An Easy Method For Calculating the Articulation Index

By H. Gustav Mueller and Mead C. Killion

In recent years there has been increased interest in the use of the articulation index (AI) for assessing hearing handicap and for measuring the potential effectiveness of amplification systems. This interest has been encouraged by studies demonstrating the ability of the AI to explain much of the difficulty that hearing impaired persons have in understanding speech.[1-4] The practical application of the AI also has been fueled by the popularity of prescriptive fitting strategies and the development of computerized probe-microphone measures. Once reserved for the research laboratory the use of the AI gradually is creeping into the clinical and dispensing settings.

It was over 40 years ago that French and Steinberg presented the original theory of AI calculation.[5] In general, the AI is an expression of the proportion of the average speech signal that is audible to a given patient, and therefore, it can vary t:rom 0 to 1.0. The calculation procedure for the AI usually consists of dividing the speech signal into several frequency bands, each weighted according to the theoretical contribution of that band to speech intelligibility. The frequency region surrounding 2000 Hz normally is rated the highest. An alternative method used in some AI procedures is to vary the band width, which then allows for equal weighting of each band. A standardized method of calculating the AI has been available for the past 20 years.[6]

Until recently, however, the clinical use of the AI has been stifled for two primary reasons: (1) the absence of an easy-to-use and understand dB HL calculation method, and (2) the belief that the clinical measurement of speech recognition/understanding is more reliable and valid than that predicted by AI calculations. This article only will address the first of these two issues, as the latter requires more lengthy discussion.

As mentioned, several researchers have studied the AI in recent years, and their work has led to various modifications and some simplification.[3,4,7] Computer programs and even probe-microphone units now can be used to facilitate AI calculation.[8,9] For the most part, however, busy clinicians and dispensers prefer to use a method that doesn't require the use of computers or other sophisticated equipment (or even a pocket calculator!). A procedure geared primarily for this end-user was proposed recently by Pavlovic.[10] His method conveniently uses an audiogram format, and rather than using several frequency bands, focuses only on four key frequencies commonly used by clinicians: 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. His calculation procedure involves adding the number of "audible decibels" in the average speech spectrum at each of these four key frequencies, and then dividing by 120, which is the total possible number of decibels (30 at each frequency, in the range between 20 dB and 50 dB HL).

THE COUNT-THE-DOT METHOD

Although the enormous simplification offered by the Pavlovic method[10] has been justifiably well received, we see two limitations to that procedure. First, our favorite half-octave frequencies, 3000 Hz and 6000 Hz, do not influence the calculation. Second, for most of us, dividing by 120 still requires the use of a calculator.

For these reasons, we are offering our own count-the-dot method of AI calculation. This procedure is not entirely new, as a similar approach using a greater number of dots was used as early as 1962 in research related to the measurement of speech privacy in buildings.s X We have taken this earlier work, simplified it to 100 dots, and translated these dots to fit into the speech spectrum on an audiogram format. The resulting audiogram form is shown in Figure 1—in a form that we hope lends itself to your reproduction and potential use.

The count-the-dot method meets the criterion of weighing different frequencies according to their importance for understanding speech. It also allows for the between-octave variations that frequently occur in hearing losses and in the insertion gain of hearing aids. The simplicity of this procedure cannot be ignored, because the only math it requires is the ability to count to 100 (actually, if one is willing to use subtraction, it is only necessary to count to 50).

In clinical situations, especially when hearing aid fitting is involved, there are at least three potential uses of these AI calculations: (1) to predict from the unaided audiogram the amount of the patient's communication handicap for normal-level conversational speech, (2) to predict the benefit that will be obtained from a given hearing aid, and (3) to compare the potential benefit obtained from one hearing aid to that of another.

The chart shown in Figure 2 can be used to relate the calculated AI to estimated intelligibility for syllables, ➤

The Count-the-Dot Audiogram Form for Calculation of The Articulation Index

Mueller & Killion, 1990.

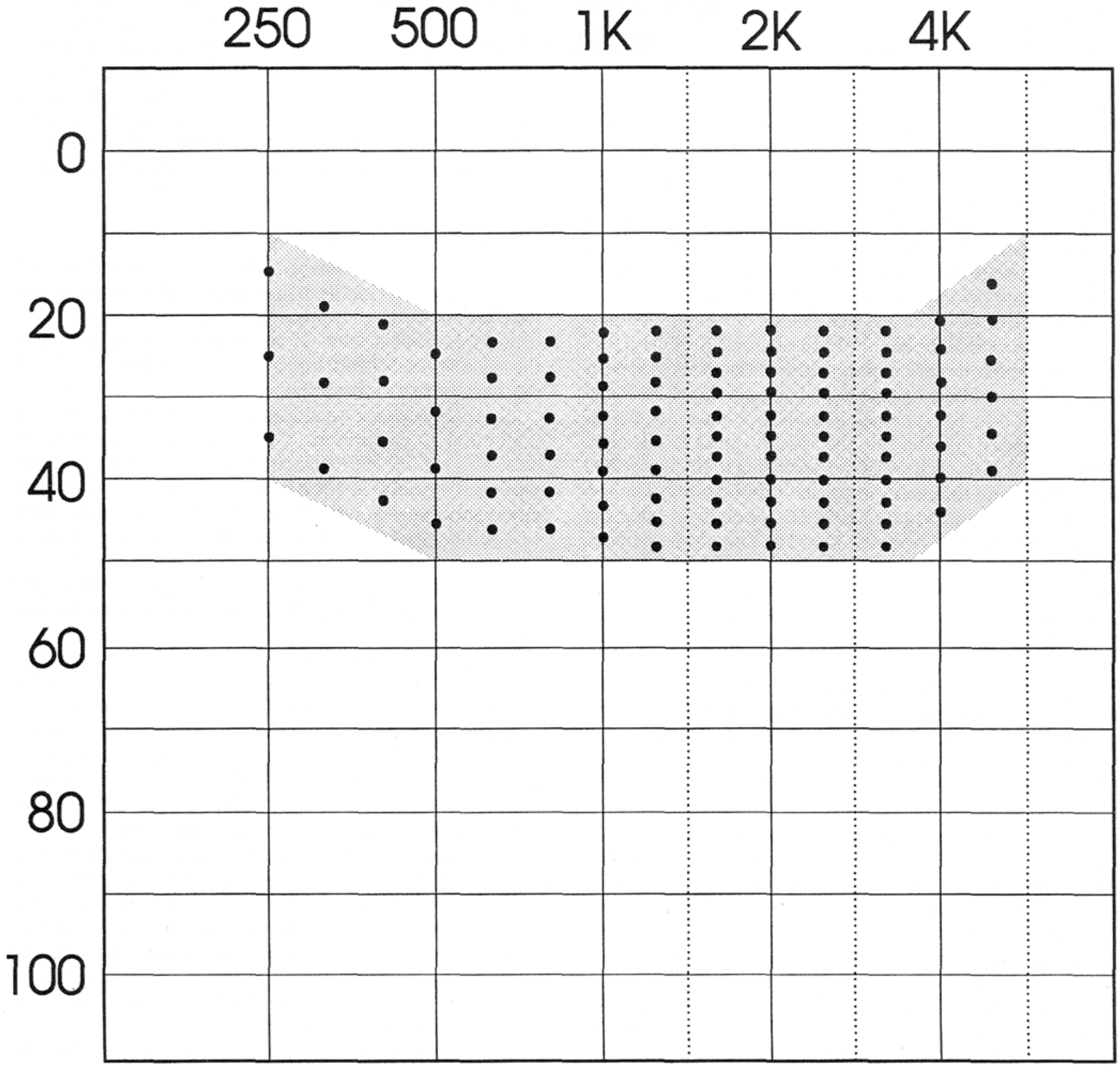

Figure 1. The Mueller-Killion Count-the-Dot audiogram form for calculation of the articulation index.

words, or sentences. For example, a patient with an AI of 0.40 would be expected to obtain an intelligibility score of approximately 60% for single-syllable words. One must consider, of course, when using this chart to predict a given patient's performance, that the clinically measured audibility (unaided or aided) often is not the level of audibility for real-life listening situations. For many communication settings, the masking effect of background noise will lower the hearing threshold, and the resulting AI can be much lower (See Killion[12] for review). Also, any attempt to predict intelligibility must be approached with some caution, as perceptual aberrations other than threshold-sensitivity loss might exist.

ILLUSTRATIVE CASE

In the subsequent figures, we will illustrate how the count-the-dot AI method can be used in conjunction with the clinical measures associated with the fitting of a hearing aid. The case presented here is a patient who was evaluated for the fitting of a new custom in-the-ear hearing aid. He also brought along his old ITE instrument, which provided us the opportunity to conduct comparative testing of the two instruments.

We used probe-microphone measures to determine if the hearing aids were at or near prescribed target gain. The real-ear insertion response (REIR) of the two instruments is shown in Figure 3. In order to compare the REIRs in a meaningful manner, the volume control wheel of each hearing aid was adjusted until the real-ear insertion gain (REIG) equaled 20 dB (approximate target gain) at 2000 Hz. The REIR labeled "ITE A" in Figure 3 is the new custom instrument. As will be shown in a later figure, these REIR values can be added to the unaided audiogram to estimate the aided audiogram for Al calculations. Alternately, the sound-field aided audiogram can be used directly.

Figure 4 depicts this patient's unaided pure-tone thresholds plotted on the count-the-dot audiogram. The more heavily shaded portion of the speech spectrum highlights the audible dots. To calculate this patient's unaided AI, therefore, one only has to count the dots that are audible to him, which results in an Al of 0.40.

To determine the potential benefits of a hearing aid to this patient, we add hearing aid insertion gain (shown in Figure 3) to his unaided audiogram, and can then calculate his aided AI. Figure 5 shows the patient's projected aided audiogram for ITE A. Observe that this fitting resulted in making audible all dots through 2000 Hz. Because insufficient REIG was present at 3000 Hz and above, however, 19 of the 100 dots remain inaudible based on the plotting of the aided threshold. The aided Al, therefore, is 0.81—a 0.41 Al improvement from the unaided calculation.

As shown in Figure 3, the REIR for the patient's old hearing aid, ITE B, differs from ITE A, as it has an undesirable dip in the response in the 3000-Hz region. Some dispensers would consider a response of this type sufficient reason to reject a given hearing aid. We questioned whether the count-the-dot AI procedure would be sensitive to this type of REIR deviation.

Figure 6 shows the plotting of the predicted aided thresholds using the REIR of ITE B. Note that for this hearing aid, because of the reduced REIG at 3000 Hz, 25 dots now remain inaudible. The resulting AI obtained with this instrument, therefore, is 0.75, as compared to the 0.81 for ITE A. Is a difference of 0.06 in the aided Al clinically significant? Possibly, especially when the presence of low frequency noise increases the importance of the high-frequency speech cues. (Note: For the purposes of this comparison, the REIR of the two hearing aids was matched to target gain at 2000 Hz. Previous testing, however, indicated that this patient typically used his old hearing aid (ITE B) at a volume-control-wheel setting lower than this, probably because of the peak in the REIR at 1500 Hz. If we match the REIG of ITE B to ITE A at l 500 Hz rather than at 2000 Hz, then the AI for ITE B drops to 0.67, a more substantial 0.14 below that of ITE A.)

We were curious as to whether the AI results obtained in the above example for the count-the-dot method would resemble those that would have been obtained using the Pavlovic procedure[10] cited earlier. The Pavlovic method would have resulted in a higher unaided AI of 0.46—vs. the 0.40 obtained with our method. The aided AI for ITE A would not differ, as both procedures result in a value of 0.81. The Pavlovic method, however, would result in a higher aided AI of 0.80 for ITE B, and therefore, would reveal less difference between these two instruments when the REIG is matched at 2000 Hz.

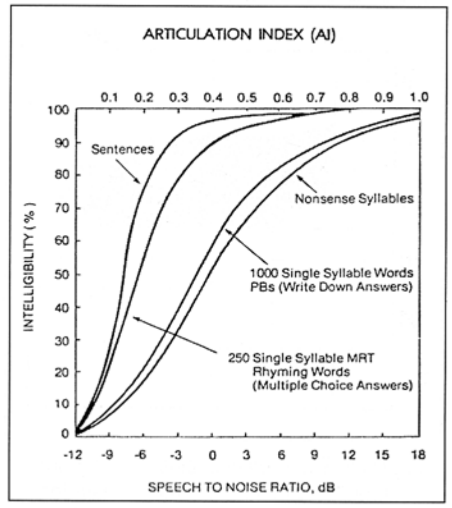

Figure 2. The relationship between the articulation index (AI) and the intelligibility of syllables, words, and sentences [from Killion,[12] adapted from Webster].[13]

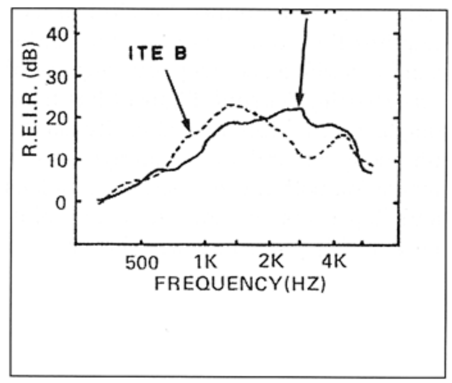

Figure 3. The real-ear insertion response (REIR) for two different custom in-the-ear (ITE) hearing aids.

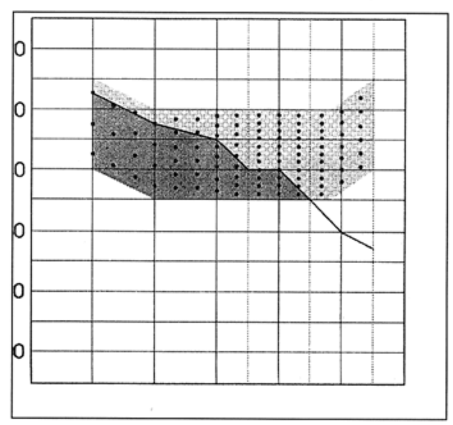

Figure 4. The unaided audiogram for a patient who was fitted with a hearing aid. The darkershaded portion of the speech spectrum highlights the dots that are audible.

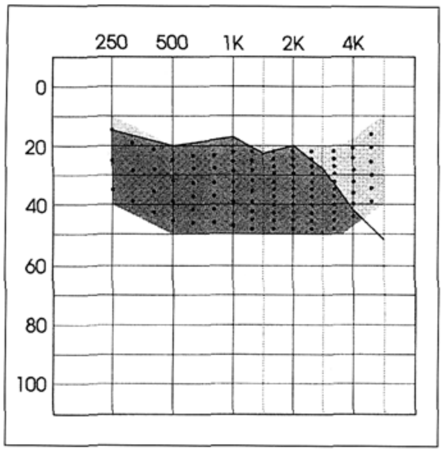

Figure 5. The projected aided audiogram obtained by adding the insertion gain for ITE A (see Figure 3) to the unaided audiogram (see Figure 4). The darker-shaded portion of the speech spectrum highlights the dots that are audible.

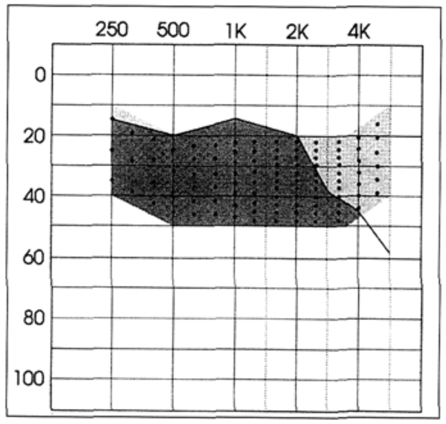

Figure 6. The projected aided audiogram obtained by adding the insertion gain for ITE B (see Figure 3) to the unaided audiogram (see Figure 4). The darker-shaded portion of the speech spectrum highlights the dots that are audible.

SUMMARY

We have presented a method of AI calculation that is simplified for clinical use, requires little time, yet does not significantly sacrifice accuracy. By courtesy of *The Hearing Journal,* Figure 1 has been displayed in a format that easily can be photocopied, and we encourage experimentation with this method by clinicians and dispensers. In addition to the usefulness of this procedure with hearing aid fittings, we have found that the 100-dot speech spectrum also serves to make the standard audiogram more meaningful to both clinicians and patients.

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