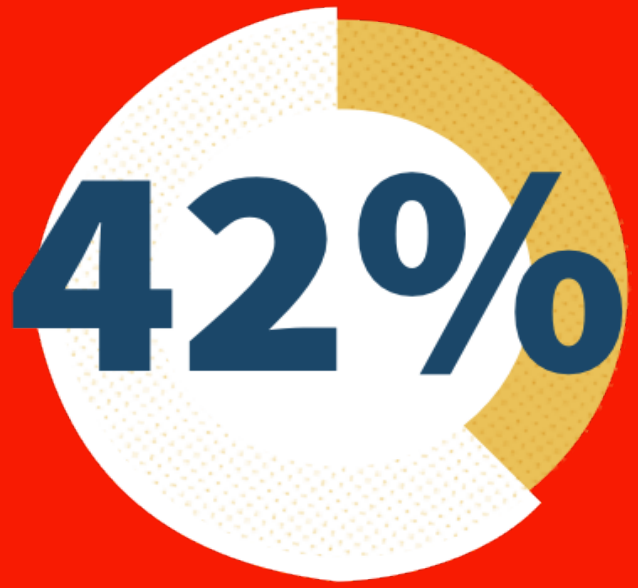
..and that is why the majority of us use real-ear verification

1995

For example, in 1995 Hearing Journal reported“routine” use of these measures was reported by 54% of audiologists (n=134).



In 1999 Hearing Journal showed 42% reported routine use.



2003 HJ showed an overall use rate of 37% (n=558 audiologists, 49 HISs).

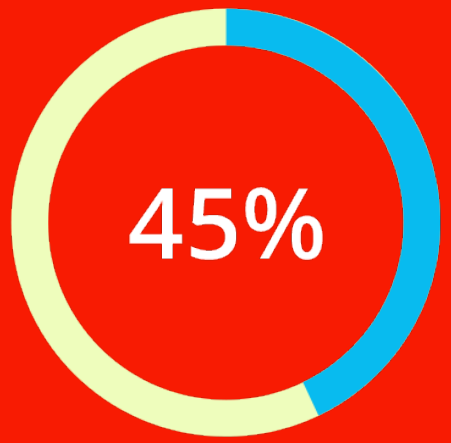
2005

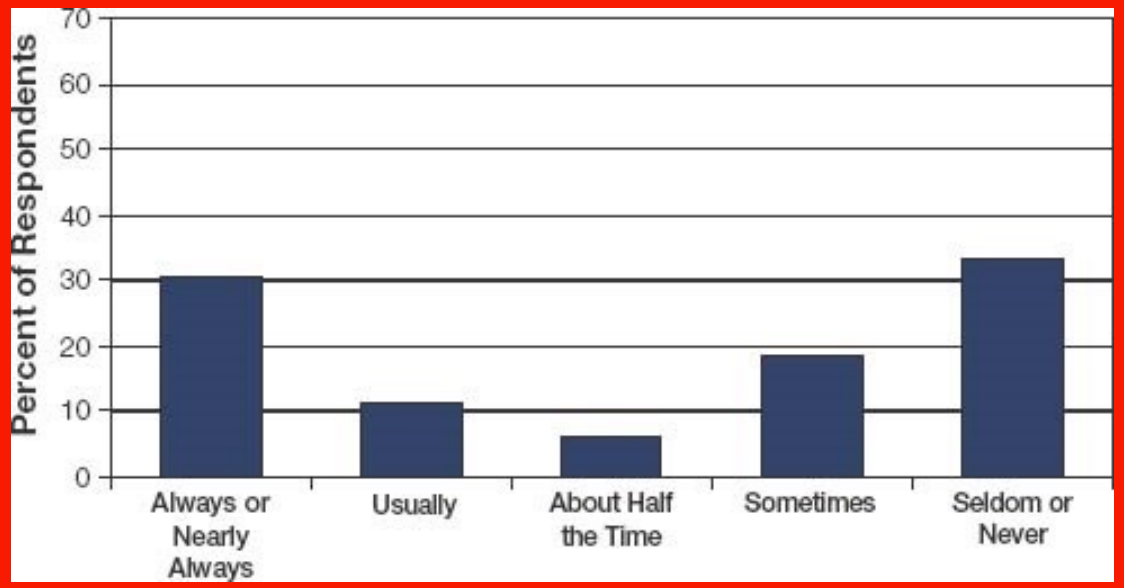
In a 2005 survey, HJ surveyed only audiologists and found an overall use rate of 34%. It was slightly higher (~40%) for recent graduates

2010 Mueller and Picou used a similar survey of real-ear practices with a twist…

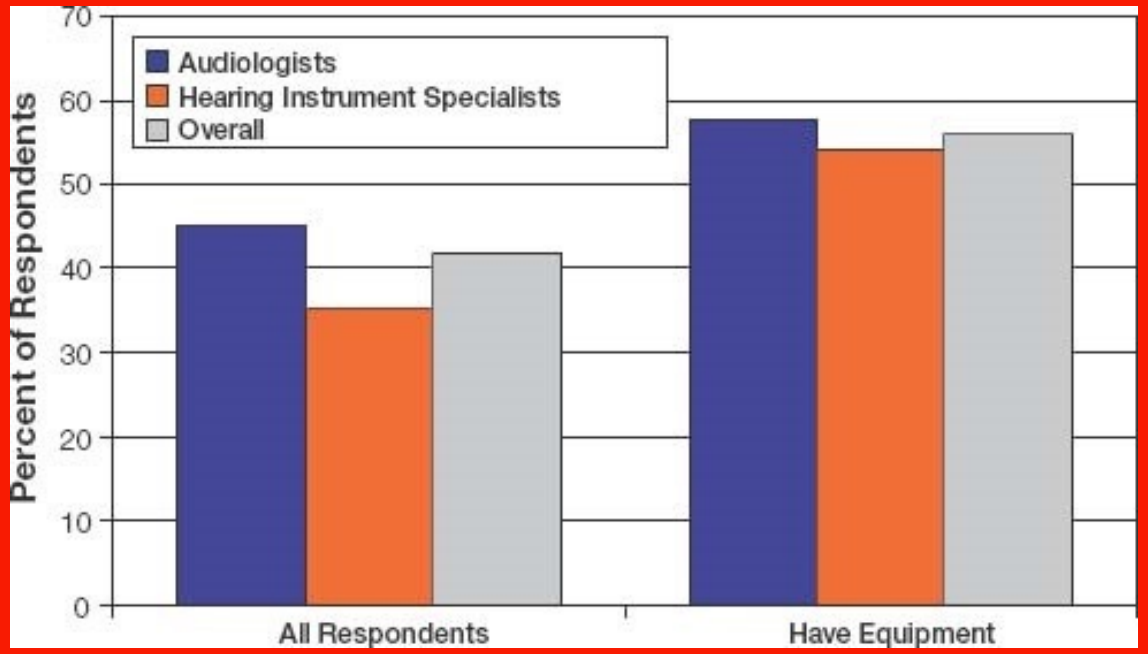
Mueller HG, Picou EM. (2010) Survey Examines Popularity of Real-Ear Probe-Microphone Measures. *Hearing Journal* 63(5):27-32.

Their initial findings were somewhat encouraging for all respondents…





Even more so when limiting the question only to those who possessed real-ear system



58%

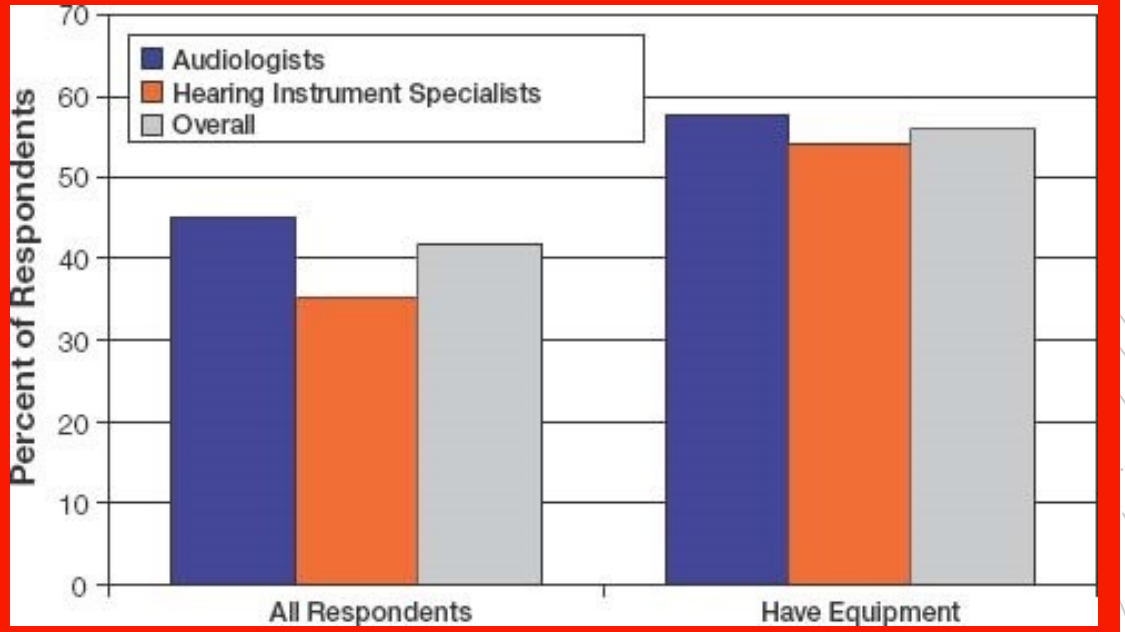
..but this survey was different from those that came before in that the authors asked which real-ear tests were used…

REUR REAR REIR RESR

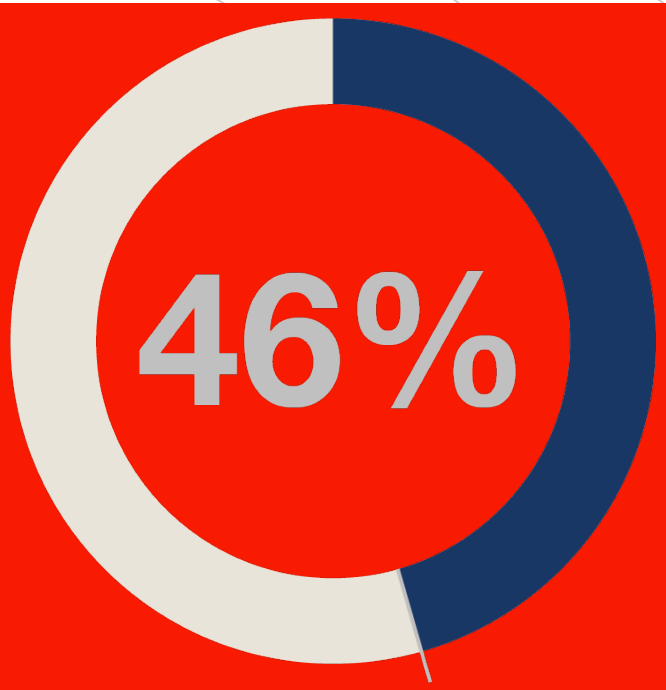
…and

The Binaural Summation Index

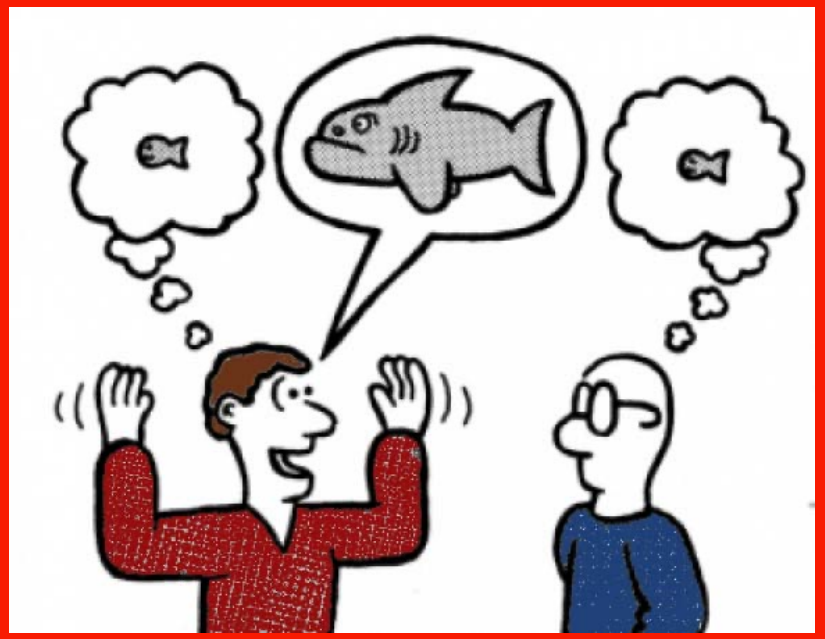
Of the respondents who reported conducting probe-mic testing routinely, 21% of the audiologists and 28% of the HISs said they did this test at least sometimes



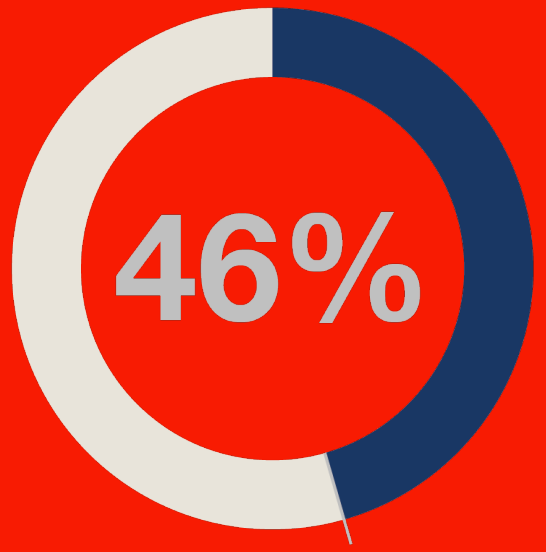
So maybe the real percentage of self-reporting audiologists was 46%

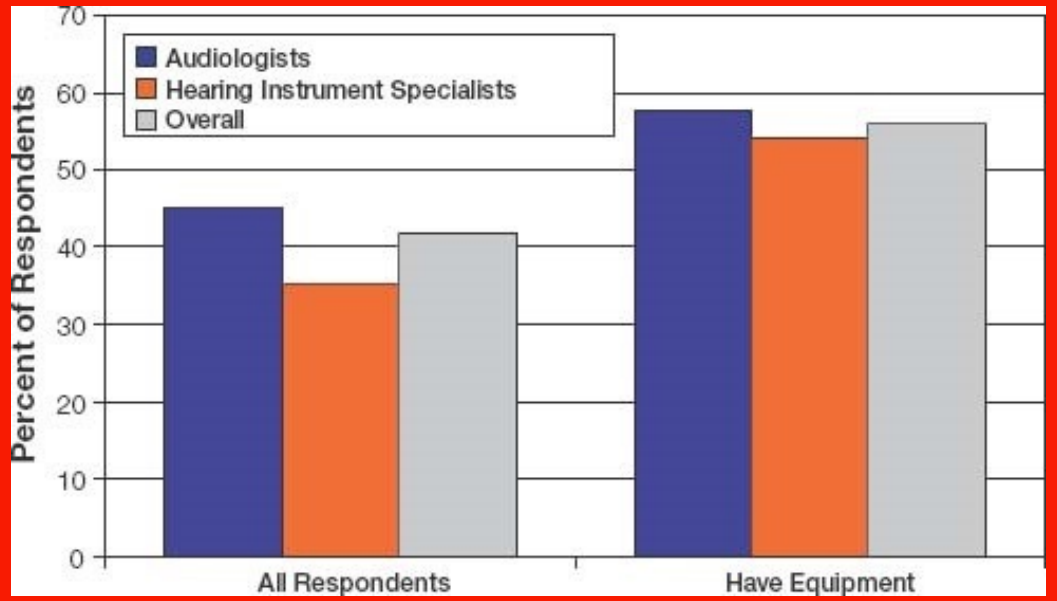


..and maybe self report is not the best way to determine who is using real-ear



..but that was 2010 mainly with adults, what about children?

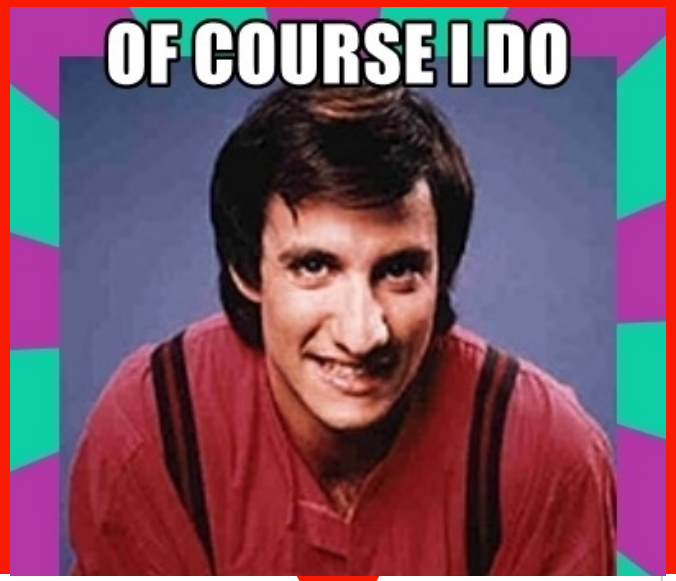




A multi-state study on children approached this real-ear question by looking at the REAR, not audiologist self report

Co

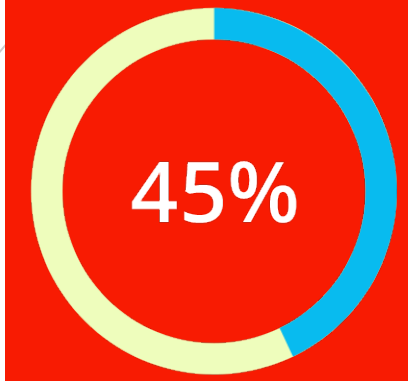
From Mueller & Picou we learned that self-report numbers may be inflated



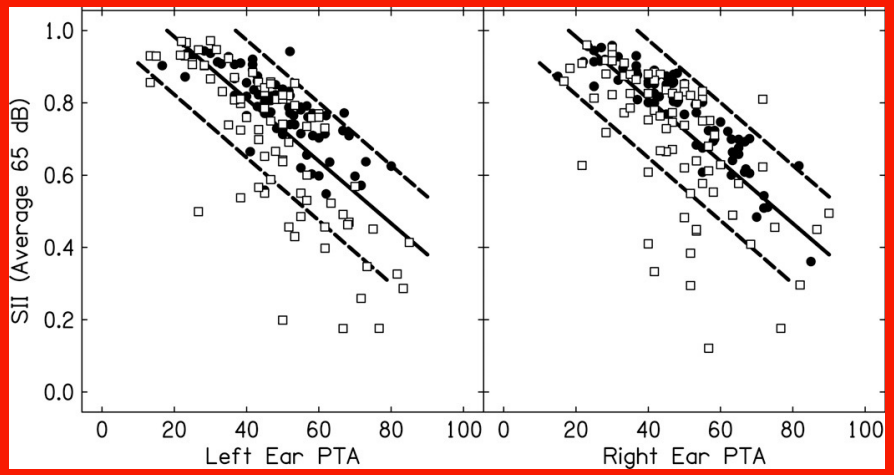
..and looking at the hearing aid as worn is more representative

..and that's what these authors did

Hearing aid fitting data of 195 children in 15 states showing 55% of these hearing aid fittings were significantly off target

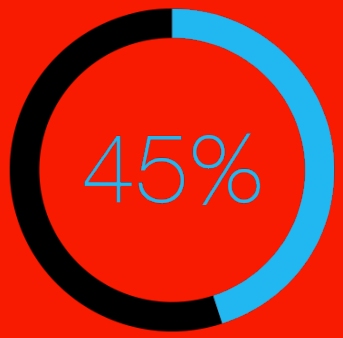


55% > 5dB RMS error

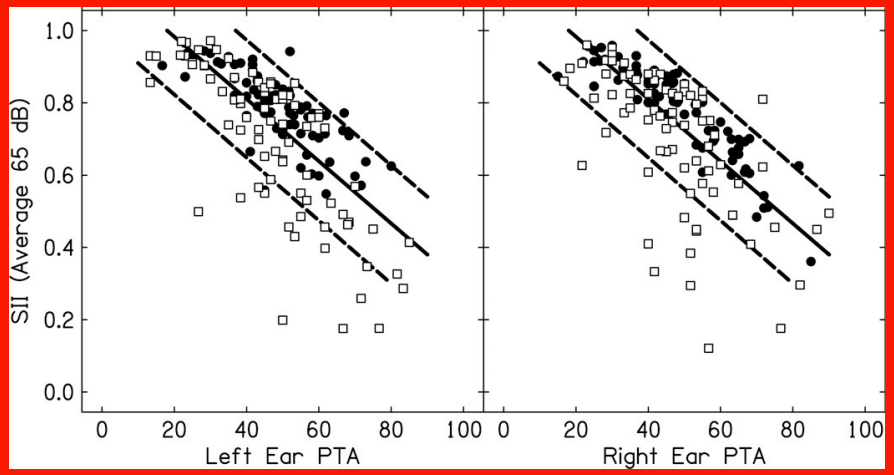


McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

Similar to the data from Mueller and Picou these authors report proper fit to target in 45% of children ± 5 dB RMS

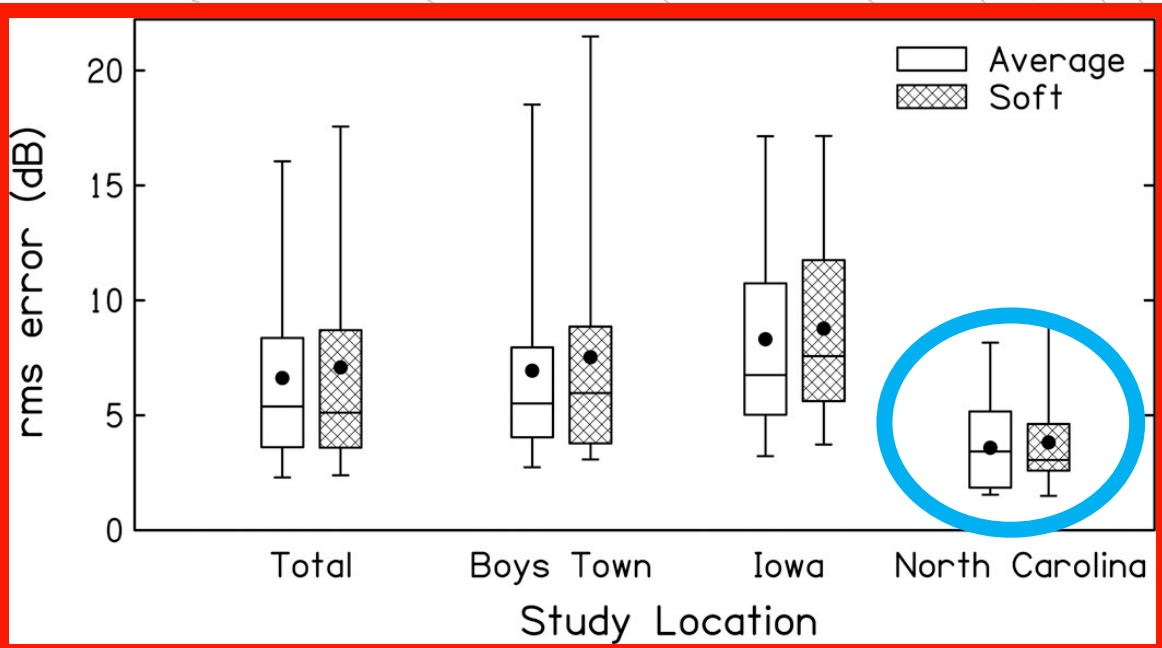


55% > 5dB RMS error



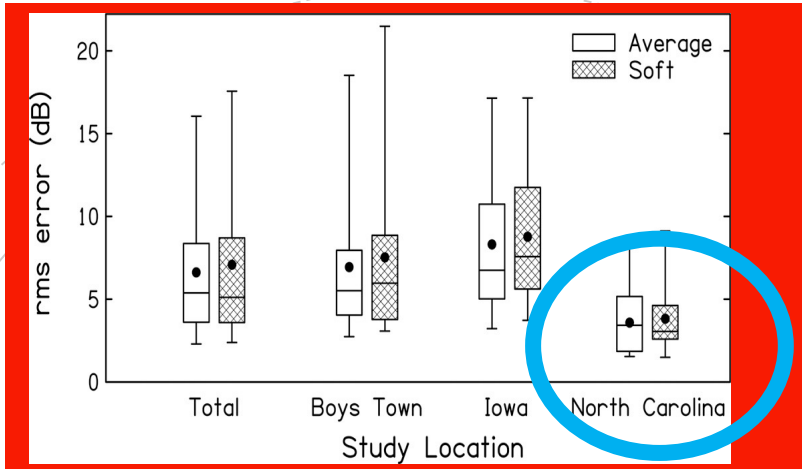
McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

..but they noted their data was skewed in a favorable direction by North Carolina data where most children were fit near target at UNC



McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

How skewed was it?



(UI; n = 68); (UNC; n=43); (BTNRH; n= 84).= 195 total

Subtract UNC 43 = 152

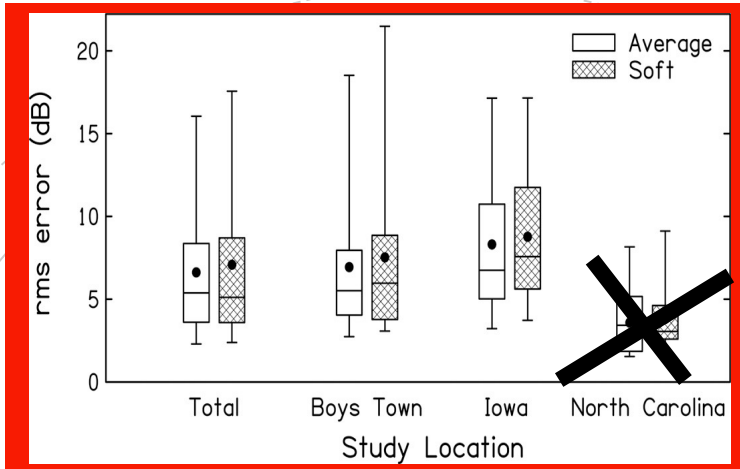
So almost 152/195 missed target
And

152/195 = x/100 almost 78 % missed target

Or about 22% got it right

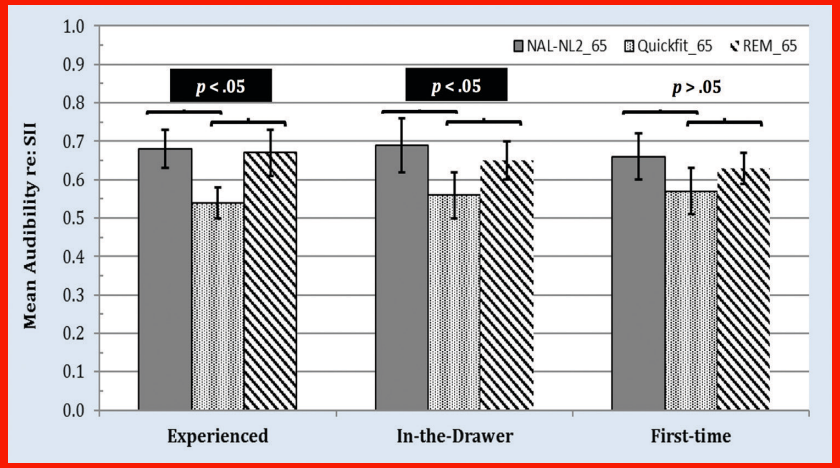
McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

To reiterate, looking at common fitting practice outside the UNC training program showed only about 22% were achieving real-ear targets..

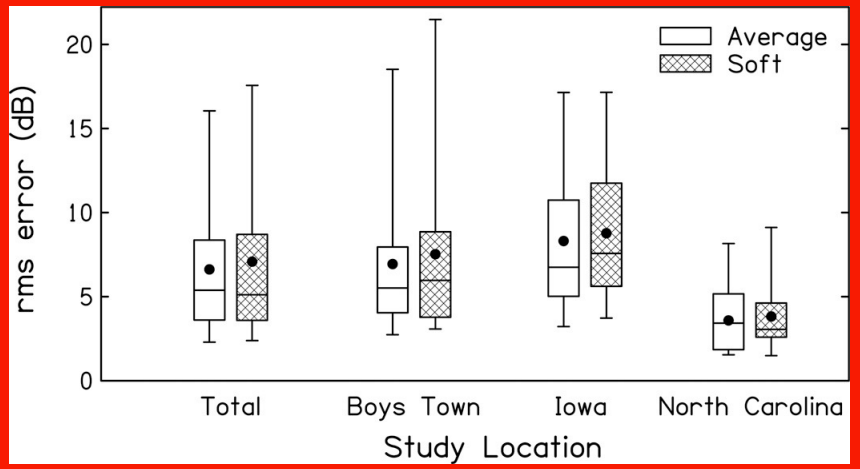


McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

In short, the majority of children and adults are wearing hearing aids that do not conform to well-researched mathematical targets.



.Amlani AM, Pumford J, Gessling E. Real-ear measurement and its impact on aided audibility and patient loyalty. *Hearing Review*. 2017;24(10):12-21.



McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

We thought it possible the number of adults who receive real-ear aided verification of target is even lower than previous estimates…

R

..and we also thought looking at the REAR data would be more meaningful than audiologist self-report of real-ear verification

2017

So we looked at 97 subjects' hearing aid fittings (n = 179 hearing aids) from 24 facilities throughout Oregon.

Ron Leavitt, AuD, owns a practice in Corvallis, Ore, and is the Founder of the Oregon Assn for Better Hearing, a non-profit consumer test group for hearing aid users; **Ruth Bentler, PhD**, is a Professor in the Department of Communication Sciences and Disorders at the University of Iowa, Iowa City; and **Carol Flexer, PhD**, is a Distinguished Professor of Audiology at the University of Akron and coauthor of the book, *Sound Field Amplification: Applications to Speech Perception and Classroom Acoustics.*

97

179

24

Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

Facilities:

Nine of these facilities were staffed exclusively by hearing instruments specialists; the other **15** were in medical centers, otolaryngology clinics, and private audiology practices staffed by Doctors of Audiology.

Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

Expectation:

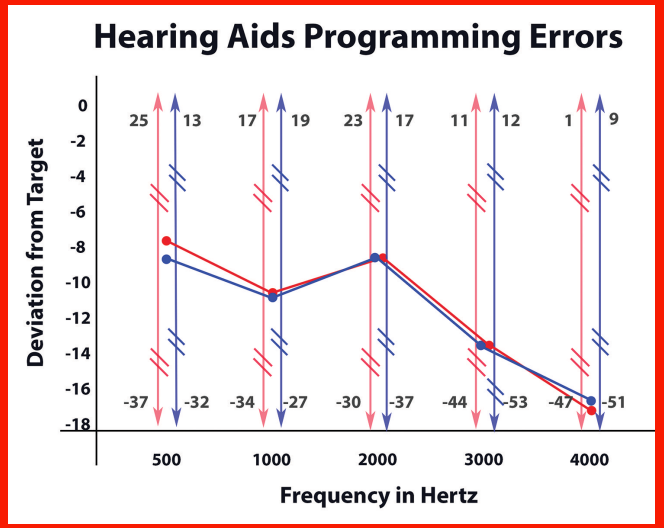
Based on previous data we would expect 45-46% of these hearing aids would approximate a DSL I/O or NAL NL-1/2 target…

.46 x 179 = 82 hearing aids would approximate these two targets..

Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

Results:

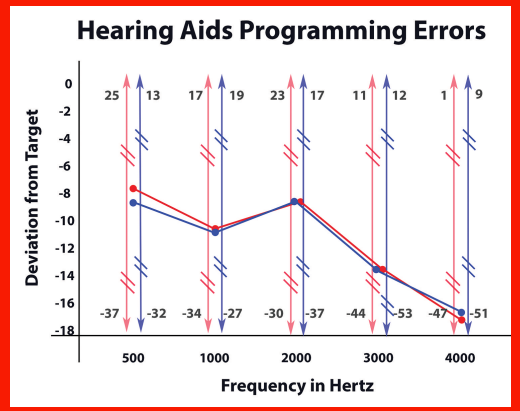
We did not find that. We found significantly larger fitting errors…



Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

Results:

Specifically using the 5 dB RMS criteria suggested by McCreery et al we found 2.3 % of hearing aids met that real-ear target criteria

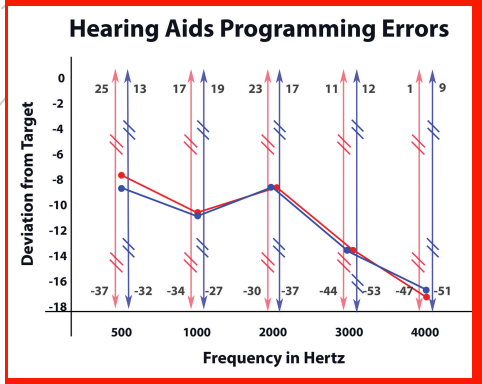


2.3% ≠46%

Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

3. Does missing target really matter?

97.7% > 5dB RMS error



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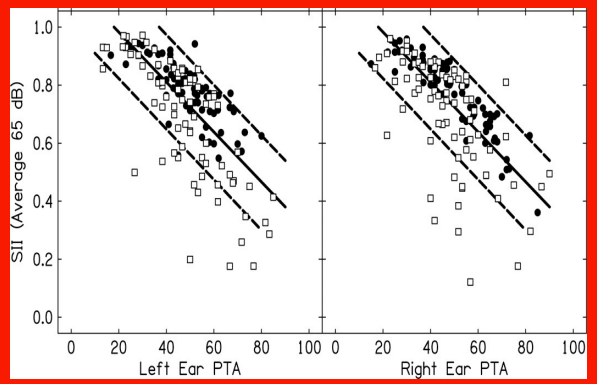
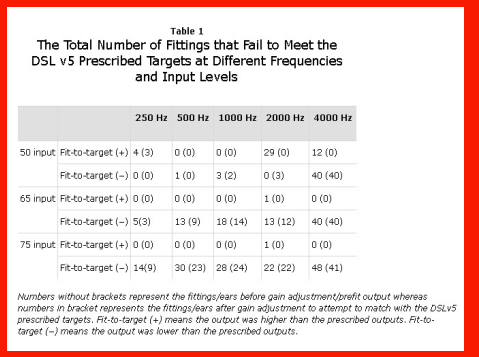
55% > 5dB RMS error



McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

73% > 5dB RMS error



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		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
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	Fit-to-target (−)	0 (0)	1 (0)	3 (2)	0 (3)	40 (40)
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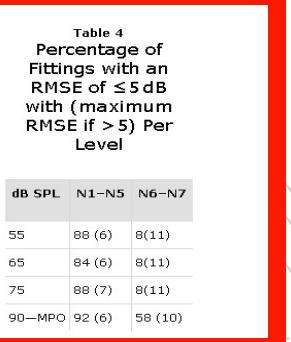
10% > 5dB RMS error



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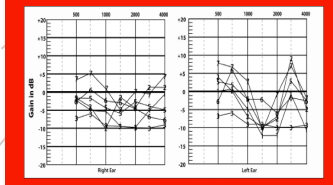
Folkeard P, Bagatto M, Scollie S. Evaluation of Hearing Aid Manufacturers' Software-Derived Fittings to DSL v5.0 Pediatric Targets. J Am Acad Audiol. 2020 May;31(5):354-362.

We already showed it lowers word/sentence recognition in quiet and noise



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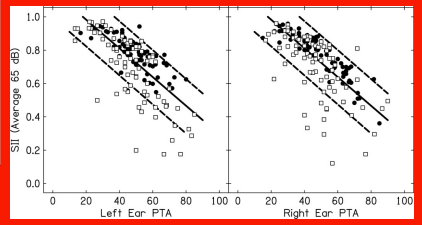

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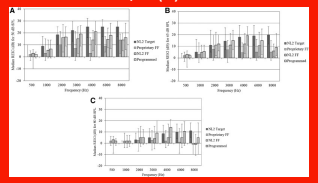

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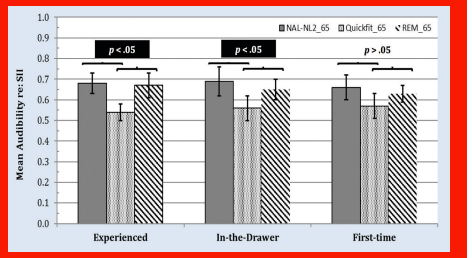

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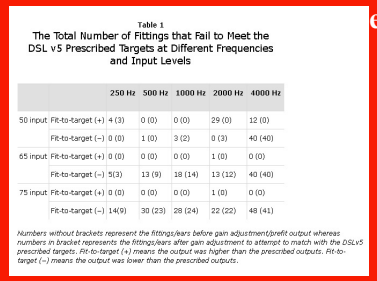

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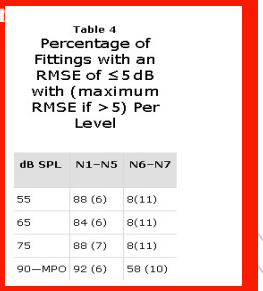

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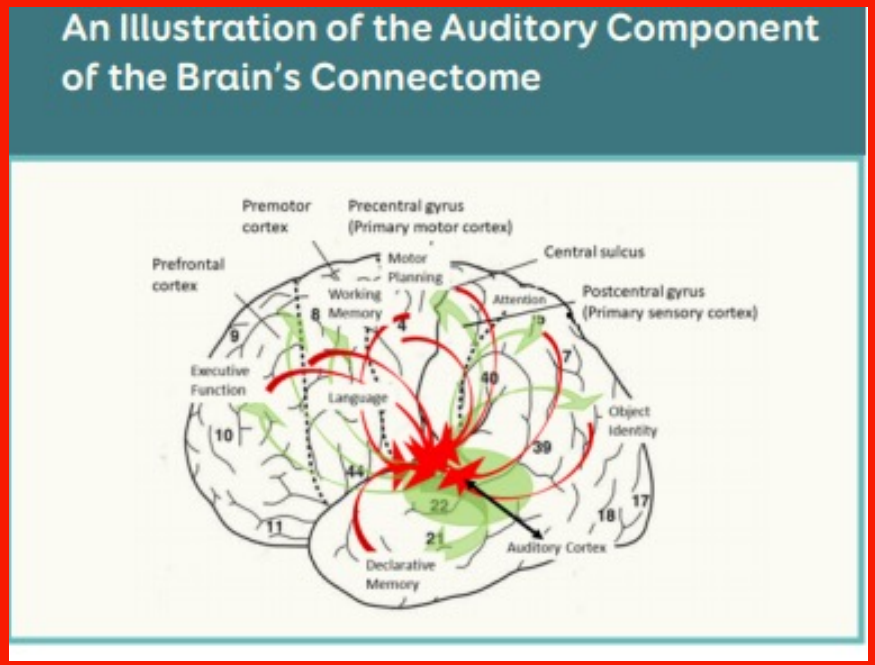
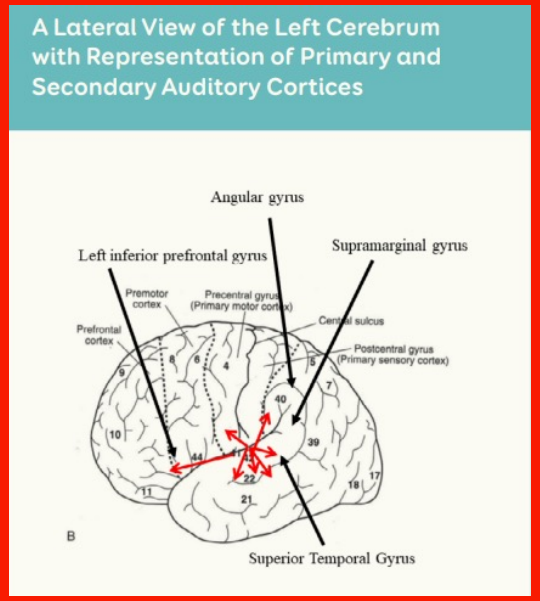
Valente M, Oeding K, Brockmeyer A, Smith S, Kallogjeri D. Differences in Word and Phoneme Recognition in Quiet, Sentence Recognition in Noise, and Subjective Outcomes between Manufacturer First-Fit and Hearing Aids Programmed to NAL-NL2 Using Real-Ear Measures. J Am Acad Audiol. 2018 Sep;29(8):706-721

..and it also matters on an anatomical & physiological basis

It adversely affects multiple regions of the brain when there is poor audibility



Poor speech audibility has an adverse reallocation of brain resources in children (and adults).

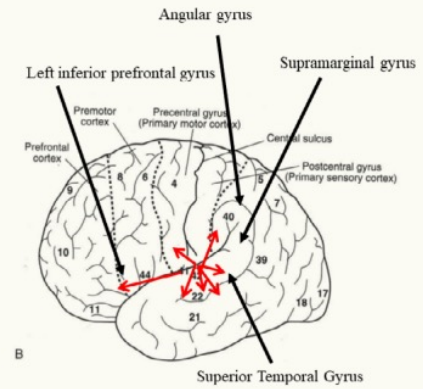


Wolf, J (2020) Entrain the brain accessed at https://f.hubspotusercontent10.net/hubfs/4253267/downloadable-documents/HF_Whitepaper_EntrainBrain_Final.pdf

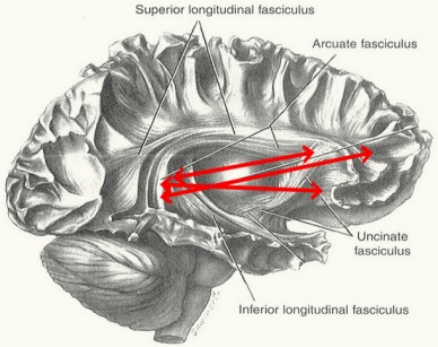
Let’s first look at normal hearing/normal brain function

Normally, both superficial and deeper brain areas are involved in listening

A Lateral View of the Left Cerebrum with Representation of Primary and Secondary Auditory Cortices



A Midline Sagittal View of the Brain with Depiction of Intrahemispheric Tracts, Including the Arcuate Fasiculus



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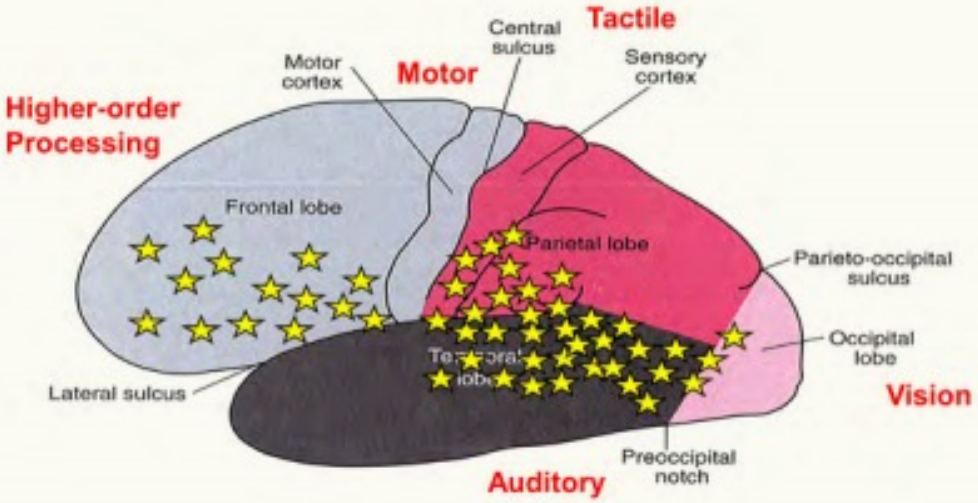
For exam ory about egg

An Oversimplified Visual Representation of Neurons Responding to a Lesson on Frying the Perfect Egg as an Egg Sizzles in a Frying Pan



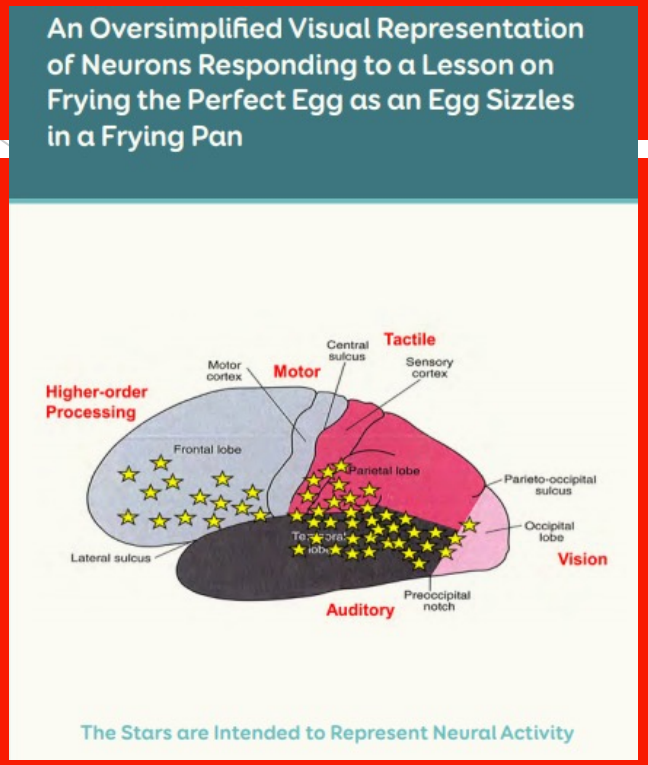
The Stars are Intended to Represent Neural Activity

Wolf, J (2020) Ent epaper_EntrainBrain_Final.pdf

The engagement of higher-order areas of the brain may cause the listener's stomach to grumble ;

Frontal lobe activity may also cause the listener to lament the high cholesterol and question whether she/he should eat just one egg or maybe exercise on the treadmill

The listener's mouth may water from the idea of how the eggs may feel in her/his mouth



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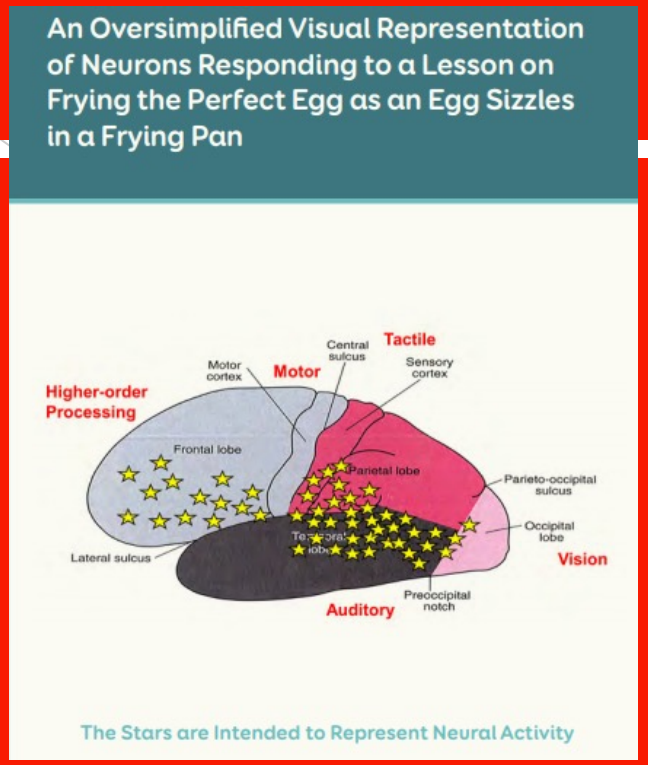
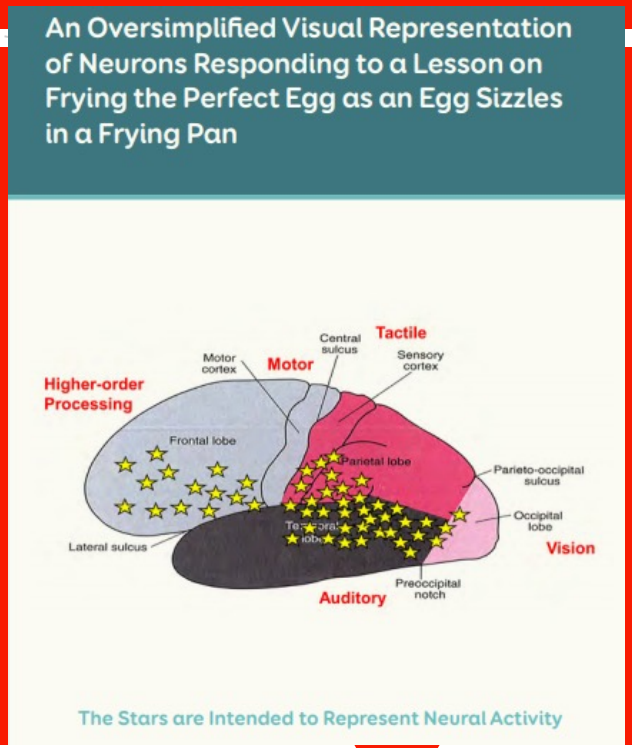
In summary, under optimum conditions, multiple lobes of the brain react in specific ways to the information provided by the primary and secondary auditory areas of the brain.



..but what happens in the brain when there is insufficient audibility?

~~CO~~ R



Let's compare two groups of Cochlear implant users: one with normal hearing until adulthood, the other without…

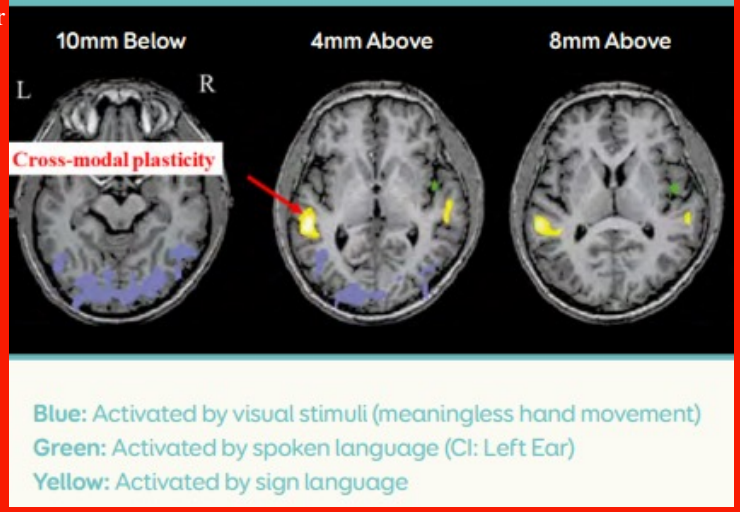
A PET Scan Image of Brain Activity Superimposed on an MRI Image of the Brain of an Individual Who Is Listening to Speech with a Cochlear Implant for the Left Ear

Appropriate audibility provided by cochlear implant to adults with normal hearing until adulthood

Green et al 2005, Hear Res. Auditory cortical activation and speech perception in cochlear implant users:.

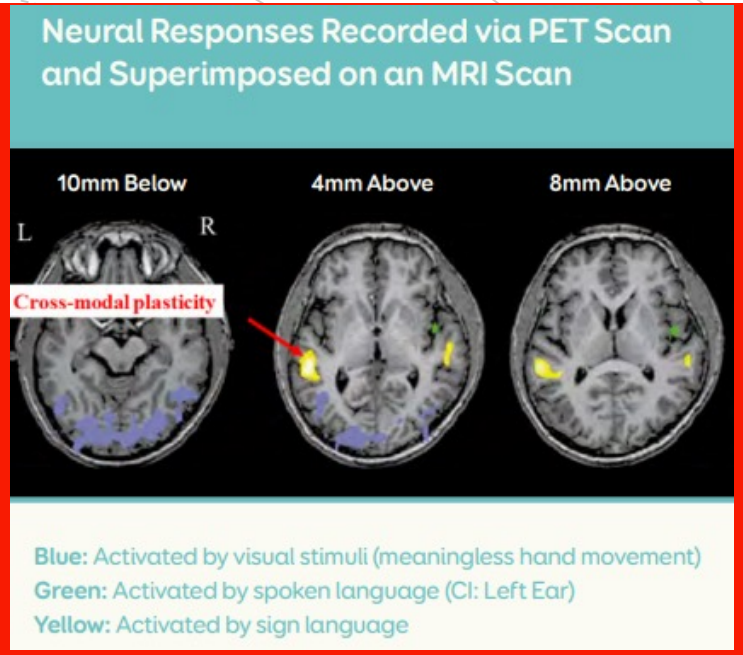
Nishimura et al (1999). Sign language "heard" in the auditory cortex. Nature, 397: 116.

Neural Responses Recorded via PET Scan and Superimposed on an MRI Scan

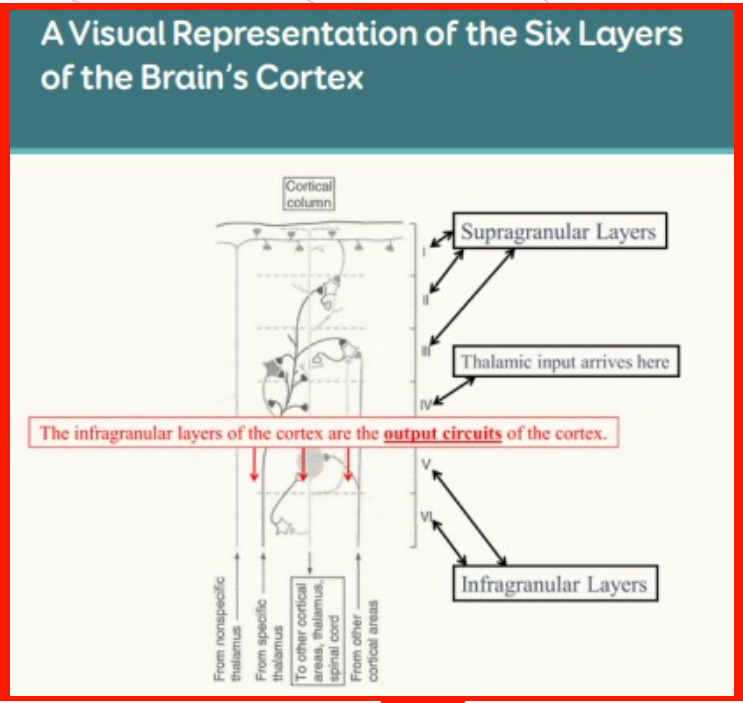


Audibility provided by cochlear implant to a patients deprived of sound until adulthood

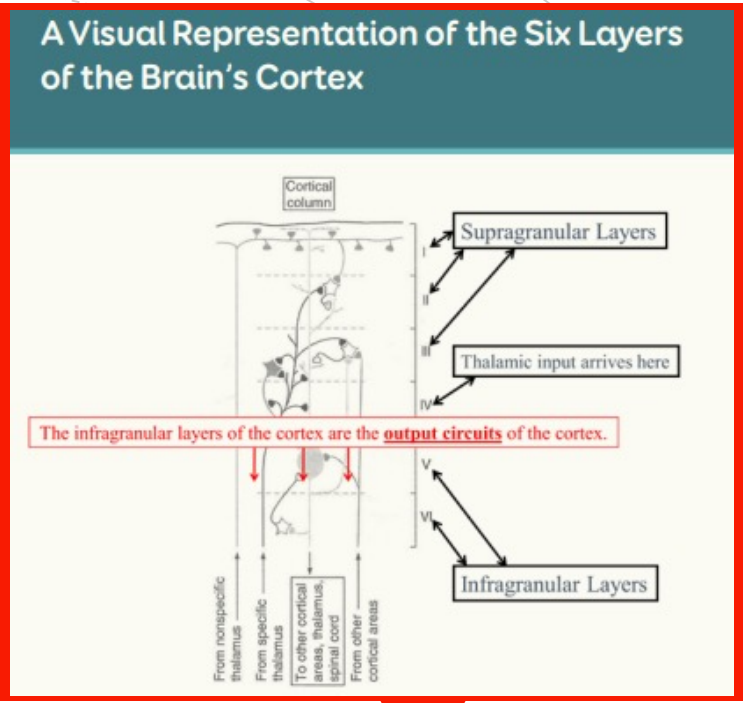
So that describes peripheral brain changes when audibility is not achieved



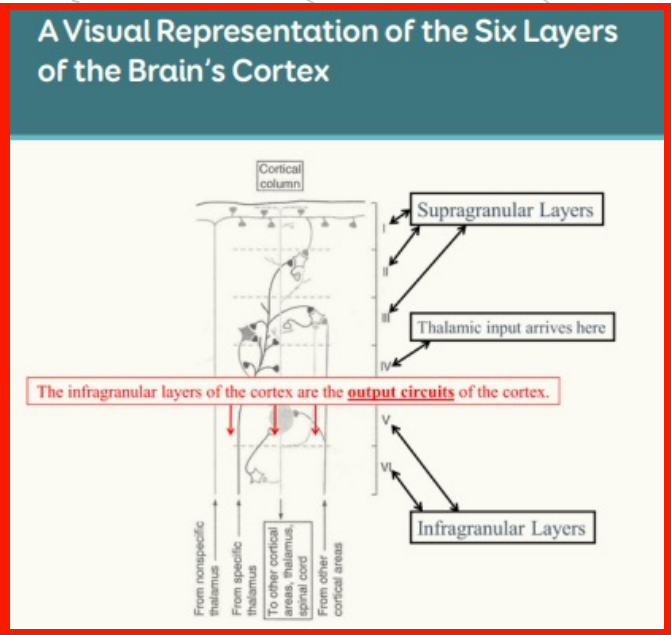
What about the deeper layers of the brain?



Much less is known about these deeper layers (1-6), however..



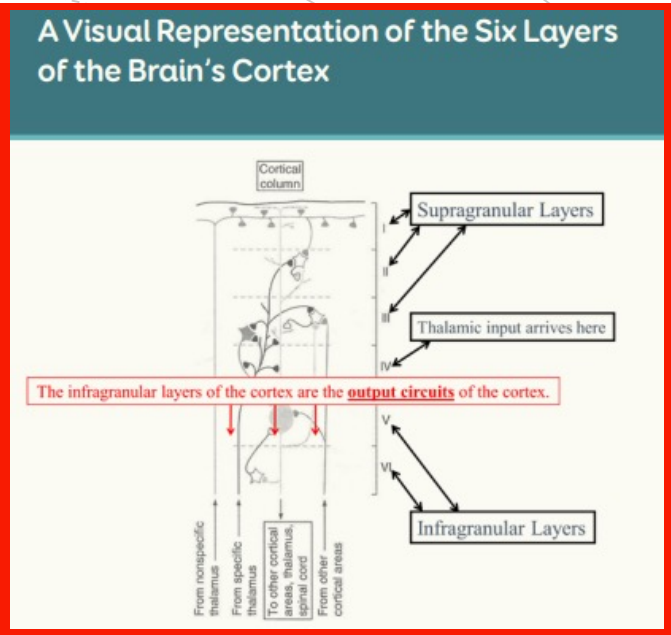
..from animal studies, post-mortem and imaging studies it is believed..



Basic auditory information from the cochlea arrives at layers 4-6 (the input circuit of the cortex)

Adesnik, H., Naka, A. (2018). Cracking the function of layers in the sensory cortex. Neuron, 100(5): 1028-1043.

Layers 1-3 are generally considered to be involved with processing input from layers 4-6



Brecht M. The Body Model Theory of Somatosensory Cortex. Neuron. 2017 Jun 7;94(5):985-992.
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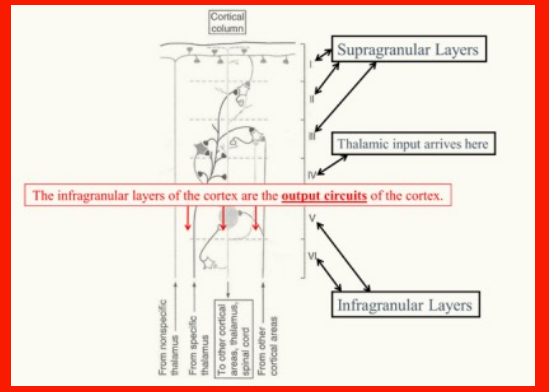
Further,…

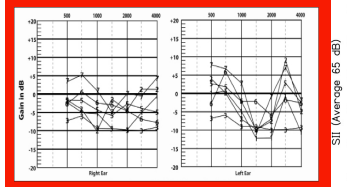
Higher order areas of the brain (e.g., secondary auditory cortex, frontal lobe, parietal lobe) deliver signals to these deeper levels to "tune" the auditory response toward signals of interest and inhibit irrelevant signals (Adesnik & Naka, 2018; Kral, Yusuf, & Land, 2017).

~~Co~~



..but all of these deep-brain functions assume optimum audibility..

…and to reiterate, we do not achieve optimum audibility for our pediatric and adult patients..



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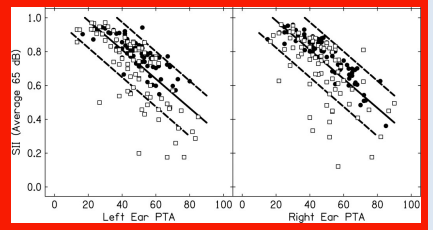

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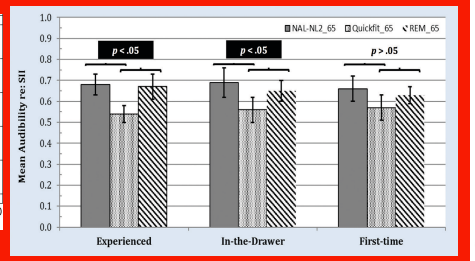

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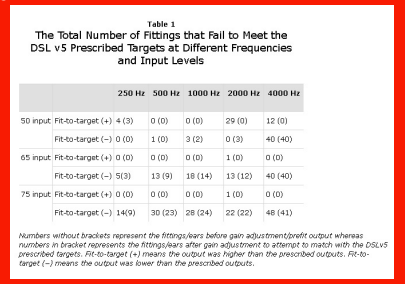

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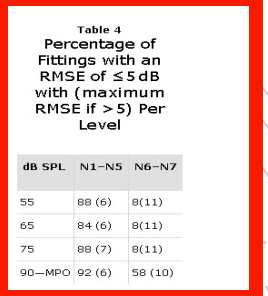

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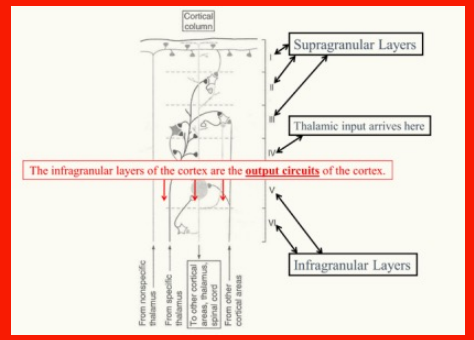
So what happens at these deeper layers without appropriate audibility?

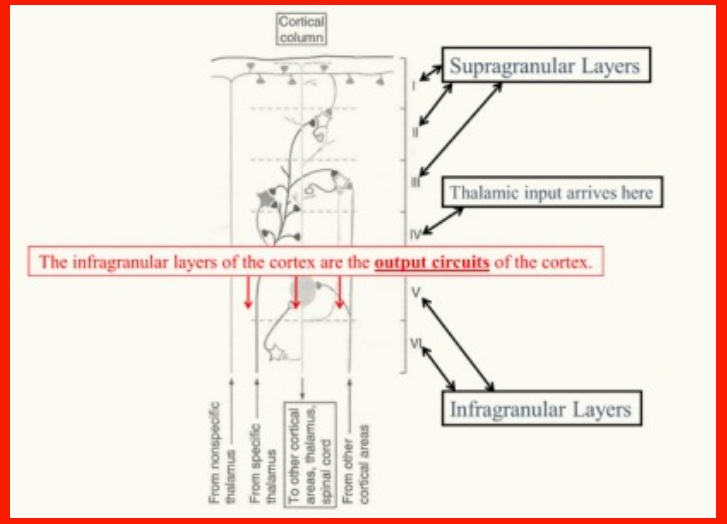
The deep layers show dystrophic changes in primary and secondary auditory areas of deaf cats, likely due to weaker activity in the deeper layers in deafness.

R



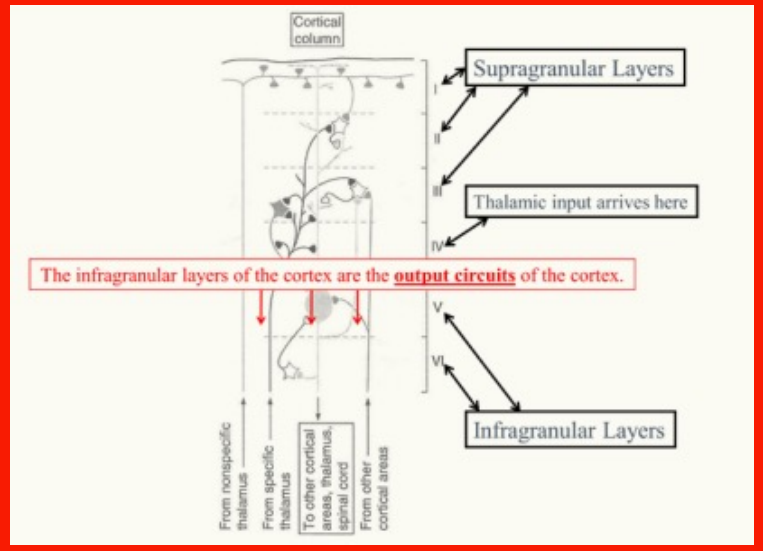
Berger, C., Kühne, D., Scheper, V., Kral, A. (2017). Congenital deafness affects deep layers in primary and secondary auditory cortex. Journal Comparative Neurology, 525(14): 3110-3125.

Kral reports the lack of activity in the deeper layers results in functional decoupling of primary and secondary auditory cortex.



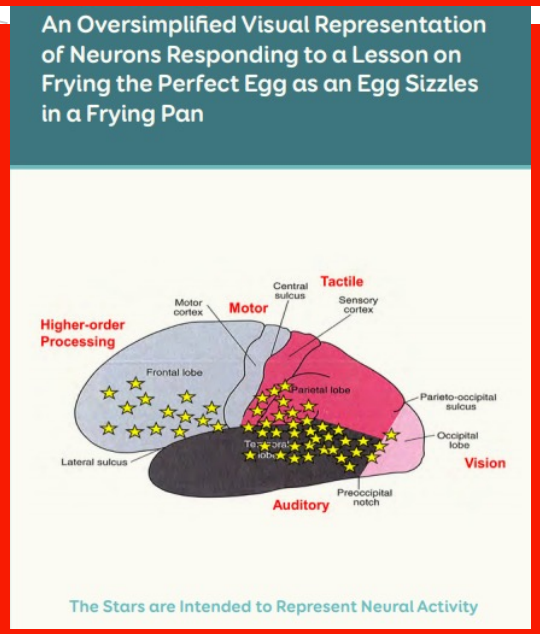
Kral A et al, (2000, 2002, 2006, 2007, 2011, 2013

When primary and secondary auditory cortices are functionally decoupled, auditory input is not optimally delivered from primary auditory cortex to secondary auditory cortex…



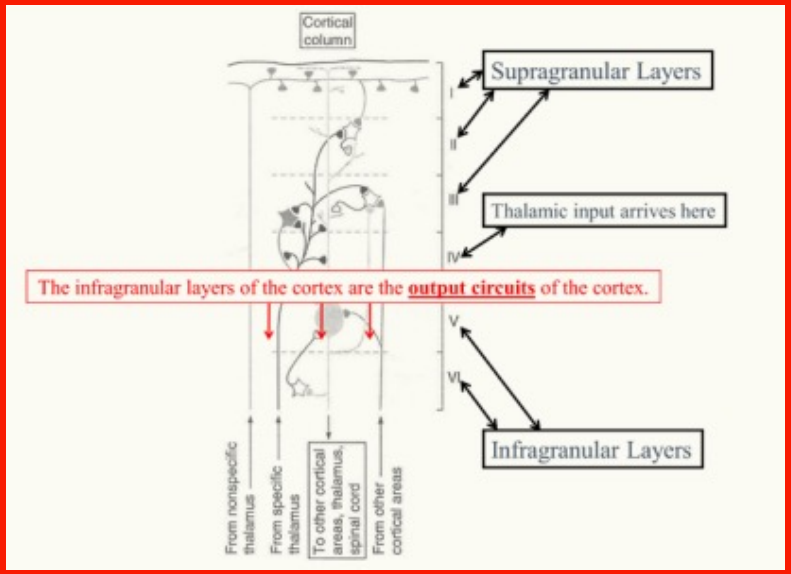
Kral A et al, (2000, 2002, 2006, 2007, 2011, 2013

… where it can be distributed to the rest of the brain so that the sound can "come to life" and possess higher-order meaning.



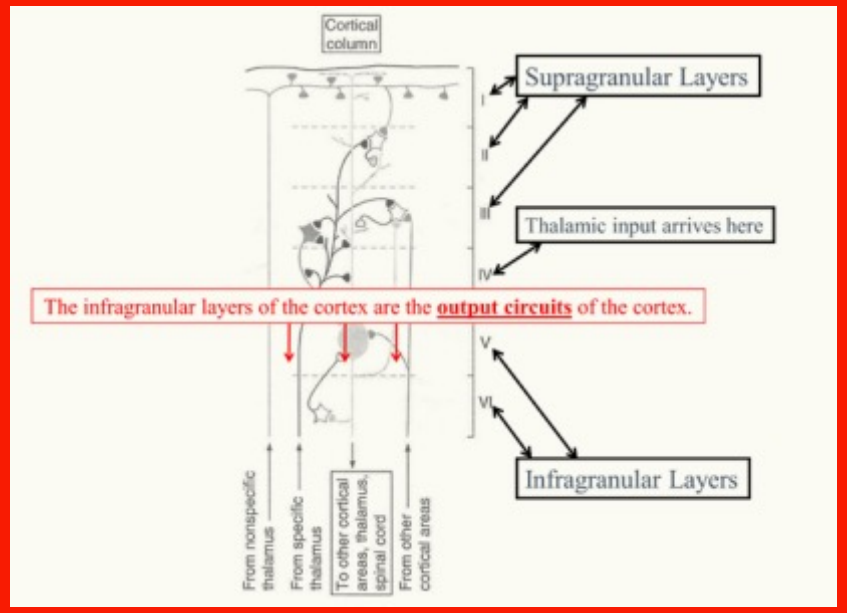
Kral A et al, (2000, 2002, 2006, 2007, 2011, 2013

This dismantling of the brain layers leads to potential deficits in a number of higher-order cognitive and behavioral functions



Kral A et al, (2000, 2002, 2006, 2007, 2011, 2013

E…including phonological awareness, literacy delays, sensory integration disorders, working memory deficits, executive function delays, and ability to predict the behavior of others.



Kral A et al, (2000, 2002, 2006, 2007, 2011, 2013

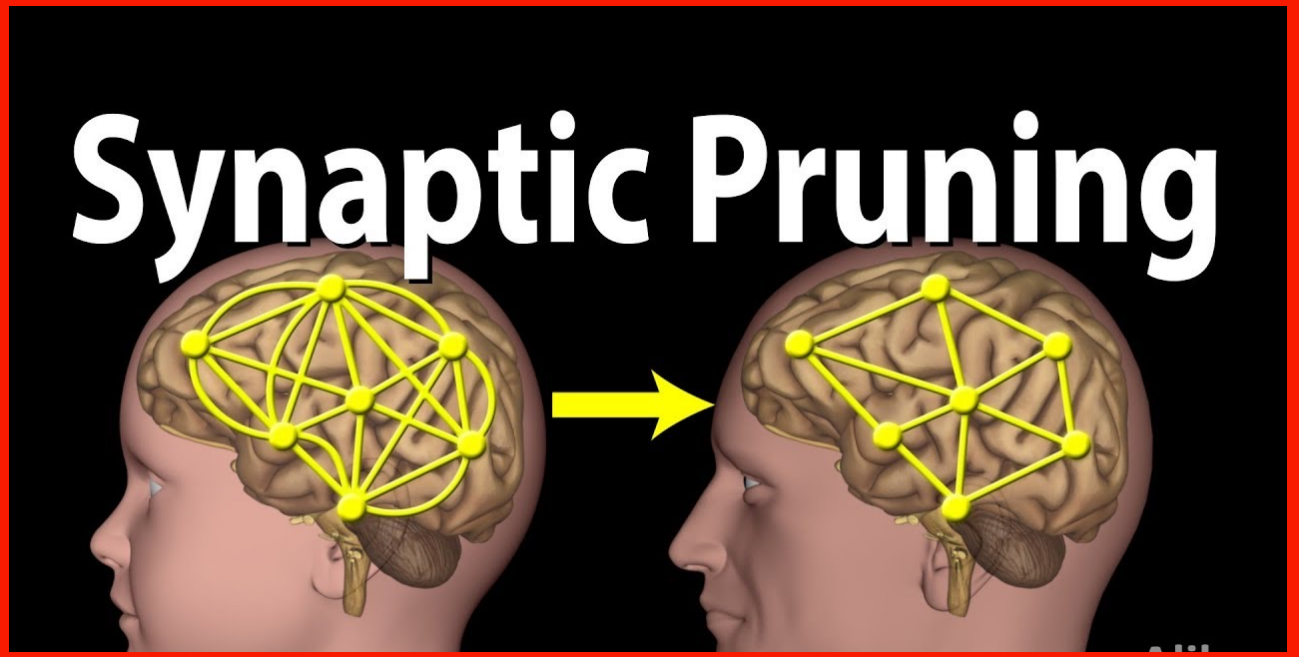
Further, unfavorable brain rewiring takes place

Co

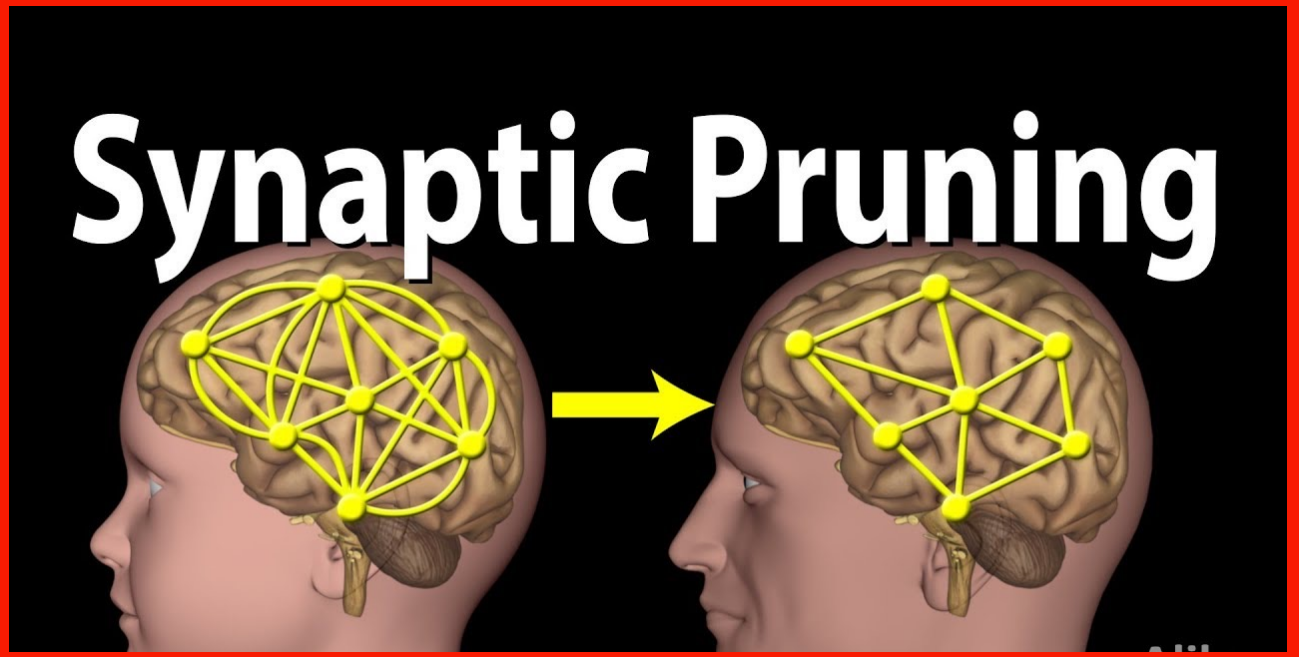
Normally, neuronal connections (i.e., synapses) that are used more frequently strengthen and become more established.

Aka
Synaptogenesis

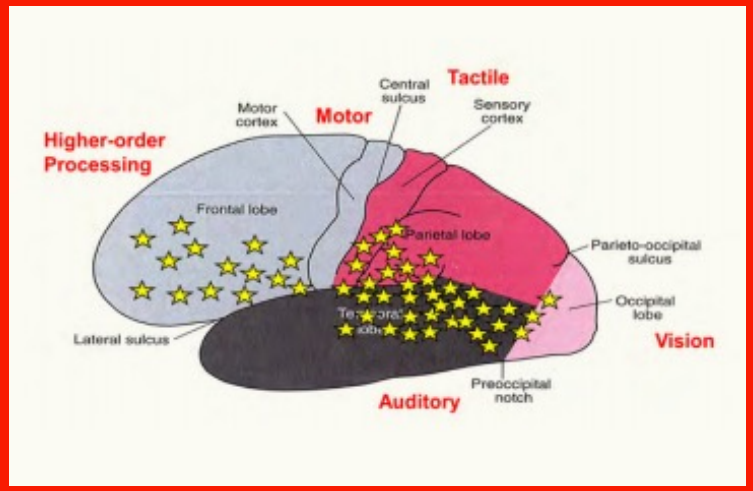
In contrast, neuronal connections that are used less are eliminated through a process known as synaptic pruning.



This synaptic pruning can occur throughout life but is most prevalent during the first few years of life.

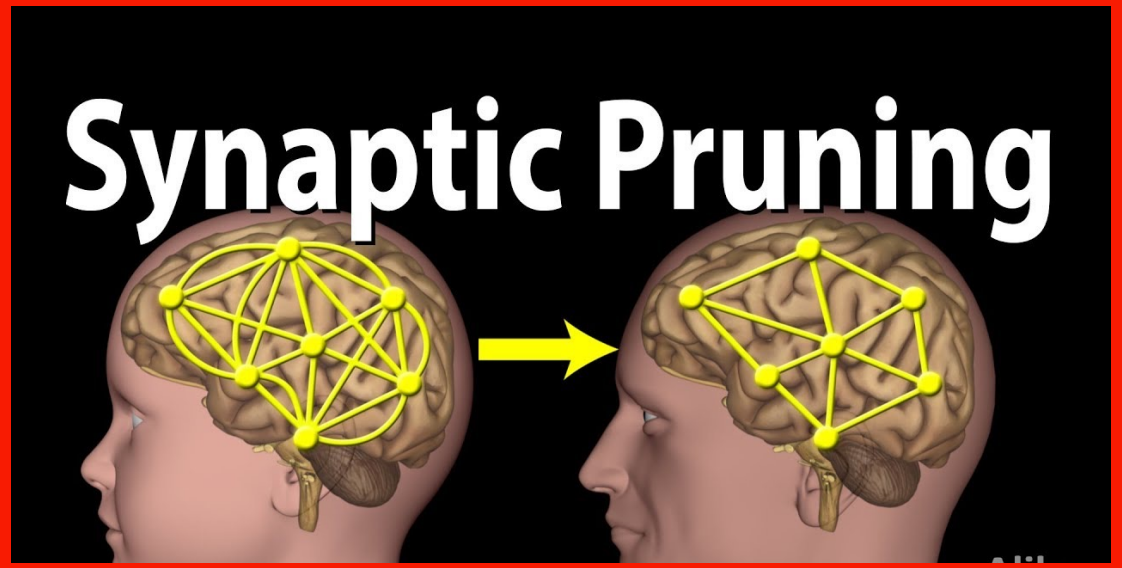


..because the newborn brain must respond to an infinite spectrum of stimuli and must shape itself so that it responds optimally to the most important stimuli while also attenuating responses to irrelevant stimuli.

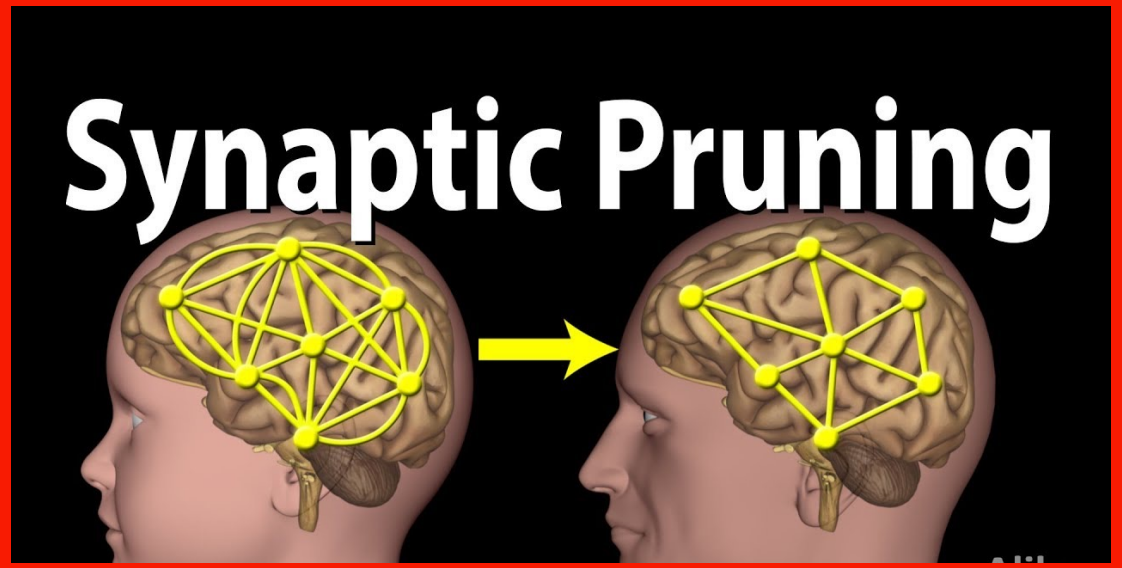


To allow sophisticated listening skills to develop, synaptic pathway building must facilitate the formation of neural networks that process the sounds that are most important to an individual's well-being, development, success, and survival…

…and must eliminate neural circuits that would contribute unimportant noise that may prevent the listener from identifying the stimuli that promote his/her best welfare.

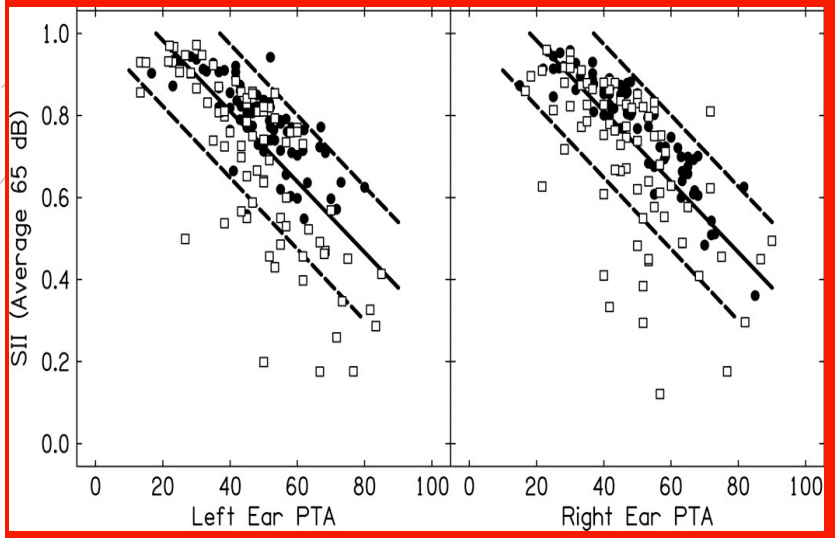


…and this synaptic pruning takes place in both children and older adults with untreated and poorly treated hearing loss.



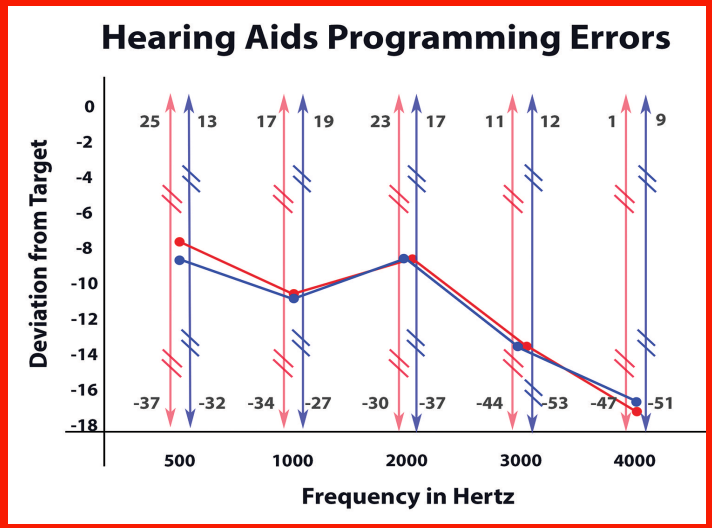
..so both children and adults must have appropriate audibility of sounds, which we don't usually achieve…

55% > 5dB RMS error in children



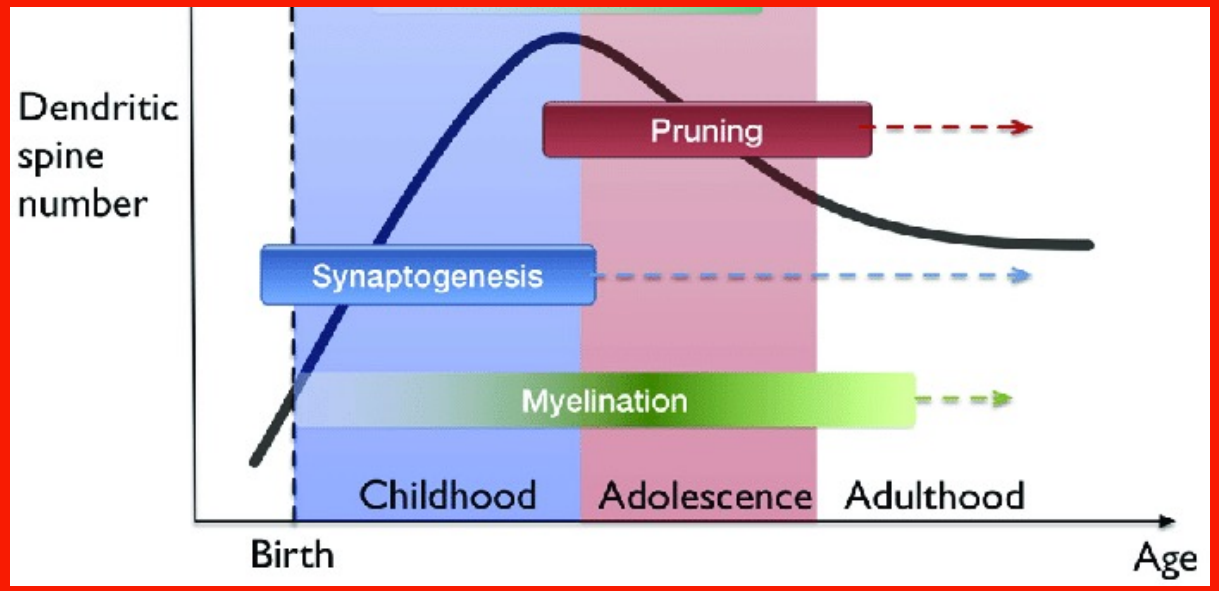
McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

97.3% > 5 dB RMS error in adults

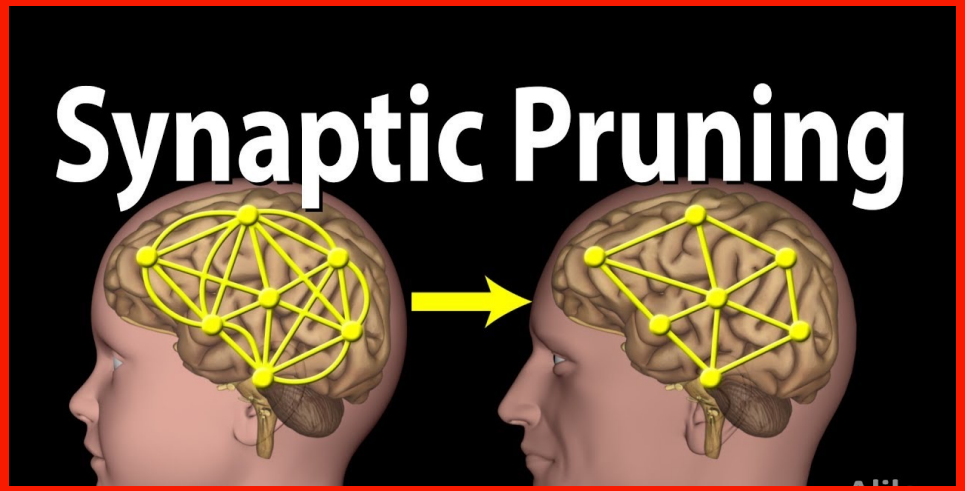


Leavitt R, Bentler R, Flexer C. Hearing aid programming practices in Oregon: fitting errors and real ear measurements. *Hearing Review*. 2017;24(6):30-33.

Untreated (and poorly treated) congenital hearing loss adversely affects brain development by significantly delaying building of synaptic pathways beyond the period in which synapses most efficiently form.



Also, congenital hearing loss leads to increased pruning, which disrupts the formation of important neural networks (Kral et al. 2005; Kral & Sharma, 2012).



Kral A, Tillein J, Heid S, Hartmann R, & Klinke R, 2005: Postnatal cortical development in congenital auditory deprivation. Cereb Cortex, 15: 552-562.

Kral, A., Sharma, A. (2012). Developmental neuroplasticity after cochlear implantation. Trends in Neurosciences, 35(2): 111-122.

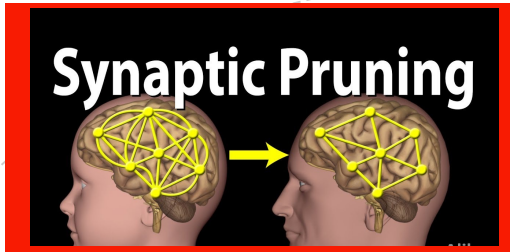
…thereby reducing synaptic counts, which leads to reduced computational power of the auditory areas. (Kral 2013)

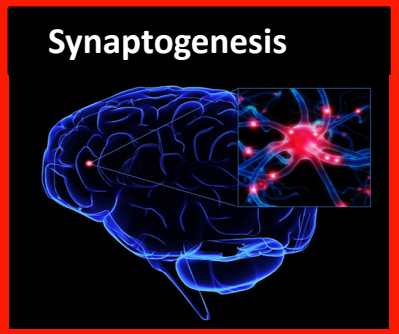
These neural networks support higher-order functions and create connections that facilitate optimal sensory processing as well as cognitive and behavioral function.

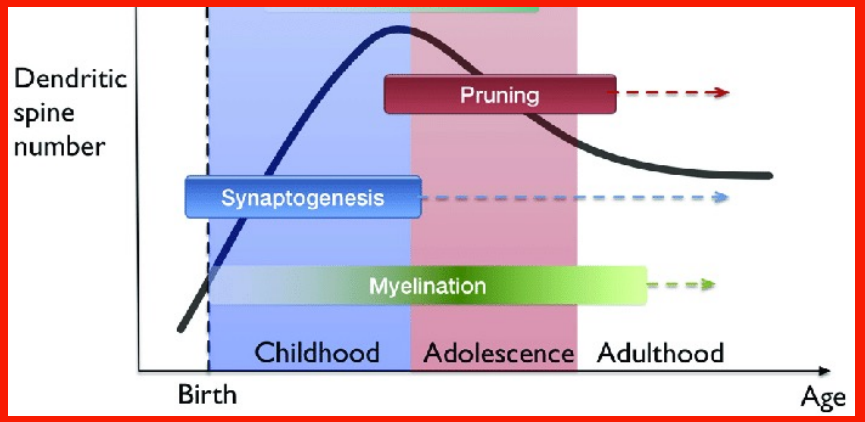
A critical question
Does form predict function

R

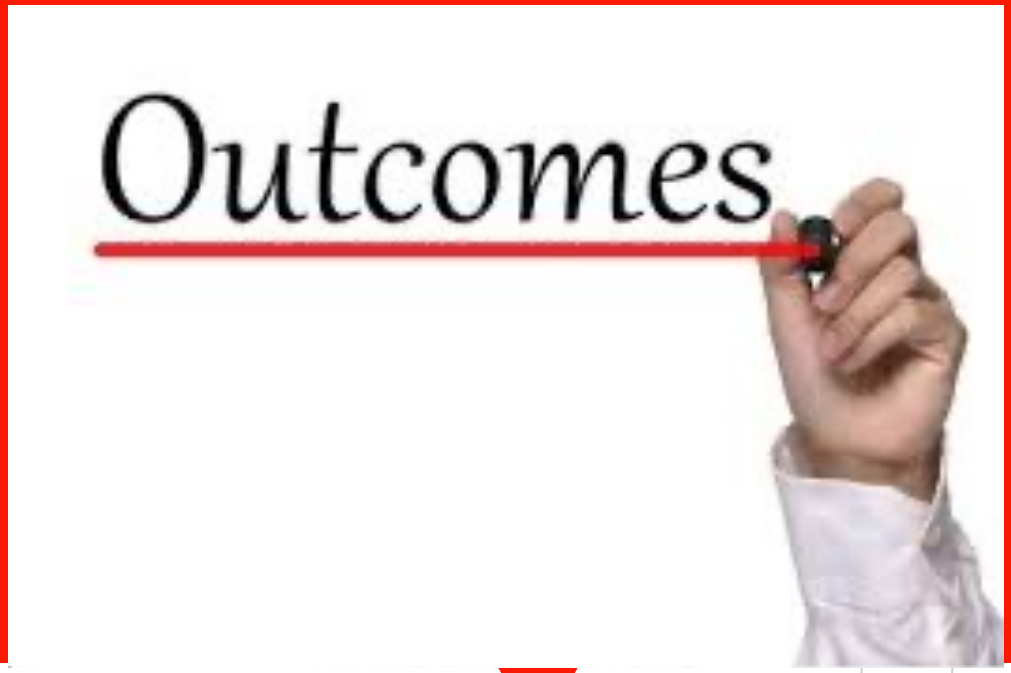
Do these images predict behavioral outcomes?







The answer is yes these images do predict behavioral outcomes



McCreery and colleagues addressed outcomes in their multi-state study

Children with hearing loss

States

McCreery RW, Bentler RA, Roush PA. Characteristics of hearing aid fittings in infants and young children. Ear Hear. 2013 Nov-Dec;34(6):701-10

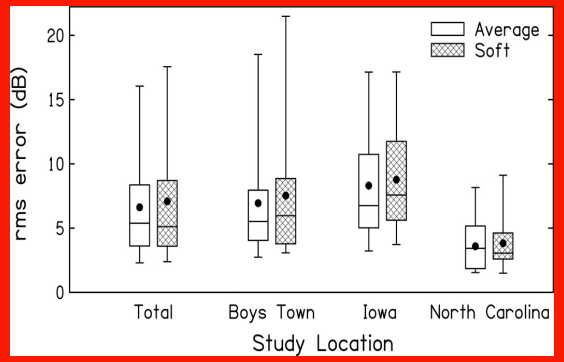
Their data supports fitting hearing aids for children who have a BEUSII value of .80 or lower to minimize the likelihood of communication differences from those with normal hearing.

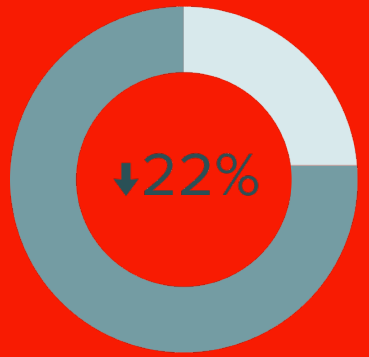
McCreery RW, Walker EA, Stiles DJ, Spratford M, Oleson JJ, Lewis DE. Audibility-Based Hearing Aid Fitting Criteria for Children With Mild Bilateral Hearing Loss. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):55-67of deafness. Hearing Research, 205: 184-192.

They also showed children with MBHL are at risk for persistent language deficits by 4th grade, particularly in aspects of language that involve form.

Walker EA, Sapp C, Dallapiazza M, Spratford M, McCreery RW, Oleson JJ. Language and Reading Outcomes in Fourth-Grade Children With Mild Hearing Loss Compared to Age-Matched Hearing Peers. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):17-28.

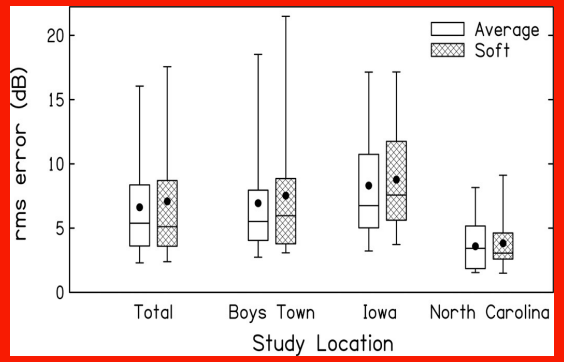
Consistent use of well-fit HAs supports listening comprehension, although the amount of benefit from HAs may be reduced for children with higher unaided hearing levels (and poorer aided SIIs).

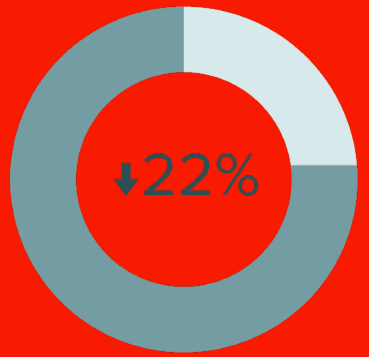




Walker EA, Sapp C, Dallapiazza M, Spratford M, McCreery RW, Oleson JJ. Language and Reading Outcomes in Fourth-Grade Children With Mild Hearing Loss Compared to Age-Matched Hearing Peers. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):17-28.

To reiterate, hearing aid benefit is often reduced for children with higher unaided hearing levels (and poorer aided SIIs).

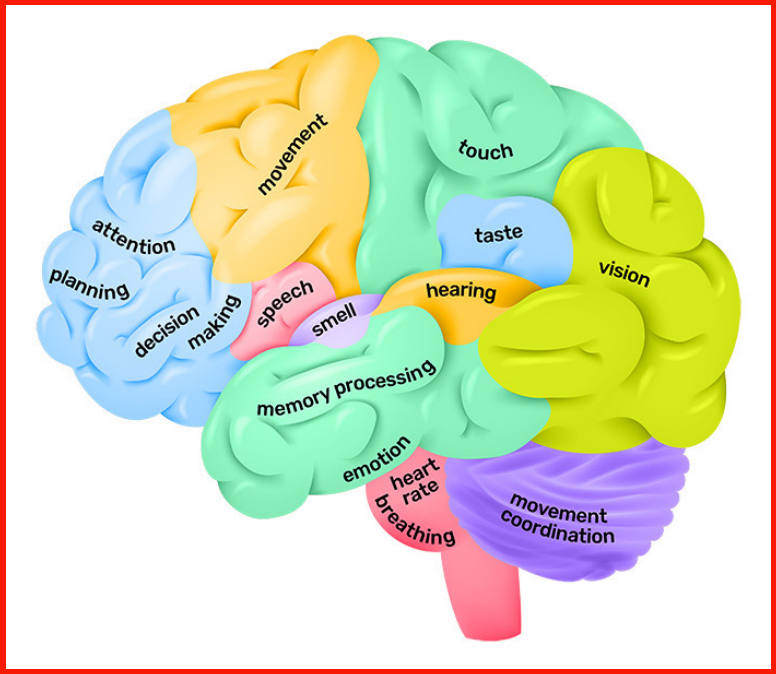




Walker EA, Sapp C, Dallapiazza M, Spratford M, McCreery RW, Oleson JJ. Language and Reading Outcomes in Fourth-Grade Children With Mild Hearing Loss Compared to Age-Matched Hearing Peers. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):17-28.

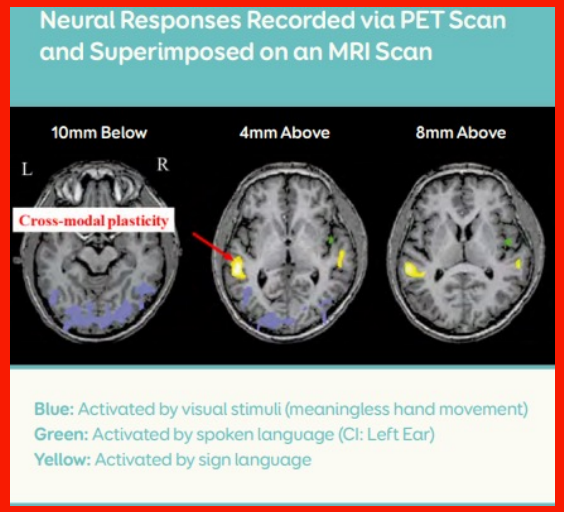
Specifically, there is evidence of unfavorable physiological and behavioral outcomes for adults & children with untreated and poorly treated hearing loss..

Let’s first examine the more superficial brain changes associated with hearing loss…



Starting with

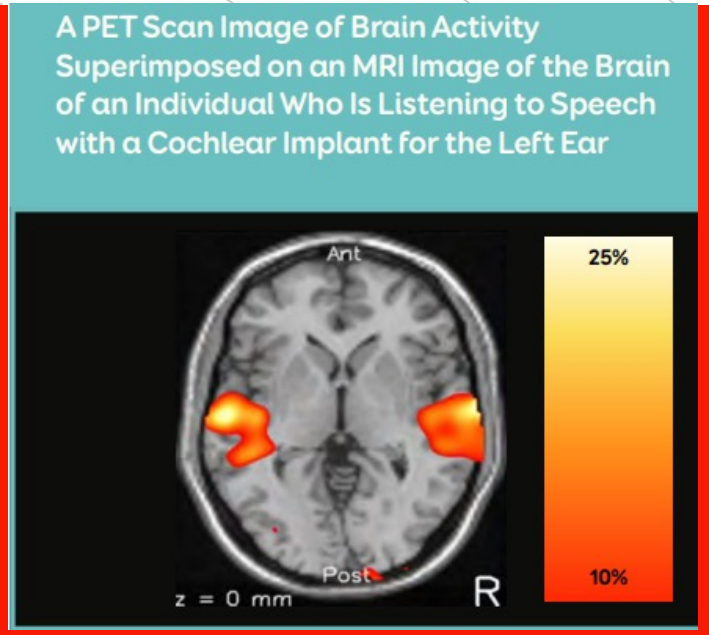
Congenitally deafened adults who grew up with sign language then got a CI as an adult



Nishimura, H., Hasikawa, K., Doi, K., Iwaki, T., Watanabe Y., Kusuoka, H., Nishimura, T., Kubo, T. (1999). Sign language “heard” in the auditory cortex. Nature, 397: 116

Compared to adults who did not wait too long to get a cochlear implant

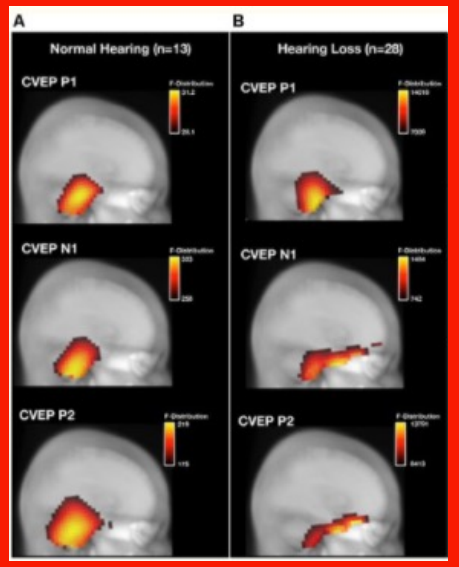
(16 Late deafened adults)



Green K.M.J., Julyan, P.J., Hastings, D.L., Ramsden, R.T. (2005). Auditory cortical activation and speech perception in cochlear implant users: Effects of implant experience and duration of deafness. Hearing Research, 205: 184-192.

In addition

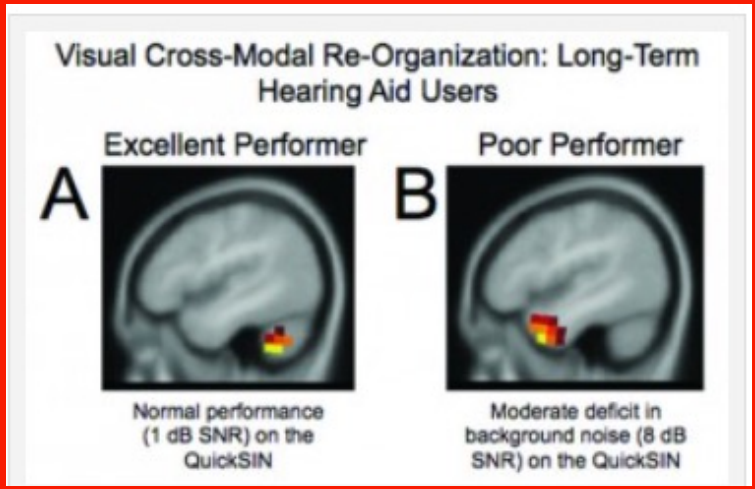
Hard of hearing adults without hearing aids completing a visual task



Glick HA, Sharma A. Cortical Neuroplasticity and Cognitive Function in Early-Stage, Mild-Moderate Hearing Loss: Evidence of Neurocognitive Benefit From Hearing Aid Use. Front Neurosci. 2020 Feb 18;14:93

Similarly…

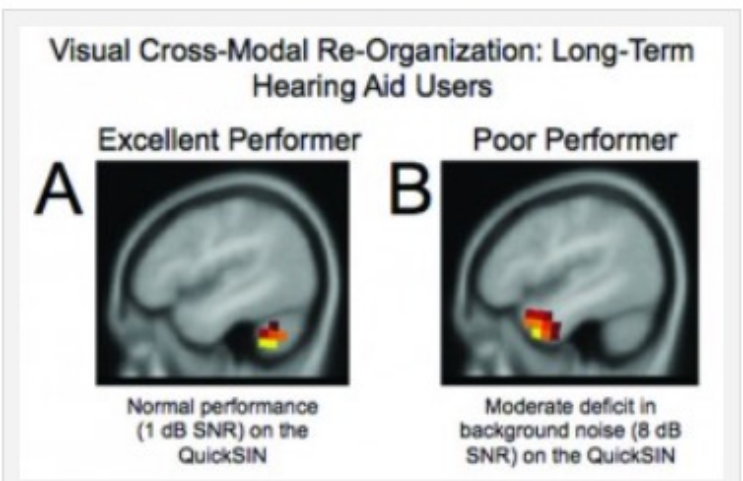
Hard of hearing adults with good & poor aided speech recognition in noise completing a visual task



Glick H, Sharma A. Cross-modal plasticity in developmental and age-related hearing loss: Clinical implications. Hear Res. 2017 Jan;343:191-201.

So these researchers say…

Even an 8 dB SNR loss on the bilaterally aided Q-SIN gives poor outcome..

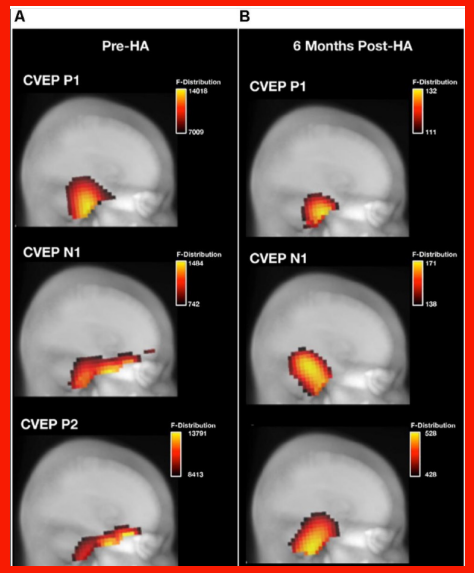


≥8 dB!

Glick H, Sharma A. Cross-modal plasticity in developmental and age-related hearing loss: Clinical implications. Hear Res. 2017 Jan;343:191-201.

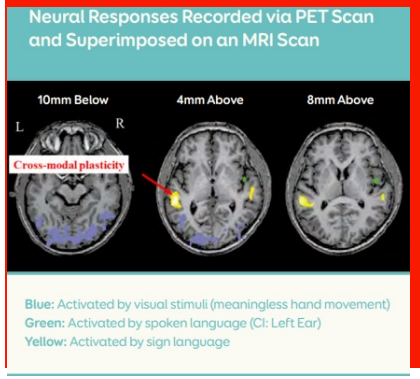
But there is hope…

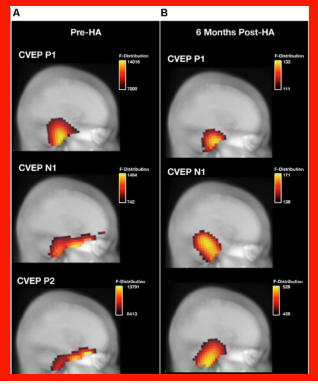
Hard of hearing adults before & after optimum audibility hearing aid use

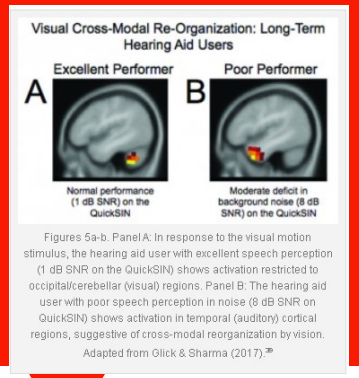


Glick HA, Sharma A. Cortical Neuroplasticity and Cognitive Function in Early-Stage, Mild-Moderate Hearing Loss: Evidence of Neurocognitive Benefit From Hearing Aid Use. Front Neurosci. 2020 Feb 18;14:93.

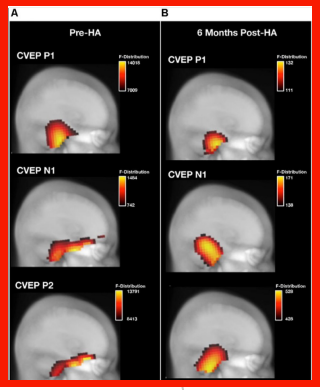
Collectively, these studies show poor audibility is associated with notable changes in the outermost regions of the brain







Figures 5a-b. Panel A: In response to the visual motion stimulus, the hearing aid user with excellent speech perception (1 dB SNR on the QuickSIN) shows activation restricted to occipital/cerebellar (visual) regions. Panel B: The hearing aid user with poor speech perception in noise (8 dB SNR on QuickSIN) shows activation in temporal (auditory) cortical regions, suggestive of cross-modal reorganization by vision. Adapted from Glick & Sharma (2017).[39]



. . .and the greater these brain resource changes the greater the measured cognitive deficits

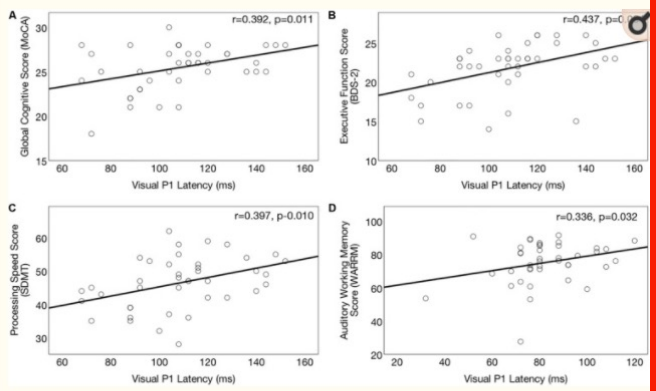
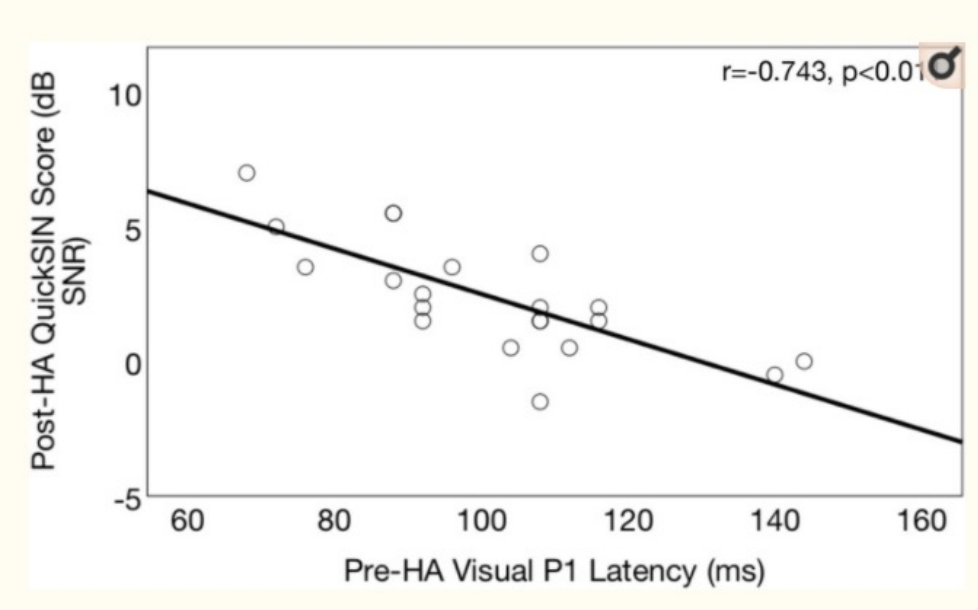


FIGURE 7

Association between cortical visual evoked potential latencies and cognitive function in the hearing loss group. Significant correlations ($p \leq 0.017$) between right temporal P1 CVEP peak latency (in milliseconds) and cognitive performance across the domains of global cognitive function on the (Montreal Cognitive Assessment) **(A)**, executive function (Behavioral Dyscontrol Scale) **(B)**, processing speed score (Symbol Digits Modalities Test) **(C)**, and auditory working memory (Word Auditory Recognition and Recall Measure) **(D)**. Higher scores on the cognitive measures indicate better cognitive performance. Earlier CVEP latencies, considered an index of visual cross-modal re-organization, are associated with poorer cognitive functioning.

Glick HA, Sharma A. Cortical Neuroplasticity and Cognitive Function in Early-Stage, Mild-Moderate Hearing Loss: Evidence of Neurocognitive Benefit From Hearing Aid Use. Front Neurosci. 2020 Feb 18;14:93.

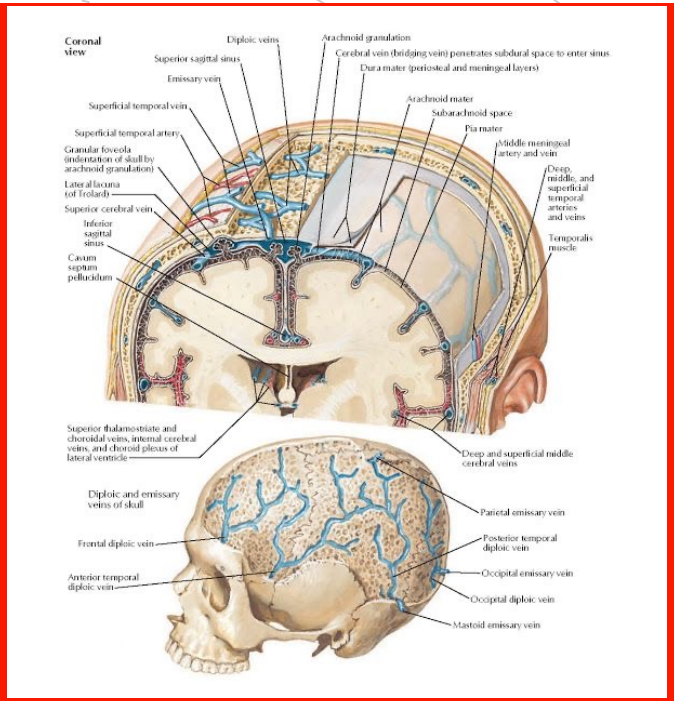
. . .and the better the aided performance in noise, the more the brain resource allocations trend towards normal



Glick HA, Sharma A. Cortical Neuroplasticity and Cognitive Function in Early-Stage, Mild-Moderate Hearing Loss: Evidence of Neurocognitive Benefit From Hearing Aid Use. Front Neurosci. 2020 Feb 18;14:93.

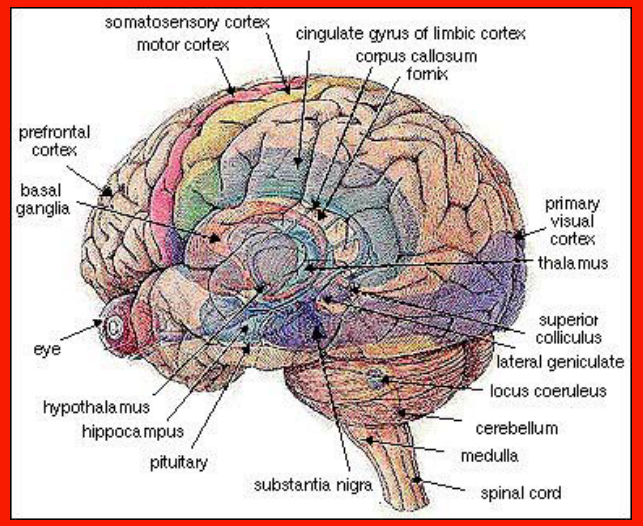
. . .but what about the effects of poor audibility on deeper brain layers?

R



As noted previously, much less is known about these deeper brain regions

However, adult patients with recently acquired unilateral deafness can serve as their own controls..



. . .and that is what this study did. . .

Heliyon. 2020 Dec; 6(12): e05658.
Published online 2020 Dec 17. doi: 10.1016/j.heliyon.2020.e05658
PMCID: PMC7754525
PMID: 33364477

Reduced grey- and white matter volumes due to unilateral hearing loss following treatment for vestibular schwannoma

Peder O. Laugen Heggdal,[a,b,*] Kristina S. Larsen,[b] Jonas Brännström,[d] Hans Jørgen Aarstad,[a,b] and Karsten Specht[c,e,f]

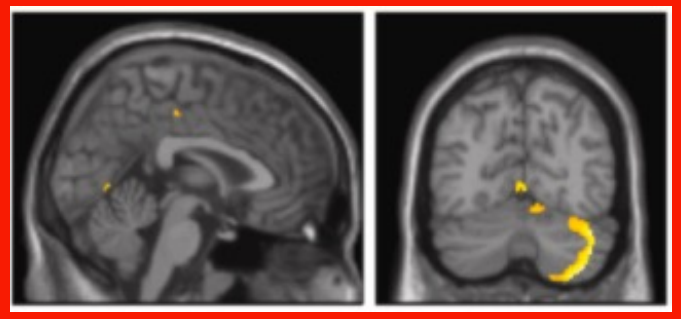
Heggdal POL, Larsen KS, Brännström J, Aarstad HJ, Specht K. Reduced grey- and white matter volumes due to unilateral hearing loss following treatment for vestibular schwannoma. Heliyon. 2020 Dec 17;6(12)

Patients with unilateral hearing loss after treatment for vestibular schwannoma have reduced GM and WM volumes in the cerebellum and in several cortical and sub-cortical areas when compared to healthy controls.

Heggdal POL, Larsen KS, Brännström J, Aarstad HJ, Specht K. Reduced grey- and white matter volumes due to unilateral hearing loss following treatment for vestibular schwannoma. Heliyon. 2020 Dec 17;6(12)

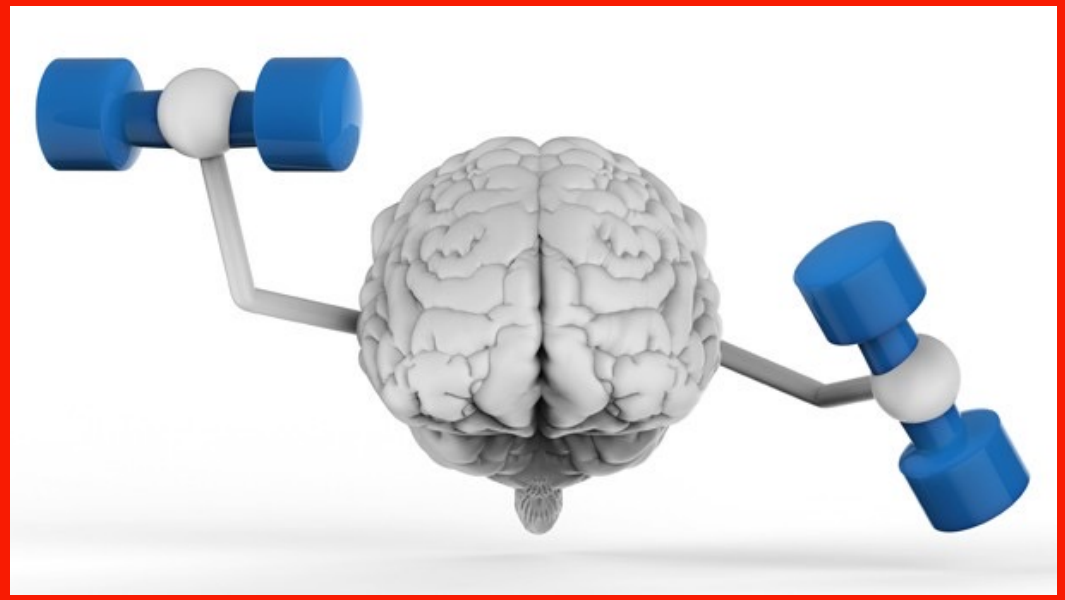
…and

Hearing loss affects regions involved in higher-order cognitive function due to functional-structural reorganization driven by deteriorated auditory input in deeper layers.



Heggdal POL, Larsen KS, Brännström J, Aarstad HJ, Specht K. Reduced grey- and white matter volumes due to unilateral hearing loss following treatment for vestibular schwannoma. Heliyon. 2020 Dec 17;6(12)

So we can agree, real-ear verified aided audibility is a critical first step for favorable brain resource/cognitive outcomes for both children and adults

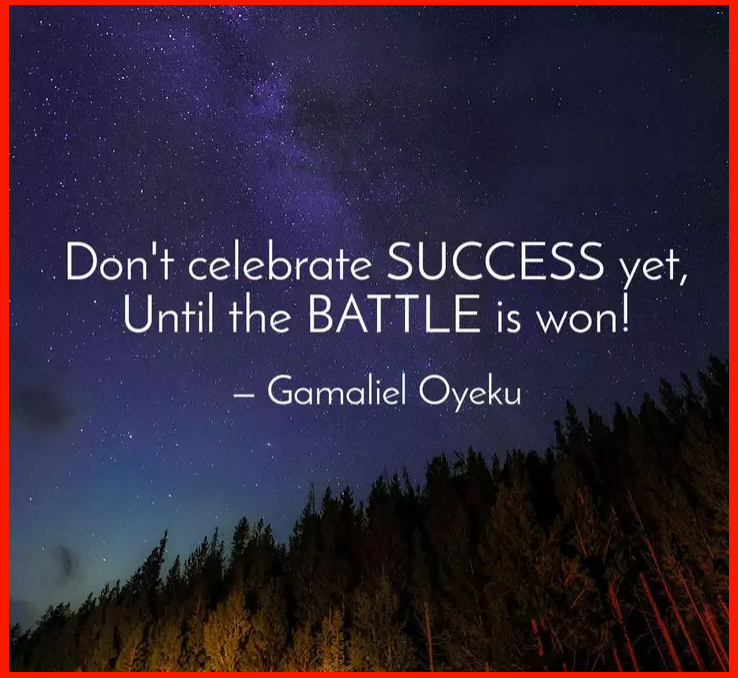


. . .and real-ear verified aided audibility is often not achieved

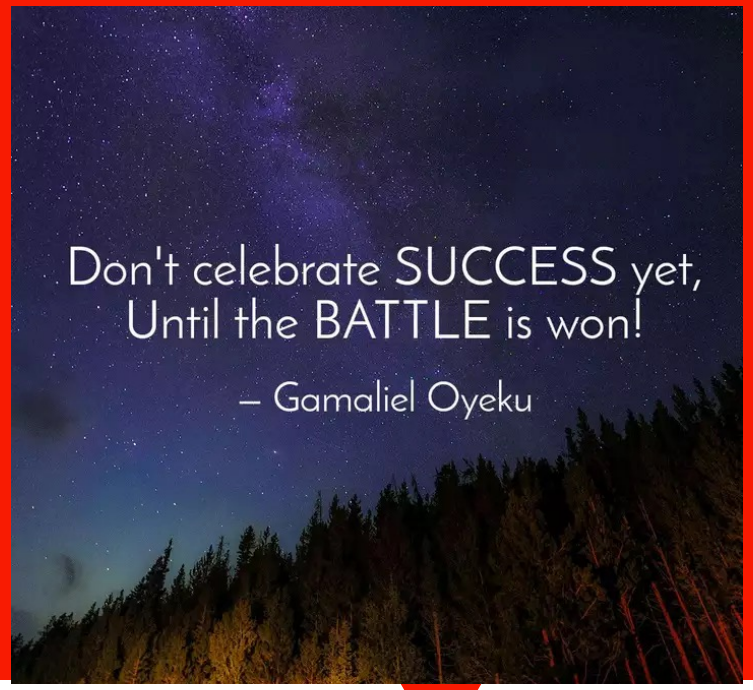
…but let's assume we all have achieved real-ear verified aided audibility…

4 Why not call it good after audibility is achieved?

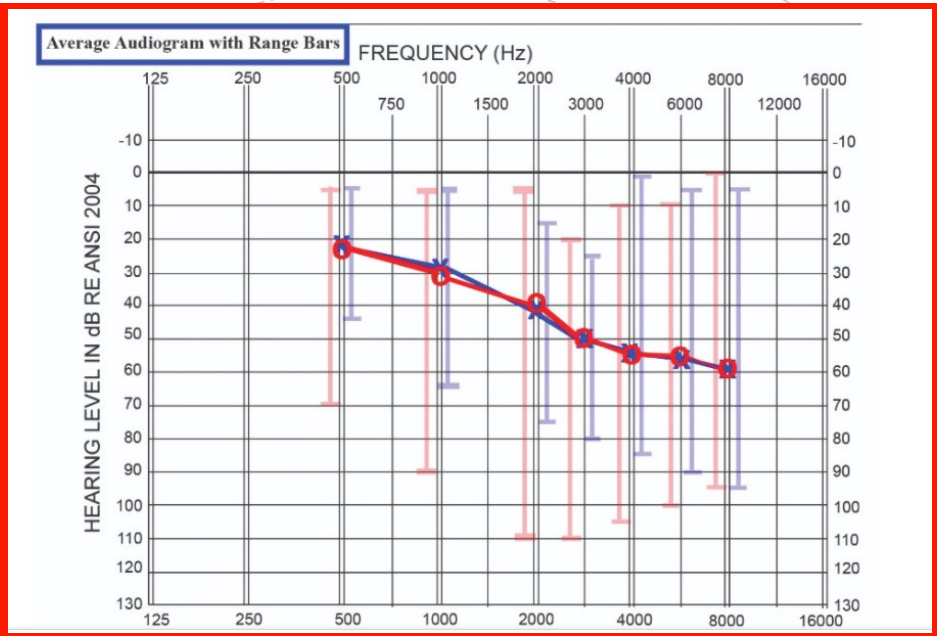
N



..because many subjects with appropriate hearing aid/ci programming show risk factors for language, cognitive & vocational failure



For example, all of these subjects scored normally on the bilaterally aided Q-SIN.



n =63 patients,26 females and 37 males

8-82 years, $\overline{x}$ =59.7 years,

All with RIC/slim-tube hearing aids

5 different manufacturers products ranging in age from 1 day to 15 years

Leavitt RJ, Flexer C, Clark N. Variables associated with attainment of normal scores on the bilaterally aided QuickSIN Test. *Hearing Review*. 2020;27(9):18-21.

…and most were fit to an NAL NL-2 target

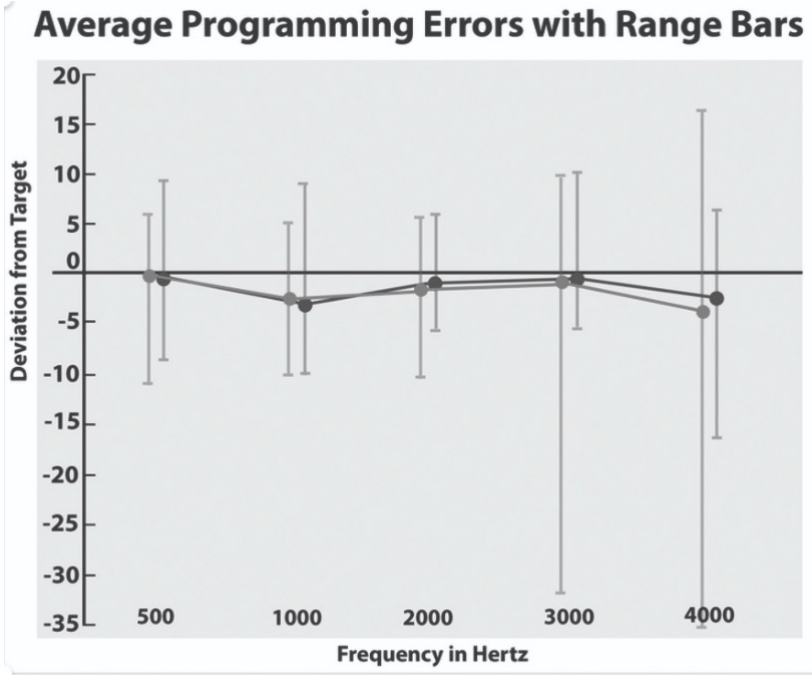
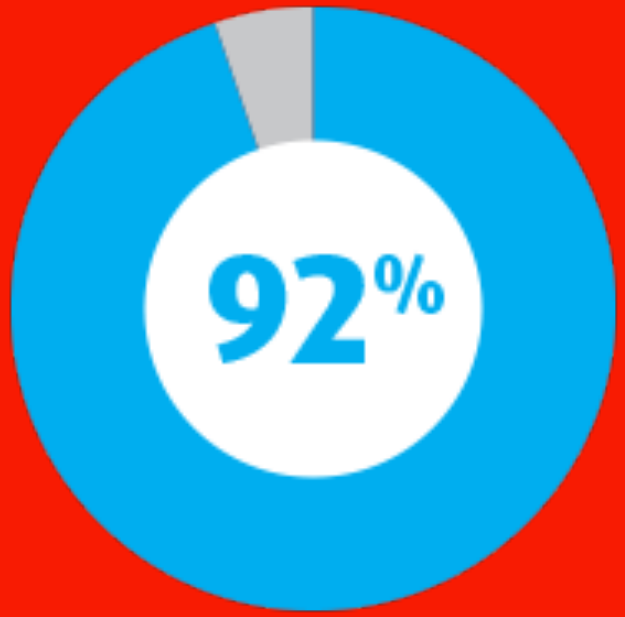


Figure 4. Deviation from NAL NL-2 target at 60 dB SPL input using the carrot passage. Right ear in gray; left ear

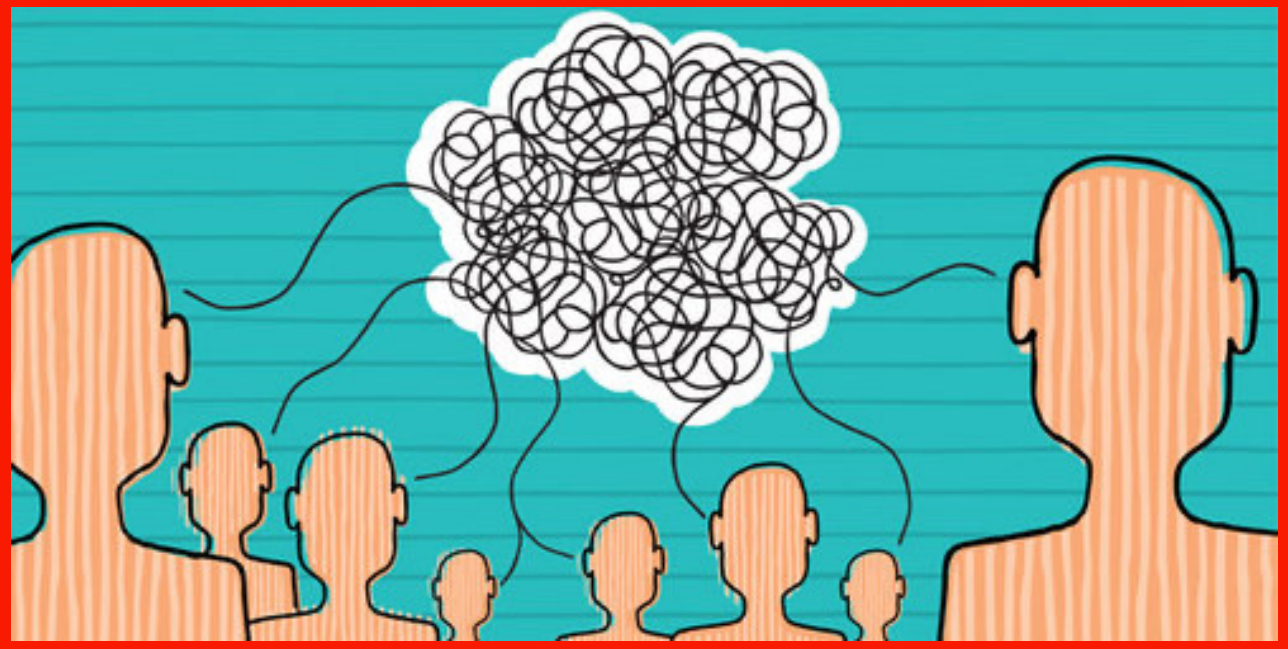
…but from our data base, only 63/831 patients of equivalent aided/unaided SII achieved this normal aided Q-SIN score.

63/831=7.6%

…suggesting >92% of our patients still are at risk for some unfavorable brain resource reallocation and anatomical/physiological brain changes



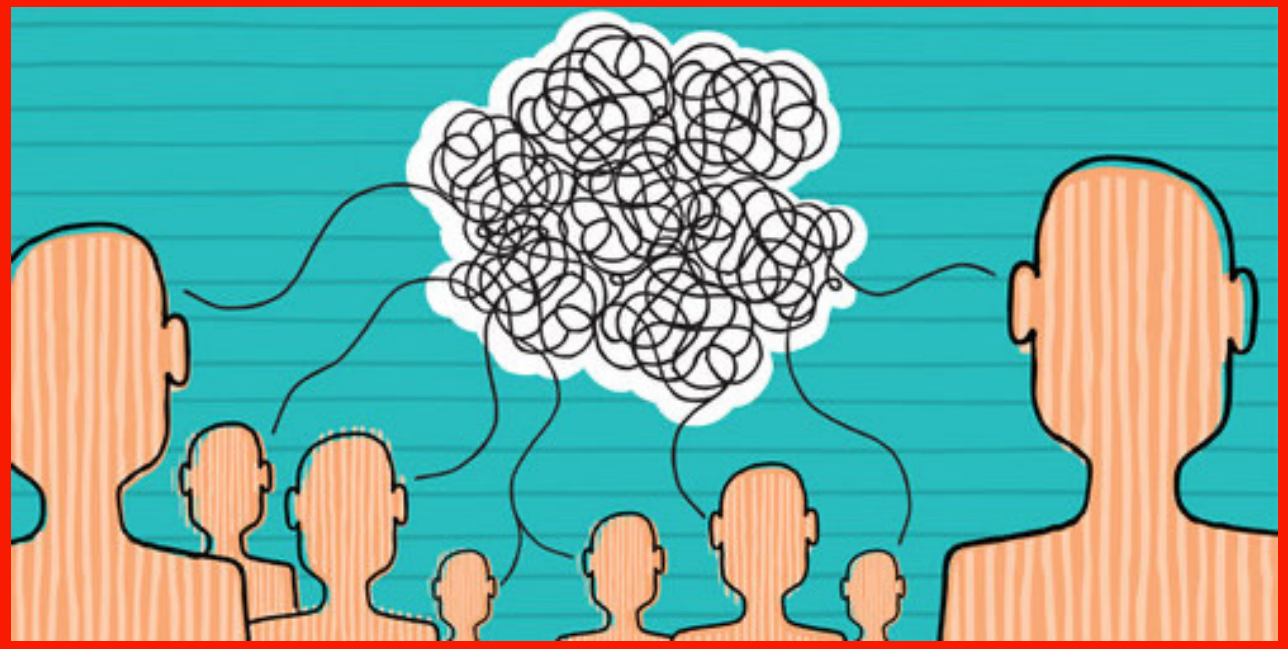
In addition several studies are showing people with normal hearing are reporting difficulty understanding speech in noise..



Co

So appropriate audibility of speech cannot be the only important variable…

Co



For example….

Example 1

Numerous studies report no relation between lifetime noise exposure and speech perception in noise (SPiN) on their subjects with **normal hearing**

Prendergast, G., Millman, R. E., Guest, H., et al. (2017). Effects of noise exposure on young adults with normal audiograms II: Behavioral measures. Hear Res, 356, 74-86

Yeend, I., Beach, E. F., Sharma, M., et al. (2017). The effects of noise exposure and musical training on suprathreshold auditory processing and speech perception in noise. Hearing research, 353, 224- 1219 236

Le Prell CG, Siburt HW, Lobarinas E, Griffiths SK, Spankovich C. No Reliable Association Between Recreational Noise Exposure and Threshold Sensitivity, Distortion Product Otoacoustic Emission Amplitude, or Word-in-Noise Performance in a College Student Population. Ear Hear. 2018 Nov/Dec;39(6):1057-1074

Fulbright ANC, Le Prell CG, Griffiths SK, Lobarinas E. Effects of Recreational Noise on Threshold and Suprathreshold Measures of Auditory Function. Semin Hear. 2017 Nov;38(4):298-318

Grinn SK, Wiseman KB, Baker JA, Le Prell CG. Hidden Hearing Loss? No Effect of Common Recreational Noise Exposure on Cochlear Nerve Response Amplitude in Humans. Front Neurosci. 2017 Sep 1;11:465..

Example 2

In addition, **26 million adults with normal pure tone results report hearing difficulty or speech in noise problems** with a reduced quality of life (QOL) due to their auditory problems

Beck DL, Danhauer JL, Abrams HB, Atcherson SR, Brown DK, Chasin M, Clark JG, De Placido C, Edwards B, Fabry DA, Flexer C, Fligor B, Frazer G, Galster JA, Gifford L, Johnson CE, Madell J, Moore DR, Roeser RJ, Saunders GH, Searchfield GD, Spankovich C, Valente M, Wolfe J. Audiologic considerations for people with normal hearing sensitivity yet hearing difficulty and/or speech-in-noise problems. *Hearing Review*. 2018;25(10)[Oct]:28-38.

Suffice to say we have evidence that even with normal pure tone hearing, speech in noise scores are depressed in millions of patients

So clearly adequate aided/implanted audibility, while important, is not always the cure

Which brings us to our last section…

5 What more might we do?

Let’s start with some basic principles for patients regardless of age

The Basics™

PRINCIPLE 1

Thoroughly test the outer, middle and inner ear (beyond pure tones)

It is estimated that 10-15 % of patients who report tinnitus have normal pure tone thresholds accounting for between 5 -7.5 million patients in the U.S.

Barnea G, Attias J, Gold S, Shahar A. Tinnitus with normal hearing sensitivity: extended high-frequency audiometry and auditory-nerve brain-stem-evoked responses. *Audiology*. 1990; 29: 36-45.

Spankovich C, Gonzalez VB, Su D, Bishop CE. Self reported hearing difficulty, tinnitus, and normal audiometric thresholds, the National Health and Nutrition Examination Survey 1999-2002. *Hear Res*. 2018 Feb; 358: 30-36.

PRINCIPLE 1

Thoroughly test the cochlea (beyond pure tones)

For example, patients with normal hearing and tinnitus show abnormal OAE results 43.8% -91% of the time

Dadoo S, Sharma R, Sharma V. Oto-acoustic emissions and brainstem evoked response audiometry in patients of tinnitus with normal hearing. Int Tinnitus J. 2019 Jan 1;23(1):17-25.

Thabet EM. Evaluation of tinnitus patients with normal hearing sensitivity using TEOAEs and TEN test. *Auris Nasus Larynx.* 2009;36:633–6.
Shiomi Y, Tsuji J, Naito Y, Fujiki N, Yamamoto N. Characteristics of DPOAE audiogram in tinnitus patients. *Hear Res.* 1997;108:83–8.

Granjeiro R C, Kehrle H M, Bezerra R L, Almeida V F, Sampaio A L, Oliveira C A. Transient and distortion product evoked oto-acoustic emissions in normal hearing patients with and without tinnitus. *Otolaryngol Head Neck Surg.* 2008;138(4):502–506

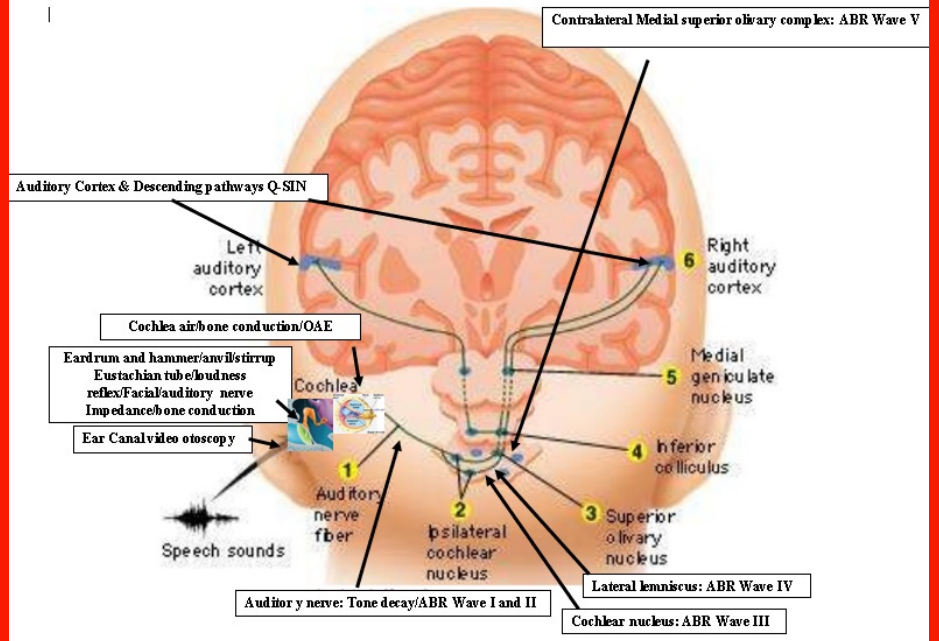
Serra, L., Novanta, G., Sampaio, A. L., Augusto Oliveira, C., Granjeiro, R., & Braga, S. C. (2015). The study of otoacoustic emissions and the suppression of otoacoustic emissions in subjects with tinnitus and normal hearing: an insight to tinnitus etiology. *International archives of otorhinolaryngology*, *19*(2), 171–175. https://doi.org/10.1055/s-0034-1374648

PRINCIPLE 2

TEST BEYOND THE COCHLEA

ANSD, APD, tinnitus, normal hearing with self-reported speech perception in noise problems are not diagnosed by pure tones

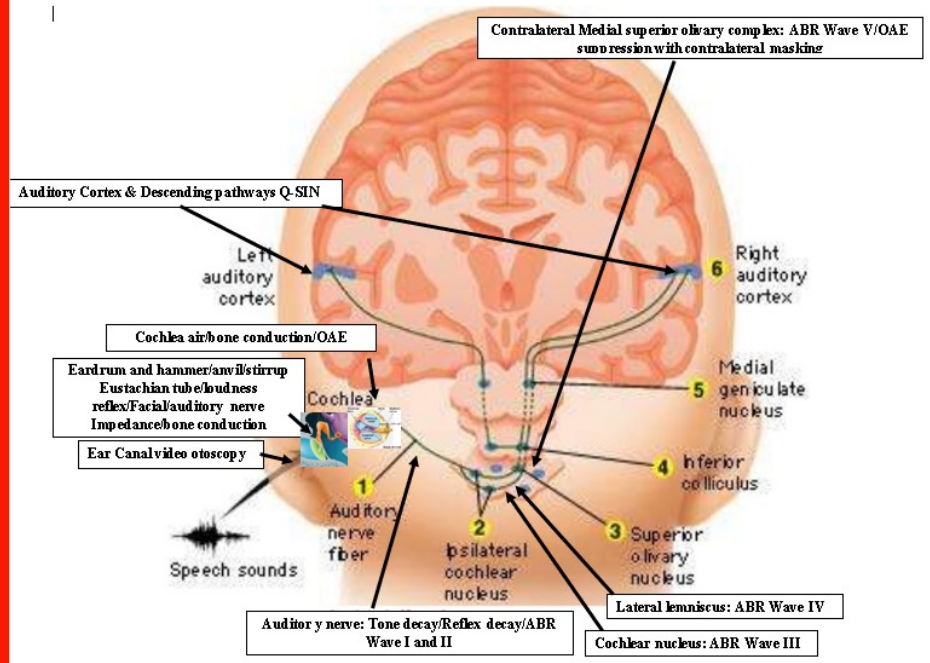
R



Eggermont, JJ (2019). Auditory brainstem response in Handbook of Clinical Neurology, Vol. 160 (3rd series) Clinical Neurophysiology: Basis and Technical AspectsK.H. Levin and P. Chauvel, Eds

R So how are they diagnosed?

Air and bone pure tones, OAE w and w/o contralat masking, multi-frequency immittance, ABR, ASSR, Degraded speech, gap detection, dichotic digits, MLD, ABR, AEPs, and..



Eggermont, JJ (2019). Auditory brainstem response in Handbook of Clinical Neurology, Vol. 160 (3rd series) Clinical Neurophysiology: Basis and Technical AspectsK.H. Levin and P. Chauvel, Eds

..and one more

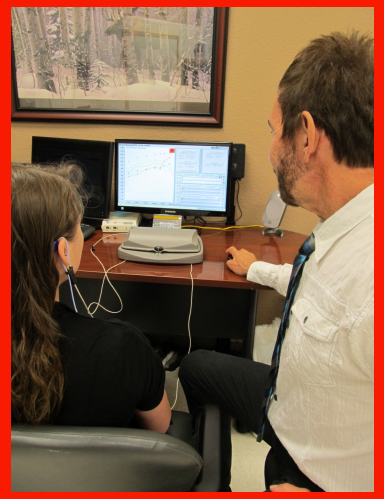
fNIRS

Co/N PRINCIPLE 3

Realize that aided and implanted audibility is not static and requires ongoing updating…[i]

PRINCIPLE 4

Realize an important limitation of real-ear aided response…[i]



1. Position the client directly in front of, and facing, the sound field speaker at a distance of 45 to 60 cm (18 to 24 in.).

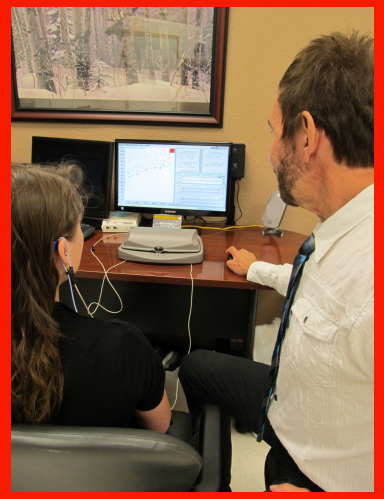
2. Position the client and the sound field speaker at least (5 feet) away from any hard surfaces.

3. Room noise can increase test time, cause errors and alter the operation of the hearing instrument being evaluated

Leavitt R (2021). In pursuit of audibility for People with Hearing Loss. *Audiology online* at https://www.audiologyonline.com/articles/20q-pursuit-of-audibility-27848

PRINCIPLE 4

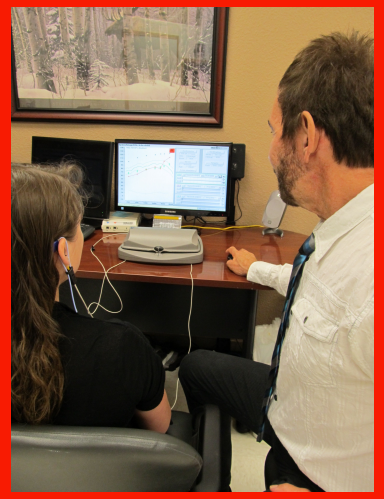
In other words…



1. Use an unreasonable speaker to listener distance (18 to 24 in.).
2. Assume the patient will be listening nowhere near a wall.
3. Assume listening is done in dead quiet

Leavitt R (2021). In pursuit of audibility for People with Hearing Loss. *Audiology online* at https://www.audiologyonline.com/articles/20q-pursuit-of-audibility-27848

PRINCIPLE 4



If you can't achieve these three criteria we know nothing about what the patient hears in the real world…

1. Use an unreasonable speaker to listener distance (18 to 24 in.).

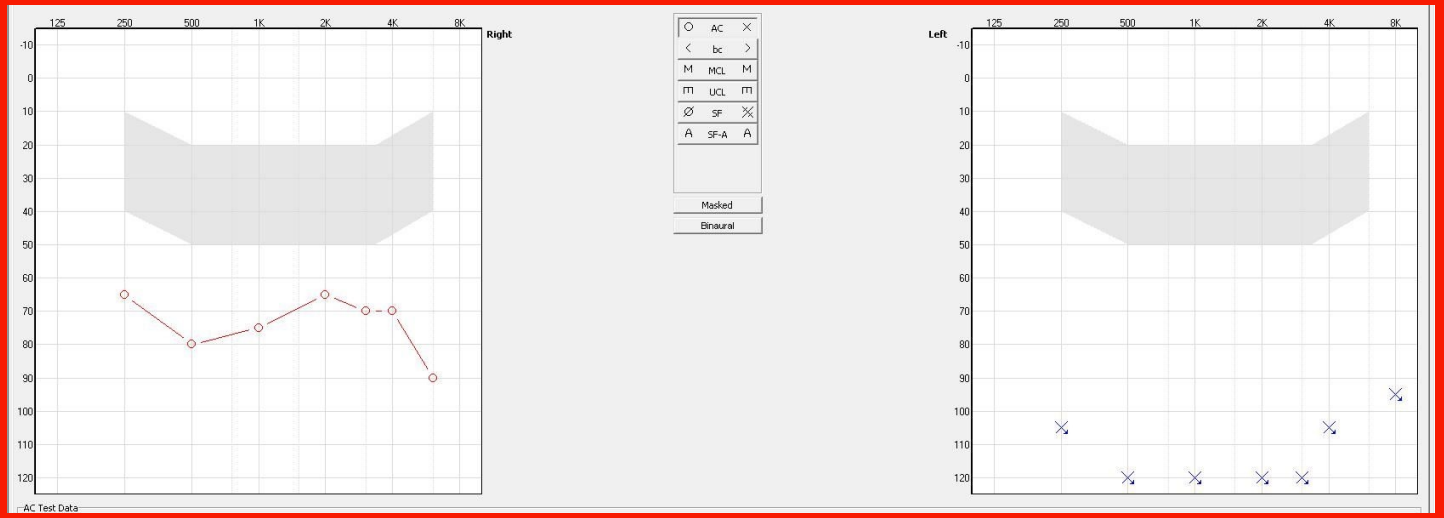
2. Assume the patient will be listening nowhere near a wall.

3. Assume listening is done in dead quiet

Leavitt R (2021). In pursuit of audibility for People with Hearing Loss. *Audiology online* at https://www.audiologyonline.com/articles/20q-pursuit-of-audibility-27848

PRINCIPLE 5

Think beyond hearing aids when appropriate…[i]



PRINCIPLE 5

Remember from McCreery et al …

These authors recommend fitting hearing aids for children who have a BEUSII value of .80 or lower to minimize the likelihood of communication differences from those with normal hearing and…

PRINCIPLE 5

Remember from McCreery et al …

..children with MBHL are at risk for persistent language deficits by 4th grade, particularly in aspects of language that involve form even with properly fit hearing aids and….

PRINCIPLE 5

Remember from McCreery et al …

.. Consistent use of well-fit HAs supports listening comprehension, although the amount of benefit from HAs may be reduced for children with higher unaided hearing levels (and poorer aided SIIs).

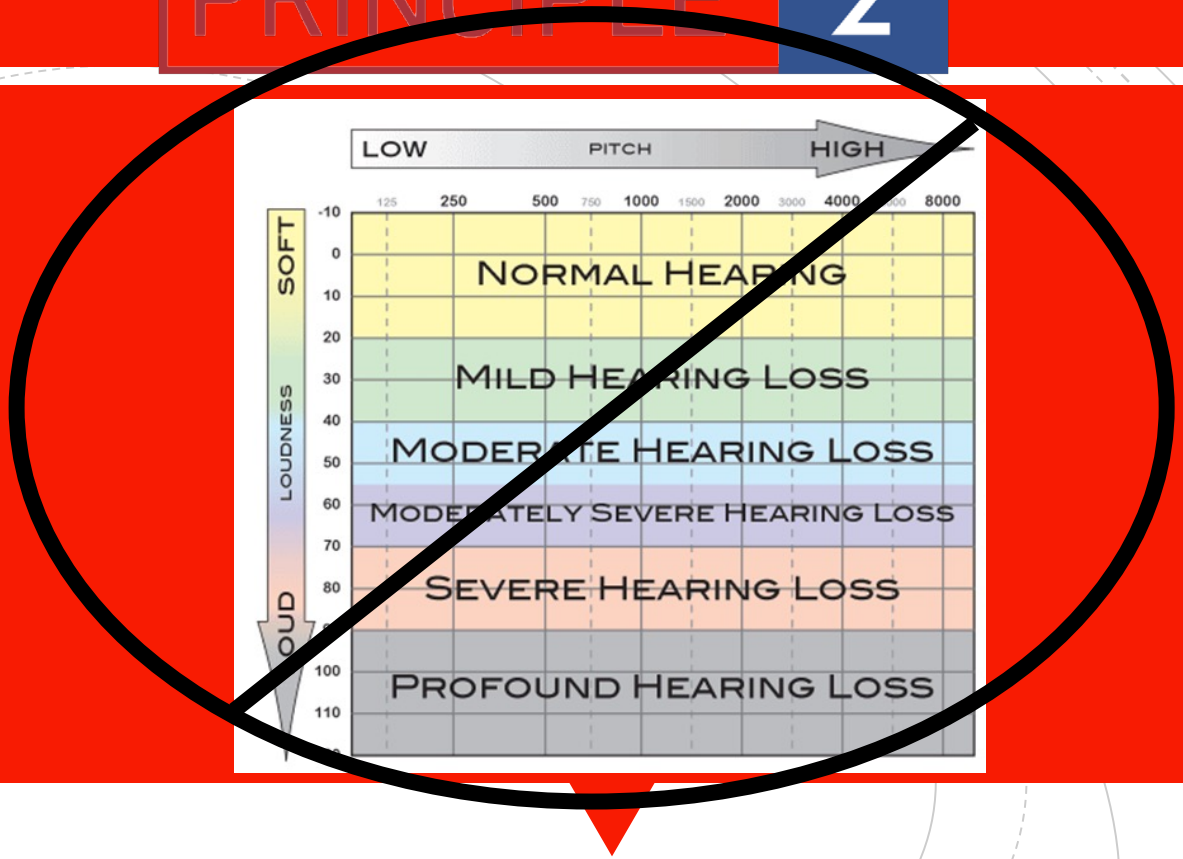
PRINCIPLE 5

So what do we do when we cannot achieve an aided SII of .80 or better?

PRINCIPLE 6

Make test results comprehensible to patient/parents/caregivers/teachers

PRINCIPLE 2


LOW
PITCH
HIGH
125
250
500
750
1000
1500
2000
3000
4000
8000
SOFT
LOUDNESS
LOUD
-10
0
10
20
30
40
50
60
70
80
100
110
NORMAL HEARING
MILD HEARING LOSS
MODERATE HEARING LOSS
MODERATELY SEVERE HEARING LOSS
SEVERE HEARING LOSS
PROFOUND HEARING LOSS

The current clinical approach of counseling/caregivers using thresholds from the behavioral audiogram can be challenging because the ..degrees of hearing loss are often not meaningful ...

McCreery RW, Walker EA, Stiles DJ, Spratford M, Oleson JJ, Lewis DE. Audibility-Based Hearing Aid Fitting Criteria for Children With Mild Bilateral Hearing Loss. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):55-67.

Describing audibility loss instead of hearing loss provides a meaningful context for the impact of the child's hearing levels on communication and a direct comparison to the child's aided hearing levels, if hearing aids are fitted.

McCreery RW, Walker EA, Stiles DJ, Spratford M, Oleson JJ, Lewis DE. Audibility-Based Hearing Aid Fitting Criteria for Children With Mild Bilateral Hearing Loss. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):55-67.

The findings indicate that standard methods of classifying hearing loss in clinics may undermine parents' understanding of their child's hearing loss, causing them to underestimate substantially the magnitude of the loss.

Haggard RS, Primus MA. Parental perceptions of hearing loss classification in children. Am J Audiol. 1999 Dec;8(2):83-92

The (hearing loss) terminology has not been standardized and does not appear to reliably predict the impact of the hearing loss on the communication, academic, or language performance of children (Davis, Elfenbein, Schum, & Bentler, 1986; Haggard & Primus, 1999; Martin & Clark, 2000).

Davis, J., Elfenbein, J., Schum, R., & Bentler, R. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. Journal of Speech and Hearing Disorders, 51, 53–62.

Haggard, R., & Primus, M. (1999). Parental perceptions of hearing loss classification in children. American Journal of Audiology, 8, 83–92.

Martin, F., & Clark, J. (2000). Introduction to audiology (7th ed.). Needham Heights, MA: Allyn & Bacon

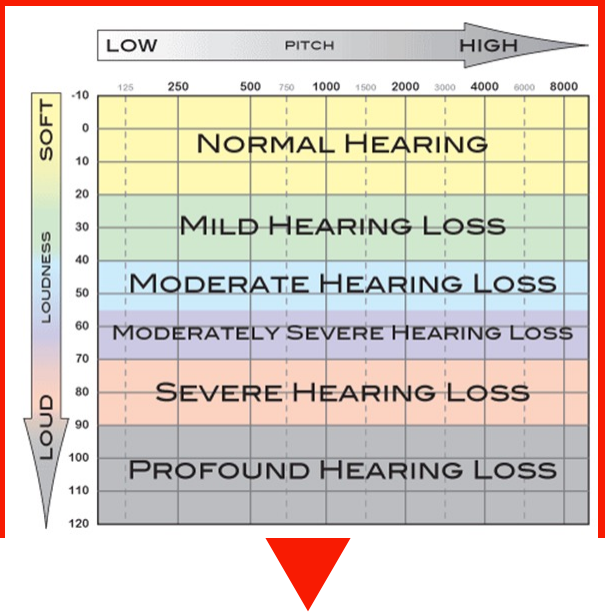
Blair, EuDaly, and Benson (1999) found that teachers at all grade levels had little understanding of their students' hearing loss despite the fact that all of the teachers had received audiologic reports and form letters describing the hearing loss using classification terms.

Blair, J., EuDaly, M., & Benson, P. (1999). The effectiveness of audiologists' information sources for classroom teachers. Language, Speech, and Hearing Services in Schools, 30, 173–182.

The teachers in the Blair et al. study made several suggestions for improving audiologic reports: (a) use lay terms (no jargon); (b) make the reports short and concise; and (c) provide practical, personalized suggestions for the classroom.

Blair, J., EuDaly, M., & Benson, P. (1999). The effectiveness of audiologists' information sources for classroom teachers. Language, Speech, and Hearing Services in Schools, 30, 173–182.

To summarize, adult patients, parents, teachers and future SLPs do not understand this classification system or find it useful…



So let’s use McCreery and colleagues suggestion

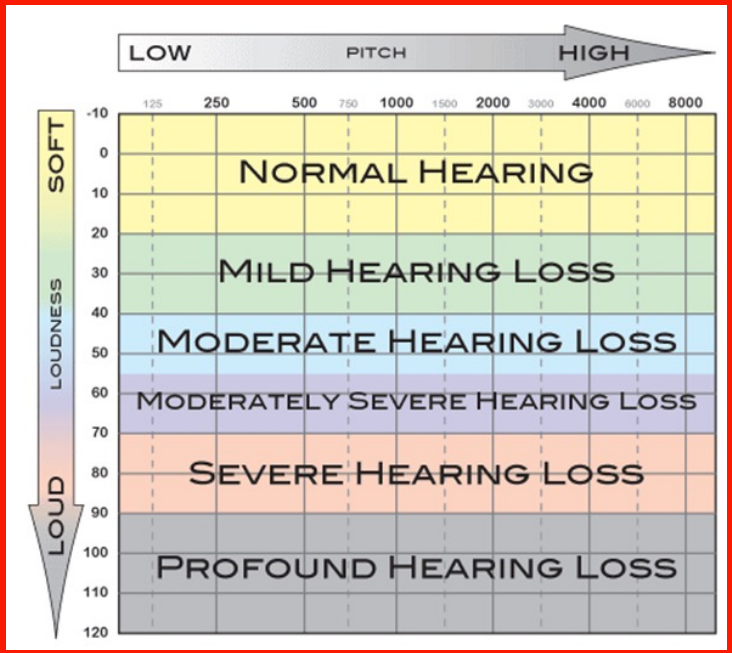
Describing audibility loss instead of hearing loss provides a meaningful context for the impact of the child's hearing levels on communication

SPEECH INTELLIGIBILITY INDEX MODEL:

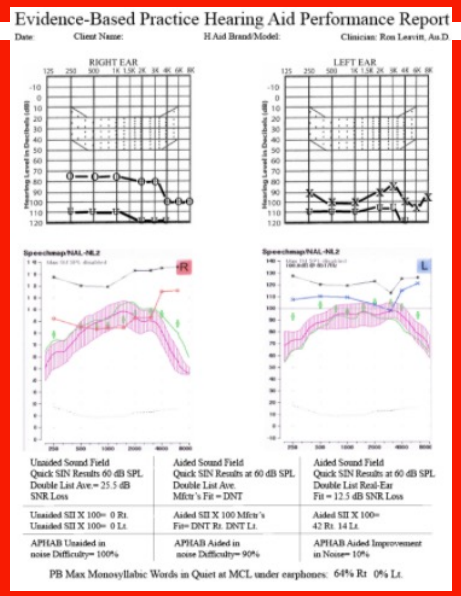
How can I do that?

	Enter an HL threshold in EACH box below. Leave no blanks.							
Frequency (Hz)	250	500	1000	2000	3000	4000	6000	8000
Enter HL Threshold >>	50	30	80	75	80	65	70	70
SPL of speech @ 1m >	65	dB	SII >	0.141	Predicted best CST score >			6%

How does this system inform the patient/family of what was gained by using the hearing aid?



..but this form can…



Evidence-Based Practice Hearing Aid Performance Report

Date: Client Name: H Aid Brand/Model: Clinician: Ron Leavitt, Au.D.

RIGHT EAR

LEFT EAR

Unaided Sound Field Quick SIN Results 60 dB SPL Double List Ave.= 25.5 dB SNR Loss	Aided Sound Field Quick SIN Results at 60 dB SPL Double List Ave. Mfctr's Fit = DNT	Aided Sound Field Quick SIN Results at 60 dB SPL Double List Real-Ear Fit = 12.5 dB SNR Loss
Unaided SII X 100= 0 Rt. Unaided SII X 100= 0 Lt.	Aided SII X 100 Mfctr's Fit= DNT Rt. DNT Lt.	Aided SII X 100= 42 Rt. 14 Lt.
APHAB Unaided in noise Difficulty= 100%	APHAB Aided in noise Difficulty= 90%	APHAB Aided Improvement in Noise= 10%

PB Max Monosyllabic Words in Quiet at MCL under earphones: 64% Rt 0% Lt.

Leavitt R & Knowles L (2013). A Time-efficient Method and Form for Documenting Hearing Aid Benefit *Hear Rev* Nov 2012

Pie in the sky

R

What goes beyond audibility

Principle 1

Cognitive function is at risk for children and adults with hearing loss, so the question becomes what facilitates improved cognitive function?

Answer: Exercise

1.Cognition is highly correlated with exercise

Acute and chronic beneficial effects of especially cardio exercise were reported with regard to several **cognitive, behavioral, and socio-emotional functions** in children and adults

Den Heijer AE, Groen Y, Tucha L, Fuermaier AB, Koerts J, Lange KW, Thome J, Tucha O. Sweat it out? The effects of physical exercise on cognition and behavior in children and adults with ADHD: a systematic literature review. J Neural Transm (Vienna). 2017 Feb;124(Suppl 1):3-26

Exercise programs that are structured, individualized, higher intensity, longer duration, and multicomponent show promise for **preserving cognitive performance in older adults.**

Kirk-Sanchez NJ, McGough EL. Physical exercise and cognitive performance in the elderly: current perspectives. Clin Interv Aging. 2014;9:51-62.

Drug treatments have a small but significant impact on cognitive functioning in AD and exercise has the potential to improve cognition in AD and MCI. Combining these two approaches might further increase the efficacy of each individual intervention.

Ströhle A, Schmidt DK, Schultz F, Fricke N, Staden T, Hellweg R, Priller J, Rapp MA, Rieckmann N. Drug and Exercise Treatment of Alzheimer Disease and Mild Cognitive Impairment: A Systematic Review and Meta-Analysis of Effects on Cognition in Randomized Controlled Trials. Am J Geriatr Psychiatry. 2015 Dec;23(12):1234-1249. d

Ten randomized controlled trials ..combined cognitive-physical intervention with cognitive function . The primary analysis showed a small-to-medium positive effect of combined cognitive-physical interventions on global cognitive function in older adults with MCI or dementia.

Karssemeijer EGA, Aaronson JA, Bossers WJ, Smits T, Olde Rikkert MGM, Kessels RPC. Positive effects of combined cognitive and physical exercise training on cognitive function in older adults with mild cognitive impairment or dementia: A meta-analysis. Ageing Res Rev. 2017 Nov;40:75-83.

Older and current studies indicate exercise plays a vital role in reducing the incidence and slowing the progression of Alzheimer's disease through production of antioxidant enzymes and growth factors, nerve growth factors, insulin-like growth factors and vascular endothelial growth factor and by reducing the production of ROS.

Rashid MH, Zahid MF, Zain S, Kabir A, Hassan SU. The Neuroprotective Effects of Exercise on Cognitive Decline: A Preventive Approach to Alzheimer Disease. Cureus. 2020 Feb 11;12(2):e6958

Note we are not recommending that audiologists develop exercise programs, only that we make appropriate referrals starting with the GP

..and remember some hearing aids are now step counting…

Principle 2: Diet for cognitive health

Principle 2: Diet for cognitive health

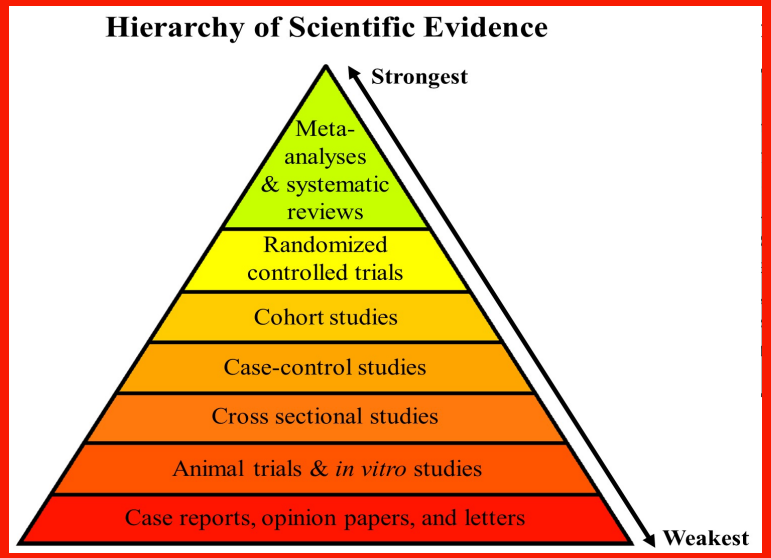
Several dietary components consumed in the **MD and DASH (omega-3 fatty acids, antioxidants and polyphenols) can inhibit neuroinflammation associated with AD.** Anti-inflammatory diets may also attenuate neuroinflammation via indirect immune pathways from the gut microbiome and systemic circulation.

McGrattan AM, McGuinness B, McKinley MC, Kee F, Passmore P, Woodside JV, McEvoy CT. Diet and Inflammation in Cognitive Ageing and Alzheimer's Disease. Curr Nutr Rep. 2019 Jun;8(2):53-65.

Adolescence may represent an optimal time for healthy lifestyle changes to have a positive and long-lasting impact on hippocampal neurogenesis, and to protect against stress-induced deficits.

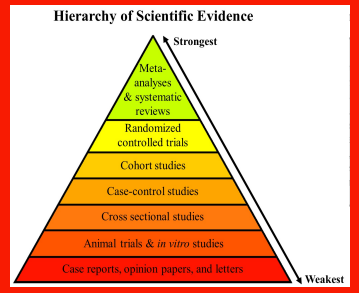
Hueston CM, Cryan JF, Nolan YM. Stress and adolescent hippocampal neurogenesis: diet and exercise as cognitive modulators. Transl Psychiatry. 2017 Apr 4;7(4):e1081.

The significant improvements in cognitive domain composites in the most robustly designed study warrant additional research.



Radd-Vagenas S, Duffy SL, Naismith SL, Brew BJ, Flood VM, Fiatarone Singh MA. Effect of the Mediterranean diet on cognition and brain morphology and function: a systematic review of randomized controlled trials. Am J Clin Nutr. 2018 Mar 1;107(3):389-404.

Adherence to the MD is associated with better **cognitive performance**. However, it should be noted that the majority of findings come from epidemiologic studies that provide evidence for a correlation between the MD and cognition but not for a cause-and-effect relation.



Petersson SD, Philippou E. Mediterranean Diet, Cognitive Function, and Dementia: A Systematic Review of the Evidence. Adv Nutr. 2016 Sep 15;7(5):889-904.

Even intelligence scores can be improved by micronutrient supplementation in children and adolescents with very poor dietary status. Overall, the literature suggests that good regular dietary habits are the best way to ensure optimal mental and behavioural performance at all times.

Bellisle F. Effects of diet on behaviour and cognition in children. Br J Nutr. 2004 Oct;92 Suppl 2:S227-32.

Note: we are not recommending audiologists do diet plans for our patients, but make appropriate referrals starting with the GP

Bellisle F. Effects of diet on behaviour and cognition in children. Br J Nutr. 2004 Oct;92 Suppl 2:S227-32.

3. Social Connection/language stimulation

Evans IEM, Llewellyn DJ, Matthews FE, Woods RT, Brayne C, Clare L; CFAS-Wales research team. Social isolation, cognitive reserve, and cognition in healthy older people. PLoS One. 2018 Aug 17;13(8):

3. Social Connection/language stimulation

Maintaining a socially active lifestyle in later life may **enhance cognitive reserve and benefit cognitive function**. This has important implications for interventions that may target social isolation to improve cognitive function.

Evans IEM, Llewellyn DJ, Matthews FE, Woods RT, Brayne C, Clare L; CFAS-Wales research team. Social isolation, cognitive reserve, and cognition in healthy older people. PLoS One. 2018 Aug 17;13(8):

3. Social Connection/language stimulation

Loneliness and isolation are associated with poorer cognitive function among older adults. Interventions to foster social connections may be particularly beneficial for individuals with low levels of education.

Shankar A, Hamer M, McMunn A, Steptoe A. Social isolation and loneliness: relationships with cognitive function during 4 years of follow-up in the English Longitudinal Study of Ageing. Psychosom Med. 2013 Feb;75(2):161-70.

3. Social Connection/language stimulation

Interventions aimed at improving and maintaining cognitive engagement may be valuable for the cognitive health of **community-dwelling older adults**.

Anatürk M, Suri S, Zsoldos E, Filippini N, Mahmood A, Singh-Manoux A, Kivimäki M, Mackay CE, Ebmeier KP, Sexton CE. Associations Between Longitudinal Trajectories of Cognitive and Social Activities and Brain Health in Old Age. JAMA Netw Open. 2020 Aug 3;3(8)

We can encourage socialization and some hearing aids are now starting to do that for us…

4. Ongoing music training

4. Ongoing music training

Evidence confirms **musical stimuli may also modify synaptic plasticity**. It is proposed that music might be used to enhance cognitive performance.

Rickard NS, Toukhsati SR, Field SE. The effect of music on cognitive performance: insight from neurobiological and animal studies. Behav Cogn Neurosci Rev. 2005 Dec;4(4):235-61.

4. Ongoing music training

Meta-analysis showed cognitive and cerebral benefits of musical practice, both in domain-specific functions (auditory perception) and in other rather domain-general functions. Moreover, these benefits **seem to protect cognitive domains that usually decline with aging.** Therefore, musical practice seems to be a promising tool to reduce the impact of cognitive problems associated with aging.

Román-Caballero, R., Arnedo, M., Triviño, M., & Lupiáñez, J. (2018). Musical practice as an enhancer of cognitive function in healthy aging - A systematic review and meta-analysis. *PloS one*, *13*(11),

4. Ongoing music training

Musical training is **positively and significantly associated with the volume of the inferior frontal cortex and parahippocampus**. In addition, musical training was positively associated with volume of the posterior cingulate cortex, insula, and medial orbitofrontal cortex.

Chaddock-Heyman, L., Loui, P., Weng, T. B., Weisshappel, R., McAuley, E., & Kramer, A. F. (2021). Musical Training and Brain Volume in Older Adults. *Brain sciences*, *11*(1), 50. https://doi.org/10.3390/brainsci11010050

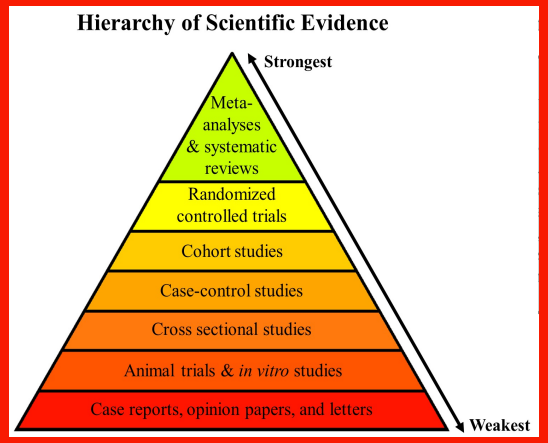
4. Ongoing music training

Our results suggest that a **focal musical activity can be a useful intervention in older adults to promote an enhancement in memory**.

Diaz Abrahan, V., Shifres, F., & Justel, N. (2019). Cognitive Benefits From a Musical Activity in Older Adults. *Frontiers in psychology*, *10*, 652.

4. Ongoing music training

Meta analysis of four studies involving 179 patients showed the benefits of using music to treat memory deficit in patients with **AD**.



Moreira, S. V., Justi, F., & Moreira, M. (2018). Can musical intervention improve memory in Alzheimer's patients? Evidence from a systematic review. *Dementia & neuropsychologia*, *12*(2), 133–142.

4. Ongoing music training

As for children, two metanalyses showed no relationship to music training and improvement in cognitive areas.

Sala G, Gobet F. Cognitive and academic benefits of music training with children: A multilevel meta-analysis. Mem Cognit. 2020 Nov;48(8):1429-1441

Aleman X, Duryea S, Guerra NG, McEwan PJ, Muñoz R, Stampini M, Williamson AA. The effects of musical training on child development: A randomized trial of El Sistema in Venezuela. *Prevention Science*. 2017;18:865–878. .

4. Ongoing music training

Musicians 10-13 y.o. showed higher activation than controls in cognitive regions such as the fronto-parietal control network. In addition encoding of auditory stimuli in musicians was **positively correlated with years of training** and higher activity in the left inferior frontal gyrus and the left supramarginal gyrus, structures that support the phonological loop.

Kausel L, Zamorano F, Billeke P, Sutherland ME, Larrain-Valenzuela J, Stecher X, Schlaug G, **Aboitiz F**. Neural Dynamics of Improved Bimodal Attention and Working Memory in Musically Trained Children. *Frontiers in Neuroscience*. 14: 554731. PMID 33132820 DOI: 10.3389/fnins.2020.554731 .

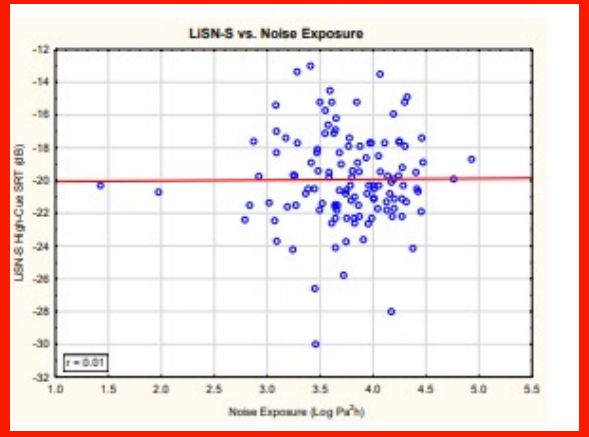
IN SUMMARY…

1. Optimized audibility is an essential first step and we don't achieve that
2. The anatomical/physiological consequences of poor audibility can be devastating to children and adults
3. Even if optimum audibility is achieved we cannot guarantee cognitive protection
4. Focusing only on audibility ignores the risk modification factors of exercise, diet, social interaction and music performance
5. Since we are not exercise physiologists, dietary experts, psychologists or music teachers we need outside referral sources.
6. We do have access to technology that monitors exercise/social interaction

End here

Example 2

In an older cohort of 122 participants aged 30-57 with laboratory-confirmed normal hearing, Yeend et al. (2017) reported **no relation between lifetime noise exposure and a range of auditory processing and SPiN tasks**.

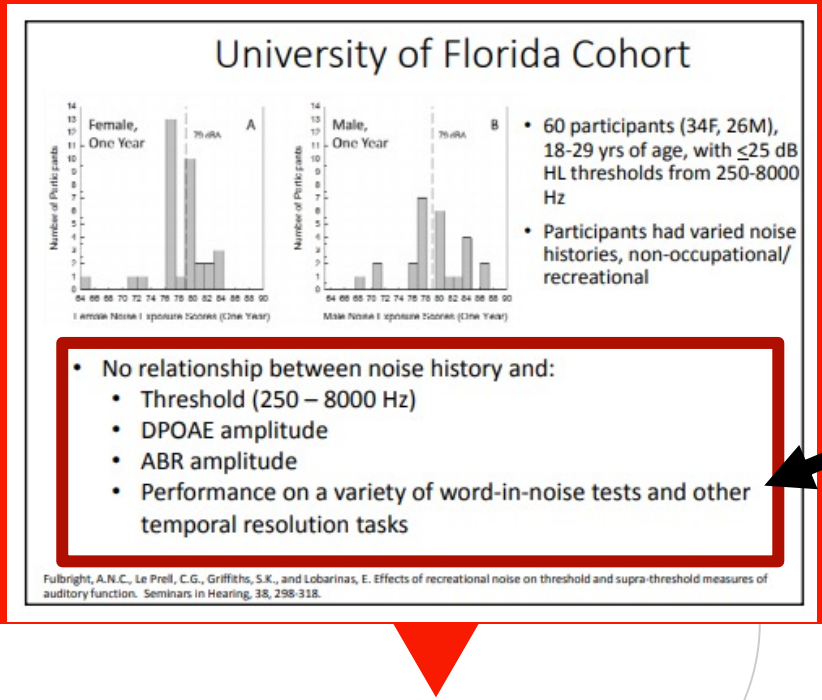


Example 3

Le Prell et al. (2018) similarly **failed to detect any statistically significant relations between performance on the WIN and threshold sensitivity** within this cohort with largely normal hearing subjects

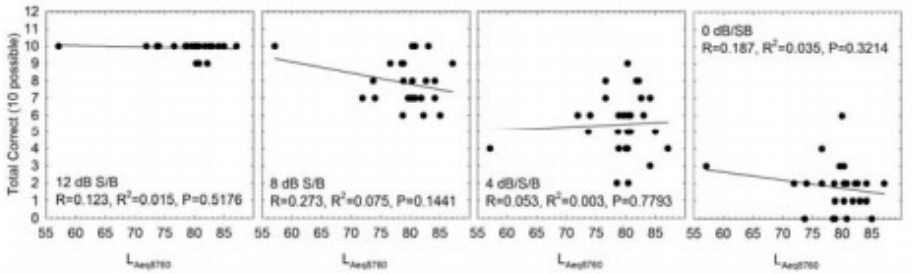
Example 4

For 60 subjects with normal hearing (26 men, 18 to 29 years old)



Example 5

No reliable relationship between previous 12-months noise exposure and Words-in-Noise (WIN) in normal hearing young adults exposed to loud recreational sound



Grinn, S., Baker, J., Wiseman, K., and Le Prell, C. G. Hidden hearing loss? No effect of common recreational noise exposure on cochlear nerve amplitude in humans. *Frontiers in Neuroscience, 11*:465; https://doi.org/10.3389/fnins.2017.00465

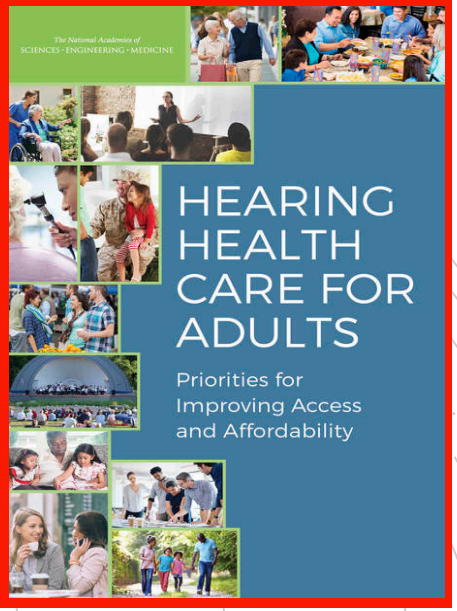
It has been suggested our profession is

Unaffordable

Difficult to access,

Often results in dissatisfaction with hearing health care

Not patient guided



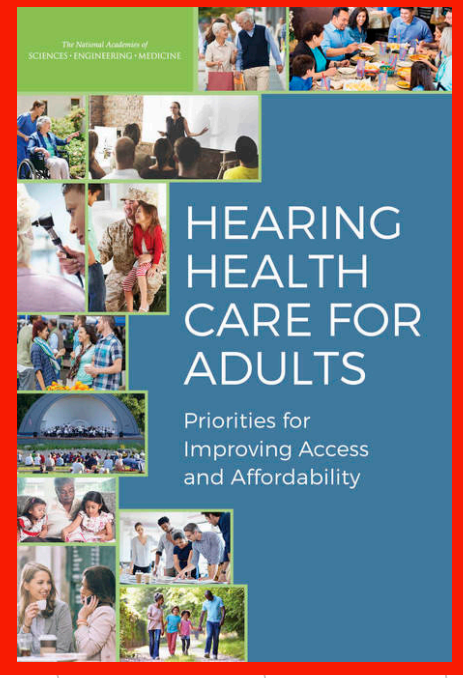
Further, our profession is

Not transparent,

Limited in treatment options,

Fails to provide evidence necessary for consumers to make informed decisions about their hearing health care, and

Using a limited health care delivery and payment system.



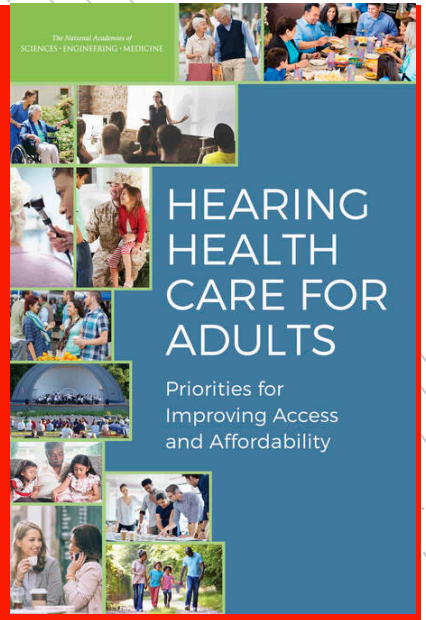
So when explaining our results we must…

Provide affordable options

Be accessible

Clearly inform patients so they can participate in their hearing health care

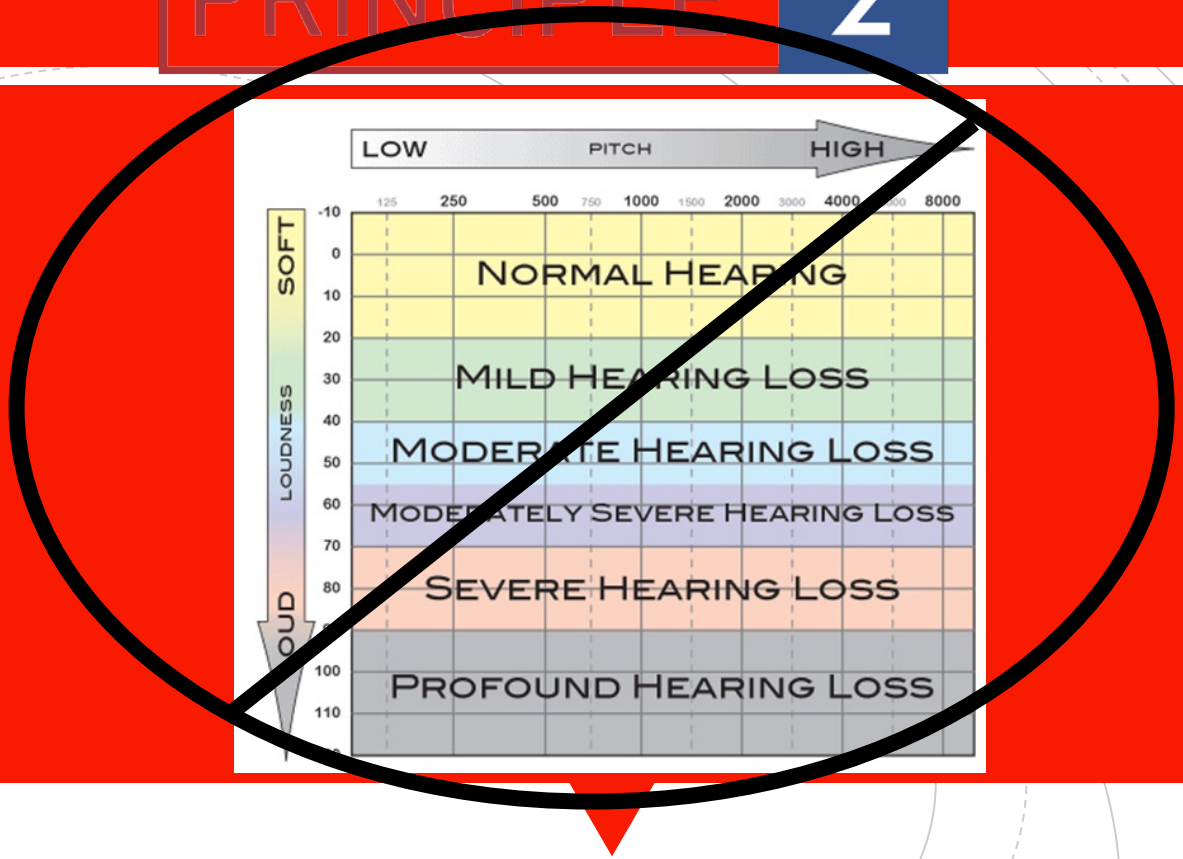
Use a variety of health care delivery and payment systems



Explain hearing loss so it's comprehensible

PRINCIPLE 2

PRINCIPLE 2


LOW
PITCH
HIGH
125
250
500
750
1000
1500
2000
3000
4000
8000
SOFT
LOUDNESS
LOUD
-10
0
10
20
30
40
50
60
70
80
100
110
NORMAL HEARING
MILD HEARING LOSS
MODERATE HEARING LOSS
MODERATELY SEVERE HEARING LOSS
SEVERE HEARING LOSS
PROFOUND HEARING LOSS

PRINCIPLE 2

The current clinical approach of counseling/caregivers using thresholds from the behavioral audiogram can be challenging because the ..degrees of hearing loss are often not meaningful ...

McCreery RW, Walker EA, Stiles DJ, Spratford M, Oleson JJ, Lewis DE. Audibility-Based Hearing Aid Fitting Criteria for Children With Mild Bilateral Hearing Loss. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):55-67.

PRINCIPLE 2

Describing audibility loss instead of hearing loss provides a meaningful context for the impact of the child's hearing levels on communication and a direct comparison to the child's aided hearing levels, if hearing aids are fitted.

McCreery RW, Walker EA, Stiles DJ, Spratford M, Oleson JJ, Lewis DE. Audibility-Based Hearing Aid Fitting Criteria for Children With Mild Bilateral Hearing Loss. Lang Speech Hear Serv Sch. 2020 Jan 8;51(1):55-67.

PRINCIPLE 2

The findings indicate that standard methods of classifying hearing loss in clinics may undermine parents' understanding of their child's hearing loss, causing them to underestimate substantially the magnitude of the loss.

Haggard RS, Primus MA. Parental perceptions of hearing loss classification in children. Am J Audiol. 1999 Dec;8(2):83-92

PRINCIPLE 2

The (hearing loss) terminology has not been standardized and does not appear to reliably predict the impact of the hearing loss on the communication, academic, or language performance of children (Davis, Elfenbein, Schum, & Bentler, 1986; Haggard & Primus, 1999; Martin & Clark, 2000).

Davis, J., Elfenbein, J., Schum, R., & Bentler, R. (1986). Effects of mild and moderate hearing impairments on language, educational, and psychosocial behavior of children. Journal of Speech and Hearing Disorders, 51, 53–62.

Haggard, R., & Primus, M. (1999). Parental perceptions of hearing loss classification in children. American Journal of Audiology, 8, 83–92.

Martin, F., & Clark, J. (2000). Introduction to audiology (7th ed.). Needham Heights, MA: Allyn & Bacon

PRINCIPLE 2

Blair, EuDaly, and Benson (1999) found that teachers at all grade levels had little understanding of their students' hearing loss despite the fact that all of the teachers had received audiologic reports and form letters describing the hearing loss using classification terms.

Blair, J., EuDaly, M., & Benson, P. (1999). The effectiveness of audiologists' information sources for classroom teachers. Language, Speech, and Hearing Services in Schools, 30, 173–182.

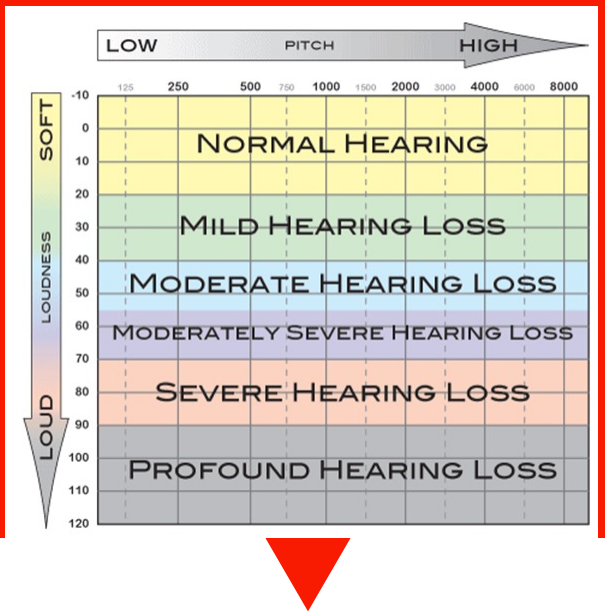
PRINCIPLE 2

The teachers in the Blair et al. study made several suggestions for improving audiologic reports: (a) use lay terms (no jargon); (b) make the reports short and concise; and (c) provide practical, personalized suggestions for the classroom.

Blair, J., EuDaly, M., & Benson, P. (1999). The effectiveness of audiologists' information sources for classroom teachers. Language, Speech, and Hearing Services in Schools, 30, 173–182.

PRINCIPLE 2

To summarize, adult patients, parents, teachers and future SLPs do not understand this classification system or find it usefull…



PRINCIPLE 2

So let’s use McCreery and colleagues suggestion

Describing audibility loss instead of hearing loss provides a meaningful context for the impact of the child's hearing levels on communication

SPEECH INTELLIGIBILITY INDEX MODEL:

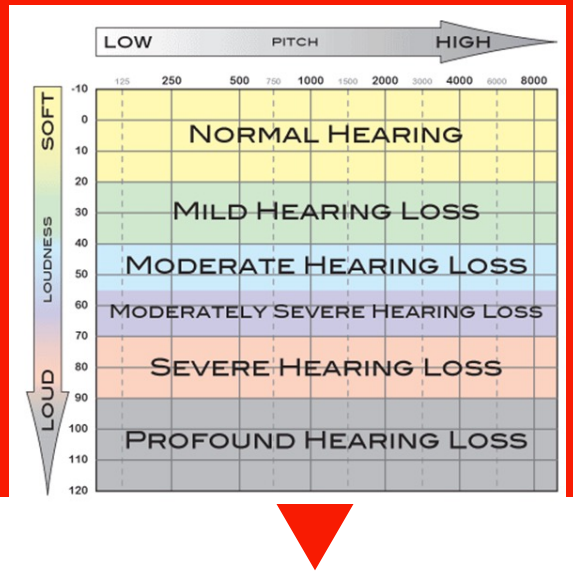
PRINCIPLE 2

How can I do that?

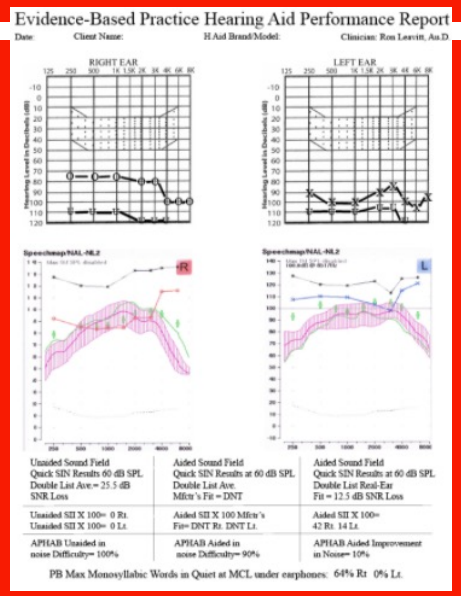
	Enter an HL threshold in EACH box below. Leave no blanks.							
Frequency (Hz)	250	500	1000	2000	3000	4000	6000	8000
Enter HL Threshold >>	50	30	80	75	80	65	70	70
SPL of speech @ 1m >	65	dB	SII >	0.141	Predicted best CST score >			6%

PRINCIPLE 2

How does this system inform the patient/family of what was gained by using the hearing aid?



..but this form can…



Evidence-Based Practice Hearing Aid Performance Report

Date: Client Name: H Aid Brand/Model: Clinician: Ron Leavitt, Au.D.

RIGHT EAR

LEFT EAR

Unaided Sound Field Quick SIN Results 60 dB SPL Double List Ave.= 25.5 dB SNR Loss	Aided Sound Field Quick SIN Results at 60 dB SPL Double List Ave. Mfctr's Fit = DNT	Aided Sound Field Quick SIN Results at 60 dB SPL Double List Real-Ear Fit = 12.5 dB SNR Loss
Unaided SII X 100= 0 Rt. Unaided SII X 100= 0 Lt.	Aided SII X 100 Mfctr's Fit= DNT Rt. DNT Lt.	Aided SII X 100= 42 Rt. 14 Lt.
APHAB Unaided in noise Difficulty= 100%	APHAB Aided in noise Difficulty= 90%	APHAB Aided Improvement in Noise= 10%

PB Max Monosyllabic Words in Quiet at MCL under earphones: 64% Rt 0% Lt.

Leavitt R & Knowles L (2013). A Time-efficient Method and Form for Documenting Hearing Aid Benefit *Hear Rev* Nov 2012