

# Speech-in-noise tests: How and why to include them in your basic test battery

By Brian Taylor

A patient walks into your clinic complaining of not hearing well in background noise. After conducting your hearing evaluation, you explain the amplification options. Since the main complaint is hearing in noise, you fit the patient with a pair of directional-microphone digital hearing aids. Two months later, after numerous adjustments, the patient says he still can't hear *that* much better in noisy places.

Another patient walks into your clinic. He insists you fit him with a pair of "those invisible hearing aids." Your hearing evaluation indicates that he might be able to wear completely-in-the-canal devices successfully. However, as with many patients, the majority of his listening situations are noisy. The CICs might help, but are they the *best* choice to improve his hearing in noise?

The routine use of speech-in-noise tests will help address these and other common clinical quandaries.

## **SPEECH IN NOISE VS. WORDS IN QUIET**

The overwhelming majority of patients who go to a hearing healthcare professional have difficulty understanding conversation in background noise.<sup>1</sup> We now have speech-in-noise tests that can accurately assess hearing loss and amplification under conditions that are representative of the real world.<sup>2,3</sup>

Several sentence-type speech-in-noise tests are available. These tests are quick to administer and easy to score. Most importantly, they provide you and your patient with powerful information directly related to some of the communication difficulties that originally brought the person to your office. Using this information, you can make a better hearing aid selection decision and better predict the improvement that various amplification devices will make.

These tests are also valuable in counseling, since they enable you to explain the benefits and limitations of amplification in a way that patients can relate to.

Monosyllabic word lists presented in quiet conditions in the sound field have been used for many years. The rationale for administering these tests during the hearing aid selection and fitting process has been to show aided benefit over the unaided condition or to demonstrate that one hearing aid is better than another for the patient.

However, as we have known for 20 years, these tests are an inadequate tool for selecting and fitting hearing aids.<sup>4</sup> Because of their unreliability and lack of real-world validity, monosyllabic word-recognition tests have very little use in a dispensing practice. Unfortunately, many professionals continue to rely on them for making important amplification decisions. Like peak-clipping hearing aids, leisure suits, and The Spice Girls, monosyllabic word lists presented in

quiet are best relegated to the dustbin of history.

There is a better way! There are several speech-in-noise tests that can be used clinically. Four sentence-type speech-in-noise tests are reviewed below. (See Mueller, 2001 for a more extensive review.<sup>5</sup>)

## **FIXED SNR TESTS**

Fixed signal-to-noise ratio (SNR) tests measure a percent correct at a fixed SNR. The SNR conditions are established by the clinician prior to the test, and remain unchanged throughout.

The potential advantage of these tests is that they provide a straightforward percent-correct score for hearing aid benefit that is easy to explain to patients.

One disadvantage with such tests is that it is difficult to know where to fix the SNR. If the test is given at a very challenging SNR (e.g., -6 dB SNR), the results may understate the amount of benefit the hearing aids are providing the patient. If the selected dB SNR is too easy, the aided benefit may be overstated.

Some estimates of real-world SNR conditions are available. Pearsons, Bennett, and Fidell determined that in typical face-to-face communication the SNR becomes more adverse as the background noise increases.<sup>6</sup> When the background noise was 55 dB SPL, average speech was 61 dB SPL (+6 dB SNR). When the noise was 65 dB SPL, average speech was 68 dB SPL (+3 dB SNR). When the noise was 75 dB SPL, average speech was 74 dB SPL (-1 dB SNR). You could select these SNR conditions in conducting fixed SNR tests.

### *A clinical application*

One clinical application of fixed SNR tests is to present three lists in the unaided condition at the following SNRs: (1) challenging listening condition (-1 dB SNR), (2) moderately difficult condition (+3 dB SNR), and (3) relatively easy listening condition (+6 dB SNR). The presentation levels for each of these conditions are listed above.

Present the fixed SNR tests in the sound field (not with earphones) with the speech and the noise both presented from the same loudspeaker. Once you obtain unaided scores in each listening condition, repeat the test in the aided condition. Compare the aided and unaided scores.

You can then explain to the patient the differences between his scores aided and unaided. To create realistic expectations, you can compare the patient's results with those of someone with normal hearing.

### *Types of fixed SNR tests*

Two readily available fixed SNR tests are the Connected

Speech Test (CST)<sup>7</sup> and the Speech Perception in Noise test (SPIN).<sup>8</sup>

The CST uses passages of speech 9 to 10 sentences in length, presented with multi-talker babble. The score is based on the percent correct of 25 key words in each passage. The SPIN, which is also presented with multi-talker babble, consists of sentences between five and eight words long. The last word of each sentence is the one scored. Half of the test items have high predictability and the other half low predictability. The test is scored as a percent correct with separate scores for the high and low (minimal contextual cues) speech and noise presented from same loudspeaker.

### ADAPTIVE SNR TESTS

Adaptive SNR tests measure the speech-to-noise ratio as the intensity level of either the speech or the noise is varied. Unlike fixed tests, which must be conducted in the sound field, adaptive SNR tests can also be conducted with earphones. These tests can be included in the routine diagnostic hearing test battery and later compared with the patient's SNR improvement with amplification. Both the Hearing In Noise Test (HINT)<sup>3</sup> and the Quick Speech In Noise (SIN)<sup>2</sup> test are adaptive SNR tests,

and can be completed quickly. The HINT takes 5 to 10 minutes and the Quick SIN 2 or 3 minutes.

### HINT

The HINT, which was developed at the House Ear Institute, consists of modified BKB sentences<sup>9</sup> delivered in groups of 10. Speech-shaped noise is the competing background noise. The patient must repeat all the key words of a sentence for a response to be considered correct. The HINT requires that the background noise remain fixed, usually at 65 dB SPL, while the presentation level of the sentences varies in 2-dB steps. The reception threshold for sentences (RTS) is calculated much like an SRT. The RTS score is the signal-to-noise ratio at which 50% of the sentences are repeated correctly.

### Quick SIN

The Quick SIN is a faster and more accurate version of the original SIN test developed by Etymotic Research. It consists of a series of IEEE sentences presented in a background of four-talker babble. In the Quick SIN, the level of the sentences remains fixed while the noise level varies. Because variability of the noise is automatic,

it is an ideal test to use clinically. Sentences are presented at a loud MCL (either 75 or 80 dB HL) while the CD automatically varies the SNR in 5-dB steps starting at +25 SNR. Five key words are scored in each sentence and one point is given for each key word repeated correctly. The number of key words correct is subtracted from the reference 25.5 dB. This score is referred to as the SNR loss. SNR loss can be determined in both ears in about 2 minutes.

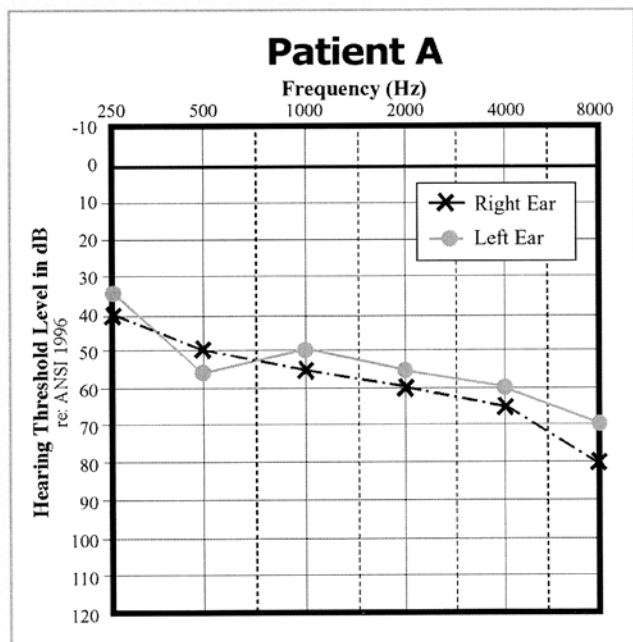
### Clinical applications

There are many ways to use sentence-type speech-in-noise tests in the clinic. These tests are most valuable for diagnosing SNR loss. A minimal investment in time rewards you with valuable information that helps you determine amplification choices and realistic expectations.

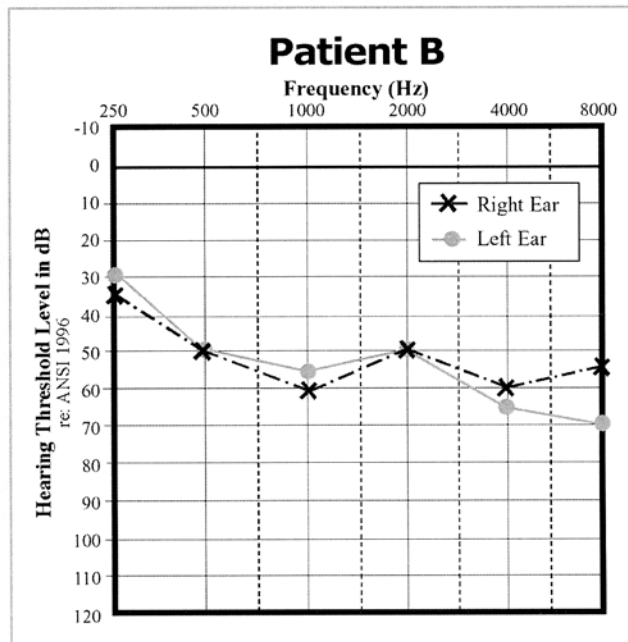
These tests can also be used for verifying hearing aid performance and the benefits of directional microphones in a manner that is clear to your patient. Following is how one adaptive SNR test can be applied in three ways in your clinic.

#### (1) Diagnosing SNR loss

SNR loss, which can be quantified with either the HINT or Quick SIN, is a mea-



**Figure 1.** Patient A has a three-frequency pure-tone average (500, 1000, and 2000 Hz) of 53 dB HL in the left ear and 55 dB HL in the right ear. Word recognition is 80% in the left ear and 84% in the right ear. SNR loss in the right ear is 1 dB in the right ear and 3 dB in the left ear as measured with the Quick SIN.



**Figure 2.** Patient B has a three-frequency pure-tone average of 52 dB in the left ear, and 53 dB in the right ear. Word-recognition scores are 76% in the left ear and 80% in the right ear. The SNR loss is 9 dB in each ear. Note the similar pure-tone averages and word-recognition scores with different SNR loss in comparison with Patient A in Figure 1.

sure of how well a patient will understand speech in noise relative to someone who hears normally in noise. SNR loss is defined as the dB increase in signal-to-noise ratio required by a hearing-impaired person to understand speech in noise as well as a normal hearer.<sup>10</sup>

SNR loss is measured through earphones as part of the standard diagnostic hearing test battery. A person with normal hearing requires an SNR of between 0 and +2 dB to understand 50% of words in a sentence. A person with a 10-dB SNR loss requires that the speech be 10 to 12 dB louder than the noise to understand 50% of the sentence (see Table 1).

**Table 1.** A summary of SNR loss.<sup>11</sup>

SNR loss	Degree of SNR loss
0-2 dB	normal
2-7 dB	mild SNR loss
7-15 dB	moderate SNR loss
>15 dB	severe to profound SNR loss

Because SNR loss is a measure of how well patients perform in real-world listening situations (including understand-

ing speech in noise), it is an ideal counseling tool.

SNR loss is not reflected in the pure-tone audiogram. Figures 1 and 2 show two nearly identical audiograms from two patients of very similar ages and lifestyles. Note that there are no significant differences on the word-recognition scores between these two patients.<sup>12</sup> Without the information from an SNR test, these patients probably would be counseled exactly the same.

The one variable that separates these two patients is SNR loss. Patient A has an SNR loss of 1 dB in the right ear and 3 dB in the left ear. Patient B has an SNR loss in each ear of 9 dB. According to Figure 1, Patient A's ability to hear in noise is essentially normal, while Patient B has a moderate SNR loss. To restore patient B's ability to understand speech in noise to normal requires that the SNR of the listening situation be improved by 7 dB.

Aside from her elevated thresholds, Patient A has near-normal hearing in noise. As long as speech is audible and comfortable, this patient will perform very well in noise with hearing aids. This patient was advised that with directional-microphone hearing aids she could expect to out-per-

form normally hearing persons in noise. However, in view of her listening needs and lifestyle, CICs with WDRC were recommended.

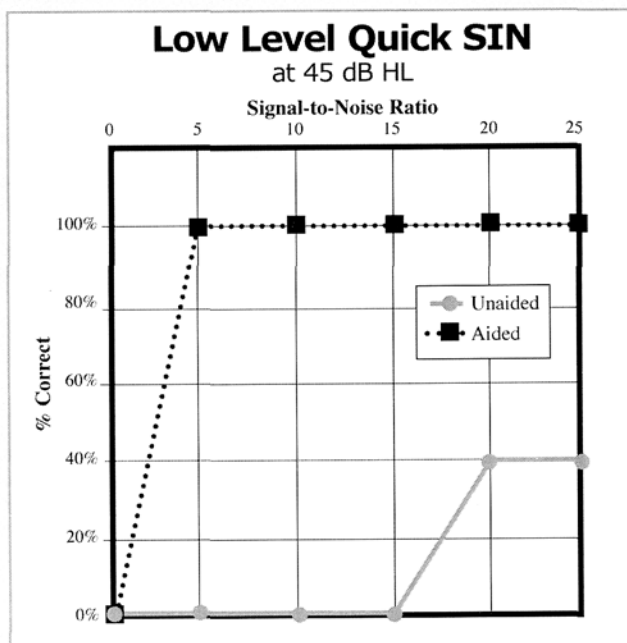
Patient B requires a more favorable SNR to hear well in noise. He was advised to go with larger half-shell instruments with directional microphones.

Both patients were fitted with the recommended models. The NAL-NL1 was used to match gain for soft, comfortable, and loud sounds. A 1-month post-fitting outcome assessment (COSI) showed that both patients were satisfied with the benefits they received.

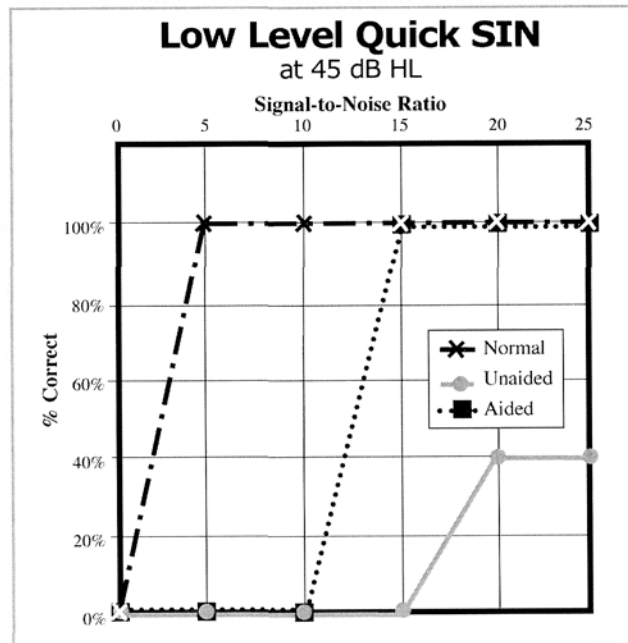
Knowledge of these patients' unaided SNR loss was an essential piece of information in the hearing aid selection process. In view of their very similar audiograms and communication needs, without the SNR loss scores these patients probably would have been fitted with the same hearing aids.

#### (2) Aided audibility in noise

Many first-time hearing aid users ask if they are hearing better in background noise with their new instruments. Both the HINT and Quick SIN can be conducted in the sound field at a moderately low level to obtain a measure of audibility in noise. This



**Figure 3.** Quick SIN presented at 45 dB HL in the sound field. Both the speech and competing noise presented from 0° azimuth. Scores indicate that in the aided condition Patient A is hearing as well as someone with normal hearing in noise for this task.



**Figure 4.** Quick SIN presented at 45 dB HL in the sound field. Both the speech and competing noise presented from 0° azimuth. Scores indicate Patient B has improved aided audibility over the unaided condition, but is still not performing as well in noise as someone with normal hearing. Aided performance in this condition is limited by unaided SNR loss.

is an effective way to demonstrate to the patient that aided performance is better than unaided for noisy conditions. By presenting both the speech and the noise from 0° azimuth, the dispenser can compare audibility in the unaided versus aided condition. This information shows the patient how much hearing aids restore missing speech cues, even in noisy conditions.

Figures 3 and 4 illustrate how the Quick SIN can be used for this purpose. The same two patients will serve as an example. The figures show the number of key words correct at various SNRs while the presentation level of speech remained at 45 dB HL in the unaided and aided conditions. (Remember, with the Quick SIN the noise level changes automatically in 5-dB steps.) In both cases, a speech-in-noise test quickly and realistically demonstrates that the hearing aids are effectively restoring quiet speech cues.

Comparing these two cases illustrates the importance of restoring audibility to improving speech intelligibility. Both patients are seeing aided improvement. However, Patient A is performing in noise better with her hearing aids than Patient B. These results are consistent with what was predicted from the unaided SNR loss.

Patient B, with a bilateral SNR loss of 9 dB, experiences limited improvement in adverse conditions in which speech and competing noise come from the same location. The test clarifies real-world improvement and limitations of his hearing aids. Even with hearing aids, SNR loss will not be alleviated when speech and noise come from the same location.

### (3) Assessing directional-mic benefit

A third clinical application of speech-in-noise testing is the verification of directional-microphone benefit. An accurate assessment of the real-world benefits of directionality requires an extensive multi-speaker arrangement.<sup>13</sup> However with two speakers mounted in strategic locations, speech-in-noise tests can quickly verify that directional-microphone hearing aids are functioning as intended.

If the patient's hearing aid microphones have a cardioid polar pattern, the loudspeakers should be placed in a front-back arrangement with the patient facing speaker 1 (speech) and speaker 2 (noise) placed directly behind the patient. If, as is more likely, the microphones have a hypercar-

dioid polar pattern, the patient faces speaker 1 at 0° azimuth. The second speaker is placed directly above the patient. (Portable loudspeakers available at electronics stores can be interfaced with your audiometer to do this test.)

The HINT and the Quick SIN can both be used for this purpose. There are 10 recordings on the Quick SIN CD in which the speech and noise are recorded on separate tracks. The speech track is presented through speaker 1 while the patient faces it (0° azimuth) wearing both hearing aids. The speech is presented at a comfortably loud level (55 dB HL). The noise track is presented through speaker 2, which is directly overhead. In this application, the noise channel must be changed manually with the dial on the audiometer. Present the first sentence of a list at +25 dB SNR. Increase the level of the noise using 5-dB steps recording the number correct at each SNR. Present one list with the hearing aids in the omnidirectional position and the second list in the directional mode.

When the Quick SIN is used for this purpose, three sentence lists for the omnidirectional and directional modes should be presented. The results obtained are an objective assessment of how much benefit directional microphones are giving the patient at various signal-to-noise ratios. Subjectively, the patient should notice an obvious difference when he switches from the omni to the directional mode at challenging SNRs.

The use of the Quick SIN revealed the improvement in SNR when two hearing aids were switched from the omnidirectional to the directional position. At 0 dB SNR, the patient was still able to understand more than 50% of the sentence. This patient was receiving outstanding benefit from the directional microphones. As this example shows, speech-in-noise tests can objectively measure the benefits of directional microphones.

## CONCLUSIONS

Despite our best efforts, many patients still cannot hear well in noise even when fitted with the latest digital, dual-microphone devices. Sentence-type speech-in-noise tests will identify these patients during the initial diagnostic evaluation. Once they are identified they can be counseled on what type of technology is appropriate.

By using speech-in-noise tests, the dispensing professional can set the stage early

as to what patients with a greater than 10-dB SNR loss can realistically expect of their hearing aids. These patients are ideal candidates for aural rehabilitation and should also consider array microphones or FM systems. Such patients will appreciate your honest assessment of their communication problems and the limited benefits they are likely to receive from hearing aids.

Simply stated, measurement of SNR loss should be part of your routine diagnostic battery. The information it provides is essential throughout the entire hearing aid selection and fitting process. **HJ**

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## REFERENCES

1. Kochkin S: MarkeTrak V: "Why my hearing aids are in the drawer: The consumers' perspective." *Hear J* 2000;53(2):34-42.
2. Erymotic Research: *QuickSIN test*. Elk Grove Village, IL: 2001.
3. Nilsson M, Soli SD, Sullivan, J: Development of the Hearing In Noise Test for the measurement of speech reception thresholds in quiet and noise. *J Acoust Soc Am* 1994;95:1085-1099.
4. Walden B, Schwartz D, Williams D, et al.: Test of the assumption underlying comparative hearing aid evaluations. *J Sp Hear Dis* 1983;48:264-273.
5. Mueller HG: Speech audiometry and hearing aid fittings: Going steady or casual acquaintances? *Hear J* 2001;54(10):19-29.
6. Pearsons KS, Bennett RL, Fidell S: *Speech Levels in Various Noise Environments*. EPA Rep 68 01-2466. Environmental Protection Agency, Washington DC, 1977.
7. Cox R, Alexander G, Gilmore C: Development of the Connected Speech Test (CST). *Ear Hear* 1987;8:1195-1265.
8. Bilger RC, Nuetzel JM, Rabinowicz WM, Rzeczkowski C: Standardization of a test of speech perception in noise. *J Sp Hear Res* 1984;27:32-48.
9. Bench J, Kowal A, Bamford J: The BKB (Bamford-Kowal-Bench) sentence lists for partially-hearing children. *Brit J Audiol* 1979;13:108-112.
10. Christensen L: Signal-to-noise ratio loss and directional microphone hearing aids. *Sem Hear* 2000;21(2):179-199.
11. Killion M, Niquette P: What can the pure-tone audiogram tell us about a patient's SNR loss? *Hear J* 2000;3(3):46-52.
12. Thornton A, Raffin M: Speech-discrimination scores modeled as a binomial variable. *J Sp Hear Res* 1978;21:507-518.
13. Revit L, Compton C, Schulein R, Killion M: Multi-channel sound-field reproduction and stimulation system for assessing hearing aid performance. Presented at the Annual Conference of Hearing Aid Acousticians, Cologne, Germany, 2000.