ALLOCATION OF MEASURED HEARING LOSS BETWEEN AGE AND NOISE

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ABSTRACT: A convenient way of allocating a person's measured hearing loss between the competing causes of age and noise is explained. It uses spreadsheets and each of the person's measured hearing thresholds. The spreadsheet compares individual data to population data in International Standards ISO 1999 and ISO 7029. The method leads to a calculated "worst case effect of age" assuming a typical pattern of age related hearing loss. This gives a measure of the individuals hearing "toughness" or susceptibility to loss due to age. Assuming the same susceptibility to noise induced loss of hearing, it is possible to calculate hearing losses at each frequency assuming we know the person's noise exposure history. The results are plotted as graphs. The technique has been found useful in court cases for industrial deafness. Apart from the calculation advantages, it graphically illustrates when there is a component of hearing loss explainable more probably than not by noise exposure.

1. SPREADSHEET CALCULATION OF "WORST CASE EFFECT OF AGE"

ISO 1999 Acoustics - Determination of occupational noise exposure and estimation of noise induced noise impairment [1] sets out two databases for the component of age related loss of hearing. The "highly screened" database A is used to calculate hearing threshold solely as a function of age. The method described in this paper initially allocates as much as possible of a person's measured hearing loss to age related hearing loss (ARHL). That component in decibels is given the symbol A when we quantify ARHL.

The reason for doing this is to test whether adoption of such an allocation still results in a person having a noise induced hearing loss (NIHL) or N when we quantify NIHL.

ISO 1999 and ISO 7029 1994 Acoustics - Threshold of hearing by air conduction as a function of age and sex for otologically normal persons [2] set out population statistics. They give median hearing thresholds and the standard deviation measure of the population variability of that median. Analysis leads to the probability of a person's measured hearing loss in the population distribution.

In his book Medical-Legal Evaluation of Hearing Loss [3], Dobie sets out the process of differential diagnosis (identifying the cause or causes of hearing loss) and of allocation (estimating the relative contribution of different causes to the total hearing loss and also to the total hearing handicap).

2. CALCULATION OF THE AGE COMPONENT

The technique described here fits the individual directly into the population statistics. By assuming a person's hearing threshold (or loss) is not worse than the measured loss, we establish the "worst case" susceptibility due to age. It is assumed that the general shape of ARHL getting worse with increasing frequency and with increasing age is exactly described by the population statistics summarised in ISO 1999 and ISO 7029.

If the audiologist has been unable to exclude all of an exaggerated loss, the person's sensorineural loss could be less. If a conductive hearing loss is present too, the person's loss could be better than indicated too. This leads to some certainty, required in court cases, that the noise induced component is no more than calculated.

International Standards ISO 1999 and ISO 7029 describe the median permanent threshold shifts (PTS) of hearing as a function of noise exposure and of age along with their standard deviations. Their data are precise and easy to use in computer spreadsheets.

To calculate how much of a person's hearing loss is noise induced, or even whether any of the losses are due to noise, assume all the losses are due to age. Compared to other allocation methods, this technique reduces uncertainty and the range of each allocation. Solving for "A" first makes the allocation of hearing loss between alternative causes easier to understand. The calculations are immediately simplified.

3. INDIVIDUALISING THE DATA

To work out a person's "worst case" susceptibility to age, the person's measured hearing threshold at each test frequency is examined to calculate the likelihood at each frequency that the threshold is entirely due to their age at the time of the hearing test. The minimum number of standard deviations better than the median explains their measured hearing threshold as a function of age. The number of standard deviations positions that person's audiometric data in the normal population statistics.

All the usual audiometric test frequencies are examined in the above analysis. It is necessary to have audiometry at 8,000

Hz to identify the often better hearing at 8 kHz in a person who has noise induced hearing loss at 3, 4 and 6 kHz. A person with a significant noise induced hearing loss might appear to have just very bad age related hearing loss unless their hearing is also measured at 8 kHz. The calculated result is illustrated in Figure 1.

A person's measured hearing threshold in decibels is tabulated as a function of frequency for each ear, shown at the top of Tables 1 and 2. The dashed line shows the person's hearing loss measured for his left ear at each frequency marked with a cross. The person's hearing loss in his right hear is shown as a solid line with circles at each frequency. The man was aged 49 at the date of his audiometry.

Table 1 Measured Hearing Threshold

MEASURED HEARING THRESHOLD [in decibels] as a function of FREQUENCY [hertz] for each EAR [Left or Right]																	
250		500		1,000		1,500		2,000		3,000		4,000		6,000		8,000	
L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
10	15	10	10	10	5	10	5	5	10	30	35	35	40	55	55	40	50

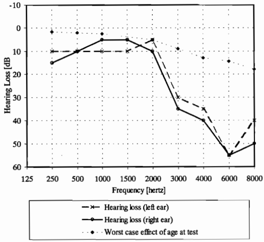

Figure 1. Measured hearing loss and worst case effect of age

The 5 dB hearing threshold in the man's left ear at 2,000 Hz corresponding to 0.21 standard deviations better hearing than the median for 49 year old men in an otologically screened population enables the "worst case effect" due to age to be calculated at the other test frequencies and plotted in the graph. It ranges from 2 dB at 250 Hz to 18 dB at 8,000 Hz. The spreadsheet calculation showing this is in Table 2.

Table 2 shows the population median hearing threshold of a man (in this case) aged 49 without ear disease other than age and noise. The spreadsheet calculation looks for the ear with the best hearing threshold at each frequency. The number of standard deviations from the median to reach the best hearing at that frequency is then calculated. At 250 Hz, the 10 dB hearing threshold in his left ear is 0.89 standard deviations worse than the median. This is shown in Table 2 in the second row labelled "Standard deviations from median". The man's best hearing compared to the normal population distribution is his 5 dB hearing threshold in his left ear at 2,000 Hz. It is 0.21 standard deviations better than the median. At all other frequencies, his best hearing in each ear is either 0.04 standard deviations better than the median (at 1,500 Hz) or worse than the median age related loss of hearing for a 49 year old man.

Because his measured hearing threshold was 5 dB at 2,000 Hz, at least in his left ear, we can assume that his hearing "toughness" is at the 58th percentile. The word "toughness" is used, instead of "susceptibility" because toughness in the population increases with increasing percentile. Note that the population susceptibility in ISO 1999, ISO 7029 and Australian Standard/New Zealand Standard 1269:1998 [4] use a population descriptor that has the 95th percentile as the least susceptible and the 5th percentile as the most susceptible.

In the absence of any better assumption, once a person's susceptibility to age is known (as a worst case assuming reliable audiometry), their susceptibility to hearing loss from noise exposure is assumed to be the same. This seems reasonable because there are unexplained differences in hearing threshold between ears at frequencies thought not to be susceptible to noise induced hearing loss (at 250 Hz in our example). Because the rate at which hearing is lost with frequency must also vary between individuals, the overall population statistics indicate where an individual fits in a population but not how unusual their particular shape of age related hearing loss is.

4. CALCULATION OF THE NOISE COMPONENT

The next part of the analysis explains some of the difference between the worst case effect of age and the person's measured hearing loss.

Hearing toughness at the 58th percentile can be used from ISO 1999 to calculate the effect of 13 years of exposure at 100 dB(A), shown in the second last row of the table. The last row of the table shows the calculated hearing losses due to age and noise added together with the slight compression (total loss = A + N - AxN/120) described in ISO 1999. The thin solid line of the graph with square boxes at the frequencies from 500 Hz to 6,000 Hz show the calculated combined age plus noise effects.

Table 2. Effect of age and effect of noise

	HEARING LOSS [in decibels] as a function of FREQUENCY [hertz] for each EAR [Left or Right]								
	250 L R	500 L R	1,000 L R	1,500 L R	2,000 L R	3,000 L R	4,000 L R	6,000 L R	8,000 L R
Loss [dB]	10 15	10 10	10 5	10 5	5 10	30 35	35 40	55 55	40 50
Std. deviations from median	0.89	0.87	0.15	-0.04	-0.21	1.49	1.29	2.20	0.94
Hearing toughness					58%				
Worst case effect of Age	2	2	3	4	5	9	13	14	18
Effect of noise 13 years 100 dB(A)		4	6	7	9	25	31	22	
Age + Noise		6	8	11	14	32	41	34	

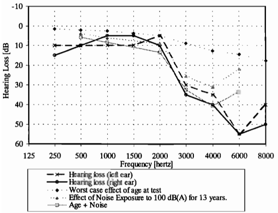

Figure 2. Effect of age and effect of noise

After the person's maximum susceptibility to age is calculated, "N" is calculated at each frequency using the same susceptibility. Figure 2 shows the person's hearing at the frequencies most susceptible to noise induced hearing loss is measurably worse than his calculated hearing loss due to age alone.

Each calculated maximum effect of age assumes a hearing loss with the same number of standard deviations from the median at each frequency. This always results in a similar curve shape.

Robert A Dobie [5] summarises other work of the relationship between ARHL and NIHL with "The inner ear degeneration that accompanies aging causes a sensorineural hearing loss that initially affects the highest frequencies in most cases. Men usually have greater losses than women of the same age." He reports that "aging affects several elements in the cochlea – at least hair cells, neurons, and stria vascularis – and these elements may deteriorate more or less independently. In this sense, ARHL is clearly different from noise induced hearing loss where … hair cells are virtually the only affected cochlea elements."

ARHL lacks the dip between 3 kHz and 6 kHz seen in NIHL; ARHL accelerates over time, while NIHL decelerates. "Allocation" is the process of determining the relative contributions age and noise have made to a person's sensorineural hearing loss (SNHL). Assuming head injury, ototoxic drugs and other otologic disorders have been eliminated by an ENT doctor (p.262).

Losses unexplained by age and noise could be due to other causes or measurement tolerances.

5. CONCLUSION

The assumptions made to arrive at the allocation between age and noise are set out. Although individuals will have patterns of loss different to population data, the probability that a person's loss includes a noise component is displayed graphically.

REFERENCES

[1] ISO 1999:1990 Acoustics – Determination of Occupational Noise Exposure and Estimation of Noise Induced Noise Impairment.

[2] ISO 7029:1994 Acoustics – Threshold of Hearing by Air Conduction as a Function of Age and Sex for Otologically Normal Persons.

[3] RA Dobie, "Diagnosis and Allocation" *Medical-Legal Evaluation of Hearing Loss* Nostrand Reinhold, New York (1993) pp. 260 to 301.

[4] Standards Australia, AS/NZS 1269:1998 Occupational Noise Management Standards Australia and Standards New Zealand, Homebush and Wellington (1998).

[5] R A Dobie "Age Related Hearing Loss" *Medical-Legal Evaluation of Hearing Loss* Nostrand Reinhold, New York (1993) p.117.