Measuring the objective and subjective limens for speech intelligibility benefits

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INTRODUCTION

The inability to provide appreciable speech-in-noise benefits can lead to the non-use of hearing aids (McCormack & Fortnum, 2013). Non-use can come from unmet expectations (i.e., benefits without satisfaction; Demorest 1984) manifest as meaningless benefits or simply undetectable benefits. Here we look specifically at objective and subjective speech intelligibility benefits based on changes in signal-to-noise ratio (SNR) when the signal is speech.

Based on the premise that a meaningful benefit should be a reliably discriminable benefit, we measured, using multiple procedures, what is a **discriminable benefit** : the just noticeable difference in SNR.

But a JND is a psychophysical benchmark. How large does a change in speech in noise need to be for it to be meaningful to someone? What is meaningful and clinically significant is often applied to service-wide treatments; here , we look at what could induce intervention-seeking behaviour for an individual. That is, how much subjective value do patients ascribe to discriminable speech intelligibility benefits?

Using the same stimuli as examples of pre- and post-benefit situations, we also measured what is a **meaningful benefit** : the minimum SNR change necessary to spur someone to seek out a clinical intervention (e.g., a new or adjusted hearing aid).

SUMMARY

We presented paired examples of speech and noise, one at a reference SNR and the other at a variably higher SNR, to examine what are discriminable and meaningful speech intelligibility benefits

The threshold for a discriminable benefit was 3 dB

The threshold for a meaningful benefit was 6~8 dB

At least 6 dB – more in less noisy situations – is necessary to motivate participants to seek an intervention based solely on changes in speech and noise levels.

There is no *wow* in demonstrable SNR benefits.

STIMULI

The same stimuli were used across experiments.

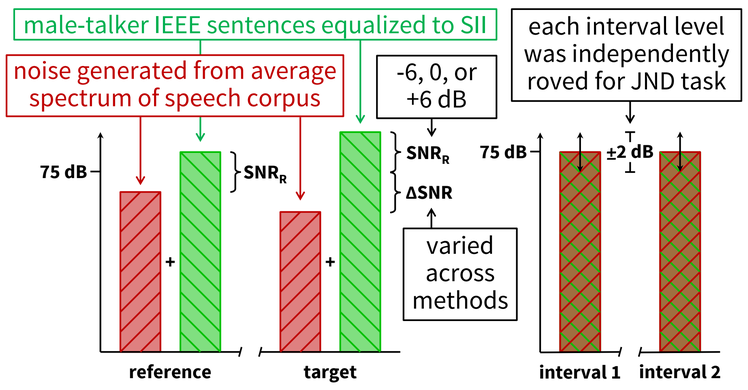


FIGURE Schematic of stimulus generation. Speech signals were recorded at 22.05 kHz sample rate (Faulkner & King 2006), equalized to match SII standard spectrum for normal vocal effort (i.e., flat to 500 Hz then -9 dB/oct). A random sentence was chosen for each trial.

APPARATUS

Participants were seated in a sound-proof audiometric booth. Stimuli presented diotically through circumaural headphones. Touch-screen monitor recorded responses.

DISCRIMINABLE BENEFIT

2AFC task

- *Which one was clearer?*
- Compare speech and noise levels in each interval

Adaptive track procedure

- 3↓/1↑ ⇒ 79% estimate
- Starting ΔSNR of 12 dB
- Ref SNRs (SNR_R) : 0 & +6 dB
- √3, √2 & √1.5 multiplicative step sizes; reversals of 2, 2 & 4
- Geometric mean of last 4 reversals ⇒ threshold
- Average best 2 of 3 thresholds

Fixed-level procedure

- ΔSNRs : 0.5, 1, 2, 3, 4, 6 & 8 dB
- SNR_R of 0 dB only
- Total of 40 trials @ each ΔSNR
- 79% estimate using MLE logistic

Results : 3 dB SNR JND

	+6 dB ref mean (σ)	**0 dB ref** mean (σ)
Adaptive (*n* = 44)	**3.5** (1.5) *	**2.9** (1.3)
Fixed-level (*n* = 25)	**3.3** (1.3)	**3.0** (1.0)

TABLE Summary of SNR JND results for adaptive and fixed-level procedures. There was a significant difference (*) between SNR_R although the η^2 was small. Excluding two listeners as outliers (i.e., JNDs ≥ μ + 3σ), fixed and adaptive results were equivalent (~**3** dB).

Issues

- Level roving to eliminate level cues may have been inadequate (underestimate)
- Order effects : 12% increase when better SNR in 2nd interval
  - Possible sign that JND may be (partly) an intelligibility JND

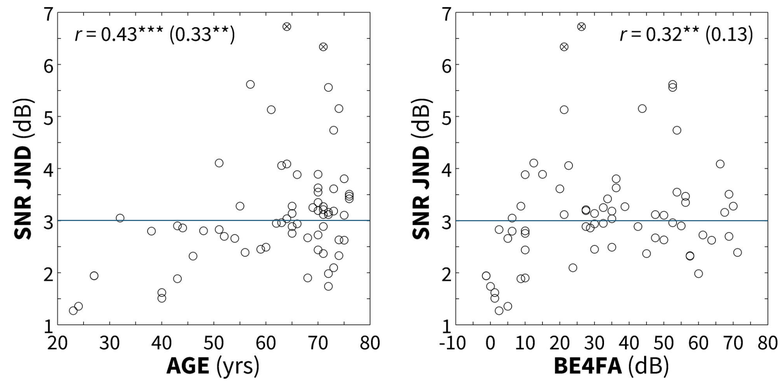


FIGURE Individual discriminable SNR results for 0 dB SNR reference as a function of age (left panel) and better-ear four-frequency average (BE4FA) hearing loss (right panel). Outliers from the fixed-level method (with means 3σ greater than the group mean) are shown with crosses. Line shows mean SNR JND excluding outliers.

SNR JND (~3 dB) > Level JND (~1 dB)

- Task difficulty of simultaneous + sequential comparison
  - Potential source of correlation between JND and age
  - Glimpsing of speech envelope in "steady" noise background
- JND possibly less for single talker, most likely more for real scenarios (multiple distractors, reverberation)

MEANINGFUL BENEFIT

Multiple subjective-comparison tasks using SNR_R and SNR_R + ΔSNR pairs as examples of situations to measure meaningful SNR change.

1) **RATING** [±5] How much better/worse is the change in SNR
2) **SWAP** [Y/N] If they would swap a current device (SNR_R) for a different device (SNR_R + ΔSNR)
3) **CLINICAL SIGNIFICANCE** [Y/N] If they would be willing to go to the clinic for the given SNR increase (benefit) or decrease (deficit)

1) RATING

- *How was the second example compared to the first?*

-5	-4	-3	-2	-1	0	1	2	3	4	5
much worse				*same*					*much better*	

- 33 HI adults
- SNR_R : 0 dB
- Clear order effect (positive vs. negative change)
  - Positive > 1 @ **4 dB** ΔSNR
  - Negative > |1| @ **~8 dB** ΔSNR
  - Possible sign of increased intelligibility with repetition
- *But what does a unit change represent?*

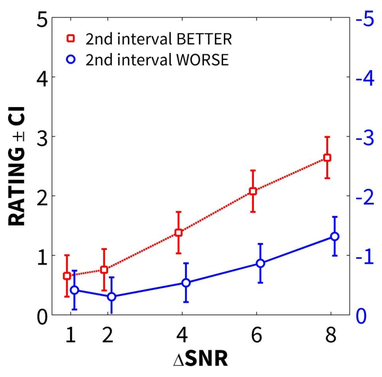
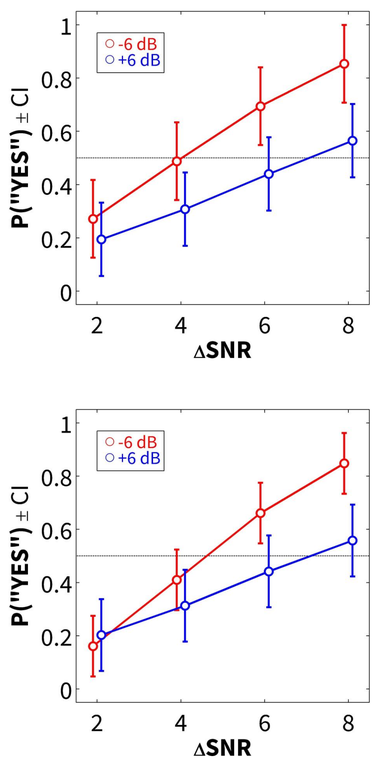


FIGURE Results of rating task for all participants showing mean better (□) and worse (○) rating as a function of SNR change; error bars show 95% within-subject CIs.

2) SWAP

- *Would you swap your current device for a different one?*
- 35 HI adults
- Using P("YES") > chance (0.5) as threshold for willingness to swap devices
- Effect of SNR_R :
  6 dB ΔSNR @ -6 dB
  8+ dB ΔSNR @ +6 dB
- Examining participant subset who at least tried hearing aids (*n* = 23) did not change results
- Used questionnaires of general health and hearing status to examine variability
  - Correlation between QoL & individual P(Y) @ ΔSNR = 4 (*r* = -0.44*)
  - No correlations between P(Y) & HA benefit, duration of use or background-noise annoyance



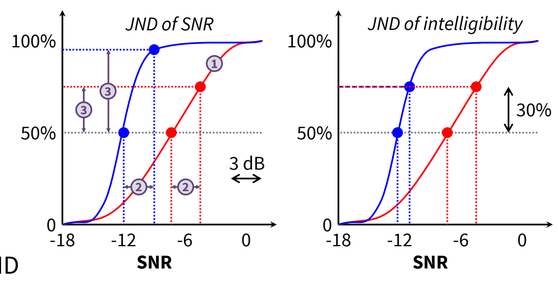
FIGURES Results of swap task for all participants (*top panel*) and only those participants that reported via questionnaire to have at least "tried" hearing aids (*bottom panel*). Willingness to swap did not exceed chance until 6 dB SNR change in -6 dB SNR condition.

SNR *vs.* INTELLIGIBILITY

Have we measured a JND of SNR *or* intelligibility?

- Used two signal/noise pairs with different psychometric functions : digit triplets/white noise & IEEE sentences/LTASS noise

① Measured % correct (PC)
② Measured SNR JND at 50% SNR_R
③ Estimated Intell. JND from logistic fits & SNR JND



- SNR *vs.* Intelligibility JND : *Which is (more) constant across stimuli?*

RESULTS (in progress)

Stimulus JND absolute difference : **0.4 dB** (σ 0.5) / **11.8%** (σ 4.5)

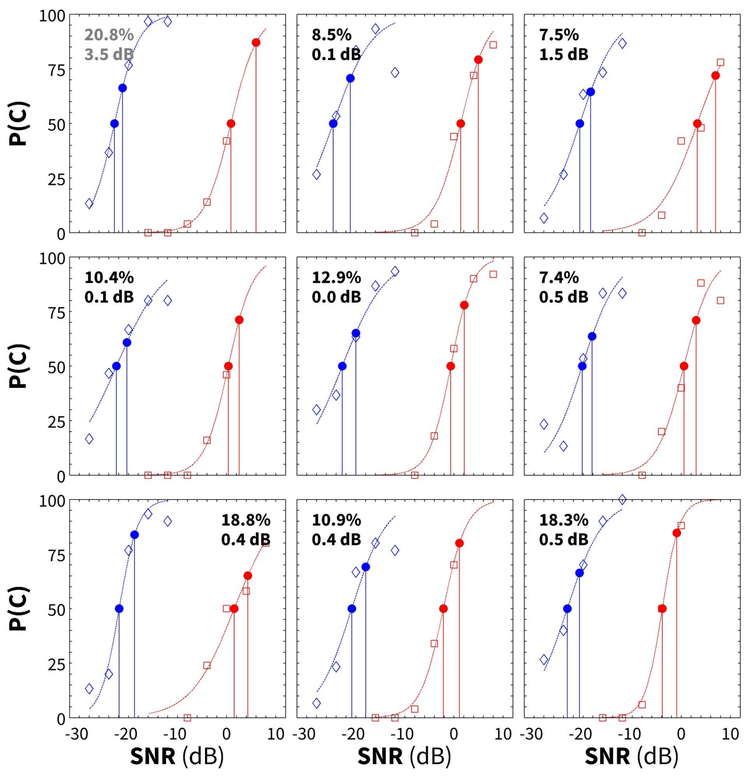


FIGURE Individual speech-intelligibility psychometric functions for digits (◇) and sentences (□) showing SNR JNDs for both (●).

3) CLINICAL SIGNIFICANCE

- *Would you go the clinic if it made the first sound as clear as the second?*
- 21 HI adults
- Using P("YES") > chance (0.5) as threshold for willingness to seek intervention
- Effect of SNR_R :
  6 dB ΔSNR @ -6 dB & 0 dB
  8+ dB ΔSNR @ +6 dB

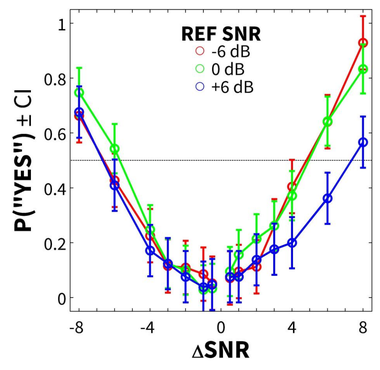


FIGURE Proportion "yes" responses in clinical significance task as a function of SNR change; error bars show 95% within-subject CIs.

- Six additional participants (22%) were unresponsive and excluded – *task-length issue?*
- Repeated task with less conditions + SNR JND task
- 35 HI adults
- Similar results without clear SNR_R interaction :
  6 dB ΔSNR @ -6 dB
  8+ dB ΔSNR @ +6 dB
- No correlations with SNR JND

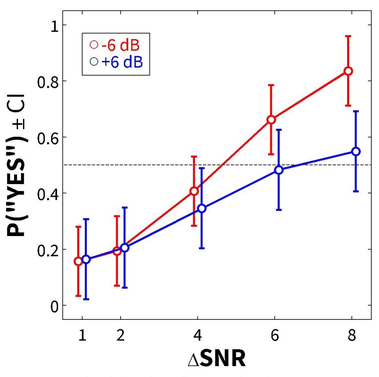


FIGURE Results of clinical significance task. Willingness to swap devices for a better SNR was only shown at ΔSNRs ≥ 6 dB.

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