The NAL Percentage Loss of Hearing Scale

Anne Greville
Audiology Adviser, ACC
February, 2010

The NAL Percentage Loss of Hearing (PLH) Scale was developed by John Macrae of the Australian National Acoustic Laboratories in Sydney during the 1970s and 1980s. The scale was incorporated into ACC’s regulations as the method for determining degree of hearing loss originally in 1992 and amended in 1996, 1999 and 2003.

The reason for development of the scale was dissatisfaction with the American scale in use at the time – the so-called AAOO (for American Academy of Ophthalmology & Otolaryngology) scale, which involved a simple average of thresholds at 500, 1,000 and 2,000 Hz. Noise induced hearing loss (and, indeed, most sensorineural hearing loss) typically affects the higher frequencies to a greater extent, so there was a need for a scale that recognised the contribution of the higher frequencies to overall hearing disability.

The reason for the original exclusion of frequencies above 2,000 Hz was probably related to technological limitations of the time. Hearing aids (and other technologies such as telephones) did not reliably amplify sounds above 3,000 Hz.

An initial study examined speech discrimination in background noise. Subjects were 309 war veterans, selected from the audiometric records of 1,000 people to ensure a variety of audiometric configurations. Speech materials were CID (Central Institute for the Deaf) sentences presented via loudspeakers in fixed positions. Presentation levels were 60 dB and 80 dB SPL. Sentences were presented in quiet, and with two different types of noise – initially shaped random noise (which resembles traffic noise), and (for the majority of Ss) cafeteria noise, which was found to have a greater masking effect on the speech material. Noise presentation levels were 70 dB SPL (57 dBA for the shaped random noise, and 67 dBA for the cafeteria noise).

The authors found on examining the data that the 3 frequency average hearing loss (3FAHL – the average of thresholds at 500, 1,000 and 2,000 Hz) in the better ear was strongly related to performance on the speech tests, whereas the 3FAHL in the worse ear was only poorly related.

The articulation index (AI) was developed in 1947, and later modified by Kryter to predict speech intelligibility for normal hearing listeners under various sets of noise conditions. Macrae & Brigden modified the procedure to calculate the AI for each individual hearing impaired listener, by replacing the normal audibility curve with a curve that reflects the audiogram of that individual.

---


with the individual’s audiometric thresholds. The portion of the speech signal above the individual’s thresholds, and the noise level, was identified and added band by band to obtain the AI for that listener – see Figure 1.

Figure 1. Audiogram showing the portion of the speech signal in shaped random noise that is used to calculate the AI for a subject with the given hearing levels in both ears. AI = 0.25 and predicted speech score = 78%; cf AI = 0.35 and 92% speech discrimination for normal hearing listener. (Macrae & Brigden, 1973)

The purpose of calculating the AI was to compare its predictive power re speech discrimination, compared with the 3FAHL. The result was a curvilinear relationship between AI and percent words correctly identified. The AI gave a marginally higher correlation ratio (0.978 cf 0.965) than 3FAHL, but a significantly lower standard error of estimate (6.9 cf 12.1).

Similar results were observed with shaped random noise, but the methodology was not applied for cafeteria noise because the authors were aware of the “binaural squelch” effect of 3 dB from stereophonic reproduction of cafeteria noise with normal hearing listeners, but were unsure how great the effect might be with hearing impaired listeners.

The authors concluded that everyday speech reception by hearing impaired listeners is very largely determined by their degree of threshold impairment. Moreover, thresholds of frequencies above 2,000 Hz were established as contributing to speech reception at least in some everyday circumstances.
During the development of the scale\(^4\), relationships were further investigated between thresholds at the different audiometric frequencies, discrimination of sentences in quiet, and scores on a questionnaire concerning difficulty hearing in everyday life. Degree of handicap was divided into six categories as follows:

Table 1. Degree of handicap, related percentage loss of hearing ranges, and associated difficulties in everyday communication

<table>
<thead>
<tr>
<th>Degree of handicap</th>
<th>Percentage Loss of Hearing (PLH)</th>
<th>Difficulty with...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0</td>
<td>Faint everyday sounds, particularly when background noise present</td>
</tr>
<tr>
<td>Slight</td>
<td>0.1 – 9.9</td>
<td>Faint speech sounds in quiet and conversational speech against a noise background</td>
</tr>
<tr>
<td>Mild</td>
<td>10 – 39.9</td>
<td>Speech at conversational levels in quiet</td>
</tr>
<tr>
<td>Moderate</td>
<td>40 – 69.9</td>
<td>Speech even with a very loud raised voice</td>
</tr>
<tr>
<td>Severe</td>
<td>70 – 99.9</td>
<td>Speech, even when shouted or considerably amplified</td>
</tr>
<tr>
<td>Profound</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

The contribution of hearing at the different audiometric frequencies was found to vary in terms of the lowest threshold associated with everyday hearing difficulties – with the frequencies above 2,000 Hz having higher thresholds. For frequencies up to 2,000 Hz, the definition of normal hearing extended to 18 dB – at 3,000 Hz it was 19.5 dB, and at 4,000 Hz, it was 22.5 dB.

The same relationship was found for the lower limits of the other degree of handicap – eg for moderate hearing loss, thresholds starting at 47 dB were generally found, but for 4,000 Hz, the starting point was 50.5 dB.

Table 2. Degree of handicap and related ranges of hearing loss for each audiometric frequency

<table>
<thead>
<tr>
<th>Degree</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0 - 18</td>
<td>0 - 18</td>
<td>0 - 18</td>
<td>0 - 18</td>
<td>0 - 19.5</td>
<td>0 - 22.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>47 - 66</td>
<td>47 - 66</td>
<td>47 - 66</td>
<td>47 - 66</td>
<td>47 - 66</td>
<td>50 - 67</td>
</tr>
</tbody>
</table>

\(^4\) Macrae, JH. A procedure for classifying degree of hearing loss (NAL October 1974); J Otolaryngol Soc Aust, 4:26-35, 1975/6
Moreover, thresholds at different frequencies contributed differentially to the
overall PLH, with the maximum potential contribution coming from 1,000 Hz (up
to 25%), and the lowest contribution from 3,000 and 4,000 Hz (up to 10% each).

Table 3. Degree of handicap and related percentage loss of hearing ranges for each audiometric
frequency

<table>
<thead>
<tr>
<th>Degree</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Slight</td>
<td>0.1 - 2</td>
<td>0.1 - 2.5</td>
<td>0.1 - 2</td>
<td>0.1 - 1.5</td>
<td>0.1 - 1</td>
<td>0.1 - 1</td>
</tr>
<tr>
<td>Mild</td>
<td>2 - 8</td>
<td>2.5 - 10</td>
<td>2 - 8</td>
<td>1.5 - 6</td>
<td>1 - 4</td>
<td>1 - 4</td>
</tr>
<tr>
<td>Moderate</td>
<td>8 - 14</td>
<td>10 - 17.4</td>
<td>8 - 14</td>
<td>6 - 10.5</td>
<td>4 - 7</td>
<td>4 - 7</td>
</tr>
<tr>
<td>Severe</td>
<td>14 - 19.9</td>
<td>17.5 - 24.9</td>
<td>14 - 19.9</td>
<td>10.5 - 14.9</td>
<td>7 - 9.9</td>
<td>7 - 9.9</td>
</tr>
<tr>
<td>Profound</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Presbycusis correction

Macrae’s original research on war veterans\(^5\) was designed to examine the
relationship between noise-induced hearing loss and presbycusis. Veterans were
chosen who had documented noise damage from their war service, but no other
occupational noise exposure. On average, their hearing was tested 8 – 15 years
after their initial audiometry showing NIHL. Changes in hearing loss averaged 3 - 7
dB at 1,000 Hz and 10 – 13 dB at 4,000 Hz. These changes were closely in line with
Spoor’s\(^6\) presbycusis formulae for 4,000 Hz, and slightly greater than predicted at
1,000 Hz (though all were within 3 dB). Macrae concluded that despite his
subjects having considerable hearing loss at 4,000 Hz when first tested, their
hearing continued to deteriorate at the same rate that would be predicted from
presbycusis alone. He therefore concluded that presbycusis and NIHL are
independent and additive at least at 4,000 Hz.

The 1974 version of the PLH tables did not include any allowance for presbycusis.
The 2\(^{nd}\) version of the tables published in 1982 included a table for presbycusis
corrections to use if desired. This version did not have separate corrections for
men and women. It showed presbycusis starting at 53 years, extending to 16.3% at
80 years, and 33.5% at 90 years of age.

\(^5\) Macrae, JH. Noise-induced hearing loss and presbycusis. Audiology 10, 323-33 (1971),
The next published version of the tables was in 1988, and the presbycusis tables included were quite different from the earlier version. Features included different tables for men and women, with corrections for men starting at 56 years, and for women at 69 years. No corrections for ages above 80 were supplied. Maximum correction figures were 12.5% for men, and 3.9% for women.

The 1988 versions had been modified in light of the publication of ISO7029, which collated hearing loss for otologically normal people, presented as a function of gender and age.

Table 3. Percentage loss of hearing for men and women at selected ages.

<table>
<thead>
<tr>
<th>AGE</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤55</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>2.4</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>4.9</td>
<td>0.4</td>
</tr>
<tr>
<td>75</td>
<td>8.3</td>
<td>1.7</td>
</tr>
<tr>
<td>80</td>
<td>12.5</td>
<td>3.9</td>
</tr>
</tbody>
</table>

Macrae later evaluated two models for expressing the relationship between hearing loss from age and hearing loss caused by other factors. Under ISO1999 (Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment), a relationship less than additive between the effects of age and other factors was proposed. Humes & Jesteadt proposed that the relationship was instead non-linear, and could be better described by a modified power relationship. Macrae evaluated the proposals using the data from the war veterans who contributed to the earlier studies, in which 240 veterans had their hearing retested approximately 15 years after their initial assessment. The changes in hearing observed were better predicted by the ISO 1999 formula (on average 3 dB more than predicted by the ISO 1999 formula) than the modified power law (on average 7 dB more than predicted by the model). Macrae concluded that if, indeed the modified power law explains the combined effects of threshold-elevating factors, then age is the exception, and he speculated that this might be because age affects not only the sensory cells of the inner ear, but also other parts of the auditory system.

A further study evaluated the formulation devised by Bies & Hansen, which proposed that presbycusis and NIHL are additive on an anti-logarithmic basis. The data again supported the ISO formulation.

---

7 Macrae, JH. Improved procedure for determining percentage loss of hearing. NAL Report No 118, January 1988


It should be noted that the presbycusis corrections provided by Macrae, being
adjusted to be consistent with the ISO 1999 data, if anything tend to under-
estimate changes expected by presbycusis in the absence of occupational noise
exposure, and therefore represent a conservative approach for evaluating ONIHL.

Abnormally poor speech discrimination

Some clients, particularly those whose hearing loss is due to head trauma rather
than ONIHL, have poor speech discrimination which means that their hearing
difficulties in everyday life are significantly greater than would be assumed from
the PLH. An alternative procedure for this group was introduced in 1991¹². Abnormally
speech discrimination was defined as performance on the CID
sentence material at levels below the range observed with the original sample of
war veterans, as shown in Figure 2. An equivalent graph is available for
presentation level of 80 dB.

Figure 2. Region of abnormally poor speech discrimination (hatched region) for CID everyday
sentence lists presented in quiet sound field conditions at 60 dB SPL.

The essence of the procedure is to match a client's speech discrimination (using
CID sentences) at 60 dB (normally, or at 80 dB if the client scores 0% at 60 dB
presentation level) with the corresponding average 3FAHL (for examples, see
Table 4). A link is also provided between 3FAHL and PLH as determined from
examination of audiograms of 697 NAL hearing aid clients¹³ (see sample values in
Table 4).

¹¹ Bies, DA & CH Hansen. An alternative mathematical description of the relationship between

¹² Macrae, JH. A procedure for determining percentage loss of hearing of clients with abnormally
poor speech discrimination. NAL Report No. 124, 1991

¹³ Dillon, H & JH Macrae. Derivation of design specifications for hearing aids. NAL Report No 102,
1984
Table 4. Mean values of 3FAL and PLH for selected word scores on CID sentences presented in sound field at 60 dB SPL

<table>
<thead>
<tr>
<th>Word score CID sentences (%)</th>
<th>3FAHL</th>
<th>PLH</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>39</td>
<td>36.7</td>
</tr>
<tr>
<td>80</td>
<td>45</td>
<td>46.6</td>
</tr>
<tr>
<td>70</td>
<td>49</td>
<td>53.0</td>
</tr>
<tr>
<td>60</td>
<td>52</td>
<td>57.4</td>
</tr>
<tr>
<td>50</td>
<td>55</td>
<td>61.9</td>
</tr>
<tr>
<td>40</td>
<td>57</td>
<td>64.8</td>
</tr>
<tr>
<td>30</td>
<td>59</td>
<td>67.7</td>
</tr>
<tr>
<td>20</td>
<td>61</td>
<td>70.5</td>
</tr>
<tr>
<td>10</td>
<td>64</td>
<td>74.8</td>
</tr>
</tbody>
</table>

Tinnitus

Macrae discussed the issues relating to tinnitus, its impact on the reliability of audiometry, and whether it was appropriate to factor in tinnitus in some fashion to the calculations for PLH. The conclusion was that it was inappropriate for tinnitus to impact on the PLH calculation. If tinnitus was to be compensated, it should be treated separately from the degree of hearing loss.

Bibliography


