EVALUATION OF SPEECH INTELLIGIBILITY DURING THE TRACKING OF NOISE TOLERANCE (TNT) TEST

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INTRODUCTION

The amount of background noise that an individual is willing to accept while listening to speech is predictive of his/her hearing aid satisfaction[1]. The Tracking of Noise Tolerance (TNT) test was designed to measure how much noise an individual accepts over time while understanding 90% of the speech. The TNT is a reliable and efficient clinical test that allows measurement of a listener's acceptance for noise — with and without hearing aids — so that the results can be compared to normal-hearing listeners, across various hearing aid features, and on the same individual over time. The test has a within-session test-retest reliability of 2 dB and a between-session reliability of 4 dB[2]. The tolerable noise level has been shown to correlate with hearing aid satisfaction in real-life noisy situations[3].

What constitutes 90% subjectively estimated speech understanding varies among individuals. People who overestimate their speech understanding would likely accept a higher noise level than those who underestimate. Furthermore, it would also be reasonable to suspect that people who overestimate their speech intelligibility will be more accepting of their hearing aids in noise than those who underestimate. Listener's subjective criterion for speech intelligibility in noise could be an important piece of profiling information to identify challenging patients, and to select the necessary hearing aid features to meet different criteria needs. In this study we developed a method to estimate speech intelligibility during the noise tracking task using objective and subjective performance-intensity (P-I) functions generated for each listener individually, as well as with SII-based estimates in normal-hearing and hearing-impaired listeners.

METHODS

Participants

- NH GROUP: N = 22 (mean age = 63.9 yrs, SD = 8.2 yrs, 16 female).
- HI GROUP: N = 17 (mean age = 76.9 yrs, SD = 8.4 yrs, 6 female).
- Bilaterally symmetrical (+/- 10 dB) mild-to-moderately severe sensorineural hearing loss.
- All native speakers of American English.
- >24 on the Montreal Cognitive Assessment (MoCA) test (Nasreddine et al., 2005).

Tracking of Noise Tolerance (TNT)

During the TNT test the listener adjusts the noise level adaptively while listening to a continuous speech passage (8 passages available).

> *"You will hear some noise in the background while you listen to the male talker. The noise will automatically get louder. I want you to monitor the noise level and maintain the loudest noise level you can put up with while still understanding 90% of the words in the story. If the noise becomes too loud, where you can no longer put up with it or understand, 90% of the words in the story, you can turn the noise down by pressing and holding the space bar. If it appears softer than before, you should allow the volume to increase by letting go of the space bar. If it is louder than before, you should turn the volume down to keep at the same level by pressing the space bar again. Your ability to understand speech should never change to < 90%. The test will run for 2 min and then stop."*

A fixed 75 or 82 dB SPL speech level was used to approximate the speech level in loud background noise. The passages were filtered to reflect speech spectrum changes at different the vocal efforts[4]. The background noise was continuous speech shaped noise (ICRA). The speech and noise were presented in free field from 0°. The noise level started at 10 dB below the speech level. The rate of noise level change was initially 1 dB/sec and reduced to 0.5 dB/s after the first 6 reversals. The participants adjusted the noise level using the keyboard spacebar. The passages and test levels were counterbalanced across participants and test conditions. A practice trial was provided to ensure participants understood the instructions.

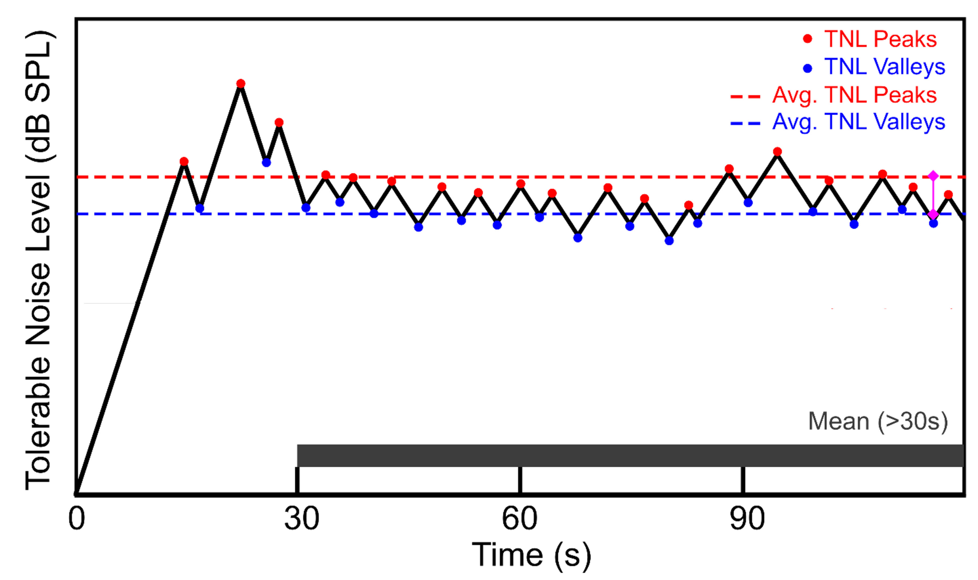

Figure 1. An example of the TNT trace. Average Tolerable Noise Level (TNL) from 30 sec until end of testing is converted to TNT score by subtracting the speech level. Avg. Peak/Valley TNL is average TNLs across all peaks/valleys in single TNL trace, converted to TNT score by subtracting the speech level.

Intelligibility estimation

P-I functions were estimated for the TNT materials by isolating fifteen sentences from each TNT passage. The full P-I functions were measured using SNRs of -9, -6, -3, 0, and 3 dB with NH listeners, while HI listeners were tested at individualized SNRs.

SUBJECTIVE (PERCEPTION): A scale from 0 to 100%.

OBJECTIVE (PERFORMANCE): Participants repeated the sentences. Scoring was based on keywords (3 sentences / 10 keywords per SNR).

P-I functions were derived for each participant individually by fitting a logistic regression function

$$\varphi(x) = (1-\lambda)\left(1 + e^{(-\beta*(x-\alpha))}\right)^{-1}$$

where x is the SNR, α is the threshold parameter (i.e., SRT-50), β is the rate of change parameter (i.e., slope), and λ is the lapse rate parameter (i.e., upper asymptote).

SII BASED ESTIMATE:
Audibility based estimates for speech intelligibility were calculated using SII[4]. The transfer functions to relate SII values to speech recognition scores was estimated based on NH objective performance data. Each NH listeners own data was excluded from the SII transfer function estimation when estimating his/her performance (k-fold cross-validation). Transfer functions derived for each participant individually by fitting an exponential function

$$S = \left(1 - 10^{-SII/Q}\right)^{N}$$

where S is the proportion correct speech recognition score, SII is the calculated SII for each condition, and Q and N are fitting constants that define the slope and curvature of the transfer function.

RESULTS

Intelligibility during tracking

Because the P-I functions were measured using the TNT materials, and the testing conditions were identical, we could use each listener's individualized P-I functions to derive a running estimate of the speech intelligibility during each noise tracking trial (Figure 2). Intelligibility estimates provide ranges of speech intelligibility during the trial. Also, the intelligibility measure provides a tool to verify that the listener is performing the task in a meaningful way (e.g., understanding at least some of the speech).

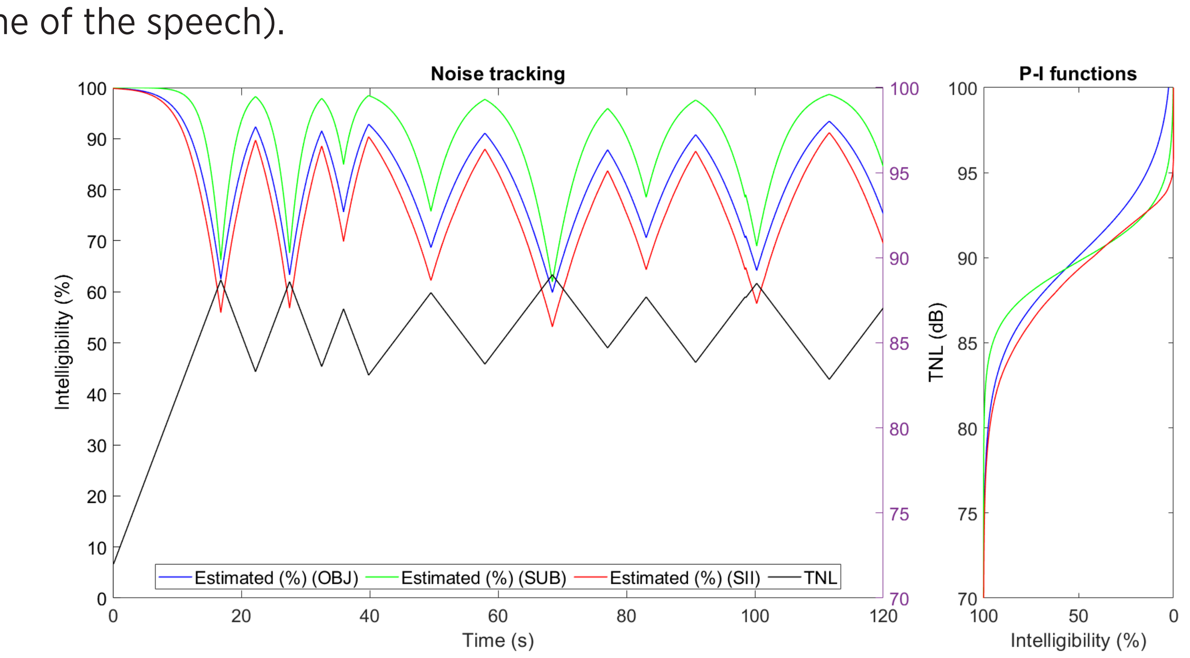

Figure 2. An example of a single noise tracking trial with noise level (black), estimated objective (blue), subjective (green), and SII based (red) speech intelligibility.

NH listeners set the noise at higher level on average than the HI listeners (Table 1). NH listeners selected 1.4 dB lower noise-to-signal (NSR) ratio at the 82 dB SPL speech level than at 75 dB SPL. HI listeners selected 0.5 dB higher NSR at 82 dB SPL than at 75 dB SPL. The range of noise values explored throughout the test (= excursion) was greater for HI than for NH listeners.

		Avg. Peak (dB)	Mean TNT (30 ... 120sec)	Avg. Valley (dB)	Excursion (dB)
NH	75 dB SPL	6.8	4.9	3.1	3.7
	82 dB SPL	5.3	3.5	1.7	3.6
HI	75 dB SPL	2.9	0.3	-2.2	5.1
	82 dB SPL	3.4	0.8	-1.7	5.1

Table 1. The average TNT scores (i.e., noise-to-signal ratio) of different TNT outcome measures (average, avg. peak, and avg. valley).

For the NH listeners, the objective, subjective, and SII based speech intelligibility estimates during the noise tracking task were similar (Figure 3). Noise level associated with the average of valleys of the TNT trace more consistently coincided with the 90% intelligibility criterion across NH listeners. The speech intelligibility at the mean TNT and at the average TNT peaks was below the 90% intelligibility criterion that listeners were instructed to maintain during the task.

For HI listeners, the subjective intelligibility estimate at average valleys of the TNT trace coincided with the 90% intelligibility (Figure 4). The estimated objective speech intelligibility was poorer than the estimated subjective intelliligibility. This reflects the differences in the average objective and subjective speech performance in the HI group. The SII based estimation using the NH listeners objective SII-to-intelligibility transfer functions overestimated the measured performance at 75 dB SPL. The estimation was more accurate at 82 dB SPL level.

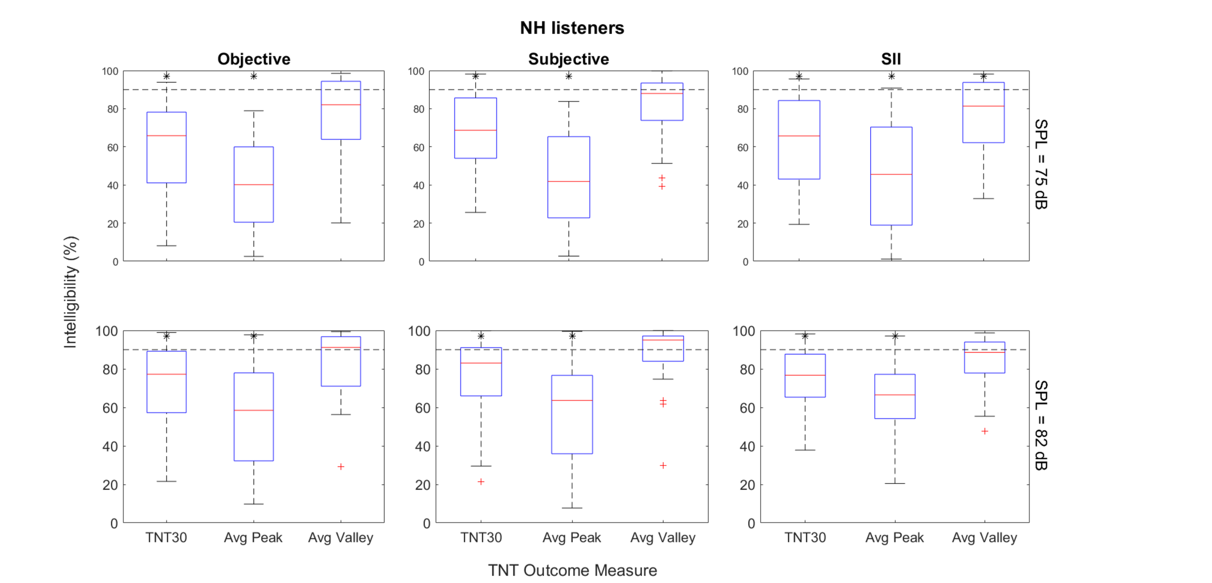

Figure 3. The distribution of estimated objective (left), subjective (center), and SII based (right) intelligibility measured at SNRs equivalent to the average TNT score, as well as the average of the peaks and valleys in the TNT trace. The intelligibility criterion of 90%, (as per the TNT instructions), shown in the dashed line.

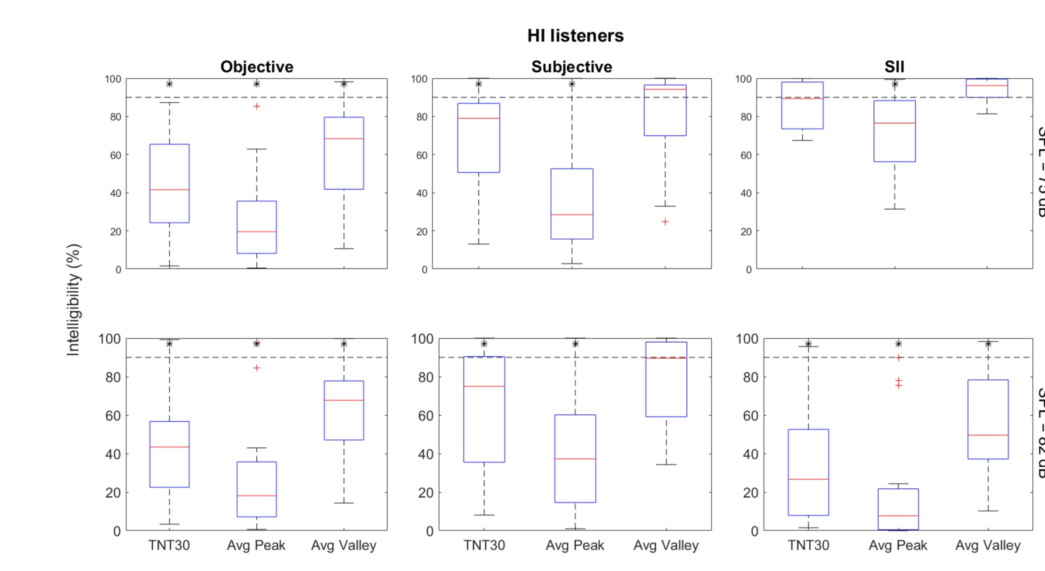

Figure 4. HI listeners (see Figure 3 caption).

SUMMARY

We developed test materials that allow evaluation of noise acceptance and speech intelligibility using the same stimuli. This allowed us to estimate the speech intelligibility during the noise tracking task. NH listeners accepted 2.7 - 4.6 dB more noise than HI listeners. NH listeners adjusted the noise level to reflect estimated ~90% objective and subjective intelligibility as instructed at the valleys of the noise tracking. For HI listeners the valleys of the noise tracking reflected ~90% estimated subjective speech intelligibility, whereas the estimated objective speech intelligibility was <90%. SII based intelligibility estimation derived from NH data did not accurately predict performance for the HI listeners.

REFERENCES

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