

# Kessler Was Right—Partly: But SIN Test Shows Some Aids Improve Hearing In Noise

By MEAD C. KILLION & EDGAR VILLCHUR

U.S. Food and Drug Administration Commissioner David Kessler, MD recently criticized advertising that claimed certain hearing aids could reject noise the wearer didn't want to hear. This criticism was followed by an FDA "Talk Paper," which said: "Many claims made for hearing aids—particularly that they help people hear better in a noisy environment—are not substantiated by clinical data."<sup>1</sup>

In these criticisms, the Commissioner and the FDA failed to make a fundamental distinction. Unfortunately, we—audiologists, dispensers, and manufacturers alike—have been so careless ourselves about this distinction that the Commissioner can hardly be blamed for exhibiting the same confusion. What distinction is that? It is the distinction between (a) hearing aids that attempt to filter out background noise and (b) hearing aids that help people hear in noisy environments, more precisely, that help people understand speech at a given level of noise.

The above distinction may be clarified with a simple observation. Normal listeners hear *all* the noise and do quite well in noise. Unaided hearing-impaired listeners are equipped with a highly effective noise-rejection circuit—their own hearing loss—and typically do *not* do well in noise. Too many speech cues are inaudible to them.

Although many hearing aids help their wearers hear in noise, to our knowledge no hearing aids—including advanced lab-

oratory digital signal-processing hearing aids that would require 40,000 #13 batteries a week to keep alive—have improved the intelligibility of speech in noise by filtering out the noise in the most important case, i.e., when the noise consists of competing speech.<sup>2,4</sup> This supports the commissioner's criticisms of advertising claims that suggest current noise-rejection circuits can help people understand speech in noise. In this, the Commissioner was right.

The weakness of current *noise-rejection* circuits is that they don't address themselves to the primary problem—the loss of audible speech cues resulting from the hearing loss. This loss deprives the brain of the redundant information it needs to separate speech from noise. Noise-filter circuits sometimes *reduce* the number of available speech cues by filtering them out, instead of restoring them.

Many hearing aids *do*, however, improve the intelligibility of speech in noise for their wearers. They do so by increasing the portion of available speech cues delivered to their wearer's brain (simultaneously increasing the portion of the available noise that can be heard). This enables that person's brain to perform the task for separating speech from noise more efficiently.<sup>5,6</sup>

Improving on the brain's performance in this task with the help of a computer is not likely. The most powerful computer currently available, the Thinking Machine, which contains 65,000 computers wired in parallel, requires 30 minutes to recognize a face. A baby can do it in a half second.<sup>7</sup>

Anecdotal reports regarding one wide-dynamic-range-compression (WDRC) hearing aid with treble-increases-at-low-level (TILL) processing include statements such as: "Now at square dances I can stand in the back of the room with the normal-hearing people and still hear

the caller," or "I can now enjoy a conversation in a noisy restaurant; I never thought I'd hear this well with hearing aids." One hearing aid wearer has actually accused another of "pretending to hear in situations that are impossible to hear with a hearing aid."<sup>7</sup>

What has been missing, with only a few exceptions,<sup>8-10</sup> is widespread verification in the scientific literature of these anecdotally reported improvements. The July 9, 1993 FDA "Talk Paper" states: "In the future, manufacturers who wish to make such claims will be required to conduct clinical studies to support them."<sup>1</sup>

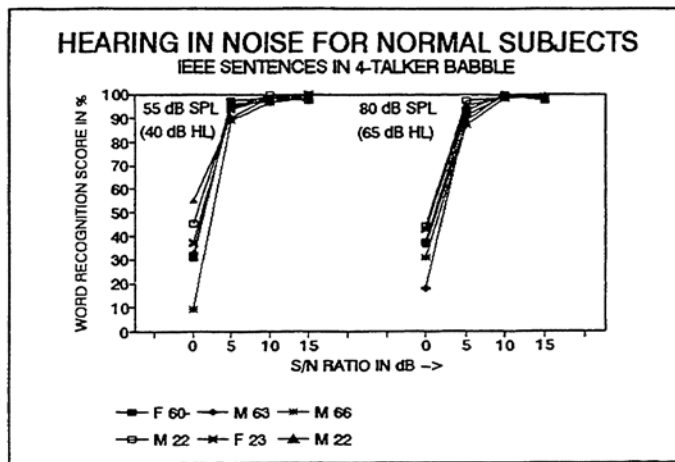
The purpose of this paper is to describe a readily available prerecorded test that can be used to determine the relative degree to which a given pair of hearing aids helps an individual understand speech in noise. This test takes approximately 24 minutes for good reliability in comparing two listening conditions, using two 40-sentence test blocks (described below) for each condition. It is applied here to three subjects who wear hearing aids. Their scores with different hearing aids and without any aid are compared.

## METHODS

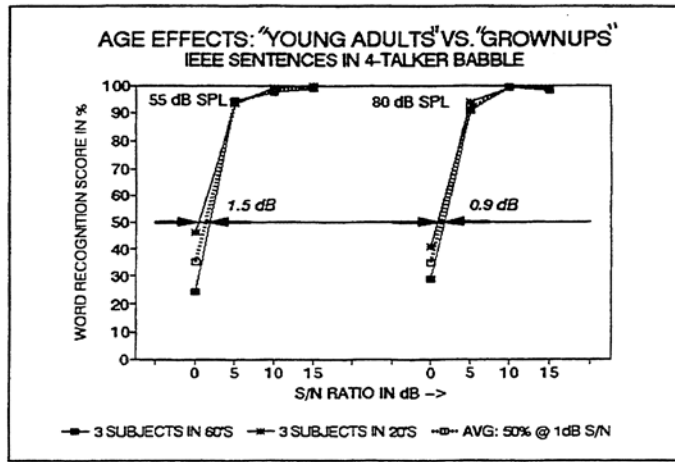
### Test Material

In her recent PhD dissertation, Fikret-Pasa explained the choice of four-talker babble as the noise and so-called IEEE (modified Harvard) sentences as the target speech for a speech-in-noise test.<sup>11</sup> The 720 IEEE sentences represent conversational speech, but the context offers the listener little help in identifying the five key words, e.g., "Her purse was full of useless trash." The sentences are organized in 72 lists of 10 sentences each, spoken by a woman. The recording used here was obtained from the Massachusetts Institute of Technology on digital audio tape (DAT),<sup>12</sup> and subsequently equalized to partially correct for the

Mead C. Killion, PhD is president of *Etyimōtic Research and Adjunct Professor of Audiology, Northwestern University*. Edgar Villchur is president of the *Foundation for Hearing Aid Research, Woodstock, NY*. Correspondence to Dr. Killion, at *Etyimōtic Research, 61 Martin Lane, Elk Grove Village, IL 60007*.



**Figure 1.** Hearing in noise for normal-hearing subjects using the speech-in-noise (SIN) test (IEEE sentences in four-talker babble): Three "young adults" (subjects in their twenties) and three "grownups" (subjects in their sixties), four men and two women.



**Figure 2.** Age effects: Performance of "young adults" vs. "grownups" on the SIN test. Average performance was 50% correct at 1-dB S/N ratio.

high-frequency attenuation caused by the use of a lapel location for the recording microphone.<sup>11</sup>

The four-talker babble recording was obtained on DAT from Auditec of St. Louis, and represents two women and two men in a more or less realistic simulation of a social gathering. Just as at a party one can turn one's attention from a boring talker and concentrate instead on a more interesting talker, it is possible to selectively follow individual talkers in the four-talker babble. (When the babble level is high, subjects will sometimes repeat a sentence from the babble rather than the target sentence.)

#### SIN Test Recordings

The present speech-in-noise (SIN) test consists of a series of DAT recordings made with five sentences, each recorded at decreasing signal-to-noise (S/N) ratios of 15 dB, 10 dB, 5 dB, and 0 dB. This required 20 sentences (two IEEE lists) for the complete set of four S/N ratios. (Note: A S/N ratio of 0 dB means that the frequent peaks of the IEEE sentences are about equal to the frequent peaks of the four-talker babble, as measured separately on a VU meter.) The levels of both the four-talker babble and the IEEE sentences were taken to be equal to the 1000-Hz calibration tone contained on each tape.

Ten independent test blocks have been recorded. Each block contains 40 sentences organized in two subblocks (A and B) of 20 sentences each. The level in each of the B subblocks is 25 dB below that in the A subblocks.

#### Test Application

The DAT player (or CD player—see below) is connected to a standard sound-field audiometer (a clinical audiometer with calibrated loudspeakers in a sound-proof test

booth). Using the prerecorded calibration tone, the audiometer speech circuit is adjusted to a reading of 0 VU. With the attenuator set to 65 dB HL, the frequent peaks of the talker in the first (A) half of each block should produce approximately 80 dB SPL in the sound field. The second (B) half of each block will then be at 55 dB SPL, corresponding to 40 dB HL.

The subject is told that he or she is at a party, which starts in the next room and gets closer and closer until it will become difficult for the subject to understand the target talker, a woman. The subject is asked to repeat the sentence spoken by the target talker. The target talker is easily identified during the first few sentences because her voice is so much louder than the background party babble noise. Guessing and partial answers are encouraged. Five key words in each sentence are scored, and half-word credit is given for nearly correct answers such as "task" instead of "tasks."

#### Test Levels

The test as used here represents both fairly loud speech, characteristic of parties as reported by Teder<sup>13</sup>, and fairly soft speech, approximately 10 dB below the normal conversational speech level of 65 dB SPL. The chosen levels also correspond to the ANSI standard test SPLs (55 and 80) used for testing attack and release times on automatic gain control (AGC) hearing aids. One can introduce additional levels by the choice of audiometer attenuator setting.

## RESULTS

#### Normals

Figure 1 shows the results obtained from six normals: three adults in their twenties ("young adults") and three in their sixties ("grownups"). The intention was to balance men and women, but there

were more suitably aged men readily available on the day of the test.

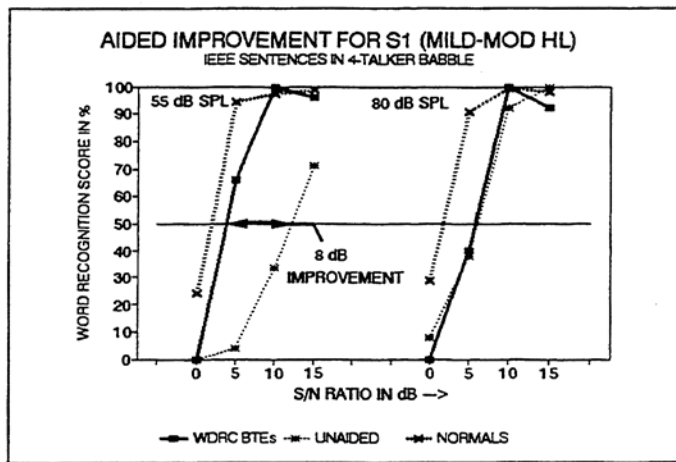
As shown in Figure 2, there was a small difference in scores associated with age, which could have been because two of the "grownups" had 30 dB HL thresholds at 4000 Hz (20 dB or better below that frequency). The effect of age or mild high-frequency loss was 1.5 dB or less in terms of S/N ratio for 50% correct responses, so the results from the six normal-hearing subjects were averaged and used as a reference for Figures 3 and 4.

Note: The frequency response of the loudspeaker used in the test booth had a 160-Hz-to-8000-Hz bandwidth with  $\pm 7$ -dB response variations within that bandwidth. Also, the test booth had very little reverberation, which made this application of the SIN test less representative of real-life conditions. The SIN test has not yet been evaluated in normally reverberant rooms, where it might prove especially useful for evaluating the reduction of reverberation by directional microphones.

#### Subject 1

Subject 1 (male, age 66, mild-to-moderate high-frequency loss) is the president of a prominent audio-equipment manufacturing firm and has had years of training in listening. He has worn wide-dynamic-range-compression (WDRC) hearing aids for roughly a year.

Figure 3 shows the results obtained for Subject 1. Note that for loud speech in loud noise, his own ears were just as good as the hearing aids. This is an expected result for someone with mild-to-moderate loss, who already hears all of the loud-speech cues: Amplification should not make any more cues audible. For such an individual, hearing aids should neither provide unwanted amplification nor stand in the way of his own hearing.<sup>8</sup> The subject's hearing deficit



**Figure 3.** SIN test aided improvement with binaural wide-dynamic-range-compression (WDRC) BTE hearing aids for Subject 1 with mild-moderate hearing loss.

relative to a normal subject for loud speech in loud noise suggests there may yet be some room for improvement.

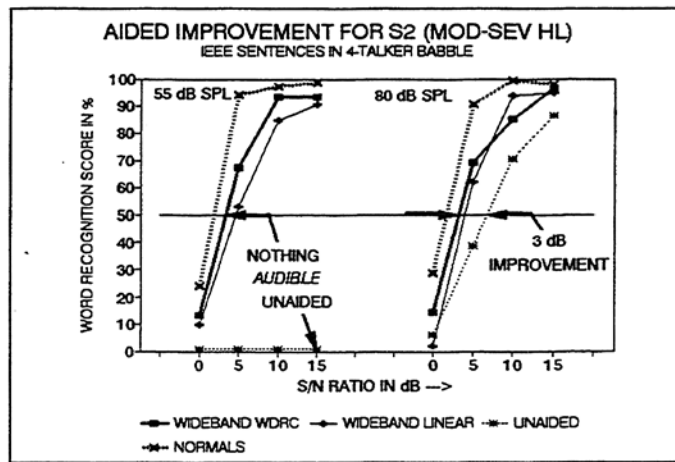
For quiet speech in quiet noise, on the other hand, the data in Figure 3 show an 8-dB improvement in the S/N ratio required for a 50% correct word score. This is equivalent to an 8-dB reduction in the noise. As discussed above, the improvement is produced, not by reducing the noise, but by increasing the number of speech cues available. At a 5-dB S/N ratio, his word-recognition scores went from approximately 5% of the words to roughly 60% of the words. These hearing aids clearly help Subject 1 understand speech in noise, or, to use the FDA's expression, "hear in noise."

### Subject 2

Subject 2 (male, 66, moderate-severe mixed loss with mild-moderate sensorineural component) is the sales manager for Etymo-tic Research. He has worn hearing aids for 30 years, WDRC canal hearing aids for 3 years.

For Subject 2, even loud speech in loud noise is not clear when he is unaided: He hears muffled speech in muffled noise. As shown in Figure 4, the use of either wide-band linear peak-clipping or WDRC hearing aids improves the S/N ratio he requires for 50% correct responses by about 3 dB (bringing him within 2 dB of normal). At a 5-dB S/N ratio, his score improved from about 40% to about 70% with either type of hearing aid.

For quiet speech in quiet noise, the improvement in his hearing aided as opposed to unaided was even more dramatic. After repeated presentation of the unaided sentences drew no response, an inquiry revealed that Subject 2 heard "nothing at all." His aided score for quiet speech in quiet noise was within 2 dB of that for normal subjects when he used the wide-band WDRC canal aids and within 3 dB when he used the wide-band linear peak-clipping aids. In this case the selection of hearing aids becomes more subjective. Subject 2's response to the instruction: "Now put back in your regu-



**Figure 4.** SIN test aided improvement with binaural wide-band linear canal aids and binaural wide-band WDRC canal aids for Subject 2 with moderate-severe mixed hearing loss.

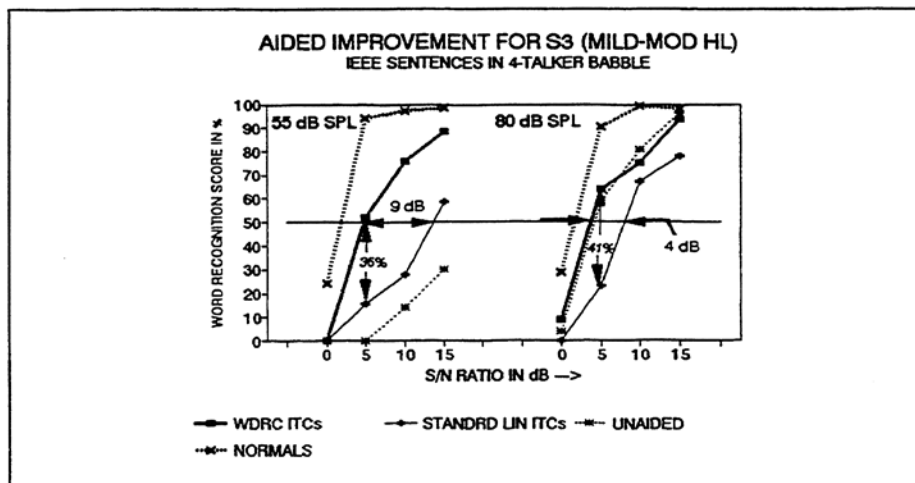
lar (WDRC) hearing aids" was "Thank goodness!" The linear peak-clipping hearing aids did not distort under any of the test conditions, but did distort his own (higher-level) voice, causing it to sound "raspy" when he repeated the target sentences.

### Subject 3

Subject 3 (male, 51, mild-severe sensorineural hearing loss) was first fit with conventional linear peak-clipping canal hearing aids a little over a year ago. As a consultant to Etymo-tic Research, he became interested in WDRC hearing aids. After obtaining a pair of WDRC canal aids (from the same manufacturer that made his linear peak-clipping aids), he almost immediately waxed ecstatic about the difference between the two types of aids in all listening situations. We noticed that he stopped whispering to avoid discomfort from his own voice. He volunteered: "I just don't want to take them out at night. The old ones were just the opposite. I couldn't wait to take them out."

For quiet speech in quiet noise, Figure 5 shows that both hearing aids were better than none, but that the WDRC canal aids improved his score by some 36% over the linear peak-clipping canal aids. This change is equivalent to a 9-dB reduction in noise at the 50%-correct level. Again, this improvement is a result of the increased audibility of the speech, not of any attempt on the part of the hearing aid to distinguish speech from noise or to filter out the noise.

For loud speech in loud noise, the WDRC hearing aids provided Subject 3 with neither benefit nor harm. This was the expected result. The linear peak-clipping hearing aids reduced his score by 41% at a 5-dB S/N ratio. He was better off removing these hearing aids in loud noise, which was consistent with his dislike for them.



**Figure 5.** SIN test aided improvement with binaural wide-band WDRC canal and "standard linear" canal hearing aids for Subject 3 with mild-moderate hearing loss.

## DISCUSSION

At one time, many if not most hearing aids reduced the intelligibility of loud speech in loud noise. They *did* substantially increase the intelligibility of speech in quiet, and even increased the intelligibility of low-level speech in low-level noise, but only because neither the speech nor the noise would have been audible without the hearing aids!

The SIN test makes it easy to demonstrate that properly designed modern hearing aids improve the intelligibility of low-level speech in low-level noise, and also that they either don't degrade the intelligibility of high-level speech in high-level noise (for typical users with mild-moderate hearing loss, whose high-level hearing is normal or near normal), or improve it (for users with moderate-severe loss who need gain to make even high-level sounds clear).

This is not to say that all hearing aids help people hear well in noise. Although at least 10% of the hearing aids sold in the United States last year were wide-band, low-distortion instruments that used some kind of wide-dynamic-range compression circuit, Hawkins determined that over 80% of the hearing aids sold in 1991 used Class A linear peak-clipping circuits,<sup>14</sup> circuits that typically exhibit excessive distortion in high-level noise.<sup>7</sup> And it is still common for manufacturers to roll off the high-frequency response of their hearing aids. A high-frequency rolloff improves sound quality in the face of excessive distortion.<sup>7</sup> It also helps avoid problems with feedback, thus reducing the number of shell remakes required (some impressions provide little evidence of where the ear canal goes), but sacrifices speech cues.

The linear peak-clipping hearing aid shown in Figure 5 was such a "standard linear" design. It had a peak-free frequency response, but was otherwise typical of this class of aid. It used a starved Class A circuit that distorted badly for 80-dB SPL inputs (80-dB SPL speech contains 90-dB-to-95-dB SPL peaks), and rolled off the highs by 15 dB at 5000 Hz. At least one manufacturer has recently dropped that type of circuit entirely, going to wider-bandwidth Class D linear circuits as a minimum.

Thus, although it is certain that virtually all modern hearing aids are better than the narrow-band instruments on which Tillman et al. reported in the 1960s (which produced a degradation of 20 dB in effective S/N ratio for their hearing-impaired subjects),<sup>15</sup> it is also likely that most of the existing standard

Class A linear peak-clipping circuits either do not help much or, in high-level noise, make things worse. ■

**Acknowledgement:** The SIN test described here, including the choice of four-talker babble, the corrected recordings of the IEEE sentences, and the idea of using multiple-S/N-ratio recordings at two presentation levels, resulted from extensive discussions with, and the work of, Selda Fikret-Pasa, as well as the earlier teachings of T.W. Tillman. Recordings of this test in DAT form are now available, and recordings in CD form will be available, from Auditec of St. Louis, (314) 781-8890, fax (314) 781-4946. A spreadsheet program for producing graphs identical to those used here is included with the recordings.

The WDRC hearing aids used in this study were K-AMP® hearing aids made by various manufacturers.

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## CORRECTION NOTICE

1. Under METHODS, Test Material, "The four-talker babble recording...represents two women and two men..." should read: "...represents three women and one man..."
2. Under SIN Test Recordings, "The level in each of the B subblocks is 25 dB below that in the A subblocks." Should read: "...is 30 dB below that in the A subblocks."
3. Under Test Application, "The second (B) half of each block will then be at 55 dB SPL, corresponding to 40 dB HL." Should read: "...will then be at 50 dB SPL, corresponding to 35 dB HL." And the "55 dB SPL" shown on each of the graphs should read "50 dB SPL."

## COMMENT

The actual DAT recordings were made with a 30-dB reduction level for the second half of each block, not 25 dB as reported. A quick check in the sound field with a Sound Level Meter indicated 25 dB was correct, but a more painstaking check both in the sound field and of the levels on the DAT tape, indicated 30 dB was correct.

For future application of the SIN test, we recommend setting the speech audiometer to 70 HL, which in a typical sound booth with speakers located at  $\pm 45^\circ$  to the subject should produce 83 dB SPL (ANSI S3.6-1989 *Specification for Audiometers*, p16 section A.6). The second half of each block would then automatically be presented at 40 dB HL (30 dB less), or 53 dB SPL.

The reasonableness of these levels has been confirmed recently, as reported by Killion (November, 1993 *Hearing Journal*, "Three Types of Sensorineural Hearing Losses"). Additional informal confirmation was obtained in a recent hotel room meeting, where Dennis Van Vliet—making a forceful point—was measured at 85-90 dB SPL, and a moment later Gus Mueller—at the telephone ordering coffee—turned and asked in a normal voice, "anyone want sweet rolls?" at peak level of 54 dB SPL.

—Mead C. Killion