Evaluation of Hearing Handicap

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Abstract

The American Academy of Otolaryngology and American Council of Otolaryngology (AAO-ACO) define hearing handicap as a disability to understand sentences under everyday vocal and listening conditions, and describe procedures for its estimation from pure-tone threshold hearing levels. Research now reveals that the AAO-ACO procedures underestimate measured hearing handicap by the equivalent of averaged pure-tone threshold losses of 17 dB at high-percentage handicaps to 35 dB at low-percentage handicaps. It is proposed that AAO-ACO procedures be modified as follows: (a) adjust hearing levels for presbycusis when estimating handicap due to noise or other factors than presbycusis; (b) change averaged hearing level "fences" from present 25 dB to 15 dB for 0 percent and from present 92 dB to 75 dB for 100 percent handicap; and (c) change weight for "worse" ear contribution from present 1/6 to 1/4 for binaural listening.

Key Words: AAO-ACO handicap, binaural weightings, hearing disability, hearing handicap, hearing impairment, speech

Guides issued by the American Academy of Ophthalmology and Otolaryngology (AAOO; 1959) and the American Academy of Otolaryngology and American Council of Otolaryngology (AAO-ACO; 1979) specify procedures and criteria to be used for estimating the handicap, or disability, people with losses in hearing sensitivity have for understanding everyday speech in everyday listening conditions. These guides are widely used for (1) the evaluation and adjudication of medical-legal issues related to hearing loss from exposures to noise and (2) setting allowable limits of noise exposure in noisy occupations, that is, the levels of exposure that will not cause more noise-induced losses in hearing thresholds than those allowed before "compensable" or "material" hearing handicap is reached. The guides are obviously of both scientific and practical medical-legal interest and importance.

Except for two laboratory experiments on speech intelligibility (Aniansson, 1974; Suter, 1978), the presently operative AAO-ACO 1979 guide is based on research published prior to 1965. However, since those publications, studies have been conducted on the voice and noise levels present during real-life speech communications, and laboratory and field studies of the relations between amounts of permanent threshold shifts and measured and self-rated hearing handicap for speech communications in real-life conditions.

These new, and some older, research findings and their implications for modifications of the AAO-ACO guides are described below. Much of the material to follow is derived from a recent book by Kryter (1994). Discussion of some of this research, and related problems, is also to be found in a recent British review (King et al, 1992).

HEARING IMPAIRMENT AND HANDICAP

The principal definitions and procedures of the AAOO and AAO-ACO guides were promulgated in the following documents:

- **AAOO (1959).** To quote from the AAOO 1959 guide, "The ability to hear sentences and repeat them correctly in a quiet environment is taken as satisfactory evidence of correct hearing for everyday speech" (p. 236).

- **AAOO (1965).** The AAOO 1965 guide recommended dropping the word "impairment" in favor of "handicap" when referring to a
speech-hearing deficiency, and to use "impairment" when referring to a loss in pure-tone hearing sensitivity. The handicapped behavior described in the guideline is the ability to understand sentences under everyday quiet and noise conditions.

- **AAO-ACO (1979).** The most recent guide, AAO-ACO 1979, recommends that the hearing level at 3000 Hz be averaged with those at 500, 1000, and 2000 Hz for measuring impairment. The number of decibels the specified average hearing level exceeds a lower "fence" of 25 dB, up to an upper fence of 92 dB (re ANSI, 1970), multiplied by 1.5, equals the percent hearing handicap for everyday speech of that ear. Percent binaural handicap is taken as the percent handicap of the better ear multiplied by 5, added to that of the worse ear, and the sum then divided by 6.

**Understanding Everyday Speech under Everyday Listening Conditions**

To conduct adequate laboratory research on "everyday speech communications" requires knowledge of what constitutes, in acoustic terms, the intensity levels of everyday noise and conversational speech as found in the home, stores, vehicles of transportation, etc. Such information, which was largely unknown at the time the AAOO and AAO-ACO guides were prepared, has since been measured in a study by Pearsons et al (1977).

Figure 1 shows that in the presence of background noise of about LAeq of 50 or less, the approximate level of speech 1 meter from the talker averages to about LAeq 52 (L, unweighted, eq of about 55 dB). It also appears that the talkers adjust their vocal effort to provide a speech-to-noise ratio of about +3 dB until the vocal effort is between raised and shouting, a speech level at 1 meter of about LAeq 70. In higher noise levels, the speech-to-noise ratios become progressively negative. (These levels were derived from computer analyses of 1000 samples per second of A-weighted sound pressures, integrated over 10-second periods of connected speech. They are numerically about 5 dB less in magnitude than the speech levels reported in the literature as the arithmetic average of maximum A-weighted sound level meter readings [LA, dB] occurring during each uttered word. They are also 5 to 10 dB less than equally loud levels of speech heard under an earphone, when the earphone is calibrated by typical "coupler" methods of measuring sound pressure levels; see Kryter [1994]).

This everyday speech- and noise-level information allows for the calculation of the Articulation Index (AI; ANSI S3.5, 1969) for a wide variety of possible speech-to-noise listening conditions with hearing levels of noise-exposed persons as a parameter. The AI can be used to predict the percentages of incorrectly perceived words in simple sentences. As seen in Figure 2, handicap for speech understanding—expressed as percent incorrect words heard in simple sentences—varies over a wide range for most hearing levels, given here as the average of hearing levels at 1, 2, and 3 kHz (see Kryter [1994] for details of the AI calculations). Results obtained with sentence tests administered to persons with different degrees of noise-induced hearing loss are consistent with the AI predictions (see the dashed curves in Fig. 2).

**Figure 1** Speech and background noise levels found in various real-life situations, after Pearsons et al (1977).

**Figure 2** Percentage of incorrect words in sentences for various speech-to-noise ratios, estimated by calculated Articulation Index (Kryter, 1984), and as measured in speech intelligibility tests by Suter (1978).
Rating of Hearing Handicap in Real-Life Situations

Subjective Self-Ratings of Hearing Handicap

Nett et al (undated) found in a study of “critical incidents” of hearing handicap in a population of 378 hard-of-hearing persons that half of the people had hearing handicap of 34 percent, or less, as estimated by AAOO procedures (equivalent to about 42% by AAO), but 60 percent of the group self-estimated their loss in hearing ability as being in excess of 60 percent.

Kell et al (1971) reported data for (a) 96 noise-exposed weavers whose hearing levels averaged 37 dB, average 500, 1000, and 2000 Hz; and (b) 96 controls, matched for age, whose average hearing levels at those three frequencies was 13 dB. The average of the percentages of persons in the two groups reporting difficulties with speech communications in a variety of real-life situations, defined in a questionnaire, was 73 percent for the weavers and 10 percent for the control subjects. For what they are worth, with but two levels of hearing tested, these data indicate about a 2 percent point increase in the percentage of people with difficulties with speech communications for each decibel increase in hearing level above 13 dB.

Robinson et al (1984) tested 44 otologically normal adult subjects, 24 of whom had histories of exposure to noise. The information collected in that study of interest in the present discussion is of two kinds: (a) percent errors made on speech communication tasks performed in three simulated real-life situations and (b) self-assessments, recorded on a questionnaire, of hearing difficulties and handicaps with respect to general real-life situations.

The self-assessment questionnaires required the subjects to scale any hearing difficulties or handicap they experienced with respect to nine real-life social and work situations, with four to five questions per situation. The answers were converted to a percentage of difficulties, or disabilities/handicaps, depending on the definitions attached to the different situations and questions. The open-square data points, and a connecting trend curve, in the upper-left sections of the graphs in Figure 3 show the average of the relations found by Robinson et al between hearing level and the various performance and self-rating handicap/disability scores.

Lutman et al (1987) gave questionnaires to 1691 subjects chosen at random from the British adult population. The subjects self-rated the difficulty, on a scale from none to great (or a similar scale depending on the exact question), that they had experienced in real-life situations involving hearing. Four of the questions were considered as probing of a hearing “handicap” component (“cut-off from things,” “restricts social life,” etc.) and four other questions were directed toward everyday speech understandability, or, in the investigators’ terminology, “disability” component (“can you follow television news,” “can you localize position of talker,” etc.).

The questions were scored as being indicative of either a behavioral “handicap” or a speech hearing “disability” component. The results were plotted against the average hearing levels at various test frequencies for the better ear multiplied by 4, plus the average for the worse ear, with the sum divided by 5. The functions found between hearing levels and the handicap and disability components differed somewhat from each other, but not greatly. The solid data points and trend curve drawn thereto (see upper-left section of Fig. 3) were scaled to 100 percent for the handicap component.

Similarity of Self-Ratings of Hearing Handicap and Misunderstanding of Words in Sentence Tests

A linear dotted curve is drawn in the upper section of Figure 3 to visually approximate the average of the various curves plotted on Figure 2 showing percent incorrect words in simple sentences as estimated by AI and as measured
in speech tests. Clearly, estimated average percentage of incorrect words in sentences over the various everyday listening and speech-level conditions falls along the same general path as the subjective percentage handicap/disability ratings for the understanding of everyday speech in real life and simulated real-life conditions. While the numerical similarities among these various percentages are no doubt somewhat fortuitous, considering the different scaling procedures involved, they are also sensibly similar.

**Underestimation of Hearing Handicap in Self-Ratings**

Retrospective subjective self-ratings of hearing handicap and deafness have been found to underestimate those hearing deficiencies. Data from Robinson et al (1984) showed that in light of the immediate actual listening experiences, the subjects lowered their initial retrospective judgments of their speech reception abilities under real-life conditions.

Merluzzi and Hinchcliffe (1973) and Lutman and Robinson (1992) also found evidence that subjective retrospective ratings of hearing ability tend to be significantly higher than is measured by performance tests. This has been attributed to (a) some psychological adaptation because of the usual slow, over time, increase in loss of hearing sensitivity, due to either age or noise, or both; (b) some vanity-driven self-denial of a handicap; and (c) some unawareness of many sounds, including speech, that they do not hear. In any event, the self-ratings of hearing handicap and disability appear to be, if anything, conservative estimates of objective measures of those abilities.

**Proposed Modifications in Procedures for Estimating Percent Hearing Handicap**

**Adjustment for Normal Hearing Handicap for Everyday Speech**

Figure 3 shows that a person with normal, 0-dB hearing levels has about a 15 percent self-rated handicap for understanding everyday speech and words-in-simple-sentence scores. With about a 75-dB hearing level, average 500, 1000, 2000, 3000 Hz, the handicap reaches 100 percent—a linear function of about 1.67 percentage points in handicap for each decibel of hearing level 15 dB to 75 dB.

The data in Figure 3 provide empirical bases for “lower” and “upper” hearing level fences for estimating percent handicap. As near as can be determined from the bibliographic references given in the AAO-ACO guides, the specified fences were based largely on observations made in otologic clinics and, perforce, not on directly relevant research findings.

It is surmised that this 15 percent hearing handicap occurs at 0-dB hearing levels because some everyday speech is somewhat masked by everyday noise, thereby making it inaudible, or misunderstood, even to persons with normal hearing sensitivity. The propriety of setting a lower “fence” at hearing levels at less than 15 dB is a debatable matter. For example, the person with a 15-dB hearing level, induced by age or noise, will have a greater handicap than the normal, 0-dB hearing level person for understanding weak speech signals in quiet or near quiet. However, the 15-dB lower fence is inherent with the AAO-ACO criterion that hearing handicap be assessed in terms of average “everyday noise and speech conditions.”

The upper fence, as presumably shown by the higher self-ratings of speech hearing handicap/disability, is due to the fact that a person with the averaged hearing levels of 75 dB (coupler measured sound pressure levels of about 83 dB), open-field shouted speech of LA 80 dB per word, would be inaudible. The reason is that the narrow, critical-for-detection, band sound pressure levels of words are but 55 dB when the overall frequencies level is LA 80 dB. Allowing 12 dB for a speech peak-to-rms factor, plus 8 dB for ear canal resonances of speech sounds, the effective peak critical-band sound pressure levels of the speech would be LA 75 dB, 8 dB below the 83-dB level required for threshold detectability.

**Adjustment for Normal Presbycusis**

The procedures prescribed in the AAO-ACO guide lead to an estimate of total percent hearing handicap, regardless of the cause of losses in threshold sensitivity—presbycusis, noise, disease, etc. The basic procedure herein proposed can be used to achieve the same goal (i.e., estimate the total percent monaural and binaural hearing handicap due to losses in hearing sensitivity from all causes).

The following steps are also proposed to permit estimation of percent hearing handicap due solely to a secondary, nonage-related cause, such as exposure to noise, of losses in hearing sensitivity thresholds.
Step 1: subtract normal, median, presbycusis losses, re ISO 7029 (1984), from a subject's post-noise exposure hearing levels before estimation of percent hearing handicap.

Step 2: subtract the result from percent hearing handicap found without presbycusis correction to estimate the percent handicap attributable to noise or other nonage factors.

**Adjustments for Binaural Listening (Asymmetric Hearing Levels)**

A third proposed change to the AAO-ACO method has to do with the treatment of monaurally measured hearing levels when estimating hearing handicap for binaural listening. As indicated earlier, the AAO-ACO guides estimate that the contribution of the hearing levels of the less sensitive, "worse" ear of a person is taken to be the equivalent of 1/6 the contribution made to speech understanding by both ears.

Data for self-ratings of hearing handicap for speech in real-life conditions and laboratory intelligibility tests indicate that a weighting for worse ear hearing levels of between 1/2 to 1/3 would be more appropriate than the 1/6 weighting (see reviews of related research by Kryter [1994] and King et al [1992]). A 1/4 weighting would perhaps be a reasonable, but tentative, compromise. Accordingly, estimated binaural percent hearing handicap = (% percent handicap better ear × 3) + (% percent handicap worse ear)/4, where percent hearing handicaps are based on monaural hearing levels.

**Comparisons of Measured and Predicted Percent Hearing Handicap**

The lower three curves in Figure 3 depict, as a function of hearing level, linear representations of the calculated percent of hearing handicap as predicted by the AAO-ACO method and the proposed method. Two examples for male ears are given for the proposed method, one with 0-dB presbycusis (age 20–25 years) and one with 11-dB normal presbycusis, an average of 500, 1000, 2000, and 3000 Hz as follows: (a) a 15-db lower "fence" (an adjustment for normal-hearing handicap) is subtracted from the average of the specified measured hearing levels for each ear; (b) a decibel amount of presbycusis normal for a given-aged ear is subtracted from the normal-hearing-handicap-adjusted hearing level for each ear; (c) a percent monaural hearing handicap attributable to nonaging factors (e.g., noise or general nosocussis) is found by multiplying by 1.67 the number of decibels, up to a maximum of 60, remaining in hearing level, measured and normalized as specified in (a) and (b) above; (d) percent hearing handicap for binaural listening is estimated by multiplying the percent hearing handicap for the "better" ear by 3, adding that for the "worse" ear, and dividing the sum by 4; (e) total percent monaural or binaural hearing handicap without regard to possible causes is to be calculated without normalization (b, above) of hearing levels for presbycusis.

3. Compared to the proposed procedures, the procedures of the AAO-ACO guide underestimate hearing handicap for everyday speech by the equivalent of -1 to 17 dB, depending on the age of the individual.

**REFERENCES**


Calculation of the Articulation Index. (ANSI S3.5-1969). New York: ANSI.


