The 2006

Libby Harricks

Memorial Oration

Libby Harricks Memorial Oration number 8

Honouring the Deafness Forum's first president & profoundly deaf achiever

Elisabeth Ann Harricks AM 1945 – 1998

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Introduction to the 8th Libby Harricks Memorial Oration

Dr Jenny Rosen, Chairperson, Libby Harricks Memorial Oration Committee

Having developed profound hearing impairment as a young wife and mother, Libby Harricks went on to become a passionate advocate for equal access for all hearing impaired people, and for raising awareness in the community regarding the issues relating to this. She was a founding member and longterm President of SHHH Australia Inc (Self Help for Hard of Hearing People), and represented the needs of hearing impaired people on the Sydney 2000 Olympics Access Committee. In 1990, in recognition of her contributions on behalf of hearing impaired people, Libby was made a Member of the Order of Australia. Amongst her many activities, Libby was also the first President of Deafness Forum, the national peak body in deafness which is responsible for this weekend's 4th National Deafness Sector Summit. In this role, she travelled widely throughout Australia, constantly lobbying on behalf of hearing impaired people, and raising awareness of their needs.

After her death in 1998, the Libby Harricks Memorial Oration Series was established in her honour, to continue her commitment to this cause.

To date we have been extremely fortunate with a series of excellent Orations reaching both across our area of interest, and geographically speaking, across our wide land. The Oration series, which is published by Deafness Forum, commenced in Sydney in 1999 with Emeritus Professor Di Yerbury speaking on 'Hearing Access Now!'. In 2000, at the International Federation of Hard of Hearing Conference, also in Sydney, Professor Bill Gibson spoke on tinnitus and Menieres Disease. In Canberra in 2001 Senator Margaret Reid presented on 'The Politics of Deafness'. In 2002 in Melbourne at the XXVI International Congress of Audiology, Professor Paul Mitchell presented findings of the Blue Mountains Hearing Study. In 2003, as the keynote address to a full day hearing access seminar at Macquarie University in Sydney, Donna Sorkin updated us regarding Disability law and hearing loss. In 2004 Dr Peter Carter spoke at the 3rd National Deafness Sector Summit on the present status of Aboriginal ear health. For 2005, we moved to the Blue Mountains, and Alex Jones presented his excellent Oration, 'Deafness and Disability Transformed'. As the first Oration presented in Auslan, this was yet another new direction.

The series speaks for itself in carrying forward Libby's passion, and the aims of Deafness Forum. None of this, however, 'just happens'. It is essential here to acknowledge the hard-working Libby Harricks Memorial Oration Committee, and the very supportive Deafness Forum national secretariat, without whom this Oration series would not be possible. We are delighted also to acknowledge the generosity of Siemens in assisting with the cost of presenting the 2006 Oration, and Australian Hearing for their equally generous contribution to the publication of this Oration. This year, we are very pleased to be able to add Perth to our list of venues, and would like to acknowledge the help of Barry McKinnon and other local people in bringing this opportunity to the attention of the local community here in Western Australia.

It is now my pleasure and privilege to present to you the Orator for 2006, Professor Harvey Dillon.

Harvey is Director of the National Acoustic Laboratories in Sydney and Deputy Director of the Cooperative Research Centre for Cochlear Implant and Hearing Aid Innovation. He is also a much respected long term colleague and friend of many of us. Harvey has been employed at the National Acoustics Laboratories (NAL) which is now the research arm of Australian Hearing, since 1979, and Research Director of NAL since 2000. Over that time, and increasing under his leadership, NAL has developed a well-deserved national and international reputation as a leader in many areas relating to habilitation/rehabilitation of hearing impairment. Harvey's own work ranges widely over many aspects of hearing aids, including signal processing schemes and procedures for fitting and evaluating hearing aids. Included in his list of over 90 publications is an internationally renowned text book on hearing aids.

It would be hard to find anyone better equipped to talk about Hearing Loss: The Silent Epidemic. Who, why, impact and what can we do about it? Harvey's innovative approach to this topic will draw on his extensive knowledge across this area, and will be based in NAL research, in the research of others, and in very well informed conjecture.

Will you please welcome Professor Dillon.

Hearing Loss: The Silent Epidemic.
Who, Why, Impact and what can we do about it.

Harvey Dillon, Ph.D.

It is well known that difficulty in hearing is widespread in the population, and that only a small proportion of people with hearing loss use hearing aids or other assistive devices. It is not so clear, however, just why the many people with hearing loss who do not use hearing help make that decision, and it is even less clear whether they are making a decision that is good for them, or one that is against their best interests. Good answers to these questions just don't exist yet, but in this talk we will look at some of the factors involved.

Prevalence of hearing loss and penetration of hearing aids

Let's first examine who in the community has a hearing loss. It's well known that the prevalence of hearing loss increases rapidly with advancing age. Figure 1 shows that during the later decades of life, the proportion of people with a moderate loss or greater, and the proportion with a severe loss or greater, both increase rapidly with increasing age (Wilson et al, 1998). It is believed that people are more likely to successfully adapt to using hearing aids if they receive them prior to age 70 than if they receive them at an older age (Alberti, 1977; Brooks, 1985)), presumably because cognitive ability and physical manipulation ability decreases (on average) with increasing age. This creates a conundrum, as benefit is likely to be much greater for a moderate or severe loss than for a mild loss, yet moderate and severe loss is relatively uncommon prior to age 70. Only 2.5% of those aged 61 to 70 years have a four-frequency average (4FA; average of 0.5, 1, 2, and 4 kHz) loss in their better ear greater than or equal to 45 dB HL. It is thus important that we gain a much better understanding of the benefit that can be provided by fitting hearing aids to those with a mild hearing loss.

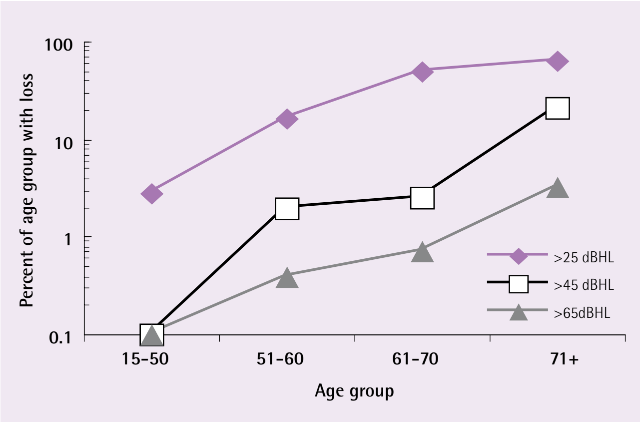

Figure 1: Percentage of different age groups in the population who have greater than or equal to the indicated degree of hearing loss (4FA in the better ear). Based on Wilson et al (1998).

The data from Wilson et al (1998) shown in Figure 1 can be applied to Australian Bureau of Statistics (ABS) population data (Trewin, 2003) to show that there are currently 2.8 million people in Australia with a 4FA loss greater than 25 dB HL in the better ear. How many of these own hearing aids? Good data exist for people receiving their hearing aids under the Department of Health, Office of Hearing Services (OHS) scheme. In financial year 2004/05, 91,675 return clients redeemed vouchers for hearing aid fittings. On the assumption that re-fittings occur once every five years, this is equivalent to 458,375 people in the population owning hearing aids and finding them useful enough to eventually want to be refitted. However, it is estimated that approximately 20% of people fitted never use their hearing aids (see later in this report), and it is presumed that these do not return for a refitting after five years. (Some eventually will, when hearing further deteriorates, of course.) Consequently, one estimate of the number of people who have hearing aids fitted under the OHS scheme is 573,000. Based on information received from the hearing aid manufacturing industry, I estimate that hearing aids provided under the OHS scheme account for about 77% of the total supplied. Consequently, the total number of people with hearing aids in Australia can be estimated at 744,000. That is, only 25% of people with hearing loss in their better ear of 25 dB HL or worse own hearing aids.

This figure is considerably higher than the 14% figure found in a survey of 590 randomly selected people in one province in Sweden (Johansson & Arlinger, 2003), but is comparable to the figure of 23% of people with self-reported hearing loss (though not the same definition of hearing loss) calculated for the USA by Kochkin (1992).

Of course, raw statistics such as "one-in-four with hearing aids" give no insight as to why the proportion is so low. Further analysis of the proportions by degree of loss gives us some clues. Applying the distribution of hearing loss from Wilson et al (1998) to the population numbers from ABS gives the number of people in the population with each degree of hearing loss, as shown in column 2 of Table 1. The number of people with hearing aids in each category can be estimated by multiplying the distribution of hearing losses among hearing aid owners by the total number of people with hearing aids. The result is shown in column 3. The ratio of column 3 to column 2 shows the penetration of hearing aids within each loss range, which is shown in column 4. As the data come from a variety of sources, and involve a number of assumptions, these figures should be taken as very approximate, and the figure of 107% ownership among those with severe and profound hearing loss is obviously not possible. The amount should be less than 100% as some people are too deaf to benefit from hearing aids and some who could benefit from hearing aids have a cochlear implant and no hearing aid. The discrepancy arises because the audiograms used to calculate the number of hearing aid owners were obtained from the database of Australian Hearing, which is more heavily weighted to people with severe and profound loss than occurs for the service industry as a whole. None-the-less, the trend is very clear, with a hearing aid ownership penetration of approximately half for those with a moderate loss, much less for those with a mild loss, and much greater for those with a severe and profound loss. The figures are reassuringly similar to the hearing aid ownership figures observed in the Blue Mountains population (17% for 26 to 40 dB HL; 55% for 41 to 60 dB HL, and 92% for >60 dB HL; Mitchell, 2002). Any investigation of the reasons for the low penetration of hearing aids has to cover the range of hearing losses up to around 60 dB.

Table 1. Hearing loss and hearing aid ownership			
Hearing loss range (4FA dB HL in better ear)	Number with hearing loss in population	Number with hearing aids in population	Percentage hearing aid ownership
0-24	17,736,763	150,288	1%
25-44	2,274,194	249,240	11%
45-64	425,026	240,312	57%
>65	97,218	104,160	107%
All	20,533,200	744,000	4%

Use and benefit of hearing aids

Peoples' attitudes to many things, including hearing aids, are greatly influenced by the attitudes of those around them. Many people possibly elect not to acquire hearing aids because they have observed (in specific situations), or been told by others, that "hearing aids did not help". One way to increase our understanding of why many people do not get hearing aids is therefore to understand the factors underlying different degrees of use and benefit reported by those who have taken the step of acquiring hearing aids. To this end, NAL, in conjunction with OHS, undertook a survey of 400 OHS clients, with a focus on clients with mild hearing loss.

Method

A sample of 400 subjects was obtained by sampling the records of 41,521 cases (referred to as the population sample) fitted from February to September inclusive during 2004. Sampling was random, except that an attempt was made to get a uniform distribution of three frequency average hearing levels (3FAHL; average of 500, 1000 and 2000 Hz) in the better ear from 0 dB to 45 dB HL, and 3FA losses in the worse ear from 0 dB to 60 dB HL. The study focused on these mostly mild losses, for whom use of hearing aids is most questionable.

In February 2005, survey forms were sent to these 400 people. Simultaneously, audiograms were sought from the providers who serviced each subject. Non-respondent subjects were followed up by a phone call (though contact was not always achieved), and where the subject had lost the survey form, or no contact was achieved, a second survey was posted. Questionnaires with at least some questions answered were eventually returned by 317 subjects. For a further 7 clients, information obtained over the phone indicated that the client was making no use of the hearing aid(s). For these clients, there was assumed to be no benefit from the hearing aid fitting. The effective response rate can thus be considered to be 324 out of 375, or 86%, though the true return rate is higher than this, as many of the 14% for whom there is no response will presumably not have received the questionnaire due to either death or the contact details being incorrect.

The subjects for whom there was no questionnaire responses available had a 3FA hearing loss in both the better and worse ears that was 3 dB greater than the corresponding losses of those for whom there was a response. The subjects not responding were 6 months younger than those that responded. One-way ANOVA indicated that none of these differences were significant ($p>0.05$).

The mean age of respondents was 71.0 years, with a standard deviation of 10.1 years. The minimum age was 35.8 years and the maximum was 103.7. The inter-quartile range extended from 66.0 to 77.9 years.

Given the high return rate, and the lack of demographic differences between the responders and non-responders, the results will be taken to be representative of the group sample chosen. For each degree of loss in the better or worse ears, the sample chosen should be representative of the general population with the same degree of loss receiving hearing aids under the OHS scheme, due to the random sampling method employed. The distribution of losses in the sample (Figure 2), is however, markedly different (by design) than the distribution of losses in the OHS population receiving hearing aids (Figure 3). As can be seen, the sampling achieved the goal of getting a greater representation of very mild losses than in the population sample.

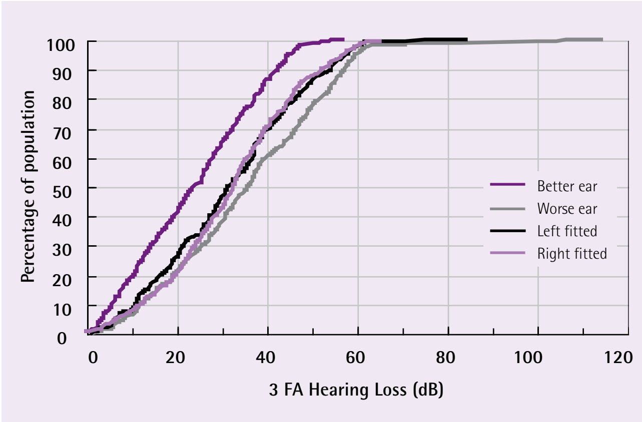

Figure 2: Distribution of 3FA hearing losses of clients selected for the study.

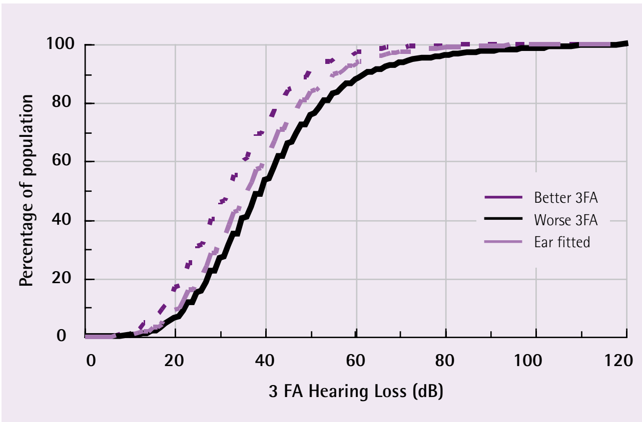

Figure 3: Distribution of 3FA hearing losses of new clients receiving their first hearing aids during 2004.

The OHS data base records only the 3FAHL in each ear. The 4FAHL can, however, be estimated if we know the typical relationship between 3FAHL and 4 FAHL, which we can find from the study sample. The average relationship is 4FA = 9.7 + 0.90*3FA. Using the relationship derived from the study sample, the distribution of 4FA losses in the OHS new client population is shown in Figure 4.

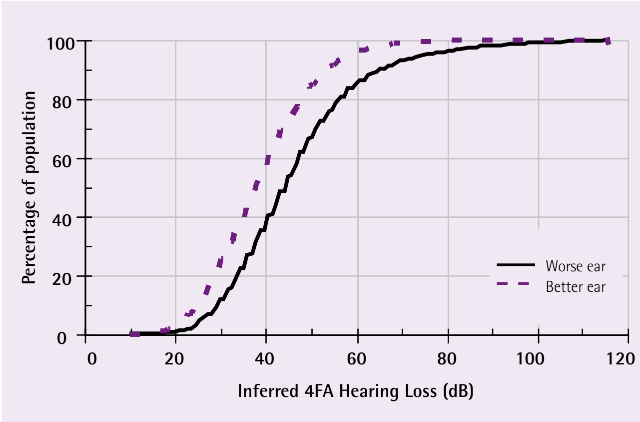

Figure 4: Distribution of 4FA hearing losses of new clients receiving their first hearing aids during 2004.

Results

Factor structure of questionnaire

The questionnaire comprised the seven items of the IOI-HA and an additional six purpose-designed questions. Subjects' responses were subjected to principal components analysis to examine commonality between the responses to different questions. A scree plot of variance accounted for indicated that three factors could justifiably be extracted. The loading of each question onto the first three factors is shown in the next table.

Table 2. Factor structure of the questionnaire results, with significant factor ($p<0.05$) loadings shown in bold.

	Factor 1	Factor 2	Factor 3
Q1: Want aids	0.69	0.30	0.21
Q2: Difficulty unaided	0.70	0.41	0.25
Q3: Use	**0.74**	-0.18	0.08
Q4: Benefit	**0.82**	-0.32	0.00
Q5: Resid difficulty	0.03	**-0.76**	-0.33
Q6: Worth it	**0.83**	-0.33	-0.00
Q7: Resid handicap	-0.29	**-0.56**	-0.06
Q8: Bother to others	-0.18	**-0.68**	-0.26
Q9: QOL	**0.82**	-0.32	0.02
Q10: Replace them	0.34	-0.15	-0.23
Q11: Face vision	-0.29	-0.42	**0.74**
Q12: paper vision	-0.22	-0.47	**0.70**

Factor 1 has heavy loadings for the four IOI items that usually group together, and which can be taken to represent the beneficial change accompanying aiding. Note that questions 1 and 2 (wanting hearing aids, and experiencing difficulty unaided) also load heavily onto factor 1. Factor 2 has heavy loadings for the three IOI items that usually group together and which can be taken to represent residual difficulty after receiving hearing aids. Factor 3 is dominated by the questions on vision loss. The relatively high loadings onto Factor 1, and the agreement of this factor structure with previous studies using the IOI-HA support the validity of the questionnaire responses, at least for questions 1 to 9.

A new variable called "Composite benefit" was defined, and calculated as the average of Q3, Q4, Q6 and Q9. These are the scores loading heavily onto the first factor.

Motivation to get hearing aids

The factor analysis showed that the desire to obtain hearing aids, and acknowledgement of hearing difficulties prior to obtaining hearing aids had a reasonable loading onto Factor 1, and were therefore related to benefit reported, but did not load as highly as the four items used to define composite benefit.

Motivation to get hearing aids was strongly related to the difficulty the person had hearing prior to getting hearing aids. The most common response to the question of how much the person wanted to get hearing aid(s) was the same as the subject's response to the question of how much difficulty in listening they reported before getting hearing aids. The Spearman rank-order correlation coefficient was 0.63. The two responses were therefore averaged to produce a composite measure of need which will be referred to as need strength.

Simple correlations between predictors and outcome measures.

Correlation analysis was performed between each of the potential predictors and the individual outcome variables. Simple correlation analysis shows significance for the following generalizations, with correlation coefficients around 0.4.

People who more strongly wanted to get hearing aids:

- Use them more (Q3)
- Benefit more (Q4)
- Say they are worth it (Q6)
- Improve their enjoyment of life by using them (Q9)
- Would replace their hearing aids if lost (Q10)

People who had the most difficulty unaided:

- Use their hearing aids more (Q3)
- Benefit from them more (Q4)
- Say they are worth it (Q6)
- Improve their enjoyment of life by using them (Q9)
- Would replace their hearing aids if lost (Q10)

All other correlations were relatively small (r<0.3), implying no strong connection between the various outcome measures and the potential predictors involving hearing loss, age, vision, and number of devices fitted.

Multilinear regression between the predictors in the previous table and the composite benefit measure was carried out. The only significant predictors were the degree to which they wanted hearing aids and the difficulty they had listening unaided. Each was highly significant (p<0.000 001), and the combined multiple regression coefficient was 0.56.

The correlations between the summary predictors and the composite outcomes are shown in Table 3. Although all the values shown in bold are significant (p<0.05), the only relationships of even a moderate strength are that on average, those who reported the greatest need when unaided received the greatest benefit and after completing the program had the greatest remaining difficulty. Note that need strength has been included as a column as well as a row so that its relationship to the other predictors can be seen. As expected, those with greater loss had more need, but the relationship was weak, especially when the better ear was used as the indicator of loss. 3FAHL and 4FAHL seem to be equally poor indicators of need. Similarly, they are equally poor indicators of benefit or of remaining difficulty.

Table 3. Correlations between potential predictors of benefit and need strength, composite benefit, composite residual difficulty. Significant correlations (p<0.05) are shown in bold.

	Need strength	Composite benefit	Composite difficulty
Better ear 3FA	**0.22**	0.09	**-0.18**
Worse ear 3FA	**0.28**	**0.13**	**-0.17**
Better ear 4FA	**0.23**	0.08	**-0.23**
Worse ear 4FA	**0.30**	**0.13**	**-0.20**
Age	**-0.13**	**-0.15**	0.03
Need strength	1.00	**0.51**	**-0.44**
Vision summary	**-0.22**	-0.08	0.19

Usage and benefit of hearing aids

Figure 5 shows the proportion of people who reported different amounts of use. There were 21% of people reporting no use, and a further 10% reporting use of less than 1 hour per day. Zero use in a two-week period is not synonymous with zero benefit, as several subjects made unsolicited comments that they have received benefit on specific past occasions. Given the high loadings of questions 3, 4, 6, and 9 onto factor 1, however, it seems unlikely that zero use over the preceding two weeks is associated with significant benefit.

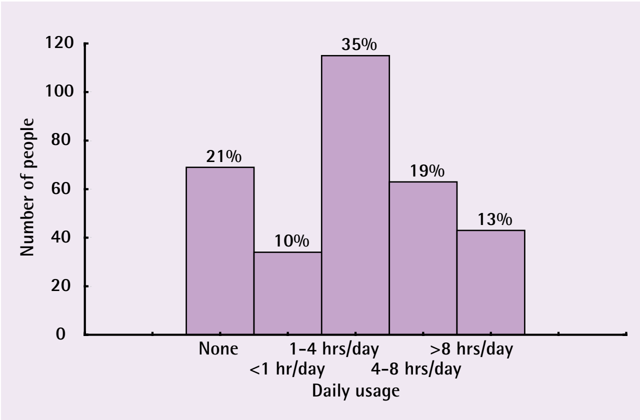

Figure 5: Distribution of hearing aid usage.

Figure 6 shows the distribution of composite benefit scores for each of the possible values of hearing aid use. There is, of course, an inevitable relationship between the scores, as hearing aid use is one of the four scores contributing to the composite benefit score. It is clear, however, that most subjects who report no use in the last two weeks have composite benefit scores of less than 2.0. Similarly, most clients who report using their hearing aids more than 4 hours per day have composite benefit scores of 3.0 or greater. Composite benefit scores of less than 2.0 will therefore be taken to represent "poor benefit", and apply to 21.6% of respondents. Composite benefit scores of greater than or equal to 3.0 will therefore be taken to represent "good benefit", and apply to 63.0% of respondents. (The remaining 15.4% can be considered to report medium benefit.)

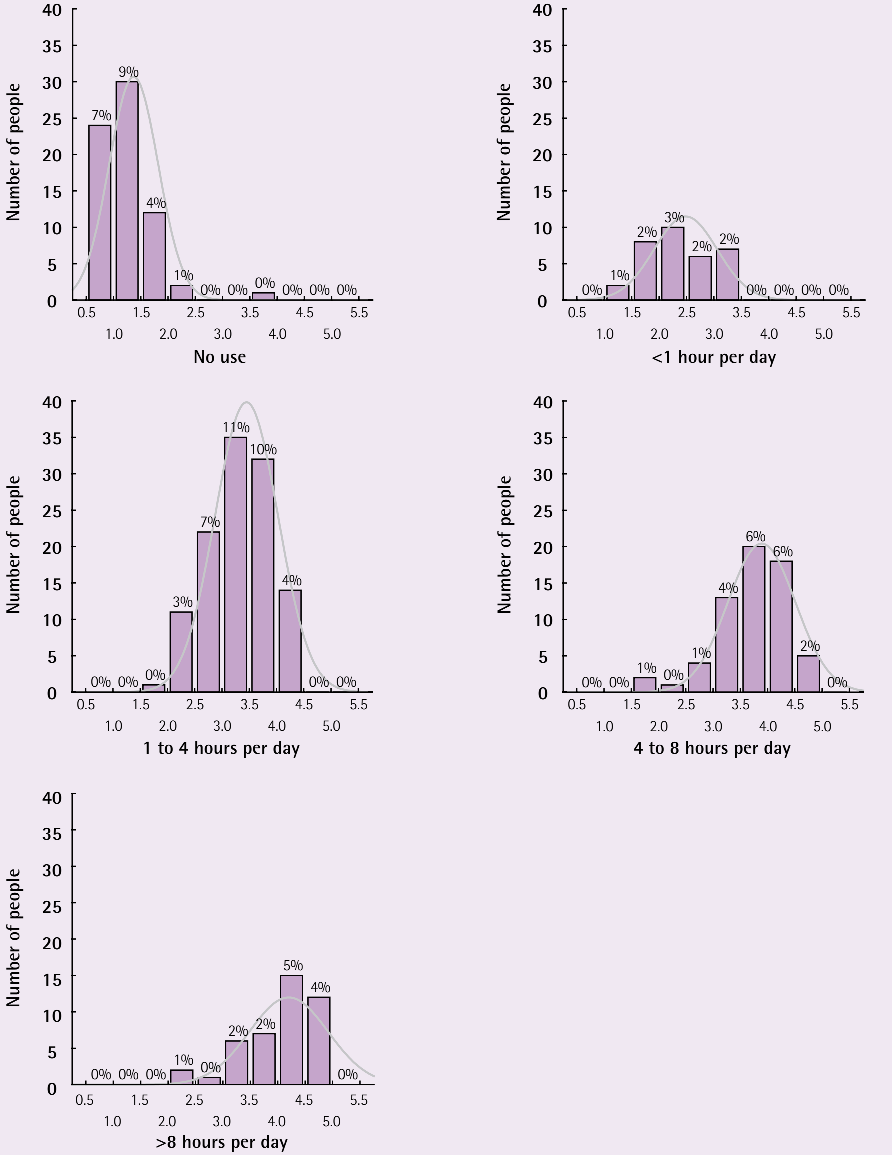

Figure 6: Distribution of composite benefit scores for people reporting different degrees of use of the hearing aids.

Relationship of benefit to hearing loss

Subjects were divided into those receiving "poor" or "good" benefit as described previously. There is little difference between the worse-ear median hearing losses, or the worse-ear inter-quartile ranges for the two groups.

Figure 7 shows the range of hearing losses in the better ear (with the "better ear" at each frequency defined as the ear with the lesser loss at that frequency). Although the differences in median hearing loss between those getting poor versus good benefit are in the expected direction, there is clearly a huge overlap between range of hearing losses in the two groups. Very similar results were obtained for hearing loss in the poorer ear.

500Hz and 4kHz look the same please check

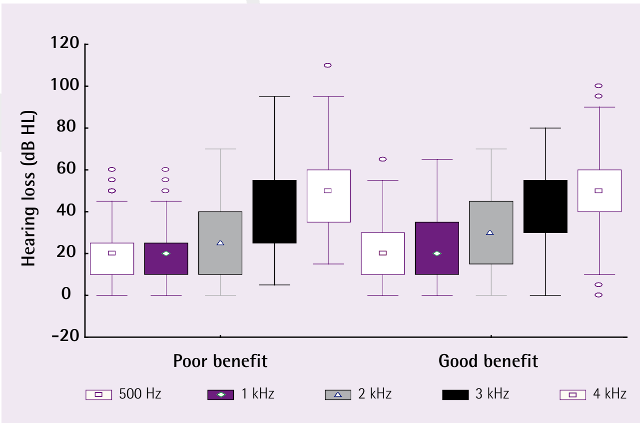

Figure 7: 4FA hearing loss of the groups showing poor and good benefit. Results shown are for the median (central symbol), inter-quartile range (box), non-outlier range (whiskers) and outliers (circles).

The relatively weak impact of hearing loss on composite benefit can be viewed in another way. Figure 8 shows the better ear 4FA hearing loss plotted relative to the worse ear 4FA hearing loss, for those receiving poor and good benefit. Within the range of mild and moderate loss, there is no combination of better and worse ear hearing losses that is associated with unambiguously poor or good benefit.

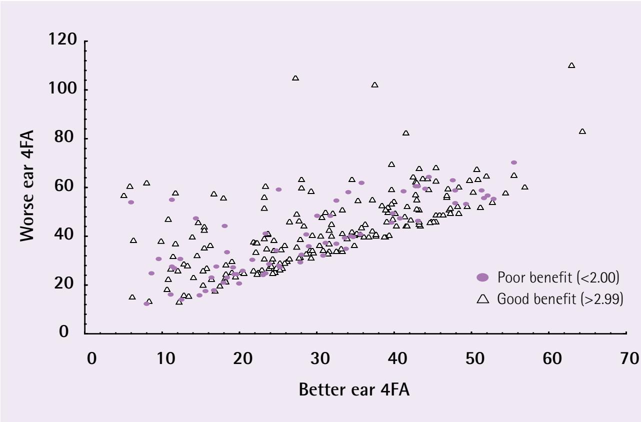

Figure 8: Better and poorer ear 4FA hearing loss for those reporting good benefit and those reporting poor benefit.

Figures 9 and 10 show the effect of better and poorer ear hearing loss on composite benefit. Results are shown for 3FA hearing loss, but similar results occur when hearing loss is expressed as 4FA. The trend is in the expected direction of increasing benefit with increasing loss, but the trend is extremely weak and is far from significant.

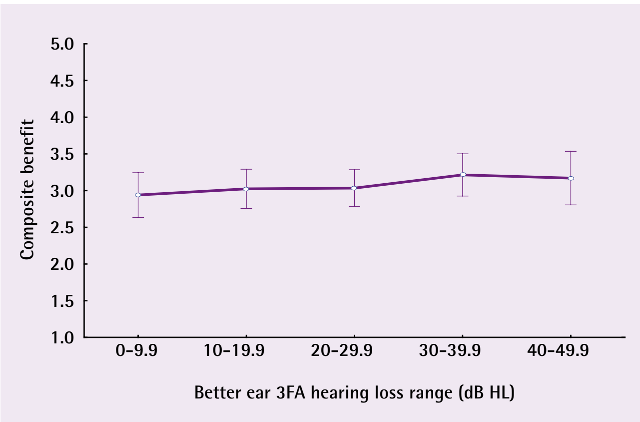

Figure 9: Composite benefit versus better ear 3FA hearing loss. The whiskers show the 95% confidence intervals.

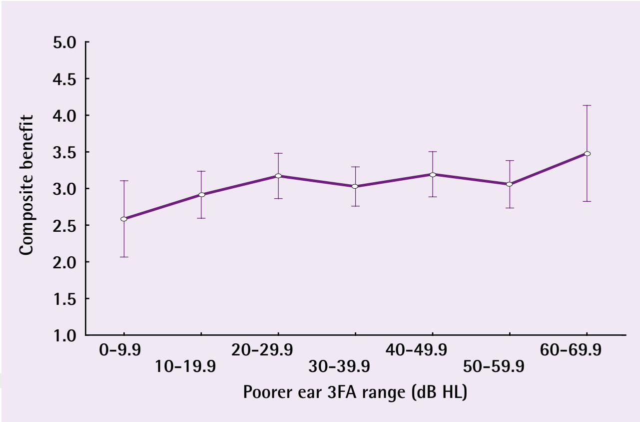

Figure 10: Composite benefit versus poorer ear 3FA hearing loss. The whiskers show the 95% confidence intervals.

By contrast, self-reported needs strength impacts markedly and significantly ($p<0.00001$) on benefit, as shown in Figure 11.

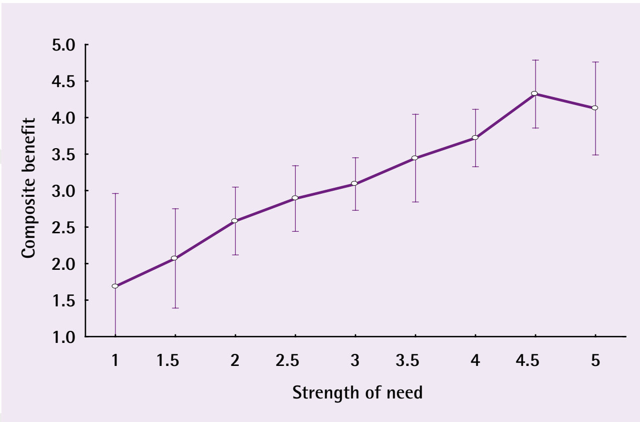

Figure 11: Composite benefit versus self-reported strength of need for hearing aids. The whiskers show the 95% confidence intervals.

For each of these needs values, we can compute the proportion of people who get poor and good benefit, as defined previously. This is shown in the Figure 12. Note that for each needs strength, the sum of the percentages for poor and good benefit is less than 100 % as those with composite benefit from 2.0 to 2.99 fall in neither group. Note also that the proportion for the groups with the lowest and highest need strengths are less accurate, as there were only 14 and 11 people respectively in these two groups.

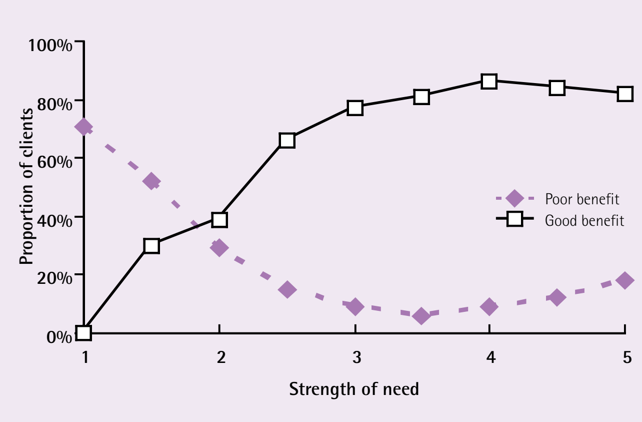

Figure 12: Proportion of clients receiving good and poor benefit versus the strength of self-reported need for hearing aids.

Differences between contractors

Contractors were formed into five groups. Each of the four contractors with 15 or more respondents in the study population formed a group of its own. The remaining contractors formed a group, and was given the code E. There were highly significant differences (ANOVA; p=0.0004) between the mean composite benefit found for different contractor groups. Contractor, and contractor group E both produced significantly higher composite benefit than contractor C, as shown in Figure 13.

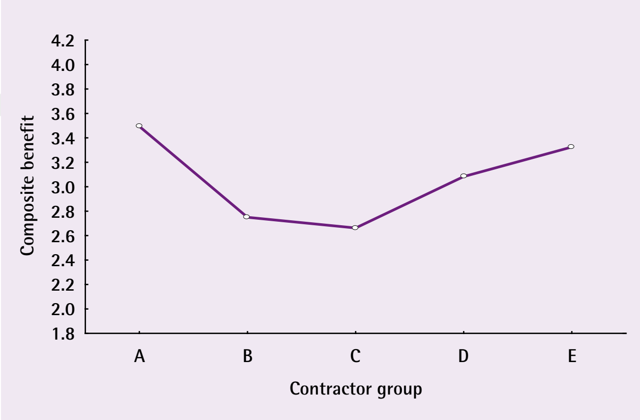

Figure 13: Composite benefit scores for clients seen by each of the contractor groups.

The contractors also differed highly significantly with respect to how strongly their clients expressed the need for assistance. Those clients attending Contractor C expressed much less need for hearing aids than those clients attending contractor groups A, D, or E, as shown in Figure 14. The difference between contractors was highly significant ($p<0.00001$) and the needs expressed by clients of contractor C were nearly a whole scale point lower than those of the contractor D and contractor group E.

Figure 14: Mean self-reported strength of need for rehabilitation for clients seen by each of the contractor groups.

Degree of hearing loss also differed between the contractors. Clients of contractor C had significantly less loss ($p<0.00001$) than those serviced by the other contractors, as shown in Figure 15.

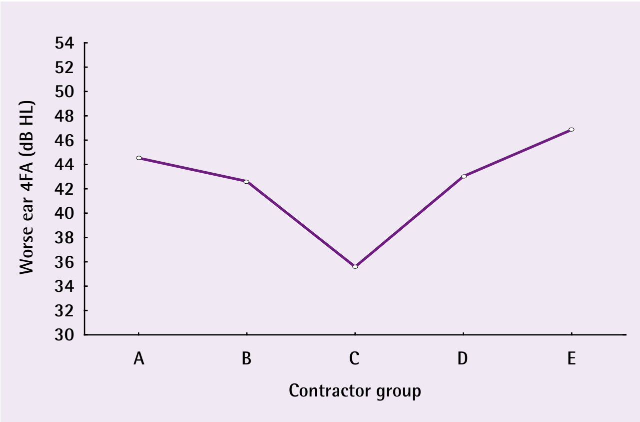

Figure 15: Mean 4FA hearing loss in the poorer ear for clients seen by each of the contractor groups.

We thus have two potential reasons why the clients of contractor C on average receive less benefit: they have less hearing loss, and they felt less need for assistance. The relative importance of these can be separated with appropriate statistical analysis. When the ANOVA of Composite benefit was repeated with Needs Strength as a covariate, the significant effect of contractor disappeared, indicating that the poorer benefit experienced by clients of contractor C resulted from them having much fewer needs prior to aid fitting. The greater importance of self-reported needs over objective hearing loss in determining success is confirmed by a repeat of the ANOVA, but with 4FA HL in the better and poorer ears as covariates. Significant differences between the contractors remained.

The contractors also differed in terms of the residual difficulty experienced by their clients. Clients of contractor C emerged with fewer residual difficulties. This is presumably because they had fewer difficulties before aid fitting, as there were no significant differences in Composite benefit of rehabilitation once Needs Strength was used as a covariate in the analysis.

Comment on results of study

Why is motivation such an important determinant of the benefit of hearing aids? Surely benefit should be more strongly determined by the degree of loss, and the acoustics of the situations in which people communicate? The wide variation in benefit from one situation to another may actually make motivation so all-important. If hearing aids were to give the wearer a huge benefit in all situations, their advantages would be plain to the wearer no matter what the wearer's initial attitude, and their use would be commonplace by everyone with a hearing aid. Who wouldn't want a device that restored their hearing to normal, or better? It is common in life for people to look at any situation and see only the things that support their own beliefs. Perhaps those who start out with the belief that they have hearing difficulties, and the desire to do whatever is necessary to hear more clearly, focus on the situations where hearing aids help them, and so adopt hearing aid use as a part of their life. Conversely, those who either do not accept they are having difficulty hearing, or are not wanting to wear hearing aids because of practical issues or because they believe hearing aid use is stigmatized, focus on the situations that support their view that hearing aids are not for them. Whatever the reason, initial motivation is a powerful factor in determining outcomes, as previous studies have also shown (Erdman & Crowley, 1984; Gatehouse, 1999; Hickson et al., 1986; Hickson et al., 1999.

Reasons for non-acquisition of hearing aids

Why do so many people with hearing loss not get hearing aids? It is difficult to uncover real reasons, but the reason that is by far most commonly stated is simply "My hearing loss is not bad enough to need them" (Kochkin, 1993). In making that statement, people doubtless are using it as a summary of many things, including the difficulties they believe they are facing without hearing aids, the practical and emotional consequences they believe they will encounter if they obtain hearing aids, and the benefit they believe hearing aids will confer were they to wear them. We will examine these benefits from an acoustic perspective in the next section.

Implication of untreated loss for communication

People commonly explain not getting hearing aids by saying that they don't need them. Yet others with the same hearing loss wear, use and benefit from them. Is it possible to objectively quantify a person's ability to understand speech without a hearing aid, and to compute the effect that hearing aids will have on speech understanding? It is, but there will be as many answers as there are combinations of hearing loss, speech level, noise level distance from the talker, and reverberation characteristics. Let's look at the benefit we can expect from a pair of hearing aids for the median hearing loss in the sample of 400 people referred to earlier in this paper. The audiogram is shown in Figure 16. It corresponds to a 36 dB 4FA hearing loss. We saw from Table 1 that only 11% of people with such losses own hearing aids. Hearing aids can improve speech understanding by two distinct processes: amplification and directivity. We will consider each of these separately.

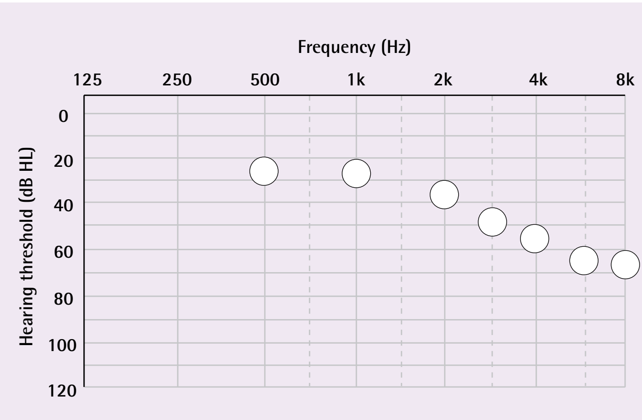

Figure 16: Audiogram used to calculate the benefit of amplification.

Amplification will make speech more intelligible when portions of the speech are below, at, or perhaps just above, a person's hearing thresholds. Figure 17 shows the speech spectrum, for speech at a level of 55 dB SPL, which is a commonly experienced conversational level. (The typical conversational level is around 60 to 65 dB SPL). The figure also shows the hearing thresholds (expressed in dB SPL in the free field) of the median person whose audiogram was shown in Figure 16.

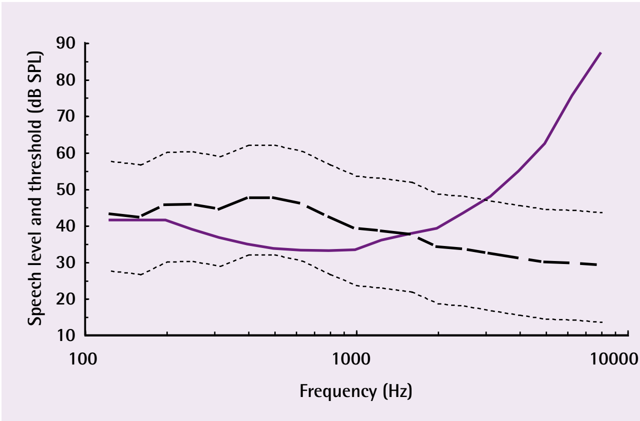

Figure 17: Hearing threshold (solid line) and 1/3-octave speech spectrum (the region between the dotted lines, above and below the long-term rms levels shown as the dot-dash line), for speech at 55 dB SPL.

The region between the two dotted lines that is also above the solid line (the hearing thresholds) therefore represents the portion of the speech spectrum that is audible, assuming that audibility is limited just by the person's elevated hearing thresholds, and not by background noise. This region of audibility can be used to calculate the Speech Intelligibility Index (SII), which represents the proportion of speech information that is audible, but with each frequency first weighted by the importance of that frequency region to intelligibility. For the speech level of 55 dB SPL shown, the SII turns out to be 0.45. How much speech is understood depends on the nature of the speech material, but for sentence material (with some context and redundancy within each sentence) an SII of 0.45 translates into 93% of words being correctly understood. Mistakes will be more frequent for unfamiliar or unexpected words, and intelligibility for isolated words will be only 71%. We can repeat this calculation for sentence material at different speech levels, and the resulting predicted speech intelligibility scores are shown in Figure 18.

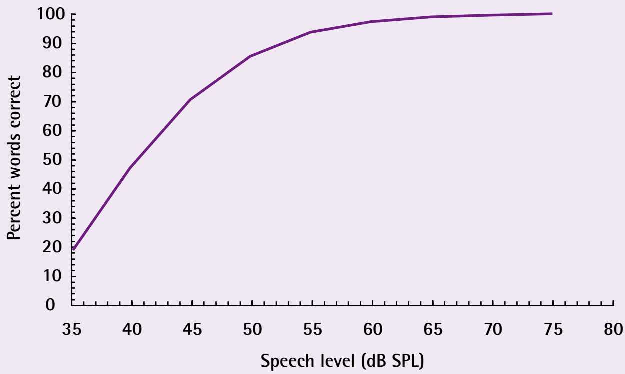

Figure 18: Percentage of words understood, calculated using the SII method, for speech at different levels, without hearing aids, and assuming no background noise and no reverberation.

We can see that for speech levels of 55 dB SPL and above, speech intelligibility is reasonable, even without a hearing aid, which gives some insight into how some people with this degree of loss may decide they don't need a hearing aid, as they will be able to identify situations where they can hear well, and these situations may provide evidence that their hearing is fine. Were hearing aids, adjusted to meet the NAL-NL1 prescription, to be used then the score will increase from 93% to a near perfect 99%. All of these calculations assume that there are no visual cues available to assist understanding, and that there is neither background noise nor reverberation, either of which would decrease intelligibility below the calculated amounts.

In the above examples and calculations, audibility was totally determined by the person's hearing thresholds. Let's now examine the opposite extreme, where audibility at each frequency is totally determined by some combination of background noise and reverberation. That is, either reverberation or background noise are higher than the person's hearing thresholds at all frequencies. In this case, amplification cannot help, as both speech and noise/reverberation are amplified together, leaving audibility unchanged. The only thing a hearing aid can do is increase the wanted signal relative to the noise and reverberation through use of a directional microphone. The degree to which this occurs is know as the directivity index, which indicates the amplification applied to nearby sounds directly in front of the aid wearer relative to the average amplification provided to sounds arriving from all directions. The higher the figure (which is usually in the range of 3 to 6 dB for directional microphones in BTE and ITE hearing aids) the greater the degree to which the user can focus on a talker directly in front at close range. In fact, the directivity index directly indicates the improvement in SNR that the aid wearer will appreciate in the special case of a talker directly in front and very close, and noise arriving uniformly from all directions. As understanding of the words in sentences increases by at least 10 percentage points for every decibel improvement in SNR, a hearing aid with a directional microphone can improve understanding of speech by 50 percentage points when listening to a talker immediately in front of the listener. Of course, people often want to hearing someone more distant than, say, half a mete away, so what advantages do directional microphones then confer?

To answer this, we will need to consider some characteristics of room acoustics. Figure 19 shows the how the SPL decreases as one moves away from a talker. There are two components to the sound we hear. The first of these is the direct field, which is the sound wave that travels directly from the talker to the listener with no reflections. Its drop-off in strength follows a precise mathematical relationship: the inverse square law. Close to the talker, the direct field dominates the sound we hear. However, sound waves travel out from the talker in all directions, bounce off walls, the floor, the ceiling, and other surfaces, and fill the room more or less uniformly with reverberant sound. This sound is much less clear, because the waves reaching a listener are smeared out in time caused by the varying distances they have travelled. Far from the talker, the reverberant field dominates the sound we hear. The distance at which the direct and reverberant field is equal is called the critical distance. In a typical lounge room, the critical distance will be approximately 1 metre. The critical distance becomes even shorter if there is less sound absorption in a room.

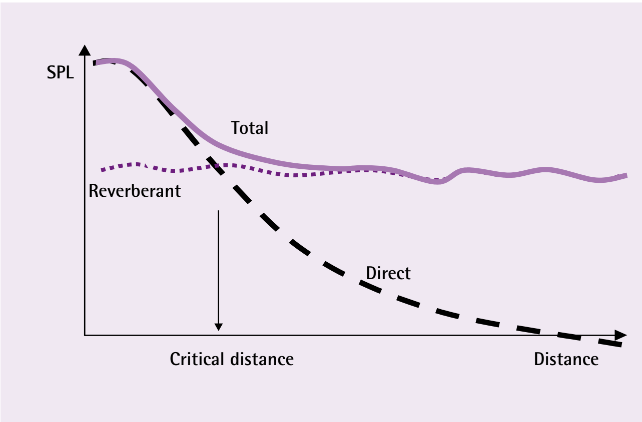

Figure 19: Variation of SPL in the room, showing the direct component (dashed) the reverberant component (dotted) and the total SPL (solid).

If a person is listening to someone who is much more than a critical distance away, a directional microphone can do very little to help. Remember that all a directional microphone does is to give extra amplification to sounds coming from straight ahead. If the talker is very distant, however, sounds from the talker are effectively coming equally from all directions. Consequently, when audibility is limited by noise, we can expect hearing aids with directional microphones to help only for a close talker. Adaptive directional microphones can help for a distant talker provided there is a single close dominant noise somewhere to the rear, but this is a less common situation.

In many real life situations, a combination of the above two situations will apply: audibility will be limited by background noise in the low frequencies, but by elevated thresholds in the high frequencies. In the high frequencies, thresholds are usually greatest and speech is weakest, whereas the reverse is usually true in the low frequencies. If a low-frequency noise were to also be present, such as might be present indoors as a result of traffic noise outside, the audibility of the low-frequency parts of speech will be reduced. This noise might have little or no effect on someone with normal hearing (because they would still be hearing all the mid and high frequency parts of speech). It would, however, have a major effect on someone who was already unable to hear most of the high frequency components of speech as insufficient overall audibility would remain. The complaint about background noise by hearing-impaired people is easy to understand from an acoustic perspective.

In this extremely common situation, the ideal hearing aid would provide amplification in the high frequencies combined with directionality in the low frequencies. Unfortunately, with today's technology, directionality is not achieved at any frequency where no gain is provided, and this is the principle limitation of the open-ear fittings that are (with good reason) becoming very widely used. These hearing aids are excellent for avoiding the occlusion effect, but offer no directivity at the low frequencies where sound directly enters the ear canal without passing through the hearing aid.

Although only a few examples have been given, the main point I would like to make is that the benefit a hearing aid provides is predictable, but the prediction depends on knowing much about the speech signal (level, spectrum, location), any noise present (level, spectrum, dynamics, location), hearing loss (at each frequency in each ear), and room acoustics (reverberation time and critical distance). It is just as easy to hypothesise commonly encountered situations in which hearing aids confer great benefit as it is to hypothesise commonly encountered situations in which they confer no benefit, at least for mild and moderate hearing loss.

Impact of untreated hearing loss on health,

There have been numerous studies showing that people with hearing loss have a higher incidence of various negative health conditions than do comparable people without hearing loss. These negative health conditions include low mood and general emotional state, reduced capability for self-sufficiency, restricted social relationships, greater depression, and even greater mortality (Apollonio et al, 1996; Bridges & Bentler, 1998; Mulrow et al., 1990; Mitchell, 2002). Many other conditions are stated by experts in the field to be consequences of hearing loss. These include loneliness, anxiety, paranoia, exhaustion, insecurity, loss of group affiliation, loss of intimacy, and anger (Trychin, 1991). It seems very likely that hearing loss does cause such effects, but there are two problems with such studies. The first is that the studies show associations, not causative effects, and it is therefore unclear whether the health outcomes are the consequence of hearing loss, or whether both are the consequence of some other cause (such as reduced cardio-vascular health). The second problem is that even a causative effect has no direct implication – it merely invites the question of whether rehabilitation is able to improve health outcomes.

The more important question (in terms of its effect on what action society should take) is therefore whether using hearing aids improves health outcomes (including social, physical, emotional, and overall quality of life aspects). Two types of studies have been performed: cross-sectional and longitudinal. Cross-sectional studies compare the characteristics of hearing aid wearers to hearing-impaired people who do not wear hearing aids. These studies have shown that hearing aid wearers have improved outcomes in the areas of mood and general emotional state, capability for self-sufficiency, social relationships, self-image, reduced depression, and even greater life expectancy (Apollonio et al, 1996; Harless & McConnell, 1982; Kochkin & Rogin, 2000). The problem with these studies is that one cannot tell whether hearing aid use causes these improved states of being, or whether people who have these more positive characteristics are more likely to go and get hearing aids. There are at least three reasons why such associations might occur, including the association between hearing aid use and longevity, as acquiring hearing aids is not usually thought of as a life preserving activity.

First, hearing aids should help avoid isolation, which in turn helps avoid the consequences of isolation such as depression, and failure to look after oneself (e.g. visiting the doctor, being physically active). These activities might improve health, which should prolong life.

Second, the types of people who take action when they realize they have a hearing loss may also be the types of people who act when other things go wrong with their health, so they are more likely to recover from, and survive, these other adverse health events.

Third, people who already have both a life threatening disease and a sensory loss are probably less likely to do something about the sensory loss than those who have only the sensory loss to worry about. There is therefore likely to be a greater proportion of life threatening disease in the group who don't have hearing aids than in the group who do, so more of the group without hearing aids will report poor health, and will have shorter life expectancy.

These different explanations have hugely different implications for the provision of hearing rehabilitation services. If the first reason is found to be a significant part of the explanation, the effect of hearing rehabilitation on health, quality of life, and life itself should provide a strong motivation for society to ensure that anyone who needs hearing aids (and, of course, associated rehabilitation) actually gets them and wears them. If the second and/or third reasons explain the apparent beneficial effects of hearing aid use, then hearing rehabilitation programs will need to look elsewhere to justify public expenditure on them.

Longitudinal studies help us resolve these alternative explanations, though few have been performed. Improved outcomes that have been shown after hearing aid fitting include better social relationships, reduced depression, better cognitive functioning, reduced paranoia, and improved memory and ability to learn (Mulrow et al., 1990; Dye & Peak, 1983). We urgently need further large scale, controlled randomised study of the effects of hearing aid use to unambiguously measure the actual effects of hearing rehabilitation.

There is an especially important issue connecting hearing loss and other health issues that on which I would like to comment, though I don't have any data on the issue. It is well established that a huge proportion of people in aged-care facilities have hearing loss, hearing loss that is often undiagnosed and uncorrected. It is anecdotally reported that hearing loss and dementia can manifest some symptoms in common, such as inappropriate answers to questions, or failure to respond in any way. It is beyond question that uncorrected hearing loss causes reduced auditory stimulation, and it is thought that reduced sensory stimulation contributes to cognitive decline. Hearing loss and dementia are thus intricately entangled, such that uncorrected hearing loss may give an impression of dementia in the absence of it, and may also contribute to dementia itself. Correction of hearing loss amongst frail elderly people in aged care facilities is no easy matter, given the reduced capacities of the patients, the changing staff and high demands on those staff, and the poor acoustics of many hard-surfaced facilities. None-the-less, a more systematic approach involving hearing assessment, assistive listening devices selected to enable both one-on-one communication with patients and also group activities, and training of staff, should significantly increase the quality of life of patients, staff, and family members. This benefit should be particularly valuable when it comes at a time of life when quality of life is often severely reduced for health reasons about which little can be done.

Hearing loss in the future

Whatever difficulties hearing loss is causing our society now, the extent of difficulties will inevitably increase over the coming decades. The first reason is the aging of the population that is underway. As Figure 1 showed, the prevalence of hearing loss increases dramatically with increasing age. If we combine these data with the Australian Bureau of Statistics projections for the distribution of age over the next 25 years (using Series B – the middle estimate of population growth), we can predict the proportion of people with hearing loss in the community (Hartley & Dillon, 2005). Over the next 25 years, the number of people with hearing loss (greater than 25 dB 4FA in the better ear) is likely to increase from 2.8 million to 4.9 million, as shown in Figure 20. The rate of growth of the hearing-impaired population due to aging is currently 2.5% p.a. and will stay between 2% and 3% p.a. for the next 20 years.

The percentage of the population affected by hearing loss will rise from 14% to 20%. Numbers will be greatest in those over 70 years of age, but there will also be a very large increase in the number of people aged over 60 years. Given the way hearing loss interferes with so many of life's activities, hearing loss may prove to be a major impediment to society's need to have people remain longer in the workforce as the proportion of "working age" people in the population keeps shrinking.

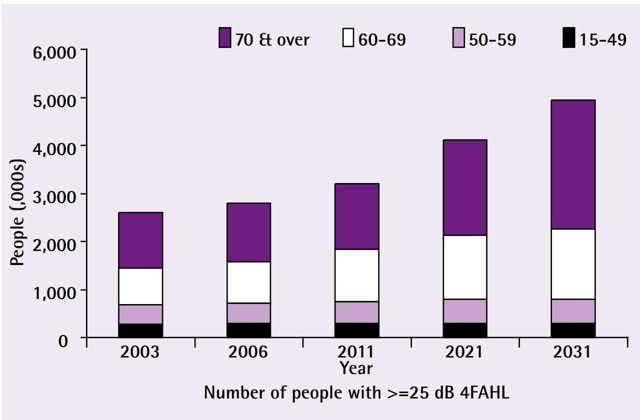

Figure 20: Number of people in the Australian population projected to have 25 dB 4FA hearing loss in the better ear over the next 25 years.

The projections in Figure 20 are based on only two assumptions: that the population will age and grow in the way predicted by the ABS, and that in the future, the prevalence of hearing loss for people of any particular age will be the same as it was in 1996 when the South Australian population survey was done. There is a major reason to doubt this last assumption: The opportunities for leisure-noise induced hearing loss have grown in the last few years with the increasing use of personal digital music players (MP3 devices, of which the iPod is the best known). Furthermore, those now in their 50s or perhaps early 60s were the first generation with widespread opportunity to listen to frequent high-level amplified music at home, in concerts, in their car, as well as from a variety of battery operated portable devices. Power tools have also become much cheaper, and more diverse, opening up even more opportunities to destroy hearing while enjoying oneself. Consequently, there is a possibility that the prevalence of noise-induced hearing loss will be greater in the immediate future than it has been in the past.

Certainly there is already evidence that leisure noise (music exposure) is causing high-frequency hearing loss among people, even while they are still teenagers (Biassoni et al, 2005). A NAL study (LePage and Murray, 1998) has shown that users of personal stereos have lower otoacoustic emission levels, reflecting greater cochlear damage, than non-users. Another NAL study on the levels used in personal stereo players suggests that they will be part of the cause of hearing loss in the future (Williams, 2005). Increasing survival rates for babies born very prematurely and/or with very low birthrate result in an increased prevalence of hearing loss (Veen et al, 1993), and for some of those, the hearing loss is auditory neuropathy/dys-synchrony, about which we still know very little (Amatuzzi et al, 2001).

Conversely, it has now been over 60 years since the last major war (involving a significant fraction of the Australian population), manufacturing activity in Australia has decreased, and Rubella epidemics appear to be a thing of the past. These factors should cause an offsetting decrease in the prevalence of sensorineural hearing loss. Without a comprehensive population survey to replicate the South Australian survey (but a decade or more later), we simply won't know how prevalence is changing, or where our preventative efforts should be focused.

Advances in technology and what this might mean for hearing aid usage

Despite their limitations in many situations, there is no doubt that hearing aids are improving. Following are some of the innovations introduced during the last decade that provide tangible benefit to their wearers.

Feedback cancellation: Adaptive feedback cancellation enables greater gain (by about 12 dB) to be achieved before feedback oscillation occurs. Greater gain enables greater audibility, and enables a larger vent (including open-ear fittings) to be used, which in turn reduces the occlusion effect (the booming sound of one's own voice when the ear canals are excessively blocked).

Adaptive directional microphones: Adaptive directional microphones automatically and rapidly change their directivity pattern so that they have minimum sensitivity in the direction of the dominant sound (assumed to be noise) coming anywhere from the side or rear. Compared to omni-directional microphones, they provide about a 5 dB increase in signal-to-noise ratio when the talker is close and noise comes uniformly from all directions. Benefit is less when the talker is more distant, but can be greater when there is a single dominant nearby noise source.

Environmental sensing hearing aids: Advanced hearing aids now know where they are, or at least, know what type of acoustic signals are reaching the aid wearer. Several advanced hearing aids continuously classify environments into categories such as speech in quiet, speech in noise, noise, wind noise, or music. The point of such categorization is so that the hearing aid can automatically change one or more amplification parameters to settings that are most likely to be optimal for that environment. Likely actions are a volume control change, microphone directionality switched on or off, and a low-tone cut or flattening of the frequency response.

Multi-channel noise suppression: Multi-channel noise suppressors cause the level of any non-fluctuating components of sound to be suppressed. As such components are likely to be noise, the overall signal to-noise ratio is increased, though the signal-to-noise ratio at each frequency is unaffected. This processing therefore improves listening comfort, but only improves speech clarity for relatively uncommon sources of noise.

Integrated wireless receivers: Integrated wireless receivers (either FM or Bluetooth) enable hearing aids to perform two additional functions. A signal can be transmitted (via radio frequency) from across the room to greatly improve speech clarity. Alternatively signals can be beamed into the hearing aid from a mobile phone, or mobile phone accessory.

Wireless-linked hearing aids: One type of wireless-linked hearing aid enables a microphone on one side of the head to transmit a signal to a receiver on the opposite side of the head. These are called CROS (contralateral routing of signals) hearing aids. There are two varieties which provide a solution for people with single-sided deafness or strongly asymmetrical hearing loss, respectively. A second type of linked hearing aid pair sends control signals from one hearing aid to the other, so that automatic or manual adjustments made to one hearing aid affect the other one in the same way, to keep the sound better balanced between the ears.

Data logging: Data logging hearing aids keep a record of the acoustic environments in which the hearing aid has been worn and/or a record of control adjustments made by the aid wearers. This record can assist the clinicians fine-tune the hearing aid at a follow-up appointment.

Wax guards and other reliability enhancements: Manufacturers have made several changes to improve the reliability of hearing aids. Chief amongst these is a variety of wax guards. Others include methods to prevent moisture ingress and the replacement of manual controls with automatic controls.

Even though improvements have been made, further improvements are needed because numerous surveys have shown that satisfaction with hearing aids is far from perfect.

Following are some of the innovations that might occur in the next decade. Doubtless the list is incomplete.

Trainable hearing aids: A trainable hearing aid is one that monitors any adjustments made to the hearing aid, learns from them, and automatically makes appropriate adjustments on future occasions so that the user has little or no further need to adjust the hearing aid. The more advanced trainable aids will also monitor the acoustic environment, and interpret the control adjustments in the light of the acoustic environment existing at the time the adjustment was made.

Improved occlusion reduction: Improved methods for overcoming the occlusion effect, in ways that do not increase the likelihood of feedback oscillation, are likely to become available.

Improved noise suppression: The ability of hearing aids to amplify target speech signals while suppressing unwanted noise is likely to substantially improve as the intelligence made possible by digital signal processing is progressively applied. One approach will be statistical in nature, making near-instantaneous decisions about which components of signals are consistent with the dynamic properties of speech, for which full amplification will be given. Signal components that are inconsistent with a frontal speech signal will be suppressed. Other complementary approaches will transmit signals received by a directional microphone in a hearing aid on one side of the head to the other side, to enable the two signals to be combined, before the cleaned up signal is transmitted back to the first side.

Hybrid cochlear implants and hearing aids: Hearing aids, with their good ability to convey pitch and other low-frequency cues, and cochlear implants, with their good ability to convey spectral and other high-frequency cues, are complementary devices (Ching et al, 2004). When people are implanted, it is therefore already common practice to recommend use of a hearing aid in the opposite ear. As research is already showing good results with hybrid devices that provide acoustic and electric stimulation in the same ear, such hybrid devices, probably applied to both ears, are likely to be commonplace in the near future.

Integrated rechargeable batteries: Aid management is a major problem for many elderly people, and an integrated battery that recharges overnight while in its case will provide a major benefit for many.

These innovations, and doubtless many others, will help those who choose to wear hearing aids, but of course will do nothing for those who don't. Is anything on the horizon for those who would not contemplate a hearing aid, perhaps because of their image?

Hearing aids have a largely negative image, probably due to their association with elderly users, being a visible indicator of an inherent impairment, and being a visible indicator that some residual disability exists. By contrast, it is becoming extremely common for people with normal hearing to wear devices in their ears so that they can hear things like personal stereos, personal digital assistants, and mobile phones. In the future, in-ear devices may also be needed for personal navigation aids, ultra-localised communication systems (e.g. in museums), local area (human communication) wireless networks, and personal internet connections, all voice controlled, of course.

Increased use of in-ear devices is likely to have two impacts. First, a device in the ear is likely to have positive, high technology connotations rather than negative ones.

Second, there will be significant merging of function and similarity of appearance. Assistive devices are already available that look like MP3 players or modular ear pieces. A likely trend is that devices will function as both a hearing aid and as some leading technology device. Clients will be able to wear the device "for its high-technology function" and will be able to benefit from its hearing aid function without having to admit, even to themselves, that they really need a hearing aid. This could lead to a very high acceptance rate of "hearing aids" if the hearing aid portion functions sufficiently well in background noise. The binaural processing innovations referred to above offer the potential for people wearing them to hear better than even a person with normal hearing, in at least some situations.

Looked at another way, it may be necessary for devices to merge function, or at least have good interconnectivity, if people who wear hearing aids are not to be locked out of using devices that provide in-ear auditory output as part of their function.

What do we mean by hearing loss?

So far in this talk we have focused on the statistics of people with sensorineural loss and technology aimed to help people with sensorineural loss. We have seen that there are two immediate consequences of sensorineural loss: elevated thresholds and the need for a better SNR than people with normal hearing require. There is, however, another type of hearing difficulty that shares the need for a better SNR. People with central auditory processing disorders have normal hearing sensitivity, but an abnormality in processing past the cochlea causes such people to also need a higher SNR than is needed by people who have normal peripheral and central auditory systems. Recent research at NAL has indicated that a randomly selected group of children believed (and subsequently confirmed) to have central processing disorders on average required a SNR 4.4 dB greater than children with no disorder if both groups were just able to follow a spoken story in the presence of some distractor signals (Cameron, Dillon and & Newall, in press). A deficit of this size should not be underestimated, and can be appreciated by several comparisons:

- It is about the same magnitude as the advantage that a directional microphone in a hearing aid provides when listening to a talker at short range.
- When noise causes people with normal auditory systems to understand about 90% of the words in a sentence (which is easily sufficient to extract meaning), a SNR deficit of this size will result in only about 30% of the words being heard correctly.
- About 97% of children with normal auditory systems will understand speech better than a child with exactly the average amount of deficit of the group (i.e. 4.4 dB).
- People with a sensorineural loss who have a loss of 4.4 dB in SNR have a sensorineural loss, on average, of around 40 dB (Killion, 1997). As amplification compensates for the elevated thresholds in a sensorineural loss, but not the SNR loss, one might expect that a child with the average deficit will have about the same difficulty understanding speech as a person with a 40 dB sensorineural loss listening with the help of a hearing aid.

The consequences may, however, be even worse than the above. Our study showed that most of the children had an underlying deficit in their ability to use spatial cues to focus on a wanted talker in the presence of distracting sounds. This deficit was even larger, averaging 6.3 dB, and it is possible that the children kept the final deficit to only 4.4 dB by focusing on other cues (like tonal qualities of different talkers) to a greater degree than children with normal auditory processing have to do. If so, a possible consequence is that listening may be a considerably more tiring task for these children than for their peers with totally normal auditory systems. For many of the children, the deficit in spatial processing was five or more standard deviations below the mean for children with no problem. This is a profound deviation from normal.

The problem of abnormal auditory processing is serious enough in terms of the degree to which an individual child is affected. The problem may be even more serious if the frequently quoted prevalence figures are even approximately correct. A prevalence of 2 to 3% of children is often stated (Chermak and Musiek, 1997), but reliable data on which to base an accurate estimate are not available, partly due to the difficulty of unambiguously defining central auditory processing disorder. None-the-less, the problem is very real, and is very consistent with the proportion of children we have encountered amongst the children we have investigated for our normative studies (Cameron, Dillon, Newall, 2006; Cameron and Dillon, submitted).

Children born with hearing loss, and children who acquire prolonged conductive loss are particularly likely to be affected by central auditory processing disorders. Evidence from animal studies suggests that the auditory system requires stimulation if it is to develop normal processing ability. As is well known, conductive hearing disorder is extremely common amongst indigenous children. If an individual child has a conductive loss of sufficient magnitude for a sufficient duration, auditory stimulation will be reduced in level. Furthermore, and perhaps more significantly, interaural differences in level, timing, and phase will also be reduced if the conductive loss is sufficiently great. Interaural differences enable people to localize sounds and selectively attend to sounds coming from particular directions. Consequently, children with a large conductive loss from an early age may not develop the ability to do these tasks. Certainly, one study has shown that indigenous children, on average, have a reduced binaural masking level difference, which indicates their reduced ability to use interaural phase differences to detect signals in background noise (Aithal et al, 2004). Similarly, recent measurements performed by NAL on children with sensorineural hearing loss indicate that almost none of them were able to benefit from physical separation of the signal and noise (Ching, personal communication). By contrast, children with normal hearing are more able to understand speech when the noise comes from other directions than when it comes from the same direction as the speech. Although these data are recent and preliminary, it appears that most children with congenital sensorineural hearing loss may also have a central auditory processing disorder.

Central auditory processing disorders are not restricted to children alone. A population study (The Blue Mountains Study) found them to be widespread in the older population. Again, it is not possible to be dogmatic about the exact prevalence due to our current uncertainty in defining presence of the disorder. Amongst the over-55 years population studied, prevalence varied from a low of 2% (when a disorder was defined as failing all tests in the battery) up to 76% (when a disorder was defined as failing any test in the battery). The presence of central auditory processing disorders in elderly people has at least two practical consequences. First, it may be possible to reverse such neural decline, or at least slow down the rate of decline, if appropriate auditory rehabilitation activities are undertaken. Secondary, some people, particularly elderly adults, have a type of disorder that causes auditory signals input to one ear to interfere with signals presented to the other ear (Arkebauer et al., 1971; Jerger et al., 1993; Siegenthaler & Craig 1981). One possible reason for this includes different processing within each cochlea, such as different mechanical tuning properties (Hood & Prasher, 1990; Markides, 1977, 1986). Another possible reason is loss of efficiency in the transfer of information from one hemisphere to the other via the corpus callosum. Whatever the reasons, such people actually understand speech better with a single hearing aid than with two hearing aids. Although most clinicians are aware that this problem exists, no one has yet done the research to determine what testing should be undertaken to identify the clients affected by this problem.

Is a cure for hearing loss on its way?

The mechanisms for cell death resulting from noise trauma are beginning to be understood, and there are now drugs available that, if taken with a few hours of noise exposure, minimize the loss of hair cells resulting from that exposure. The next step, repairing damaged hair cells, or growing new hair cells is much further away, but there are many promising developments:

- Although damaged hair cells don't naturally regenerate in mammals, nerve fibres do (Lim, 1976; Bohne & Harding, 1992)
- Birds, fish, salamanders and frogs replace and/or repair lost hair cells within a few days (Adler et al., 1992, 1995; Corwin & Cotanche, 1988; Gale et al 2002), provided the damage is not too great (Ding-Pfennigdorff et al., 1998). Regeneration in these species appears to occur by supporting cells changing their function to become hair cells following injury to the hair cells (Adler et al, 1997).
- Various comparisons of the behaviour of avian and mamamallian cochleae immediately after noise insult are rapidly shedding light on the genetic differences underlying the different behaviours. There is a belief that once the mechanisms are understood, it will be possible to alter the local environment in mammalian cochleae to repair and/or re-grow hair cells.
- Hair cells of rats have been grown in culture (Abdouh et al 1993) and in-vivo (Feghali et al., 1998) by applying appropriate growth factors.
- Adult stem cells that have been transplanted to the inner ear of mice and rats differentiated in a way consistent with developing hair cells and neural connections (Hu et al., 2005; Ito 2003).
- Insertion of appropriate genetic material (Math 1 protein) has been used to induce regeneration of hair cells in adult deaf rats (Kawamoto et al 2003, Izumikawa et al, 2005)

There appears to be wide-spread optimism that a method for regenerating hair cells will be found. There are significant problems remaining associated with physically introducing growth factors into the cochlea, ensuring that the cells grow in the places needed, and that they develop appropriate connections to the auditory nerve. The time scale is hard to predict because there is a great deal to be learned, but progress is very rapid given its overlap with other advances in genetics and cell biology. Estimates range from 10 to 25 years.

Not all hearing loss is associated with hair cell degeneration. Hearing loss in old age (presbycusis) has long been associated with degeneration of several structures in the cochlea and auditory nerve, including that of the stria vascularis which provides the "battery" in the cochlea (Paparella, et al.,1975; Schuknecht & Gacek, 1993). There is current debate about how much of the presbycusic hearing loss is caused by a decrease in the endocochlear potential (the battery) that drives the ion-transportation process that is the key to the conversion from a physical vibration to an electrical impulse (Gates, Mills, et al., 2002; Nelson & Hinojosa, 2003). The endocochlear potential is normally 80 mV in gerbils, but in gerbils and mice (good models of hearing in humans) the endocochlear potential decreases in old age, and so probably too in humans. Its reduction appears to be linked to constriction of the capillaries, and hence restriction of the blood supply, in the stria vascularis, which is the source of the potential (Gratton et al, 1997; Prazma et al, 1990). Atrophy of the stria vascularis has often been associated with a flat audiogram (Paparella, Hanson, et al, 1975; Schuknecht & Gacek, 1993; Gates et al 2002), and is thus certainly not the sole cause of presbycusis.

Compensating for a reduced potential by an implanted battery seems to be a much simpler task than overcoming the problem of missing or damaged hair cells and their neural connections, though of course they target different types of damage. As strial damage has been suspected to be a cause of outer hair cell damage (Takeshita, Iwasaki et al, 2003), there needs first to be a better understanding of whether strial atrophy causes some other loss of cochlear function and whether an externally imposed voltage would ameliorate or exacerbate these other forms of damage.

Concluding comments

The unsatisfactory level of un-managed hearing loss in the community mentioned in this talk suggests that much needs to be done. Here are some suggestions, admittedly with a research bias.

- Researchers and manufacturers need to find ways to make hearing aids better able to amplify the sounds that people want amplified and better able to suppress the sounds that people don't. A particularly promising approach is the creation of true binaural hearing aids that combine sounds arriving at the two sides of the head at least as effectively as does the auditory system of people with normal hearing.
- Clinicians need to fill the community with people who use, appreciate, and benefit from their hearing aids, so that messages spread to others about the use of hearing aids are overwhelmingly positive. Based on the research I mentioned earlier, an easy way to improve on the current situation would be for clinicians to candidly advise clients that they are unlikely to find hearing aids to be helpful if the client is starting out with a negative attitude towards the use of hearing aids.
- Researchers need to find out how much hearing loss is being caused by exposure to different types of noise in today's society. It is possible that the answer is predominantly industrial noise, possibly predominantly leisure noise, and more likely a mixture of the two. The media appear ever-ready to run stories about the dangers of leisure noise, but not about industrial noise. We need more information about the sources, extent and prevention methods for both types of noise-induced hearing loss so that we can better educate the population through the media.
- Researchers need to devise methods by which clinicians can quickly and accurately understand the perspectives of clients whose hearing they assess, and methods by which clinicians can help clients to work through and overcome negative views they hold about wearing hearing aids, if in fact they really are requiring help in situations that are important to them.

- Researchers need to devise further methods for unambiguously detecting central auditory processing disorders, diagnosing the underlying cause, and remediating it through appropriate auditory training.
- Society needs to find a way to afford to provide the detection, diagnosis, and remediation of central auditory processing disorders to all who would benefit. Given the high prevalence, there are bound to be large numbers of families who will not be able to afford the clinical time needed for these activities. The cost to society of under-education that for many will be a consequence of an uncorrected deficit is likely to be much higher than the cost of correcting the problem.
- Researchers need to push ahead with increasing their understanding of normal cochlear function, detailed mechanisms underlying the process of hearing loss, and methods for growing healthy cochlear structures in damaged cochleae.

Given the high incidence of hearing loss (of all varieties), the impact it has on quality of life, and the impact it has on education, vocational opportunities and employment, and the growing proportion of aged people in Australia, it seems appropriate for hearing to be a national priority. This would facilitate the provision of the funding needed for both further research and for intervention based on research already available.

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About the Deafness Forum

Introduction

Deafness Forum is the peak body for deafness in Australia. Established in early 1993 at the instigation of the Federal government, the Deafness Forum now represents all interests and viewpoints of the Deaf and hearing impaired communities of Australia (including those people who have a chronic disorder of the ear and those who are DeafBlind).

Structure

The representational base of the Deafness Forum is divided into four classes.

Consumer means an adult who is Deaf or has a hearing impairment or has a chronic ear disorder; or a parent of such a person.

Chronic Ear Disorder refers to such disorders of the ear as tinnitus, Meniere's Disease, Acoustic Neuroma, hyperacusis and recruitment. People with some such ear disorders may also have a hearing impairment.

Deaf refers to people who see themselves as members of the Auslan-using Deaf community by virtue of its language (Auslan) and culture.

Hearing Impairment refers to a hearing loss. People with a hearing impairment (or who are hard of hearing) may communicate orally (sometimes described as 'oral deaf') or may use a sign language or other communication methods.

All Consumers are entitled to describe themselves using whatever terminologies they prefer, and are asked to do so at the time of joining and each time they renewing membership.

Consumer Association means an incorporated Association of, or for, consumers (as defined above).

Objectives

The Deafness Forum exists to improve the quality of life for Australians who are Deaf, have a hearing impairment or have a chronic disorder of the ear by:

- advocating for government policy change and development
- making input into policy and legislation
- generating public awareness
- providing a forum for information sharing and
- creating better understanding between all areas of deafness.

Community Involvement

The Deafness Forum is consumer driven and represents the interests and concerns of the entire deafness sector, including:

- the Deaf community
- people who have a hearing impairment
- people who have a chronic ear disorder
- the DeafBlind community
- parents who have Deaf or hearing impaired children in their families

Libby's Story

Libby's story is one of courage and triumph over adversity by utilising the knowledge of her own severe hearing loss to help-others.

Libby started to lose her hearing following a bad dose of flu in the English winter soon after her marriage in 1969. Having returned to Australia in 1970 she began to find difficulty in understanding conversation and instructions, particularly on the telephone which was very important in her profession of pharmacy.

In spite of advice to the contrary, Libby tried hearing aids and found they helped. Had she heeded the negative advice, Libby believed she might never have embarked on the road to self-help, which so enriched her own life and that of many others.

She thought her two boys quickly learnt to sleep through the night and her friends remarked they had loud voices, which was the boys' mechanism for coping with a deaf mother!

The more the doctors said nothing could be done to help, the more Libby looked towards self help and so she learnt to lip read, a tool she relied on heavily in her quest to help others.

Libby's will to win led her, with the help of others, to get involved with the setting up of a support group, which became SHHH – Self-Help for Hard of Hearing people. The American founder, Rocky-Stone, was invited to Australia in 1982 and did a lecture tour entitled "The Hurt That Does Not Show" which cemented the bonds between the US and Australian groups and helped the local SHHH-develop.

Libby, with others, then began SHHH News, a quarterly publication, and with Bill Taylor set up the first Hearing Information and Resource Centre at "Hillview", Turramurra with support from Hornsby/Kuringai Hospital. This centre provided reliable information on, and demonstrated, assistive listening devices for hearing impaired people. Through this interest, Libby became an enthusiastic user of technology and with her handbag full of electronic aids was enabled to join in a full social life with family and public.

Libby became President of SHHH in 1986 and began to develop her role as an advocate for hearing impaired people generally. She became involved in ACCESS 2000, under the Australian Deafness Council, and a member of the Disability Council of NSW. Her horizons broadened further as Vice President of the Australian Deafness Council and then as the first, and two terms, President of the newly formed national peak body in deafness, the Deafness Forum of Australia. In this latter role Libby made a huge contribution to bring together all the different organisations into a central body, and actively lobbied on behalf of Deaf and hearing impaired at the highest level – the archetype of a successful achiever despite her profound hearing loss.

For her work on behalf of hearing impaired people Libby was made a Member of the Order of Australia in 1990. Later she was appointed by the Government to the Board of Australian Hearing Services and was asked to represent the needs of hearing impaired on the Olympic Access Committee.

Unfortunately, Libby faced another hurdle when she was diagnosed with breast cancer in 1995. Following surgery, she continued her family and volunteer work with undiminished vigour. She would wickedly show off her wig at public functions after her chemotherapy, and talked openly of her "mean disease". She died peacefully on 1 August 1998 and was honoured by hundreds who attended her Thanksgiving Service on 6 August.

In her own words, Libby related her outlook:

"I look back over these years since I became hearing impaired and realise that any efforts that I have made have been returned to me threefold. I have found talents I never knew I had, I have gained so much from the many people I have met and worked with to improve life for people with disabilities and through self help I have turned the potential negative of a profound hearing loss into a positive sense of purpose and direction in my life".

The Libby Harricks Memorial Oration

The Libby Harricks Memorial Oration program is supported by the Libby Harricks Memorial Fund of the Deafness Forum of Australia. Donations to this fund are tax deductible.
Please see enclosed donation form for full details.

Donations should be made payable to Deafness Forum. Additional donation forms and general information regarding deafness can be obtained from:

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"I look back over these years since I became hearing impaired and realise that any efforts that I have made have been returned to me threefold.
I have found talents I never knew I had, I have gained so-much from the many people I-have met and worked with to improve life for people with disabilities and through self help I have turned the potential negative of a profound hearing loss into a positive sense of purpose and direction in my life"

Libby Harricks Memorial Oration number 8