RESEARCH QUICK TAKES

1.1: Some Background On Background Noise

Brian Taylor & Gus Mueller

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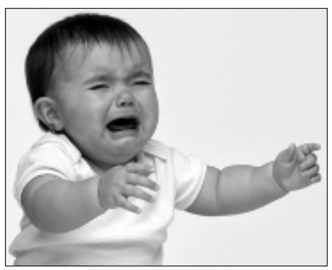
What is noise?

Depends on who you ask. Do you want the view from Physics? Astronomy? Psychology?   Or . . . (gasp) Audiology?

NOISE?



NOISE?

NOISE?

NOISE?

What do our patients consider “noise?”

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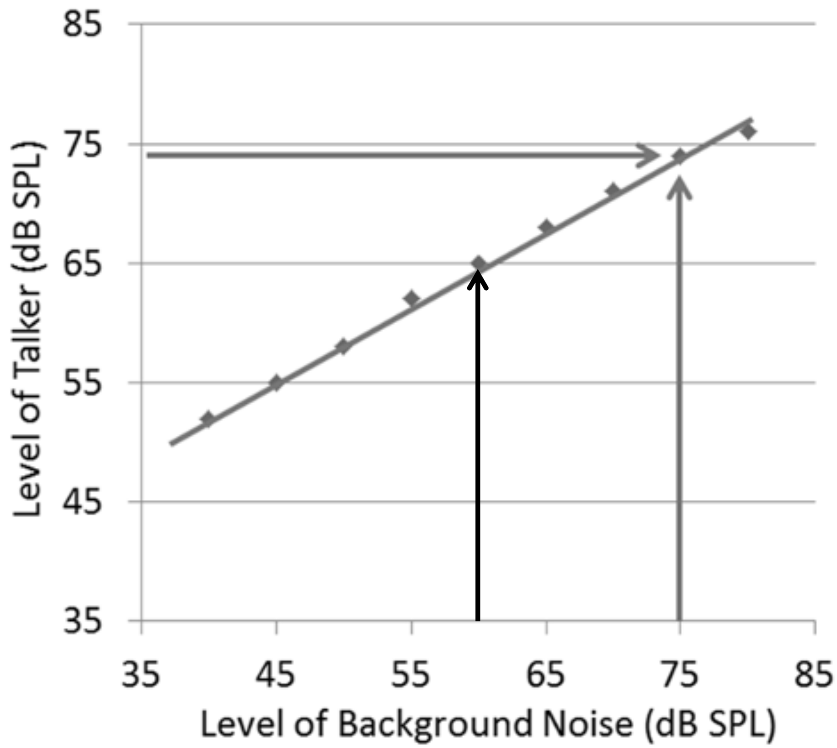
The type of noise matters:

- Energetic masking: Occurs when the neural excitation evoked by the competing signal (background speech or noise or both) exceeds the excitation produced by the target speech. You can think of energetic masking as the same principle as when narrow-band noise is used to mask out a cross-over signal while conducting pure-tone audiometry. In the real-world, an example would be someone trying to understand speech when a loud HVAC system or some motorized appliance like a vacuum is in use. In general, energetic masking is low frequency.

- Informational (perceptual) masking: As the name suggests, this type of masking has informational content, and in most cases, also has an energetic effect. This would be the masking effects of trying to understand someone, with the TV playing or when there is a second talker nearby. In this case, speech becomes noise, as it’s not the speech we want to hear, and it’s an effective masker as the speech spectrum is matched. Moreover, the brain will detect meaningful components from this background signal, interfering with the content of the target speech.

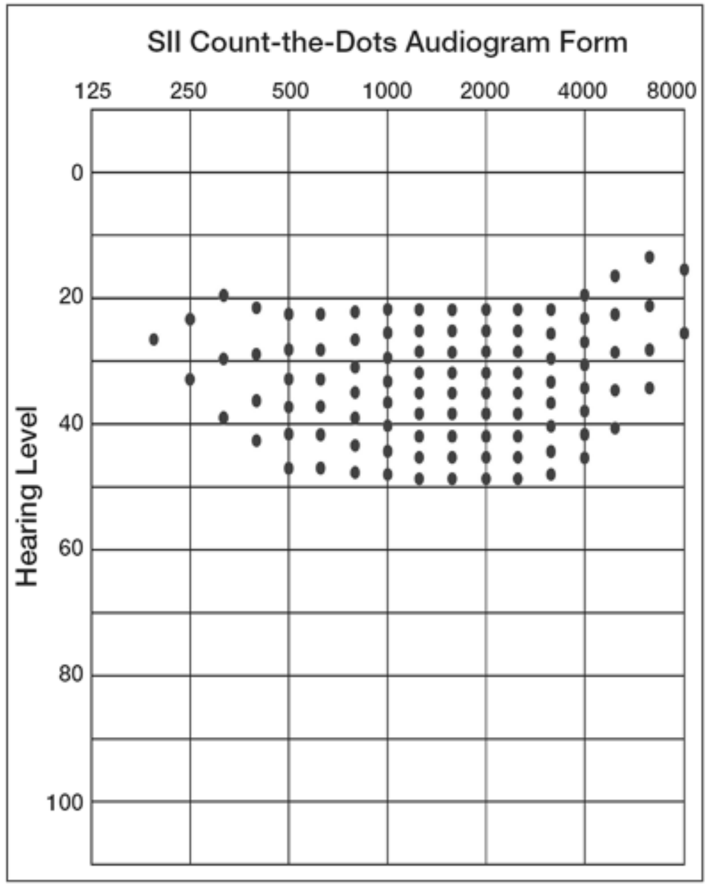
- In the real world we often have a combination of these two maskers. Party noise is a good exmaple—so much so that a much cited research article from the 1950s dubbed this the “cocktail party problem.

A contributing problem related to speech understanding in background noise:



If you need at least a +5 dB SNR to follow a conversation (common with most of our patients), the problem begins when the background noise reaches 60 dB SPL!

Noise and the Speech Intelligibility Index (SII)



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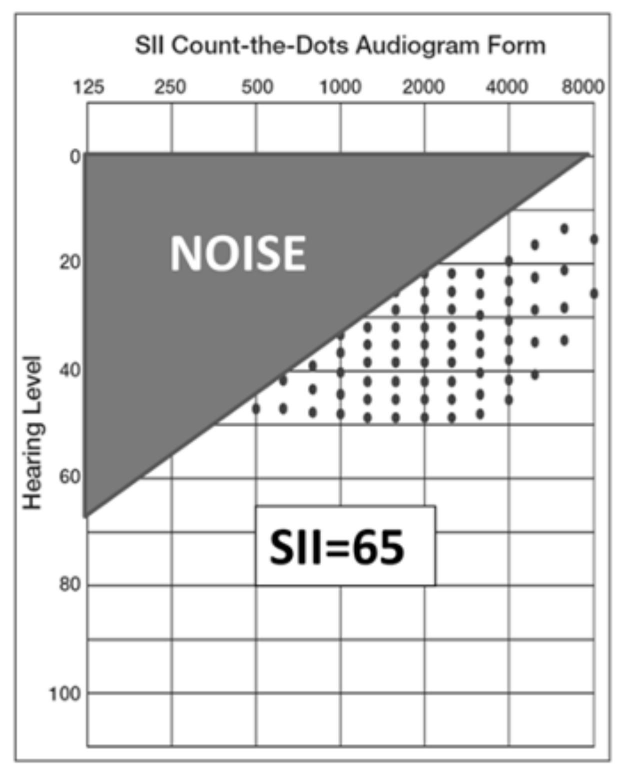
Noise and hearing loss do not get along very well!



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The impact of aging (in addition to the expected hearing loss):

- Structural and neural degeneration occurs throughout the auditory system. For example, binaural separation of signals becomes poorer, an important process for difficult listening situations.

- Cognitive decline can impact speech understanding. This includes processing involving working memory, attention, perception and executive function.

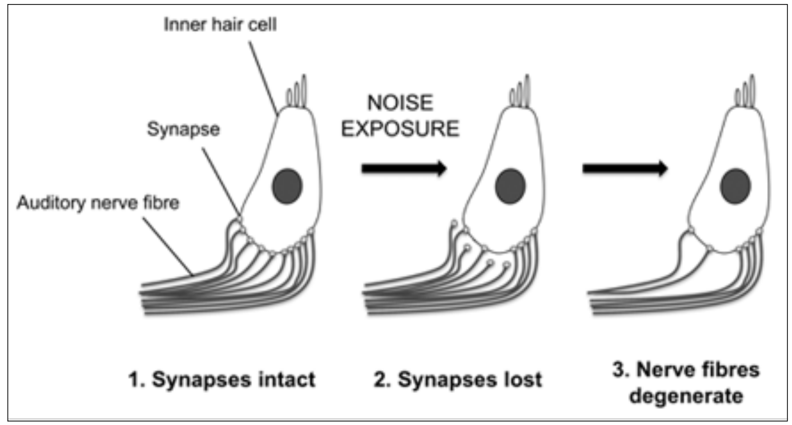
- A decline in these areas also can increase listening effort and cause listening fatigue, directly or indirectly impacting speech understanding for difficult tasks.

And . . . There are even a group of people who are younger and have normal hearing who have problems in background noise:

- Sometimes referred to as "hidden hearing loss," although might not be so hidden if a complete battery of audiologic tests are conducted.

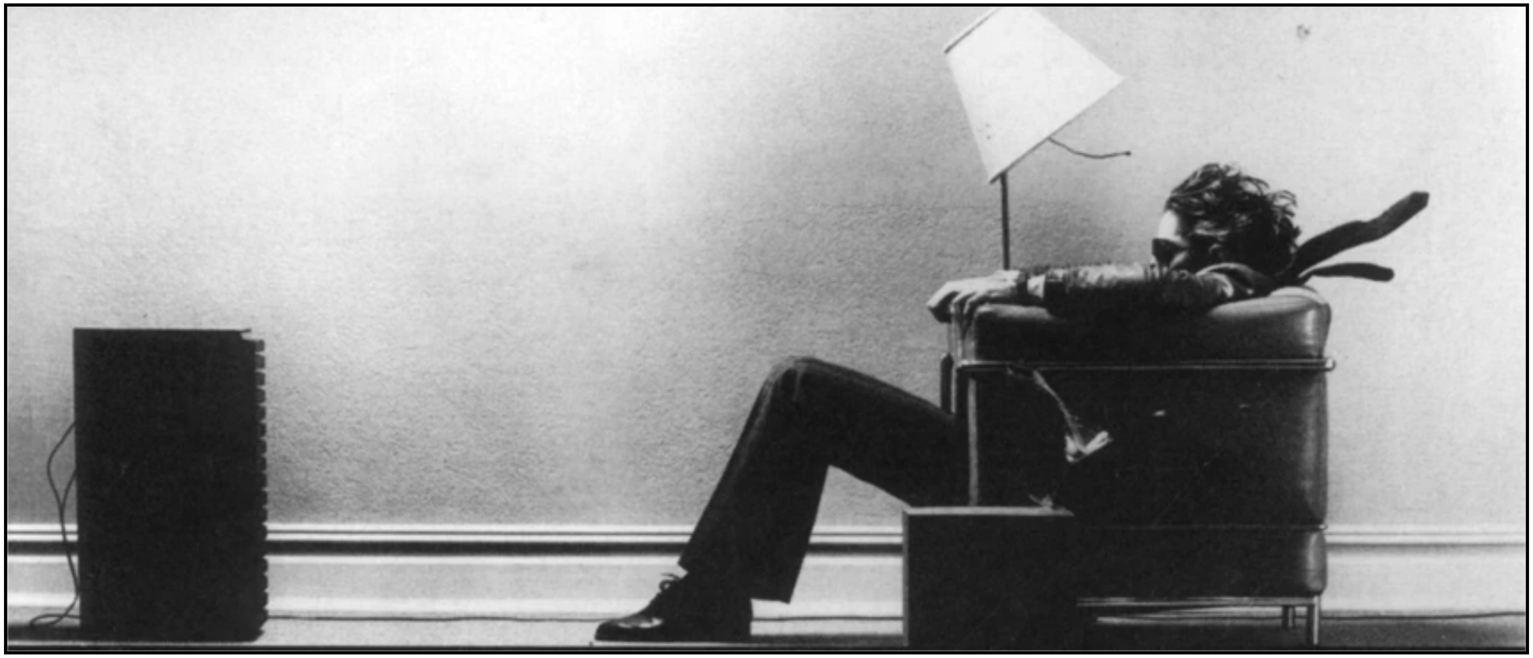
- One cause is cochlear synaptopathy—that is, cochlear synapses that were lost from noise exposure, aging, some form of ototoxicity, or their function was altered or disabled due to genetic mutation.

- There are many other possible causes, such as central auditory processing deficits. What happens to the 5 percent of school age children with APD that grow up?



An interesting link to dementia:

- Recent data has emerged showing that poor speech understanding in background noise also is related to the increased probability of dementia. Health data from more than 82,000 participants over the age of 60 were studied by researchers from the University of Oxford who were looking for dementia risk factors.
- At the beginning of the study, participants were asked to identify spoken numbers against a background of noise. Based on this test they were grouped by the researchers into three groups: normal, insufficient and poor speech-in-noise hearing.
- over 11 years of follow-up, it was found that insufficient and poor speech-in-noise word recognition was associated with a 91% increased risk of developing dementia, compared the group with normal performance on this test.
- Now . . . Many of these 82,000 particpants probably also had hearing loss (not clarified in report), but . . . Nonetheless, an interesting finding.



THIS COULD BE NOISE!

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1.2: Background Noise—How big is the problem?

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What percent of people with hearing loss have trouble in background noise?

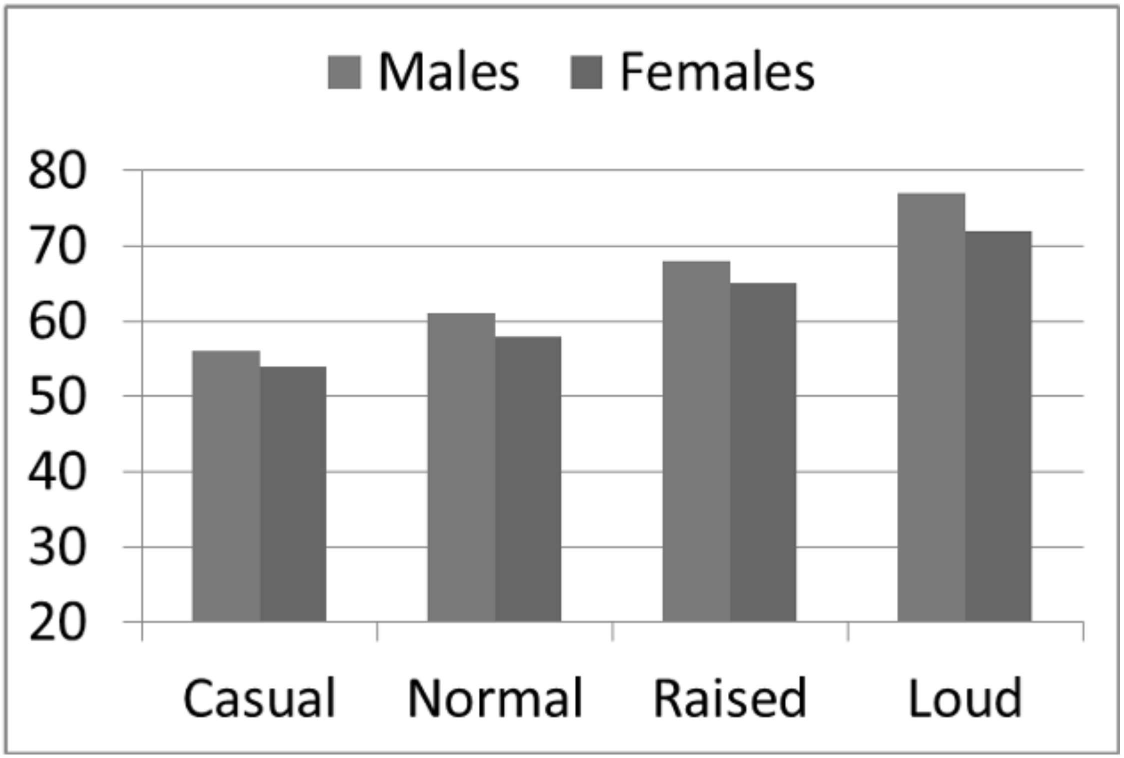
Perhaps the largest sample that we have of clinical speech-recognition-in-noise testing are the data published by Richard Wilson for 3430 veterans (6% had normal hearing).

- For the 3291 that were evaluated with the words-in-noise (WIN) test for both ears, *only 7%* exhibited normal performance (50% correct point of ≤6 d

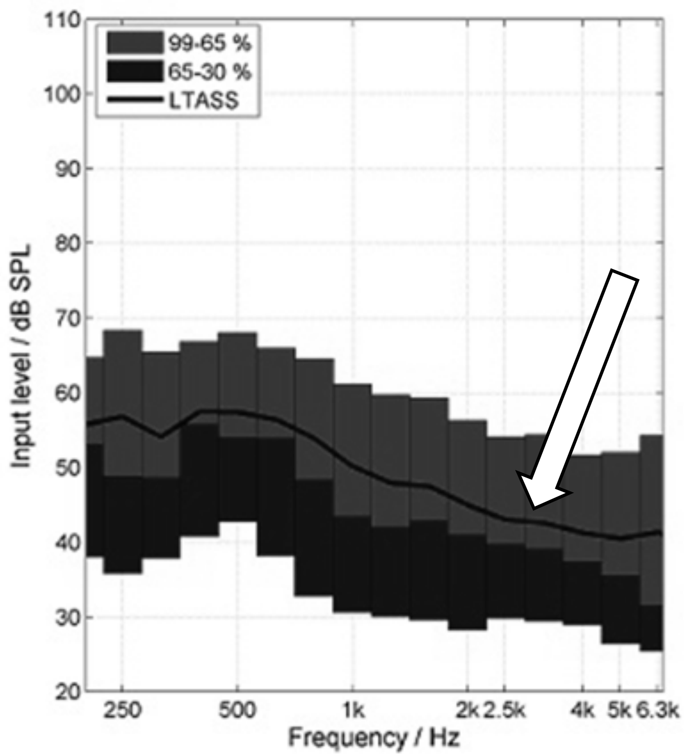
Take note: Cut-off was SNR of +6 dB

- Importantly, but not surprising, 50% of these individuals had speech-in-quiet scores (NU-6) of 90% or better.

To understand the speech-in-noise problem, we need to consider the average levels of speech:



We also need to consider the spectrum of speech; the Long Term Average Speech Spectrum (LTASS):



Note that for important high frequencies, the LTASS is only 45-50 dB SPL!

So if important speech sounds are around 45-50 dB SPL, how noisy is noise?

Some noises from around the house:

- Washing machine=55 dBA
- Dishwasher=58 dBA
- Hand-held mixer/blender=69 dBA
- Vacuum cleaner=72 dBA
- Hair dryer=77 dBA

But, the noises that bother our patients the most do not come from dish washers and blenders . . .

So . . . How noisy are restaurants?

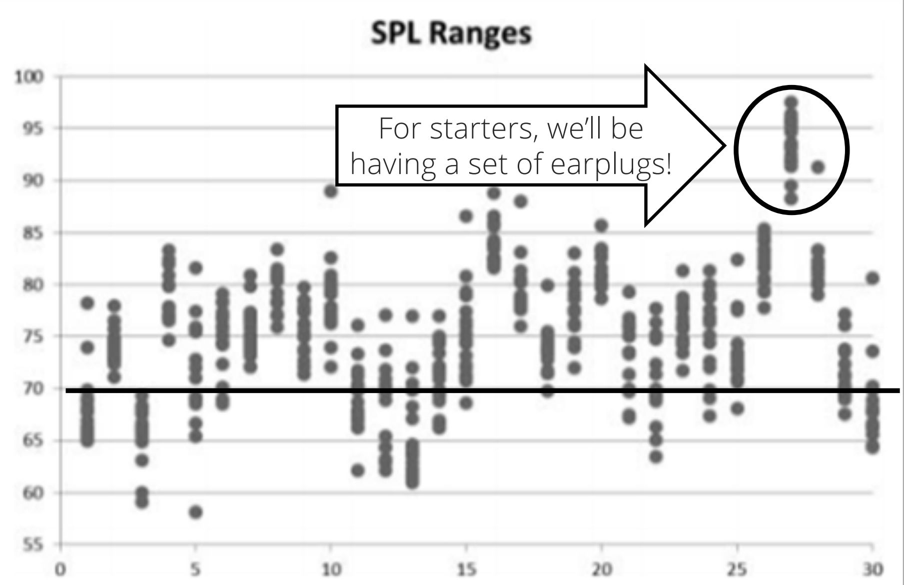


FIGURE 3. SPL ranges for each of the 30 restaurants

Assessment of noise levels in 30 restaurants in Orlando, FL, during a busy time of the day:

- More than ½ of the restaurants had average noise levels over 75 dBA, and 5 (16%) had significant portions of their noise level above 80 dBA.
- Only 7 (23%) had significant portions of their SPL range below 70 dBA.

Our typical patients probably avoid the most noisy places—but still experience handicapping SNRs:

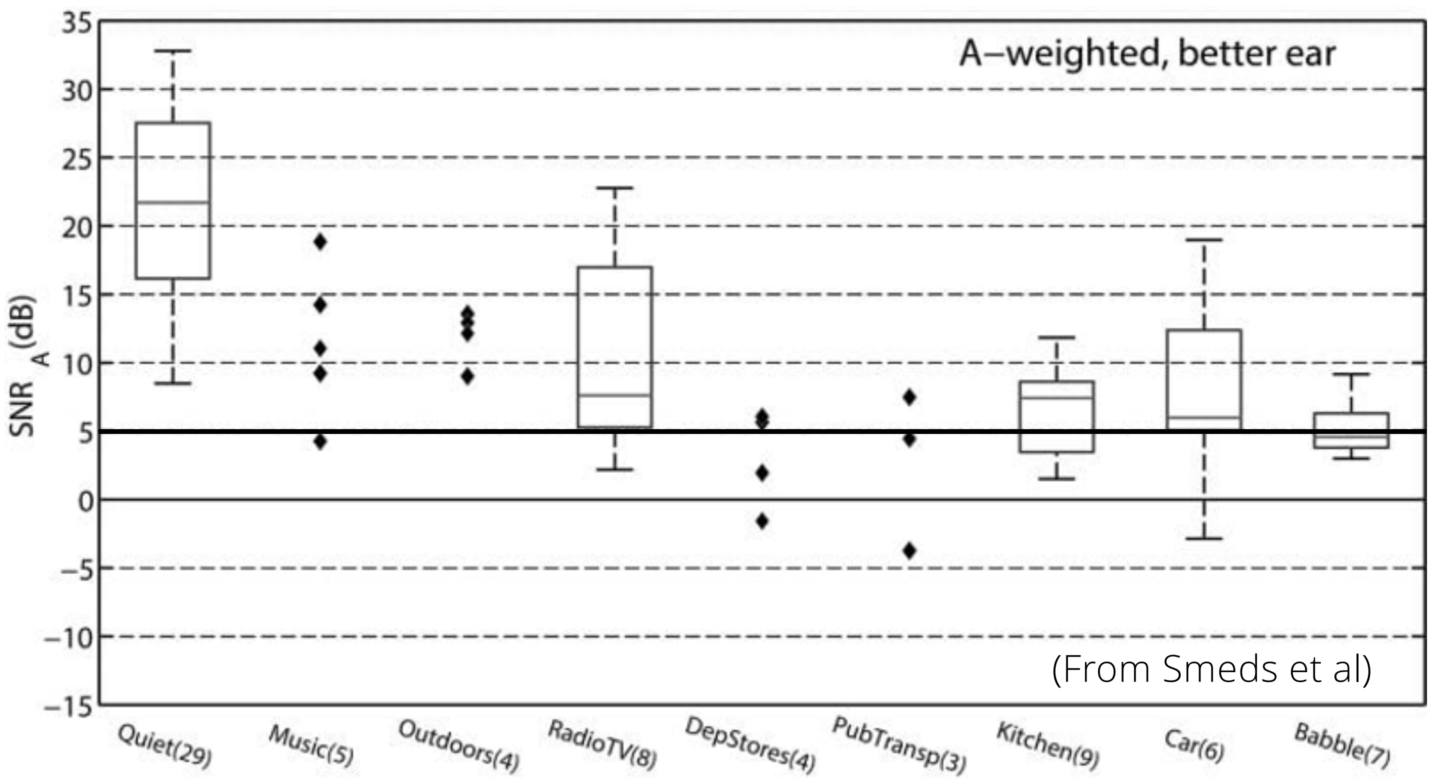
Older adults with mild to moderate hearing loss carried digital recorders for 5 to 6 weeks, recording sounds in their environment for 10 hours per day.

- The speech level, noise level, and SNR of nearly 1000 listening situations were analyzed.
- As noise levels increased from 40 to 74 dBA, speech levels systematically increased from 60 to 74 dBA, and consequently, the SNR decreased from 20 to 0 dB.
- Most SNRs (62.9%) were between 2 and 14 dB.
- Situations that had SNRs below 0 dB comprised 7.5% of the listening situations.
- The mean SNR of the "noisy environments" was 7.4 dB. A subset of the noisy observations had lower SNRs (mean=4.2 dB).

This could be a very important 7.5% of their life!

Recall earlier data: 93% could not score 50% correct at SNR=6 dB.

Another look at average SNR levels:



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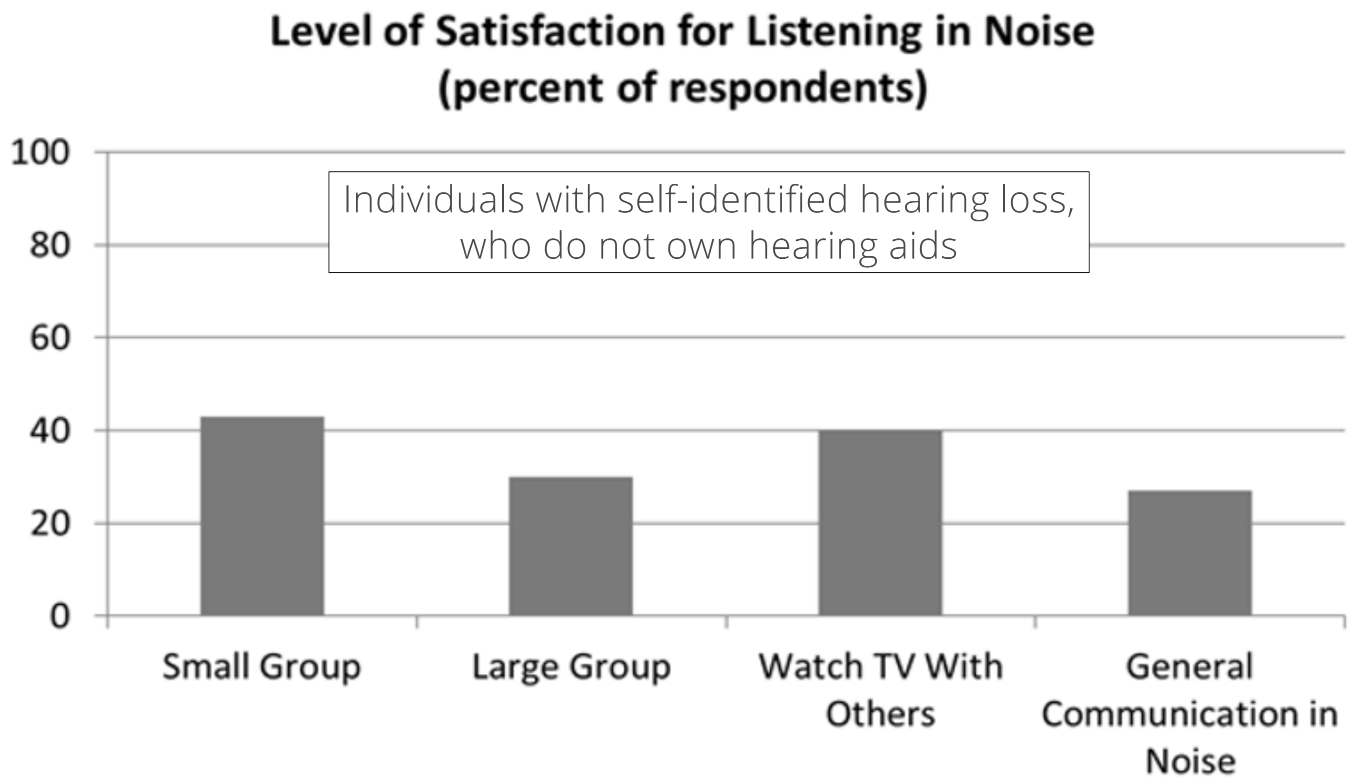
Self-report from the real world: The APHAB

- The average patient (50th percentile; mild-to-moderate loss) on the APHAB reports 75% percent-of-problems in background noise.
- Even at 20th percentile, percent-of-problems is still 58%.
- Important to remember: The average older person with normal hearing will report 25% percent-of-problems for listening in background noise—good to know when aided performance is assessed.

Self-report from the real world: MarkeTrak 10



Yes, background noise is a big problem . . .

But stay tuned—we have ways to make things better!

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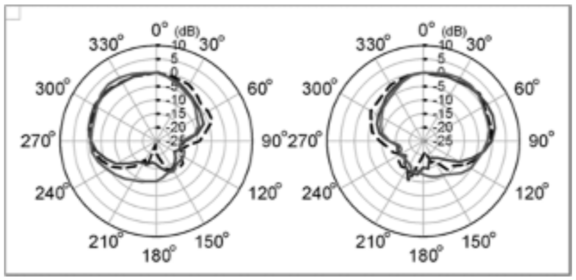
Simply stated: Improving speech understanding in background noise is all about enhancing the desired speech signal, and/or reducing the intensity of the noise

Directional technology: Applies different amounts of gain based on the azimuth of the origin of the signal. Gain is not reduced, and maybe enhanced for the azimuth of the desired speech signal.

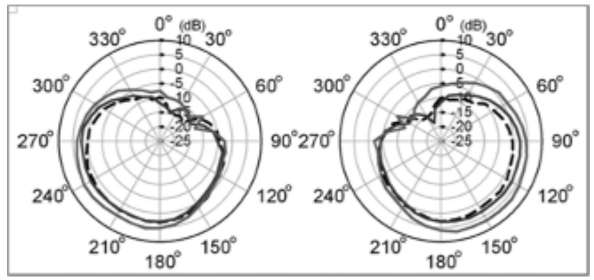
Noise reduction: Traditionally is not azimuth sensitive, but does differentiate speech from noise. In most cases the primary effect is channel-specific gain reduction.

A quick review of polar plots:

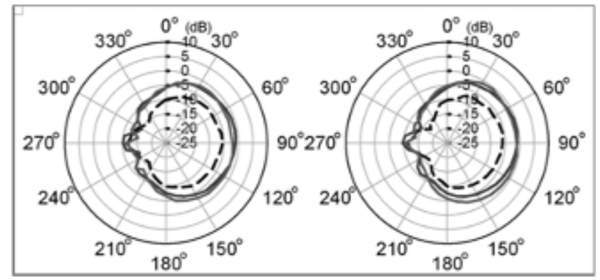
Speech at 0, Noise at 180



Speech at 180, Noise at 0



Speech at 90, Noise at 270



Representative polar plots for the right and left ears of the KEMAR: The distance that the outer curve is from the center of the circle represents the amount of gain for that specific azimuth. Polar plots are used to calculate the directivity index (DI), and indicator of the effectiveness of the directional processing.

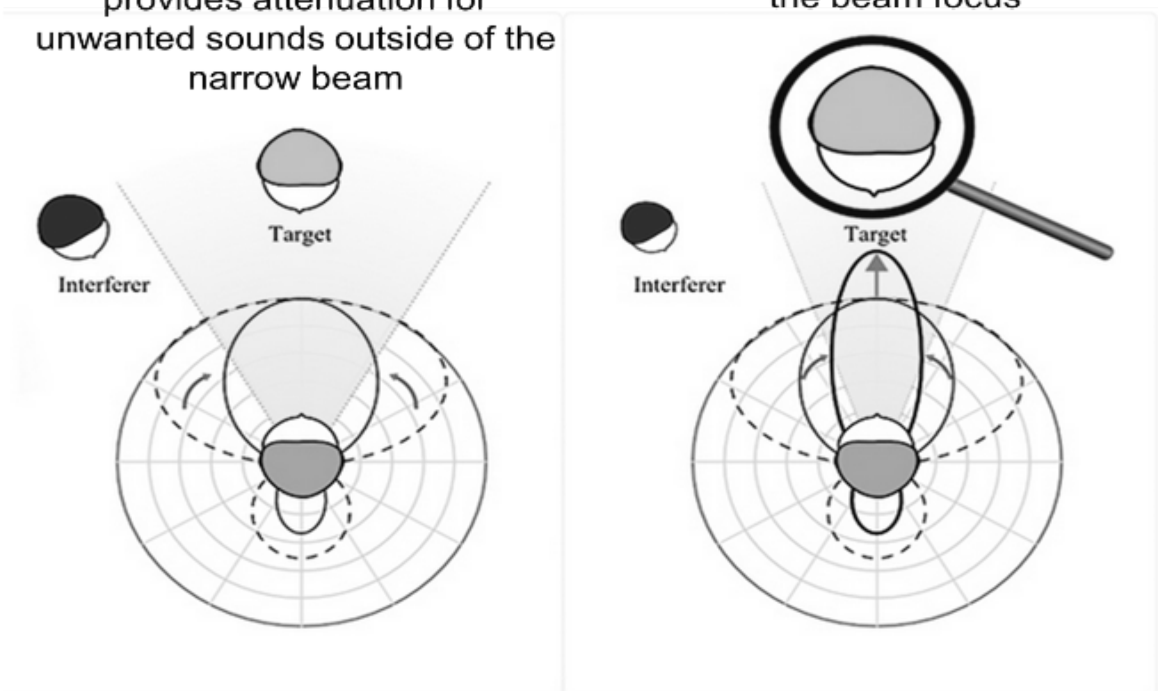
Advancement in directional technology:

- Automatic switching
- Adaptive polar patterns
- Tracking polar patterns
- Frequency specific polar patterns
- More sophisticated signal classification
- 360 Spatial Focus (e.g., focus to back and sides)
- Partnership with DNR—polar pattern focus
- Narrow directivity

Narrow Directivity: Full bilateral data sharing:

Narrow directivity allows for a focus on the desired talker, and provides attenuation for unwanted sounds outside of the narrow beam

We also can provide a boost in intensity for the signal within the beam focus



Note: Some have suggested that this focus impairs speech understanding for off-center talkers—research has shown this is not true.

How good is narrow directivity?

Over the past 6 years, four independent studies have shown that when individuals, with mild-to-moderate hearing loss, are fitted with hearing aids employing narrow directivity, their performance for speech-in-noise understanding is significantly better than their age-matched peers with normal hearing.

What we know about digital noise reduction:

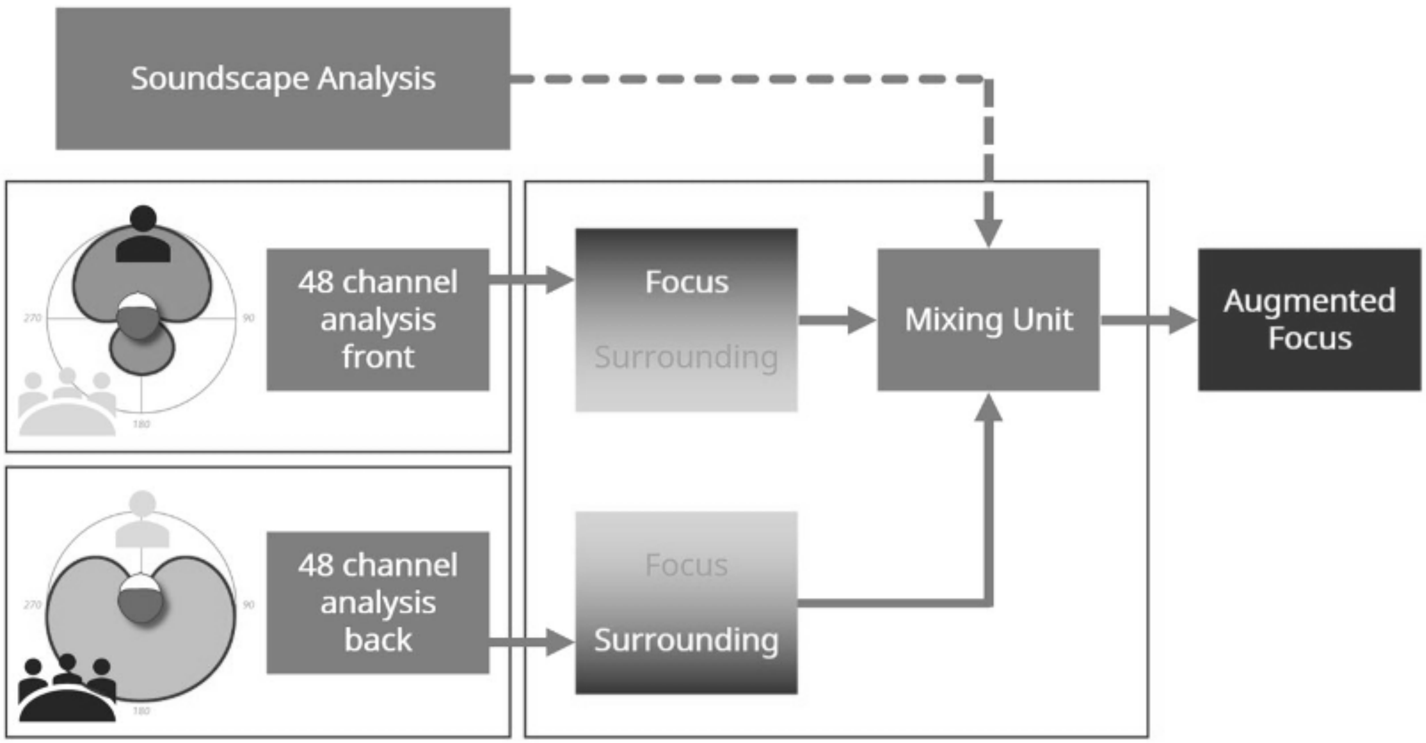
- Doesn't provide a large improvement in SNR
- Does provide relaxed listening (which might indirectly enhance speech understanding)
- Does reduce listening effort (which might indirectly enhance speech understanding)
- Does help free-up cognitive resources (which might indirectly enhance speech understanding)
- And . . . Nearly all hearing aid users prefer "DNR-On" versus "DNR-Off" for general listening in background noise

Several DNR systems exist today:

- Modulation based gain reduction
- Spectral subtraction (Wiener filtering)
- Sound smoothing—sharp amplitude peak reduction
- Echo reduction
- Wind noise reduction

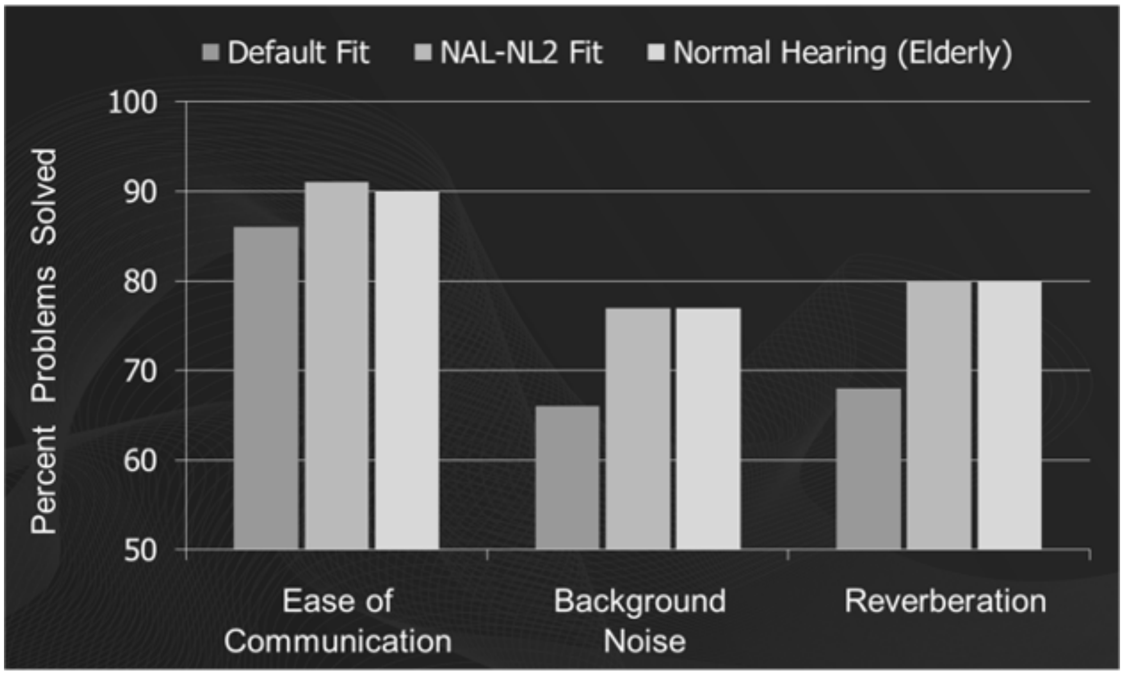
Several of these could be functioning simultaneously

The latest advancement in digital noise reduction:



So with all this advanced technology to assist with speech understanding in noise—do real-world studies show it is making a difference?

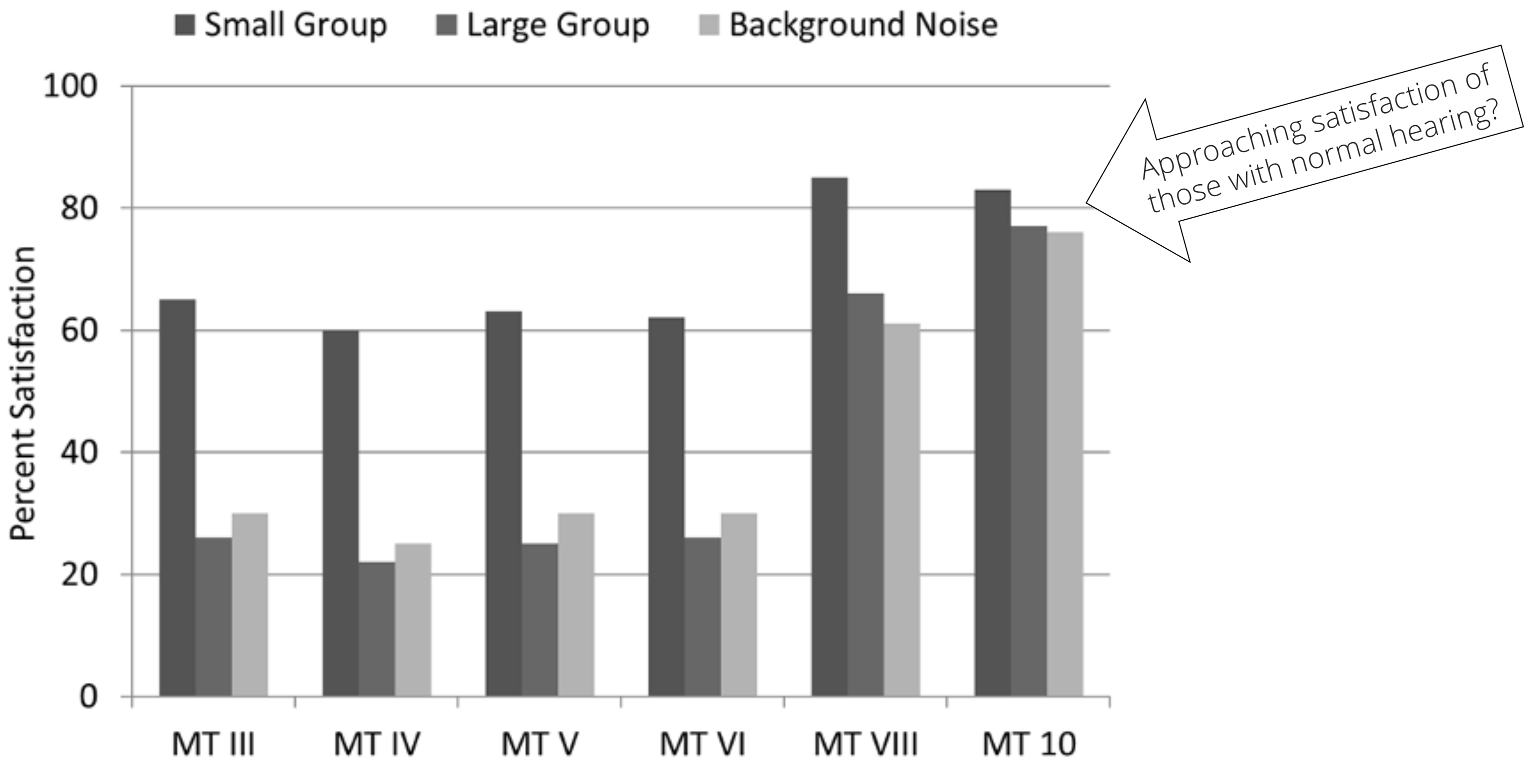
Reports from the real world: APHAB findings



From Valente et al, 2018

Note that when the participants were fitted to the NAL, APHAB ratings were the same for those with hearing loss, as for their normal-hearing peers.

Reports from the real world: MarkeTrak since 1991



Reports from the real world: MarkeTrak 10 findings