CLINICAL ASPECTS OF HEARING AID PROVISION

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CONTENTS

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Behind every thesis there is an understanding woman. Margaret has been a model of patience and encouragement on the rare occasions when I have spoken to her in the past months. I am indeed fortunate.

SUMMARY

Chapter 1

The aim of this thesis was to examine clinical aspects of hearing aid provision and to consider how these might affect hearing aid services now and in the future. The work is presented in four parts.

Chapter 2

The aim of this part of the study was to compare individuals referred to an audiology clinic (complainers) with hearing-impaired individuals in the population who had never sought advice (non-complainers).

There were 290 complainers and 82 non-complainers. Data were collected on aetiology, hearing impairment, hearing disability, lifestyle and handicap. The two groups were compared by analyses of variance and covariance, controlling for age, sex and socio-economic group along with various combinations of hearing impairment and disability.

Complainers had more middle ear disease; there was no other difference in aetiological factors. Complainers had a higher incidence of asymmetric hearing. Complainers had more disability when impairment was controlled for, and more handicap when impairment and disability were controlled for. There was no major difference in lifestyle. It appears that complainers have more disorders of central auditory function, which might limit their potential for benefit from hearing aids.

Chapter 3

The aim was to assess the accuracy of clinical voice tests and to review their role in present day audiology. The efficacy of masking of tragal rubbing and the Barany noise box was assessed.

Measurement of the free-field voice levels of two clinicians showed that there was considerable inter- and intra-clinician variability.

In a retrospective study of 291 patients and a prospective study of 101 patients, clinical voice test thresholds were compared with pure-tone thresholds. Good correlation was found. Individuals who could hear a whispered voice at arm's length would be unlikely to benefit from a hearing aid. Those unable to hear a conversational voice at six inches would require a BE 30 series aid. Asymmetric hearing loss was usually identified.

Bilateral tragal rubbing raised the clinical voice test threshold of normal subjects to a minimum of a conversational voice at six inches. Barany boxes held beside both ears were no more effective. Barany boxes held over both ears did not mask a loud voice. A Barany box held beside one ear raised the voice test threshold in the opposite ear.

It was concluded that voice testing was a useful part of clinical examination, and that tragal rubbing should be the method of masking used.

Chapter 4

The aim of this study was to identify factors of importance in predicting patients' preference for side of hearing aid use.

The subjects were 58 patients with bilateral mild or moderate hearing loss who were prescribed a hearing aid for the first time. Ear moulds were made for both ears. Subjects were fitted monaurally with a BE 10 series aid in a randomly selected ear. After 10 weeks, the aid was changed to the other ear for a further 10 weeks. At the end of this period, subjects were questionned about their preference for side of use and their reasons for this preference. Self-reported hours of use were recorded at the end of each 10 weeks.

30 subjects reported a difference in their hearing ability with the aid in either ear. 20 denied any hearing difference but preferred one ear for practical reasons. 8 denied any hearing difference and had no preference for side of use. These three groups of subjects could not be differentiated by age, pure-tone thresholds or speech discrimination scores.

All subjects who reported an aided hearing difference and who had asymmetric hearing preferred to wear their aid in their poorer hearing ear. Many of those with symmetric hearing also reported a large hearing difference. No correlation between preference and audiometric thresholds was found in those with a practical preference.

Aids were used for an average of 7 hours a day. There was no difference in use between preferred and non-preferred ears.

It was concluded that preference could not be reliably predicted, so bilateral ear moulds should be routinely provided. If only one mould is provided, it should be fitted in the poorer hearing ear.

Chapter 5

The aim of this study was to investigate differences in benefit achieved by the subjects of the previous study by using a hearing aid in either ear.

An audiovisual test, FADAST, was done initially unaided and subsequently with their hearing aid at the end of each 10 week period. A hearing questionnaire was also completed on each occasion. Both FADAST and the questionnaire showed significant differences between aided and unaided conditions. Neither was a good predictor of patients' preference for side of use.

FADAST results suggested that subjects got more benefit when their better ear was aided. This conflict between patient preference and measured benefit suggested the hypothesis that preference was based on a desire to minimise disability in the most disadvantageous listening conditions - when sounds come from the side of the poorer hearing ear. In a pilot study, 7 subjects with asymmetric hearing did FAAF word lists with the signal from different locations, unaided and with a hearing aid in either ear. The results supported this hypothesis, showing that the greatest disability occurred with the better ear aided and the signal presented towards the worse ear.

These results show that hearing is multi-dimensional. The results of tests of benefit should be regarded with caution.

Unaided FADAST results were closely related to pure-tone thresholds in the better hearing ear. This relationship was used to convert FADAST benefit scores to the equivalent aided pure-tone speech frequency average, thus presenting benefit in terms familiar to all clinicians. This method demonstrated that there is a large residual hearing deficit when using a hearing aid, and suggested that individuals with mild hearing loss get relatively little quantitative benefit from current NHS hearing aids.

Chapter 6

This is a summary of conclusions.

CHAPTER 1

INTRODUCTION

Current hearing aid research is devoted mainly to improving hearing aid design and to developing more reliable tests of hearing aid benefit. These are important areas of research, but there are also more basic topics in audiology which require investigation. The aim of this thesis is to look at some of these clinical aspects of hearing aid provision which have tended to be overlooked while research has concentrated on technological advances.

It is interesting to look at the problems of the hearing impaired and to consider why some individuals seek advice about their impairment and others do not. Chapter 2 compares a group of patients referred to an audiology clinic with a group of hearing impaired individuals in the population who have never sought advice about their hearing. If hearing aid services are to be expanded, we need to know more about the potential patients of the future. It cannot be assumed that a larger but otherwise identical service will meet requirements.

Clinical voice testing has been condemned as inaccurate, yet most clinicians still use it. Is it a waste of time, or does it have a role in modern audiology? In chapter 3, the accuracy of clinical voice testing is investigated, and its role in assessing hearing is discussed. It is important in clinical voice testing, as in all audiometry, to mask the non-test ear, yet there are no recognised rules to help the clinician in his choice of masking. The choice of appropriate masking is discussed, and its efficacy is assessed.

The vast majority of NHS patients are fitted with a monaural hearing aid. This is unlikely to change in the near future because two thirds of new hearing aid users who are theoretically suitable for binaural amplification will refuse a second aid. Monaural fitting has been the rule in the past; it is surprising that there has been no reported study of the optimum side of hearing aid provision - one would have expected this question to have been one of the first to be investigated. In medicine, scientific investigation is often omitted because there is general agreement among clinicians about the best policy. But there is no general agreement about whether a hearing aid should be fitted in the better ear or the worse ear, in the right ear or the left ear. The simplest way of investigating this question is to ask the patient. This is also the most relevant way of answering the question because the aim of hearing aid provision should be to achieve the greatest possible patient satisfaction. In chapter 4, patients' preference for side of aid use is reported, with their reasons for their preference. Methods of predicting this preference are discussed.

The alternative way to decide which ear should be aided is to try to measure the benefit achieved in each ear. In chapter 5, benefit is assessed by an audiovisual test and by questionnaire, and the results are compared with patients' preference.

CHAPTER 2

FACTORS INFLUENCING SELF-REFERRAL WITH HEARING DIFFICULTY

INTRODUCTION

It is estimated that 19% of the adult British population have a hearing loss of greater than 25 dB (mean of 0.5, 1, 2 and 4 kHz) in their better hearing ear (Browning and Davis, 1983). Haggard et al. (1981) estimate that only half these individuals have sought medical advice. These will be referred to as complainers, while those who have never sought professional advice will be termed non-complainers. Only 4% of the population have had a hearing aid at any time in their lives, and even fewer use a hearing aid. It is essential to know the prevalence of hearing impairment to plan audiological services for the future. However, in addition to the prevalence, we need to know more about the nature of the hearing impairment and the resultant disability in order to decide the type of services required.

Before proceding, it is necessary to define the terms impairment, disability and handicap as they relate to hearing. The following definitions are compatible with World Health Organisation recommendations (1980):

Impairment is a reduction in physiological function, such as sensitivity, frequency resolution and central processing.

Disability is a reduced ability to use hearing in everyday tasks, such as understanding speech.

Handicap is the disadvantage imposed on an individual in his social surroundings by impairment or disability for which he cannot compensate physically or psychologically.

Demographic and audiometric data are readily available about individuals referred to audiology clinics (e.g. Surr et al., 1978, Brooks, 1979). However, much less is known about the hearing-impaired individuals in the community who do not seek professional advice. It cannot be assumed that their impairment, disability and handicap are similar to those of patients referred for rehabilitation.

Only one study has been identified which attempts to characterise individuals who have not sought advice (Humphrey et al., 1981). This study looked at all the patients over 70 years of age who were registered with a general practice. Only pure-tone air conduction audiometry was done because this was a domiciliary study. Those subjects who had sought advice were more severely impaired and were more likely to have noticed their hearing loss before reaching retirement age. They also reported more disability, but their audiometric hearing loss was not controlled for in this analysis.

Why do some individuals complain of a hearing disability while others with an apparently similar degree of impairment do not? The aim of this study was to answer this question by comparing a group of hearing-impaired individuals who had never sought professional advice with a group of patients referred to an audiology clinic.

METHOD

Subjects

There were two groups of subjects: complainers and non-complainers.

Complainers were 290 consecutive adult referrals to the Audiology Clinic in Glasgow Royal Infirmary. Their presenting symptoms were hearing disability (92%), tinnitus (19%) and otorrhoea (7%).

Non-complainers were 82 individuals who had a Speech Frequency Average (SFA) pure-tone hearing loss (mean of 0.5, 1, 2 and 4 kHz) of more than 25 dB HL in one or both ears and who denied ever having sought medical advice about their ears and had never used a hearing aid. These individuals were identified from the Glasgow sample of the MRC National Study of Hearing whose subjects were a stratified population sample from the voters' roll.

Data were collected under the following headings:

Demographic data

This comprised age, sex and Socio-Economic Group (SEG) (Registrar General's Classification of Occupations).

Aetiology

Subjects were questionned about exposure to occupational and social noise, gunfire and explosions, and about any family history of hearing difficulties. The presence of any other physical or mental disability was noted. An otological examination was made.

Measured impairment

Pure-tone audiometry was done (appendix 2) as a measure of impairment.

Measured disability

Speech audiometry was done (appendix 2) as a measure of disability.

Reported disability

Subjective disability was assessed in two ways. Subjects were asked to give their own estimate of their hearing in each ear as a percentage of normal. They completed a hearing questionnaire (appendix 3), the first 14 questions of which relate to disability.

Reported handicap

Questions 15 to 17 of the hearing questionnaire enquire about handicap. In addition, subjects completed a questionnaire about their lifestyle (appendix 5).

Analysis

Data was analysed on a PDP-11 mini-computer using the Statistical Package for the Social Sciences (Nye and Hull, 1980). An analysis of variance was carried out on all ordered data; this permitted up to five covariates to be controlled for. A crosstabulation analysis was carried out on non-ordered data. It was not feasible to control for more than one factor in this analysis because the subjects would have been divided into too many groups which would have been too small to allow conclusions to be drawn. In addition, crosstabulation analyses of some ordered data are presented purely as illustration; conclusions are not drawn from these analyses.

The pure-tone audiometric variables used in analysis were the better ear and worse ear averages (BEA and WEA) which represent the mean pure-tone threshold at 0.5, 1, 2 and 4 kHz. All analyses were repeated substituting the mean threshold at 0.5, 1 and 2 kHz; as each method gave similar results, only the former will be reported.

RESULTS AND INTERPRETATION

Hearing thresholds

For the purpose of the cross-tabulation analysis, subjects were divided into four groups by the pure-tone threshold in their better or their worse hearing ear (table 2.1).

		total	Pure-tone threshold (dB HL) <25	25-39	40-54	>54
Better ear:	C	290	47	63	112	68
	NC	82	33	35	9	5
Worse ear:	C	290	17	29	77	167
	NC	82	0	46	26	10

Table 2.1. Distribution of mean pure-tone thresholds (0.5, 1, 2 and 4 kHz.) for complainers (C) and non-complainers (NC).

276 of the 290 non-complainers had a mild hearing loss in their better hearing ear. Only 14 had a loss of more than 40 dB in their better ear. While it would be interesting to look at larger numbers of more severely impaired non-complainers, it is difficult to identify such individuals. The findings of this study therefore

relate mainly to individuals with a better ear hearing loss of less than 40 dB, though those with more severe losses were included in the analysis.

Demographic data

The mean age of the complainers was 64 years (range 15-90) and of the non-complainers was 53 (range 19-78). Analysis of variance of age controlling for the BEA showed that the complainers were 8.5 years older than the non-complainers ($p < 0.001$). When measured and reported disability and reported handicap were controlled for, complainers were still significantly older.

47% of complainers were male and 53% female; the corresponding figures for non-complainers were 54% and 46%. Table 2.2 shows the social class distribution in each group. Crosstabulation with BEA and WEA showed no significant difference in sex and socio-economic group between complainers and non-complainers ($p > 0.05$).

S.E.G.	I	II	IIIN	IIIM	IV	V
C (%)	1	7	14	44	25	9
NC (%)	1	5	18	44	27	5

Table 2.2. Socio-economic group (SEG) of complainers (C) and non-complainers (NC).

Similar numbers in each group knew someone who had a hearing aid (68% of complainers and 55% of non-complainers), and the proportion of these acquaintances who were satisfied with their aid was also similar. Prior knowledge of hearing aids does not seem to influence referral.

Aetiological factors

17% of complainers and 18% of non-complainers reported significant occupational noise exposure, equivalent to the damage-risk criteria for British industry of 90 dB (A) over a working lifetime. Similarly, there was no difference between groups in exposure to gunfire or social noise.

28% of complainers and 39% of non-complainers reported a family history of hearing difficulties. The difference was not statistically significant ($p > 0.05$). There was no difference in the incidence of previous head injuries or exposure to ototoxic drugs.

Crosstabulation analysis of the otoscopic presence of past or present chronic otitis media and the BEA showed that there was a similar incidence of abnormalities in the better hearing ear of each group but there was a greater incidence in the worse hearing ear ($p < 0.05$). Table 2.3 illustrates the incidence of otoscopic abnormalities in individuals whose BEA was between 25 and 39 dB HL.

	n	Better ear(%)	Worse ear(%)
Complainers	60	23	30
Non-complainers	30	17	13

Table 2.3. Incidence of otoscopic abnormalities in subjects with a BEA between 25 and 39 dB HL.

20% of complainers and 10% of non-complainers had other disabilities; these figures were not significantly different when age, sex and SEG were controlled. The most commonly reported disabilities were respiratory, cardiovascular and musculo-skeletal.

<u>Measured impairment</u>

When the pure-tone threshold in the better hearing ear was controlled for along with age, sex and SEG, the WEA was 8 dB worse in complainers than in non-complainers ($p < 0.001$). Thus complainers have more asymmetric hearing.

There was no significant difference in the air-bone gap in the better hearing ear when the BEA, age, sex and SEG were controlled for, nor in the worse hearing ear controlling for age, sex, SEG, and either the BEA or the WEA.

Measured disability

Complainers had poorer Half Peak Level Elevations (HPLE) in both ears than non-complainers (table 2.4).

In 82% of non-complainers, the HPLE was within 12.5 dB of the average of the best two pure-tone thresholds between 250 and 4000 Hz. This is not statistically different from the figure for the population projection of 88% (MRC National Study of Hearing, unpublished data). Only 63% of complainers had such a relationship between HPLE and pure-tone thresholds (figure 2.1). The difference is due to the 32% of complainers whose HPLE was at least 12.5 dB worse than their best two average threshold.

Better ear HPLE

Covariates	Significance p	Difference dB
BEA	< 0.001	22.1
BEA, age, sex, SEG	< 0.001	21.0
Better ear ODS	< 0.001	23.2
BEA, ODS, age, sex, SEG	< 0.001	16.3

Worse ear HPLE

Covariates	Significance p	Difference dB
WEA	< 0.001	19.8
WEA, age, sex, SEG	< 0.001	19.5
Worse ear ODS	< 0.001	24.3
WEA, ODS, age, sex, SEG	< 0.001	17.7

Table 2.4. Analysis of variance of the HPLE in the better and worse hearing ears of complainers and non-complainers.

Note: the difference is the unexplained difference after the other factors listed have been controlled for; complainers are always worse than non-complainers.

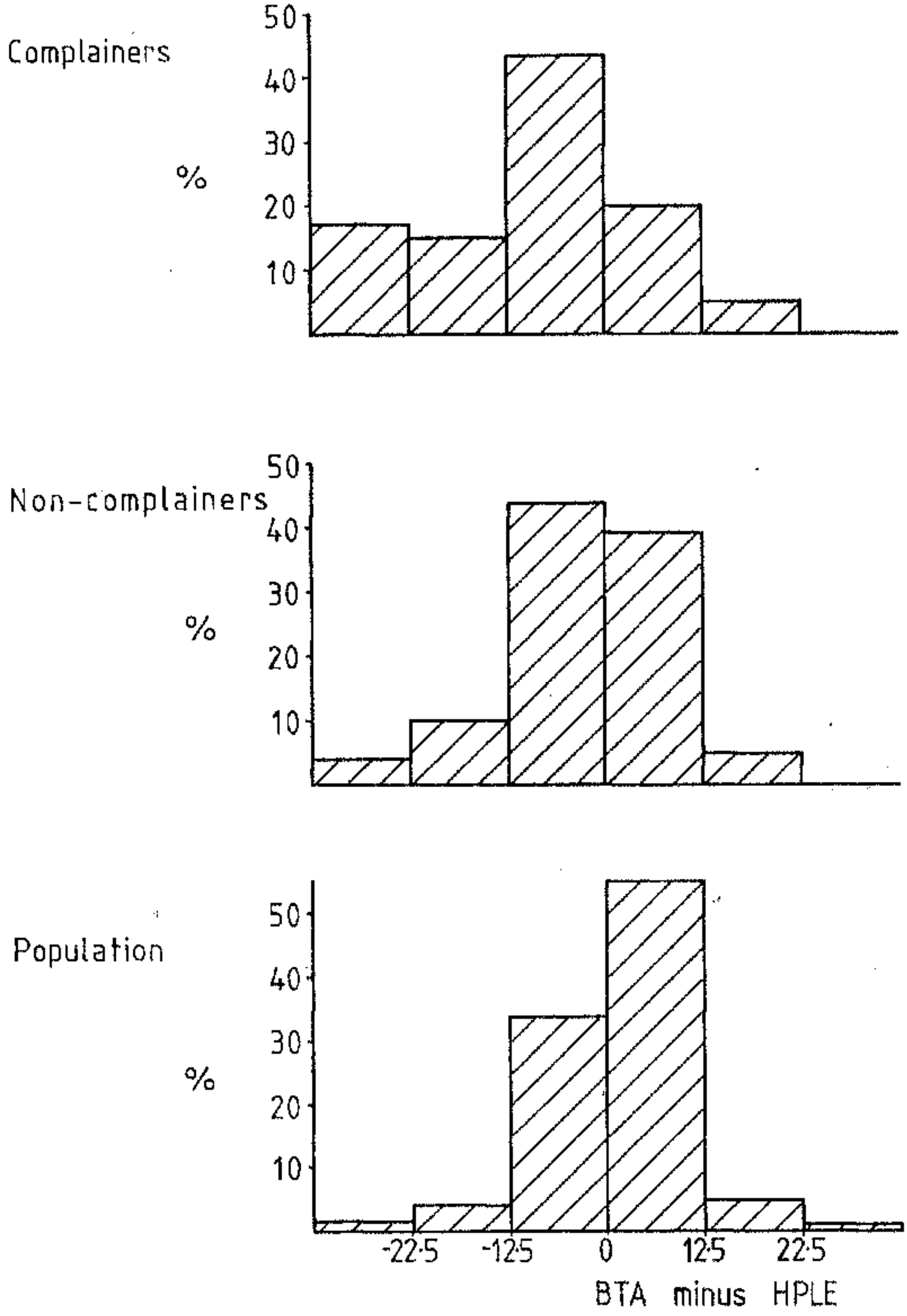

Figure 2.1. Relationship between HPLE and the best two average (BTA) pure-tone thresholds for complainers, non-complainers and the population.

Complainers had poorer speech discrimination scores (ODS) than non-complainers when pure-tone thresholds were controlled for, but when the HPLE was controlled for, there was no difference in ODS between groups (table 2.5).

Better ear ODS

Covariates	Significance p	Difference %
BEA	< 0.006	6.9
BEA, age, sex, SEG	< 0.05	5.2
Better ear HPLE	NS	---
BEA, HPLE, age, sex, SEG	NS	---

Worse ear ODS

Covariates	Significance p	Difference %
WEA	< 0.002	10.2
WEA, age, sex, SEG	< 0.03	7.1
Worse ear HPLE	NS	---
WEA, HPLE, age, sex, SEG	NS	---

Table 2.5. Analysis of variance of ODS in the better and worse hearing ears of complainers and non-complainers. See note to table 2.4.

At first sight, it seems odd that the HPLE should be different when the ODS is controlled for, yet the ODS is not different when the HPLE is controlled for. The reason appears to be that the speech curve is shifted to the right in complainers, as suggested by comparison of the HPLE with the best two average pure-tone thresholds (figure 2.1).

Coles et al. (1973) suggested that the relationship between the ODS and the Best-Two Average (BTA) pure-tone thresholds at 0.5, 1 and 2 kHz could help to differentiate cochlear and neural disorders. They drew a criterion line above which lay 90% of ears with cochlear disorders and below which lay 90% of ears with neural disorders (figure 2.2). 11% of non-complainers fell below this line, but 38% of complainers fell below the line, supporting the suggestion that complainers have poorer speech discrimination compared to pure-tone thresholds.

These results show that complainers have greater measured disability than non-complainers with similar impairment. The Coles-Priede criterion suggests that this is due to a greater incidence of neural or central problems.

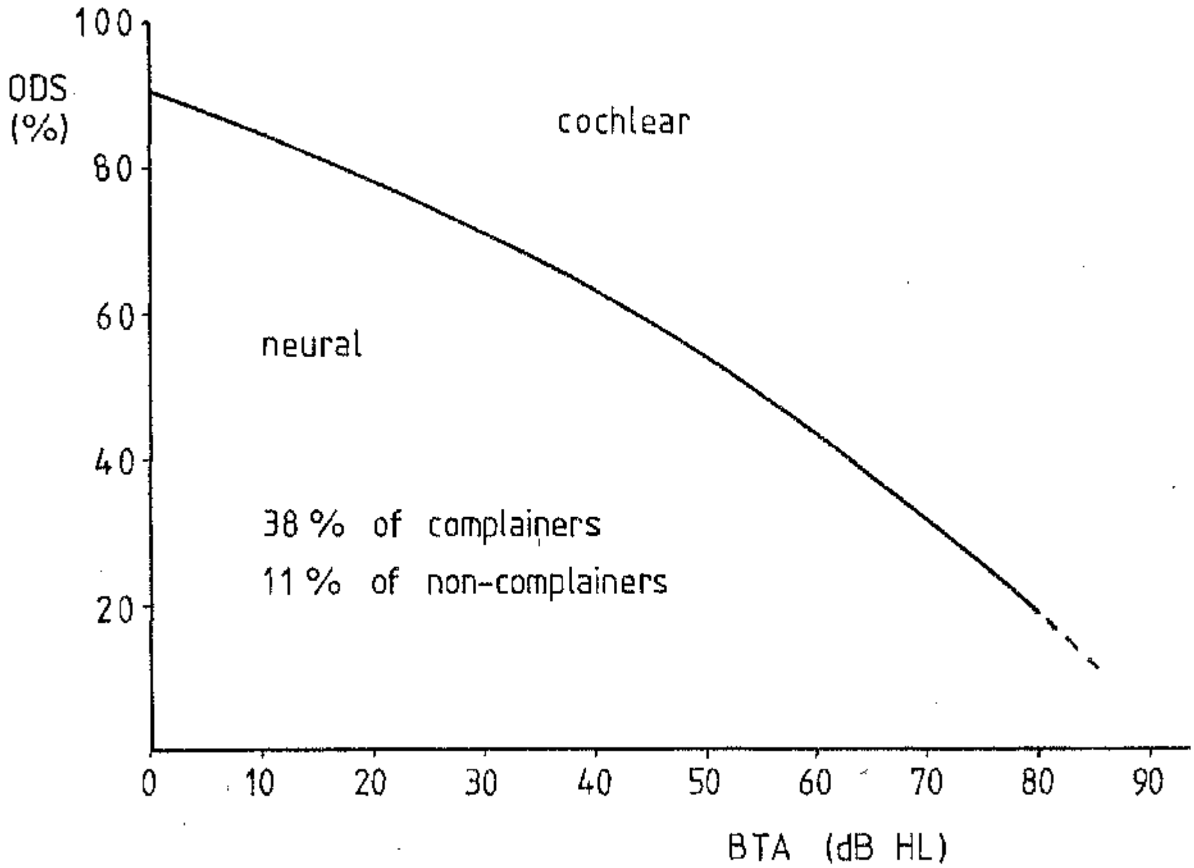

Figure 2.2. Coles-Priede criterion for cochlear and neural disorders adapted for AB(S) word lists (Priede and Coles, 1976)

Reported disability

Complainers had a poorer subjective opinion of their hearing than non-complainers with similar pure-tone thresholds. The subjects' own estimates did not simply reflect their ability to discriminate speech because complainers reported more disability than non-complainers with similar speech discrimination scores. However, there was no difference between groups when the HPLE was controlled for (table 2.6). There was a greater difference between complainers' and non-complainers estimates of their hearing in their poorer hearing ear than in their better hearing ear. It was noted earlier that complainers had more asymmetry than non-complainers. This suggests that many individuals are conscious of a much greater difference between their hearing ability in each ear than audiometrically there appears to be.

Better ear estimate

Covariates	Significance p	Difference %
BEA	< 0.03	6.4
BEA, age, sex, SEG	< 0.05	6.2
Better ear ODS	< 0.002	12.2
Better ear HPLE	NS	----
Better ear ODS & HPLE	NS	----
BEA, ODS, age, sex, SEG	< 0.04	6.4
BEA, HPLE, age, sex, SEG	NS	----
BEA, ODS, HPLE, age, sex	NS	----

Worse ear estimate

Covariates	Significance p	Difference %
BEA	< 0.001	24.2
BEA, age, sex, SEG	< 0.001	25.5
WEA	< 0.001	13.7
WEA, age, sex, SEG	< 0.001	16.0
Worse ear ODS	< 0.001	20.6
Worse ear HPLE	NS	----
Worse ear ODS & HPLE	NS	----
WEA, ODS, age, sex, SEG	< 0.001	15.3
WEA, HPLE, age, sex, SEG	< 0.03	10.2
WEA, ODS, HPLE, age, sex	< 0.01	12.3

Table 2.6. Analysis of variance of complainers' and non-complainers' own estimates of their hearing.

The hearing questionnaire was completed by 178 complainers and by 78 non-complainers. The answers to questions 1 and 2 (can you hear a watch ticking in your right/left ear?) and questions 8 and 9 (can you use the telephone with your right/left ear?) were regrouped so that they referred to the better (Q.1 & Q.8) and the worse (Q.2 & Q.9) hearing ears instead of right and left ears. Analyses of variance were then carried out on all questions using different combinations of covariates (table 2.7). The total score was calculated by giving 0 for the answer indicating no disability, 1 for the next answer, and so on. Differences were taken as significant if $p < 0.05$.

	Covariates			
Q.No.	BEA	HPLE	ODS	HPLE, ODS
1	< 0.001	< 0.001	< 0.001	< 0.001
2	< 0.001	< 0.03	< 0.001	< 0.05
3	< 0.001	NS	< 0.001	NS
4	< 0.005	NS	< 0.004	NS
5	< 0.003	NS	< 0.003	NS
6	< 0.05	NS	< 0.04	NS
7	< 0.003	NS	< 0.001	NS
8	< 0.02	< 0.04	< 0.007	< 0.03
9	< 0.001	NS	< 0.002	NS
10	< 0.001	< 0.02	< 0.001	< 0.02
11	< 0.004	< 0.02	< 0.001	< 0.02
12	< 0.03	NS	< 0.001	NS
13	< 0.001	< 0.001	< 0.001	< 0.001
14	< 0.001	NS	< 0.001	NS
total	< 0.001	< 0.001	< 0.001	< 0.001

Table 2.7. p values from analysis of variance of hearing questionnaire for complainers and non-complainers (complainers always worse than non-complainers). All audiometric covariates refer to the better hearing ear. NS = not significant ($p > 0.05$). See appendix 3 for key. Continued on next page.

Q. No.	Covariates: BEA age, sex, SEG	Covariates: BEA, HPLE age, sex, SEG	Covariates: BEA, ODS age, sex, SEG	Covariates: BEA, HPLE ODS, age, sex
1	< 0.004	< 0.001	< 0.001	< 0.001
2	< 0.001	NS	< 0.007	< 0.02
3	< 0.001	NS	< 0.003	< 0.04
4	< 0.02	NS	< 0.05	NS
5	< 0.004	NS	< 0.02	NS
6	NS	NS	NS	NS
7	< 0.02	NS	< 0.04	< 0.04
8	< 0.05	< 0.05	< 0.01	< 0.02
9	< 0.001	NS	< 0.02	NS
10	< 0.001	< 0.03	< 0.003	< 0.003
11	< 0.003	< 0.002	< 0.002	< 0.001
12	< 0.02	< 0.02	< 0.006	< 0.004
13	< 0.001	< 0.001	< 0.001	< 0.001
14	< 0.001	NS	< 0.001	< 0.03
total	< 0.001	< 0.001	< 0.001	< 0.001

Table 2.7. Continued.

It can be seen from table 2.7 that the HPLE was more closely related to reported disability than the BEA or the ODS were, as so many answers were not significantly different when controlling for HPLE, and some of those that were only just reached significance. The same finding was made in the analysis of subjects' own estimates of their hearing. It should be noted that the difficulty reported for speech in noise was much greater in complainers regardless of which covariates were included (Q.13), though the reported difficulty with speech in quiet was often similar (Q.14).

Ambulance and police sirens are very loud. Usually only those with severe hearing loss have difficulty in hearing them. This explains why the answers to question 6 were similar for each group.

There was no difference in the answers to question 12 (can you locate the speaker in a group?) by complainers and non-complainers when BEA, age, sex, SEG and the amount of asymmetry between ears was controlled for. This shows the importance of binaural cues in locating sound.

41 of the complainers and 33 of the non-complainers who completed the hearing questionnaire had a BEA between 25 and 39 dB HL. Their answers to individual questions are presented in appendix 4 purely for illustration. Figure 2.3 shows the total score for questions 1 to 14 for these subjects.

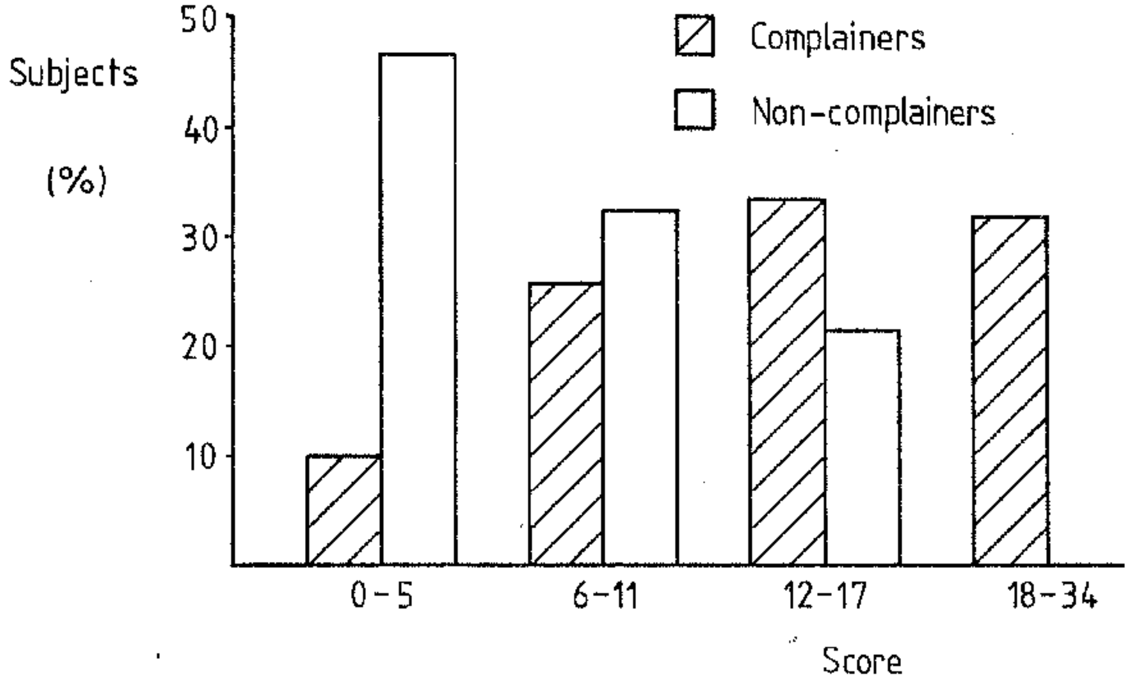

Figure 2.3. Total score for Q1-Q14 of the hearing questionnaire for complainers and non-complainers with a BEA between 25 and 39 dB HL.

Lifestyle and reported handicap

Non-complainers went to bingo more often than complainers, and the difference was just statistically significant ($p = 0.047$, analysis of variance controlling for BEA, age, sex, and SEG). There was no other significant difference in lifestyle between the groups (appendix 5). In particular, there was no difference in the proportion of subjects who lived alone (27% of complainers and 15% of non-complainers).

Analyses of variance were done on the answers to questions 15 to 17 and the total score, using the groups of covariates reported in table 2.7. The difference between complainers and non-complainers was highly significant ($p < 0.001$ in all cases). Thus complainers reported more handicap when impairment and disability were controlled for. The total score for questions 15 to 17 was also analysed controlling for the total score for questions 1 to 14; the difference was highly significant ($p < 0.001$). Complainers reported more handicap even when self-reported disability was controlled for.

The total score for 38 complainers and 33 non-complainers with a BEA between 25 and 39 dB HL is shown in figure 2.4. Their answers to individual questions are presented in appendix 4 for illustration.

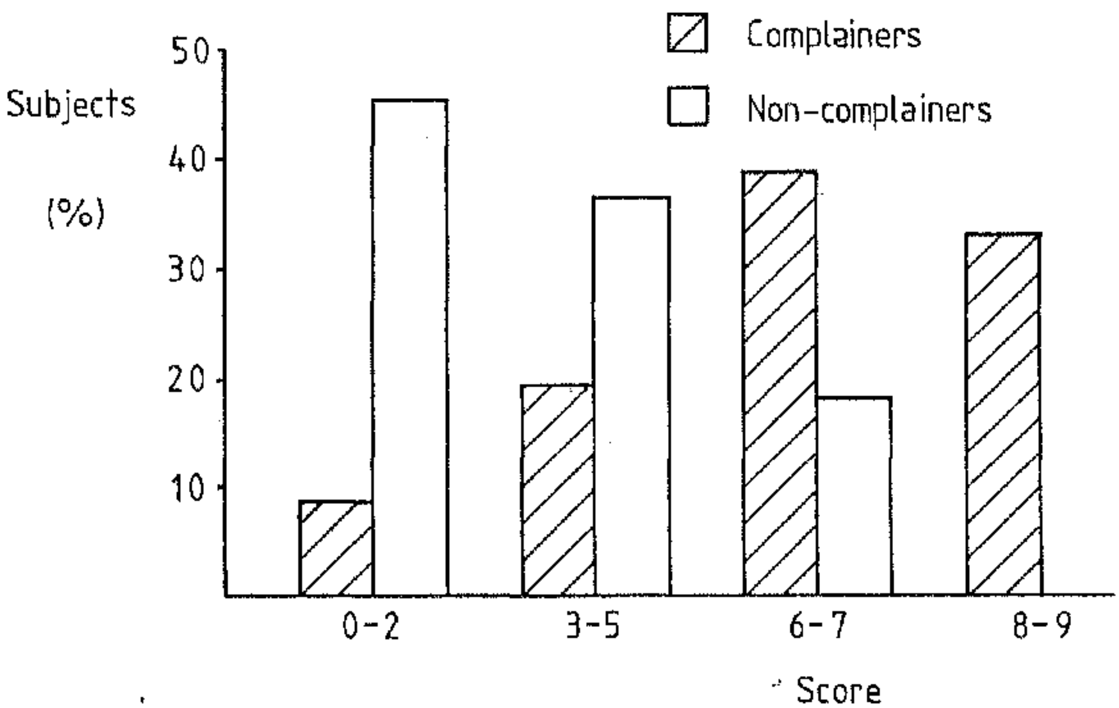

Figure 2.4. Total score for Q15-Q17 of Hearing Disability Questionnaire for complainers and non-complainers with a BEA between 25 and 39 dB HL.

DISCUSSION

It is accepted that speech-in-quiet is an imperfect measure of disability. A speech-in-noise test would have been preferable, though not ideal, but this was not practicable at the time of conducting this study.

Some might argue that speech audiometry is more closely related to impairment, but, by definition, the inability to understand speech is a disability rather than an impairment. In addition, the poor correlation between speech indices and pure-tone thresholds in this study indicate that they are measuring different aspects of hearing. The argument does not alter the conclusions of this study.

Complainers have more disability than non-complainers with similar impairment and feel more handicapped than non-complainers with similar disability. This is probably the main factor which influences self-referral. The poorer performance on speech audiometry suggests that this increased disability is due to disorders of central auditory function. This has been associated with ageing (Jerger and Hayes, 1977), but the difference was present in this study when age was controlled for. It was not due to differing incidence of sensorineural and conductive loss in each group because there was no difference in the air-bone gaps in each group.

It could be suggested that the apparently greater disability was secondary to introversion or depression; questions 15 to 17 of the hearing questionnaire could be regarded as indicators of depression rather than handicap. Against this argument is the objective evidence of increased disability from speech audiometry.

Further evidence of the real nature of the increased disability can be found in the analysis of the hearing questionnaire (table 2.7): the increase in disability was not apparent in every question, but was greatest in the situations expected from conventional teaching - speech in noise - and less in others such as speech in quiet and easily heard everyday sounds.

The similar lifestyle of each group despite the difference in handicap indicates that lifestyle is governed by social surroundings and habit; complainers spend as much time watching television as non-complainers, though they probably do not hear as much of it. Alternatively, it may be that in most activities disability can be compensated for to some extent while this is not possible at bingo. It could also be that the questions used were not sufficiently sensitive to detect differences.

The other factor which appears to be important is asymmetric hearing. Individuals with mild symmetric hearing loss may be unaware of their impairment because they have no yardstick with which to compare their hearing. Most clinicians will have seen individuals who complain of unilateral hearing loss but have a bilateral asymmetric loss. Asymmetry provides the patient with strong evidence of abnormality.

The greater age of complainers may be due to sample bias, in that previous hearing aid users were not excluded from this group. This does not alter the significance of the other findings because age is controlled for in all analyses. This will make the complainers more impaired as a group, but the findings of this study are based on differences that were still apparent when the level of impairment was controlled.

What can we learn from this study about potential requirements for audiological services? Most of these non-complainers had sensorineural hearing loss, so rehabilitation might include amplification. It might be thought that these individuals would hear very well with a hearing aid because they tend to have better speech discrimination than audiology clinic referrals. On the other hand, they are unlikely to be motivated to use a hearing aid. Also, benefit from a hearing aid can be regarded as reduction in disability; as non-complainers have less disability, their potential for benefit is smaller.

It is likely that many of these non-complainers will become complainers in the future, assuming that their disability increases. Early fitting of hearing aids should perhaps be considered, though there is no evidence that this will alter the eventual degree of disability.

Current NHS hearing aids were designed for patients with moderate hearing loss, and are stated to be medium gain, wide frequency aids (DHSS, 1977). In fact, they provide negligible gain above 4 kHz (see appendix 8). Usually the first disability noticed by the mildly impaired is in noisy surroundings. Amplification of low frequency noise (below 2 kHz) causes upward spread of masking on higher frequency elements of speech; NHS aids have their maximum gain at 1 kHz. High frequency amplification, on the other hand, greatly increases speech intelligibility in noise (Pascoe, 1975; Harford and Fox, 1978). Thus current NHS aids appear unsuitable for the mildly impaired individuals who are not referred at present. Further evidence for this is presented in chapter 5. If hearing aid services are to be expanded to manage these individuals with their present level of disability, high frequency aids with the maximum gain between 2,000 and 6,500 Hz are required.

Does this study tell us anything about the management of patients who are currently referred for assessment? It is probable that most patients in the UK are managed on the basis of pure-tone thresholds. This study shows clearly that patients present because of disability and handicap which does not necessarily correspond to their hearing impairment. The aim of rehabilitation is reduction in disability. The efficacy of such rehabilitation cannot be reliably assessed without a valid and practical test of disability. Such a test is not yet available.

CONCLUSIONS

Complainers have more middle ear disease, but no other differences in aetiological factors have been identified.

Complainers have more asymmetric hearing.

Complainers have greater measured disability when impairment is controlled for.

Complainers have greater reported disability controlling for impairment and objective disability.

Complainers are more handicapped when impairment and measured and reported disability are controlled for, though this is not generally reflected in a change in lifestyle.

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CHAPTER 3

CLINICAL ASSESSMENT OF HEARING

INTRODUCTION

Free-field voice testing was the standard method of assessing hearing until pure-tone audiometers became widely available in the 1940's. Subsequently, Trowbridge (1947) compared the results of voice testing with pure-tone audiometric thresholds in 300 patients. He used a whispered voice produced with the residual air after a normal expiration, and established the distance at which this could be heard. He concluded that the whispered voice test results did not correlate well with pure-tone thresholds. Unfortunately, his data is reported as a weighted percentage loss and cannot be translated into actual pure-tone thresholds for further scrutiny.

Fowler (1947) deplored "the use of antiquated methods in spite of the availability of accurate audiometry" and demonstrated the variable loudness of examiners' voices. In particular, he noted that their voices tended to rise as the distance from the patient increased, thus negating the effect of distance.

Both these authors assumed that pure-tone audiometry was accurate, though it has since been shown to have error margins of up to 10dB (Stephens 1969).

More recently, in a survey of 197 pre-school children, Broen (1973) compared the whispered voice test with pure-tone audiometry as a screening test for hearing impairment. He found that the whispered voice test was equally effective and had the advantage of simplicity.

King (1953) identified four sources of inaccuracy in voice tests: the lack of a standard technique, the inability of examiners to control their voice levels, the lack of control of ambient noise, and the different acoustic properties of test rooms. He found that voice levels varied, not only between examiners but also in any one examiner, and noted that examiners' voices rose as the ambient noise level rose, though in clinical practice ambient noise levels rarely vary enough to make a significant difference. Different acoustic properties of test rooms had a negligible effect on sound pressure levels.

Another possible source of error is the masking of the non-test ear. Textbooks often recommend the use of the Barany noise box in conjunction with clinical tests of hearing (Saunders and Meyerhoff, 1980). In clinical practice, however, tragal rubbing is probably the most commonly used method. King (1953) recommended that the non-test ear be "blocked by light intermittent pressure on the tragus" and stated that this "produced efficient masking which was important in testing monaural hearing". No evidence was adduced to confirm its efficacy. Tragal rubbing has been criticized, often citing experimental work by Hinchcliffe (1955) which demonstrated that "occlusion by firm finger tip pressure on the tragus" would attenuate speech by less than 30 dB, and often by a mere 10 dB. However, it is important to note that Hinchcliffe was not recommending this as an effective method of masking. On the contrary, his aim was to show that simple occlusion would not attenuate hearing sufficiently to prevent a loud voice being heard. This is the basis for Erhard's (1872) loud voice test for exposing feigned unilateral hearing loss: the normal ear is occluded while a loud voice is presented to the "deaf" ear. Hinchcliffe showed that occlusion would not prevent the loud voice being heard in the normal ear, so that denial of hearing the voice would indicate malingering.

The main role of tuning fork tests is determining the nature of a hearing loss rather than quantifying it. This role has been recently reviewed (Golabek and Stephens, 1979), and will not be discussed here.

There is insufficient data in the literature to define the present day role of clinical voice tests. There is no data to guide the clinician in deciding how to mask the non-test ear efficiently without affecting the threshold in the ear being tested. The aim of this study was to assess the accuracy and usefulness of clinical voice tests and to look at the efficacy of tragal rubbing and the Barany noise box as methods of masking the non-test ear.

METHOD

Free-field voice levels

The standard method of voice testing in the Audiology Clinic at Glasgow Royal Infirmary is to ask the patient to repeat test items spoken in a whispered, conversational or loud voice at distances of 6 inches and 2 feet from the ear being tested. The latter distance represents arm's length from the non-test ear to allow masking by tragal rubbing. Test items consist of 3 digits or digits and letters (e.g. 6 B 4). This method is similar to that described by Hinchcliffe (1981).

Before comparing the results of voice testing and pure-tone audiometry, the sound pressure levels produced by the author and a consultant otologist were recorded in a sound-reduced booth (appendix 2) with a free-field microphone representing a patient's ear. Lists of 8 to 10 test items were spoken in whispered, conversational and loud voices, at distances of approximately 6 inches and 2 feet from the microphone. Measurements were made outside the booth with a sound-level meter set on the dBA (fast) scale and a chart recorder. Tests were repeated on four different days. All equipment was calibrated before each test session.

Free-field voice test thresholds

The records of 291 consecutive patients attending the Audiology Clinic were reviewed. 201 of these patients had been tested by the author or the consultant otologist, while the other 90 had been tested by three less experienced members of junior staff. The method of testing was that described above; the method of masking was not recorded. Voice test thresholds were compared with the pure-tone average thresholds (PTA) at 0.5, 1 and 2 kHz (appendix 2). Asymmetry was defined as a difference in PTA between ears of greater than 10 dB.

A prospective study was then undertaken by the same otologist and the author. Voice test thresholds were established for 101 consecutive patients who had aural symptoms but for whom no previous audiometric record was available. The non-test ear was masked by tragal rubbing. Subsequently, pure-tone thresholds were assessed and the results were compared.

Masking

The method of masking routinely used in the Audiology Clinic is to rub the tragus sufficiently firmly to occlude the meatus and create a noise in the ear. The efficacy of this method was assessed by measuring the change in the Half-Peak Level (HPL) recorded by speech audiometry (appendix 2). The subjects were young adults who had no pure-tone threshold worse than 10 dB HL in either ear at the frequencies 0.5, 1, 2, and 4 kHz. Free-field speech audiometry was done in a sound-reduced room and the HPL was established. The subject's ears were then masked by bilateral tragal rubbing and a new HPL was established.

It was felt that the Barany noise box was too loud to hold over both ears for the time taken to do a speech audiogram. In clinical practice, the Barany box is held either over the ear or beside the ear (figure 3.1). The sound pressure levels produced by 4 Barany boxes were measured by placing the box either over or at right angles to a freefield microphone attached to a sound-level meter. Each box was then placed over or beside a subject's ear while the sound pressure level was measured at the opposite external auditory meatus.

The effect of each method of masking in free-field voice testing was investigated in another group of audiometrically normal young adults. Voice test thresholds were estimated under four conditions:

(1) Bilateral tragal rubbing.

(2) The non-test ear masked by a Barany box beside the ear.

(3) Both ears masked by a Barany box beside each ear.

(4) Both ears masked by a Barany box over the ear.

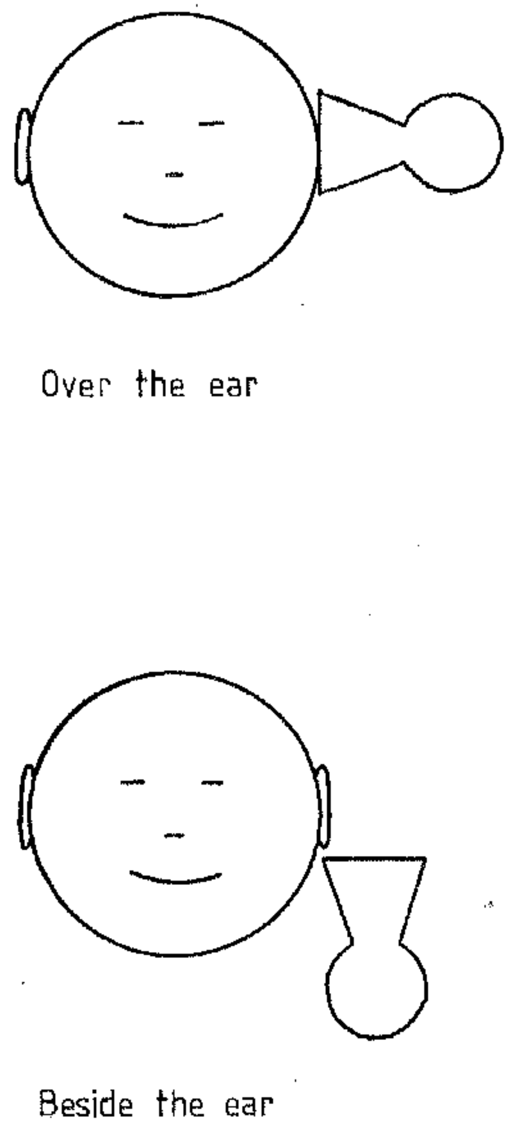

Figure 3.1. Location of Barany Noise Box.

RESULTS

Free-field voice levels

The actual distances between the clinician's lips and the microphone were measured each day. The mean distances were 7 and 21 inches; the ranges were 6 to 8 and 19 to 22 inches. For convenience, however, these distances will continue to be referred to as 6 inches and 2 feet.

Table 3.1 shows the mean sound pressure levels for each clinician on each day; the corresponding standard deviations are shown in table 3.2. The range of loudness of test items on each day was small, but there was a much larger variation between different days, as demonstrated by the standard deviations. There was a large difference between these clinicians in the sound pressure level of their whispered voice, but little difference when using a conversational or loud voice.

Clinician_A

Voice	Day 1	Day 2	Day 3	Day 4	Overall
WV 2'	61	67	70	54	63
WV 6"	67	66	67	57	64
CV 2'	66	71	73	63	68
CV 6"	74	81	78	70	76
LV 2'	87	92	92	90	91
LV 6"	92	92	93	93	93

Clinician_B

Voice	Day 1	Day 2	Day 3	Day 4	Overall
WV 2'	54	51	49	53	51
WV 6"	57	52	51	54	54
CV 2'	83	63	70	77	73
CV 6"	86	69	69	82	76
LV 2'	95	80	95	99	92
LV 6"	>102	87	100	>102	98

Table 3.1. Mean voice sound pressure levels (dBA) for two clinicians.

WV = Whispered voice

CV = Conversational voice

LV = Loud voice

Clinician A

Voice	Day 1	Day 2	Day 3	Day 4	Overall
WV 2'	1.8	2.4	1.4	1.4	6
WV 6"	2.9	2.5	3.5	1.1	5
CV 2'	1.9	2.3	1.3	1.7	4
CV 6"	1.9	2.5	1.9	2.1	5
LV 2'	2.4	0.5	0.8	2.1	2
LV 6"	0.5	0.4	0.5	0.5	1

Clinician B

Voice	Day 1	Day 2	Day 3	Day 4	Overall
WV 2'	1.9	2.1	1.2	1.6	3
WV 6"	2.4	1.4	2.9	1.8	3
CV 2'	4.2	1.9	5.5	2.4	8
CV 6"	3.7	2.5	2.4	2.5	8
LV 2'	3.3	3.9	2.6	1.9	7
LV 6"	---	3.9	---	---	---

Table 3.2. Standard deviation for each sound pressure level in table 3.1 (dB).

Voice test thresholds : retrospective study

Table 3.3 shows the mean PTA corresponding to each voice test threshold for 540 ears. Results have been omitted if fewer than 5 ears were allocated to that threshold. Table 3.4 shows the mean thresholds with the 10th. and 90th. percentiles for the 559 ears tested by all 5 clinicians.

Voice Threshold	Clinician A	B	C	D	E
WV 2'	15	18	18	15	31
WV 6"	34	26	31	35	37
CV 2'	45	42	42	44	46
CV 6"	52	47	47	56	---
LV 2'	64	---	60	---	---
LV 6"	78	73	---	---	70
Deaf	105	---	---	---	---
Ears	288	101	50	59	42

Table 3.3. Retrospective comparison of voice test thresholds and mean PTA (dB HL) for five clinicians.

Voice Threshold	No. of ears	10%	mean	90%
WV 2'	65	---	17	30
WV 6"	114	15	33	47
CV 2'	160	32	44	58
CV 6"	115	32	50	65
LV 2'	37	48	63	77
LV 6"	47	60	75	90
Deaf	21	87	104	---

Table 3.4. Mean PTAs (dB HL) with 10th. and 90th. percentiles for each voice test threshold; retrospective data for five clinicians.

Voice test thresholds : prospective study

Prospective comparison of voice test thresholds and PTAs showed very similar results for the 2 clinicians; their results are therefore presented together. Table 3.5 shows the 10th. and 90th. percentiles and the mean PTA for the 202 ears tested.

Voice Threshold	No. of ears	10%	mean	90%
WV 2'	100	—	12	25
WV 6"	36	22	34	45
CV 2'	26	40	48	60
CV 6"	24	48	56	62
LV 2'	13	67	76	87
LV 6"	2	—	84	—
Deaf	1	—	>120	—

Table 3.5. Mean PTAs (dB HL) with 10th. and 90th. percentiles for each voice test threshold; prospective data for two clinicians.

When a positive response was obtained to a whispered voice at arm's length, the PTA was invariably better than 30 dB HL, while a negative response to a whispered voice at 6 inches always indicated a PTA worse than 30 dB HL (figure 3.2). Those who heard a whispered voice at 6 inches, but not at arm's length, overlapped these groups.

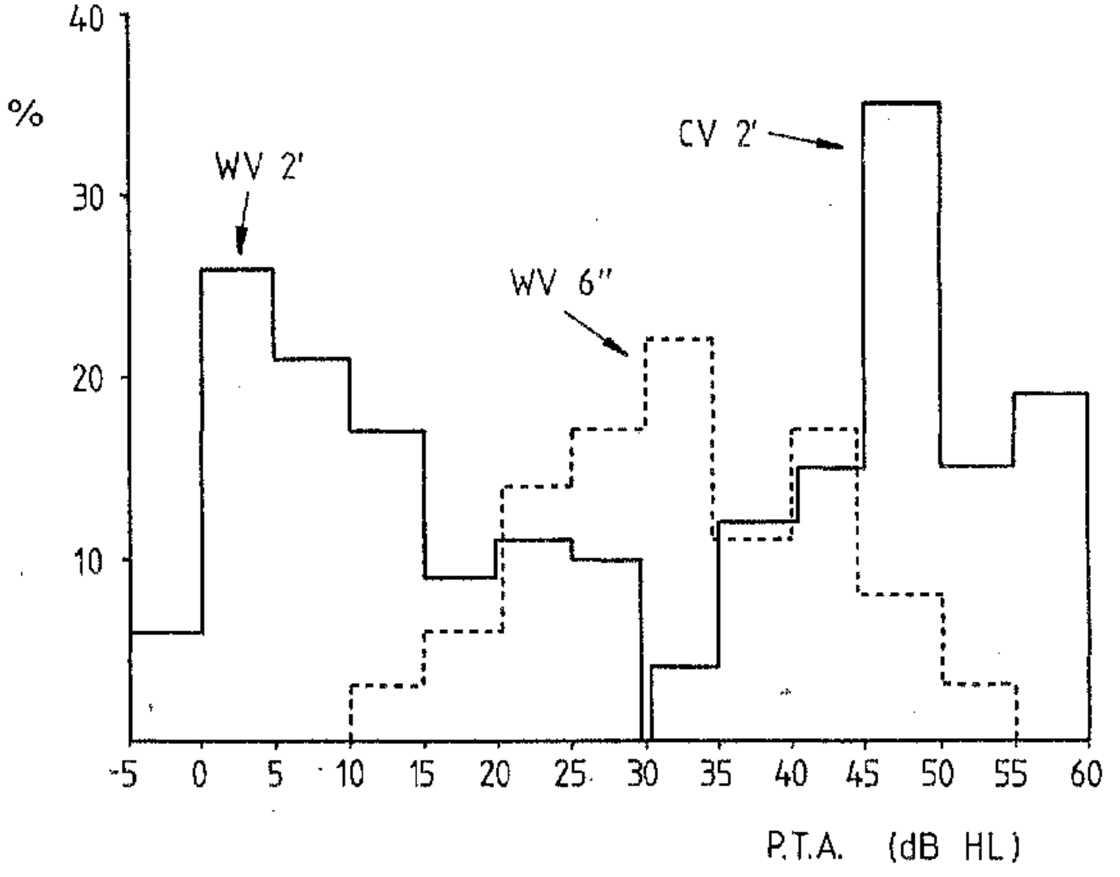

Figure 3.2. Distribution of pure-tone thresholds corresponding to voice test thresholds of WV 2', WV 6" and CV 2'.

26 subjects had symmetric hearing loss (difference of 10 dB or less). 16 (62 %) had symmetric voice test thresholds. 10 had a difference of one step in their voice test thresholds, but in 8 of these there was a difference in their PTAs of more than 5 dB and the poorer hearing ear was correctly identified. No subject with symmetric PTAs had a difference of more than one step in their voice test thresholds.

25 subjects had asymmetric hearing loss. 22 (88 %) were noted to have asymmetric hearing on voice testing, and the poorer hearing ear was always correctly identified. The remaining 3 (12 %) had symmetric voice test thresholds; only 1 had asymmetry of more than 15 dB.

Masking

Bilateral tragal rubbing caused a mean change in the half peak level for speech of 59 dB with a range of 46 to 77 dB in 9 subjects. In a further 10 normal subjects, 4 could hear a conversational voice at six inches, while the remaining 6 could only hear a loud voice.

The mean sound pressure level recorded with the Barany box placed over the microphone was 105 dBA (range 103-107); with the box at right angles to the microphone it was 98 dBA (range 95-101). The levels recorded at the opposite ear were 67 dBA (range 64-70) with the box beside the ear and 59 dBA (range 57-61) with the box over the ear.

Voice testing in 10 normal subjects with a Barany box held beside the non-test ear showed that 2 subjects could still hear a whispered voice at arm's length, but the other 8 could only hear a whispered voice at six inches.

When Barany boxes were held beside both ears, 5 subjects heard a conversational voice at six inches while the other 5 heard a loud voice at two feet. With Barany boxes placed over both ears, 4 subjects heard a loud voice at arm's length and 6 heard a loud voice at six inches.

DISCUSSION

It is difficult to reproduce the same sound pressure level when doing voice tests, and this will cause some variability in test results. The difference in sound pressure levels between clinicians is less important because individual clinicians could readily learn to interpret their own results.

Despite this variability, clinical voice test results are well correlated with pure-tone thresholds. One would not expect a closer relationship between voice and pure-tone thresholds because the former depends on discrimination as well as perception. Comparison of audiometric thresholds for pure tones and speech shows a similar degree of correlation (figure 2.1, p. 29). The prospective and retrospective studies gave similar results, though, as might be expected, the retrospective study had a greater spread of results. This was at least partly due to inaccurate recording of data.

Do we always need great accuracy when testing hearing? Accuracy is important when investigating pathology or considering the potential benefit of surgery for conductive losses. But audiometry is often done solely to estimate impairment; in these cases, the accuracy attained by voice tests may be adequate.

What can be concluded from freefield voice tests? Firstly, they will help to decide whether a patient is sufficiently impaired to be likely to benefit from a hearing aid. If a patient can hear a whispered voice at 2 feet in both ears, he will have pure-tone thresholds better than 30 dB HL and is unlikely to benefit from current NHS hearing aids (Hodgson and Skinner, 1981) because these are designed for individuals with "moderate hearing impairment" (DHSS 1977). Conversely, those unable to hear a whispered voice at 6 inches are likely to find a hearing aid of some help, as they will have a hearing loss of at least 35 dB (see Chapter 5). Humphrey et al. (1981) reported that 25% of a group of elderly subjects had consulted their general practitioner specifically about their hearing difficulty but had not been referred for a hearing aid. The mean pure-tone threshold of these individuals was 52 dB HL. Perhaps some of them would have received the help they sought if their doctor had clinically tested their hearing.

Secondly, in the otolaryngology or audiology clinic, voice testing is a useful way of checking audiometric results. Audiometers can malfunction and technicians, like all other human beings, can make mistakes. It is considered unwise in any branch of medical practice to accept laboratory results without supporting clinical evidence.

However, freefield voice testing should not be relegated to a supporting role. There are many patients - especially the elderly - in whom the aetiology of their hearing impairment is of purely academic interest as it will not alter the management of the patient: they will be prescribed a hearing aid. There is no significant difference in the frequency responses of the BE10 series hearing aids which would make one model preferable to another for a particular configuration of pure-tone hearing loss (appendix 8). The frequency response can be altered slightly by adjusting the tone control, but as there are no firm guidelines as to when this should be done, it would seem better to try each setting in the patient's ear. The frequency response can also be modified by alterations to the ear mould system. However, there are no generally accepted rules about when alterations should be made, besides which, many otolaryngology clinics make none (personal observation). So, in many cases, the only decisions to be made prior to fitting a hearing aid are which ear should be fitted, and how powerful should the aid be.

Whether a hearing aid should be fitted in the better or worse hearing ear will be discussed in the next two chapters. However, asymmetry can be readily recognised by voice tests - the third conclusion. Many clinicians would wish to investigate the possibility of a cerebello-pontine angle tumour in individuals with asymmetric hearing loss. 12 % of individuals with asymmetric hearing loss were not identified in the prospective study, but the definition of asymmetry was a difference of more than 10 dB between ears, and few clinicians would undertake further investigations at this level. If a criterion of 15 dB for asymmetry is taken, only one individual (4 %) was not recognised. On the other hand, 38 % of individuals with symmetric hearing loss had asymmetric voice test thresholds.

The fourth use for voice testing is identifying those with a severe or profound hearing loss. There is no agreed level of impairment at which a more powerful aid (i.e. a BE30 series) would be recommended, but it is usually held to be around 70 dB HL. This level corresponds very well to those who cannot hear a conversational voice at 6 inches.

Freefield voice testing should, therefore, be considered as a substitute for pure-tone audiometry in a hearing aid clinic. It is quicker, so more time is available for instructing the patient in the use of his new hearing aid. In addition, it is less bewildering and less tiring, particularly for elderly patients, so that they are more receptive to instruction about their hearing aid.

Tragal rubbing is more effective at masking than is commonly realised. It is important to create a noise in the external auditory canal as simple occlusion is much less effective. This can be demonstrated easily on one's own ears. Comparison of the mean threshold increase of 59 dB with the table of voice test thresholds (table 3.5) predicts that most normally hearing individuals should be unable to hear a conversational voice at 6 inches from their ear during tragal rubbing, and this has been confirmed experimentally. In clinical practice, the test voice is at the opposite side to the ear being masked, so it will be attenuated by about 15 dB due to the head shadow (MacKeith and Coles, 1971). Therefore tragal rubbing can be relied upon to effectively mask the non-test ear when using whispered or conversational voices.

The Barany noise box is loud. It is unpleasant having it over one's ear. Because of this, many clinicians hold the box beside the ear. This is less uncomfortable but it alters the threshold in the other ear of normally hearing subjects. This is important because a patient with normal pure-tone thresholds may appear to have a bilateral hearing loss on voice testing if a Barany box beside the ear is used to mask the contralateral ear. Patients with mild sensorineural hearing loss often have difficulty in discriminating speech in noise; it is likely that their thresholds will be more seriously affected. Holding the box beside the ear is no more effective at masking than tragal rubbing is. Placing the box over the ear reduces the noise at the other ear by 8 dB but increases the discomfort. But even with the box over the ear, a loud voice can often still be heard at arm's length. Thus a dead ear may not be diagnosed if one assumes that the contralateral ear is effectively masked by a Barany box.

There is little difference in the effective masking of the Barany box and tragal rubbing. Tragal rubbing has the advantage that it is less uncomfortable, less frightening to the patient, and does not alter the threshold in the other ear. In addition, it is cheap and readily available.

CONCLUSIONS

Voice testing is a useful part of clinical examination. Individuals who can hear a whispered voice at arm's length are unlikely to benefit from a hearing aid. Those who cannot hear a conversational voice at six inches will require a BE 30 series aid. The poorer hearing ear can be reliably identified. Audiometric errors are less likely to go unnoticed if voice testing is routinely done.

Tragal rubbing will successfully mask whispered and conversational voices. It is as effective as a Barany box held beside the ear. It should be preferred to a Barany box because it will not affect the threshold in the ear being tested while a Barany box might. A Barany box cannot be relied on to mask a loud voice.

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CHAPTER 4

PATIENTS' PREFERENCE FOR SIDE OF HEARING AID USE

INTRODUCTION

No previous study has been identified which has investigated which ear should be fitted with a hearing aid to give the maximum, monaural benefit.

Berger (1976) gives the following guidelines for choosing the side of fitting, though he does not suggest that these are based on experimental evidence:

(1) Fit the ear with the better speech discrimination.

(2) If the better ear threshold is no worse than 40dB and the poorer ear is no worse than 60dB, fit the poorer ear.

(3) Fit the ear with the larger dynamic range.

(4) Fit the ear with the larger air-bone gap.

(5) If both ears have similar thresholds, fit the one with the flatter audiometric configuration.

In constrast to Berger's first guideline, Upfold and Smither (1981) do not think speech audiometry is justified because they have "been unable to find speech tests sensitive enough to demonstrate reliably which ear should be fitted." Unfortunately, though many other aspects of hearing aid fitting are discussed, no advice is given on the choice of ear to be fitted.

In NHS clinics in Britain, the following rules of thumb are among those employed:

(1) Fit the better ear.

(2) Fit the worse ear.

(3) Fit the ear nearer to 50dB.

(4) Fit the right ear if the patient is right handed.

These rules have never been evaluated.

The aim of this study was to identify factors of importance in predicting patients' preference for side of hearing aid use.

METHOD

The subjects were consecutive adult patients attending the Audiology Clinic at Glasgow Royal Infirmary who satisfied the following criteria:

(1) No previous hearing aid provision.

(2) Right handed.

(3) No active otitis externa or media.

(4) Bilateral speech frequency average thresholds between 25 and 75 dB HL.

(5) Difference between ears in the optimal discrimination score for speech in quiet of less than 30%.

(6) Adequate mobility of both upper limbs.

(7) Sufficiently mentally alert to comply.

These criteria were intended to select individuals in whom either ear could be fitted with a NHS ear level aid. Left handed individuals were excluded because there are insufficient numbers of them in this clinic population to allow separate analysis.

All subjects had pure-tone and speech audiometry carried out in a sound-reduced room prior to selection. Ear mould impressions were taken of both ears. A BE10 series aid with an anatomical mould was fitted in a randomly selected ear. Acoustic filters were inserted in the connecting tubing to achieve a smoothed frequency response (appendix 8). Patients were instructed in the general use and care of the aid and mould. The subjects returned after 4 weeks, by which time shell moulds had been made, with an acoustic 2 mm. vent if the SFA in both ears was better than 50 dB HL. The moulds were checked to ensure they fitted well, and any necessary alterations were made. One of the moulds was selected at random and the aid refitted in the chosen ear. Patients were assessed to ensure that they could fit, manipulate and use the aid satisfactorily.

At the next clinic visit 10 weeks later, subjects were questioned about hours of use and subjective benefit from wearing the aid. Speech audiometry and shortened pure-tone audiometry (air conduction only at 0.5, 1, 2 and 4 kHz.) were carried out. The aid was changed to the other ear using the second shell mould, and the first shell mould was retained in the clinic.

After a further 10 weeks, speech and shortened pure-tone audiometry were repeated. Subjects were again questioned about use and benefit. They were asked in which ear they preferred to wear their hearing aid and and whether this preference was due to a difference in hearing, a more comfortable mould, greater ease of insertion and manipulation, or using the telephone in a particular ear. If they reported a difference in their hearing with the aid in either ear, they were asked whether this was a small, moderate or large difference.

RESULTS

76 patients were admitted to the study. 18 of these were withdrawn: 14 defaulted from attendance, 2 became seriously ill, 1 died and in one patient inactive chronic otitis media became active.

Of the 58 subjects who completed the study, 35 (60%) were male and 23 (40%) were female. The mean age was 66 years with a range of 29 to 87 years.

No subjects' speech frequency average threshold changed by more than 10 dB between recordings. The mean of the three SFAs for each subject was calculated; the distribution of the results for better and poorer hearing ears is shown in figure 4.1. The mean SFA in the better hearing ear was 46 dB HL and in the worse ear it was 56 dB HL. Figure 4.2 shows the degree of asymmetry in pure-tone thresholds. Speech audiometry results are similarly the mean values from three recordings.

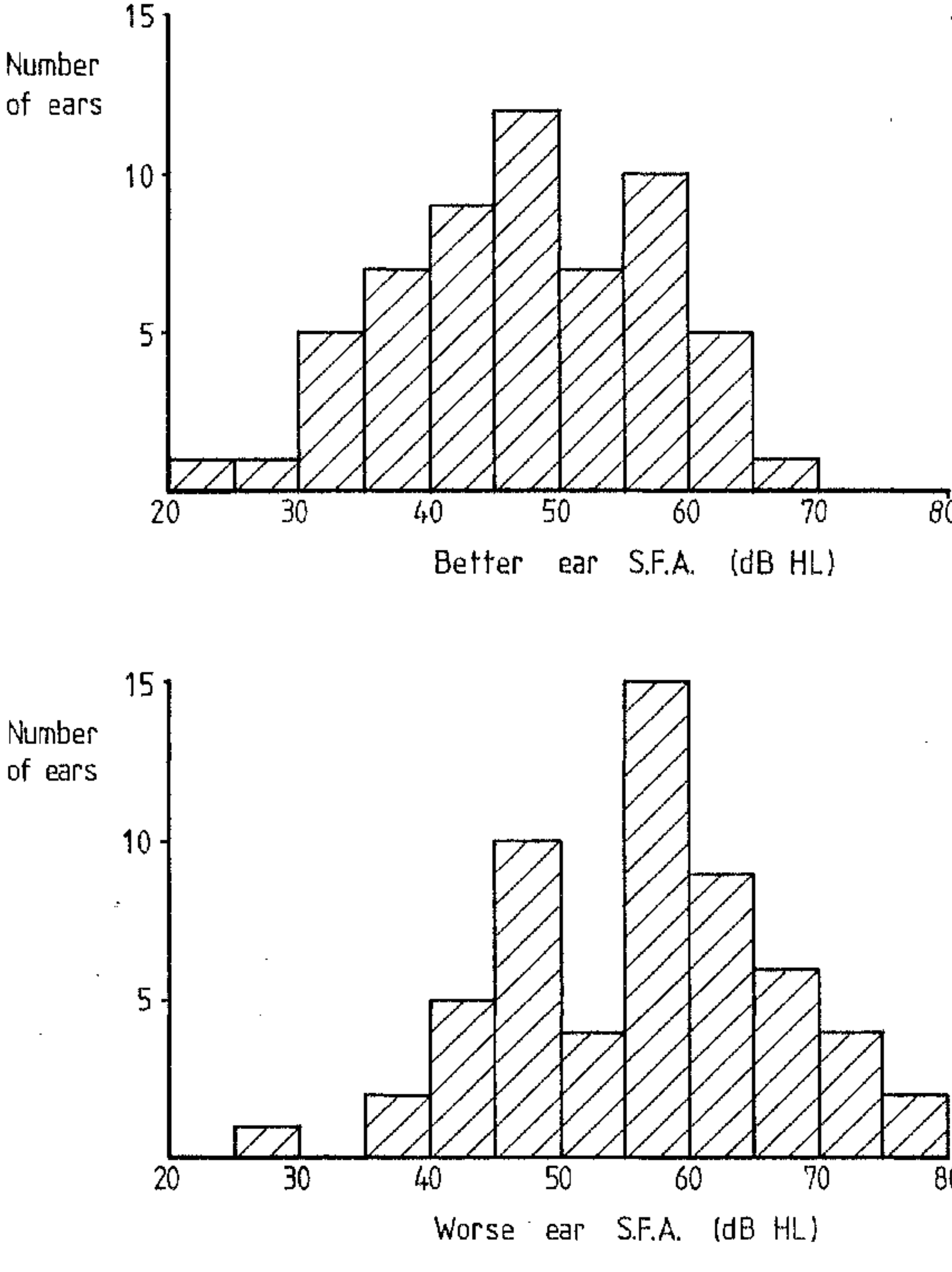

Figure 4.1. Distribution of Speech Frequency Average thresholds in the better and the worse hearing ear.

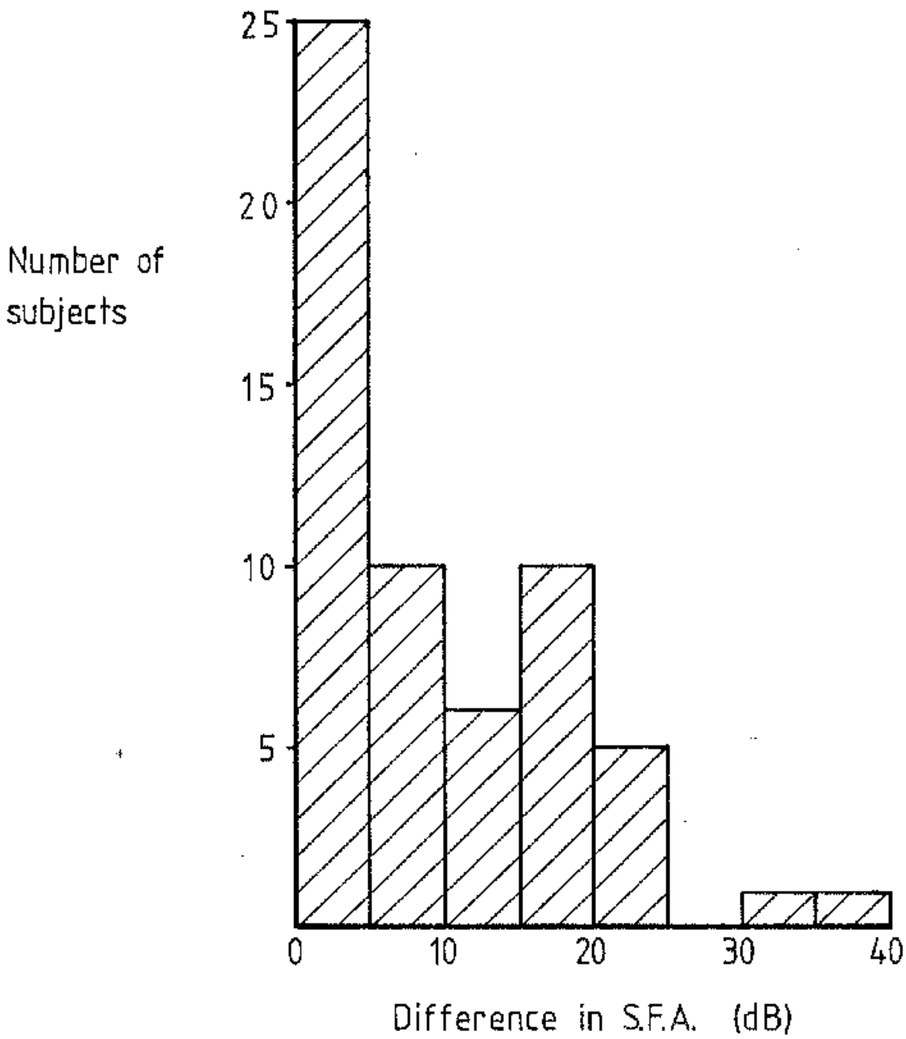

Figure 4.2. Difference between ears in Speech Frequency Average thresholds.

1 subject had a bilateral conductive hearing loss (appendix 1). 1 subject had a conductive hearing loss in his better hearing ear and a mixed loss in his poorer hearing ear. 4 subjects had bilateral mixed losses with equal air-bone gaps in each ear. 9 subjects had a mixed hearing loss in one ear and a sensorineural loss in the other ear; 8 of these had symmetric bone conduction thresholds, while the other individual had an air-bone gap in his better hearing ear. The remaining 43 subjects had bilateral sensorineural hearing loss.

There was no significant effect of the side of issue of the anatomical mould or of the order of provision of the shell moulds. 26 individuals preferred the ear in which the first shell mould was fitted; 14 of these had worn their anatomical mould in that ear. 24 preferred the ear fitted second; in 11 subjects this was the ear in which they had worn their anatomical mould.

30 (52%) patients reported that they could hear better with their aid in one ear. 20 (34%) reported no hearing difference but preferred one ear for practical reasons: 10 found the aid easier to insert and adjust in one ear, 7 found one mould more comfortable than the other and 3 used the telephone in the opposite ear. The remaining 8 (14%) subjects expressed no preference for side of use. These three groups of subjects could not be differentiated by age or hearing loss (table

4.1), or by sex or socio-economic group.

	PREFERENCE		
	hearing	practical	none
Number	30	20	8
Age	66	66	67
Better SFA	46	46	49
Poorer SFA	56	56	55
Better ODS	84	80	74
Poorer ODS	77	74	65

Table 4.1. Comparison of subjects with different reasons for preference.

Subjects with preference because of hearing

21 (70%) of the 30 individuals preferred to wear their hearing aid in the ear with the poorer SFA, and 7 (23%) in the ear with the better SFA (figure 4.3). All of the 13 subjects with asymmetry of 10 dB or more in their SFA said they could hear better with their aid in their poorer hearing ear, and all reported moderate or large differences between ears.

If the difference in the Half-Peak Level Elevation (HPLE) measured by speech audiometry is compared with side of preference (figure 4.4), 24 (80%) preferred their aid in the poorer hearing ear and 5 (17%) in the better hearing ear. 12 individuals had asymmetry of more than 10 dB in their HPLE and, once again, all preferred the poorer ear.

Comparison of preference with difference in the Optimal Discrimination Score (ODS) for speech in quiet does not show such an obvious trend, though 19 (63%) subjects chose to wear their aid in the ear with the poorer ODS, while only 8 (27%) chose the other ear (figure 4.5).

A multiple linear regression analysis was done with preference as the dependent variable and SFA and slope of the audiogram (0.5 to 4 kHz) as independent variables; the regression equation was:

$$\text{Preference} = 19 - 9.4 \times \text{DSFA} + 5.2 \times \text{Dslope}$$

where DSFA is the difference in SFA between ears (right minus left) and Dslope is calculated similarly. If the value for preference is positive, the left ear is more likely to be preferred. Using this equation, the preference of 23 (77%) subjects could be correctly predicted.

A similar analysis of preference, HPLE and ODS produced the following regression equation:

$$\text{Preference} = 22 - 7.5 \times \text{DHPLE} + 4.7 \times \text{DODS}$$

This equation would have correctly predicted 26 (87%) preferences.

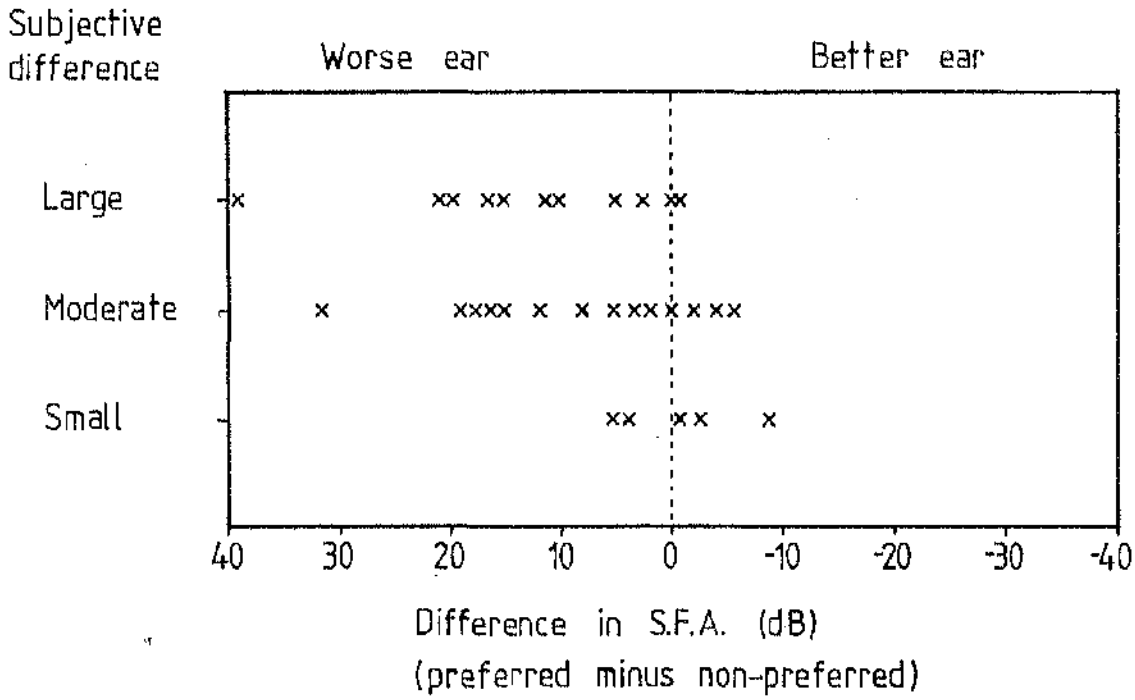

Figure 4.3. Subjective difference between ears in aided hearing versus difference in Speech Frequency Average threshold.

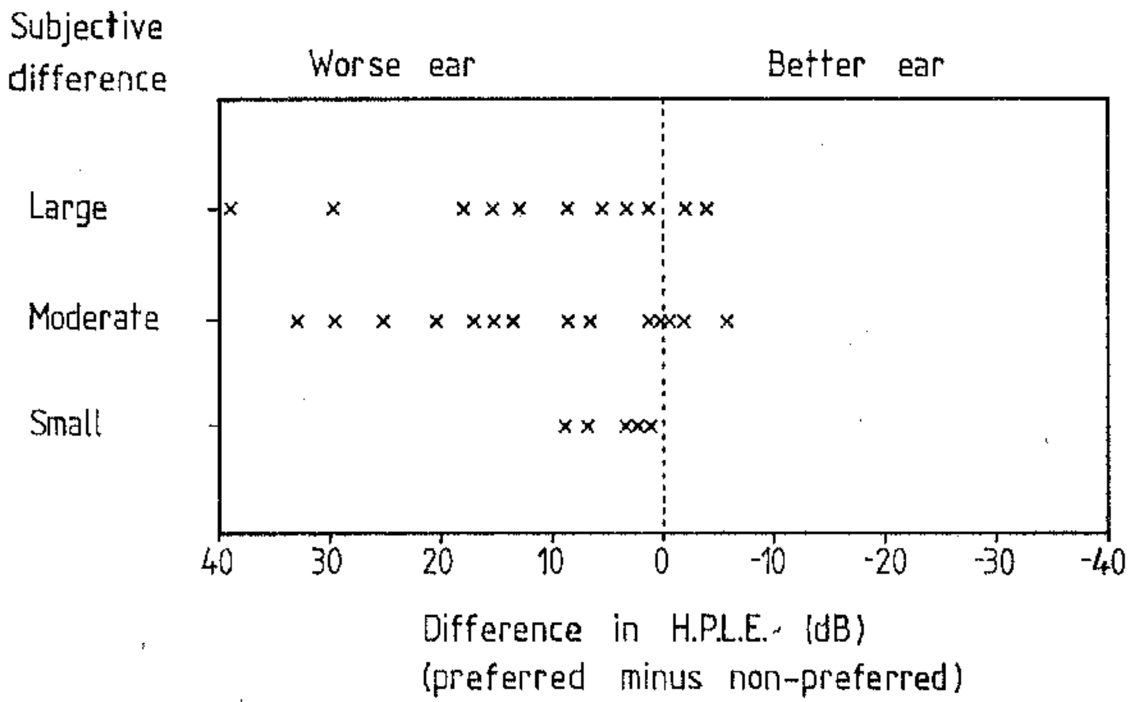

Figure 4.4. Subjective difference between ears in aided hearing versus difference in Half Peak Level Elevation.

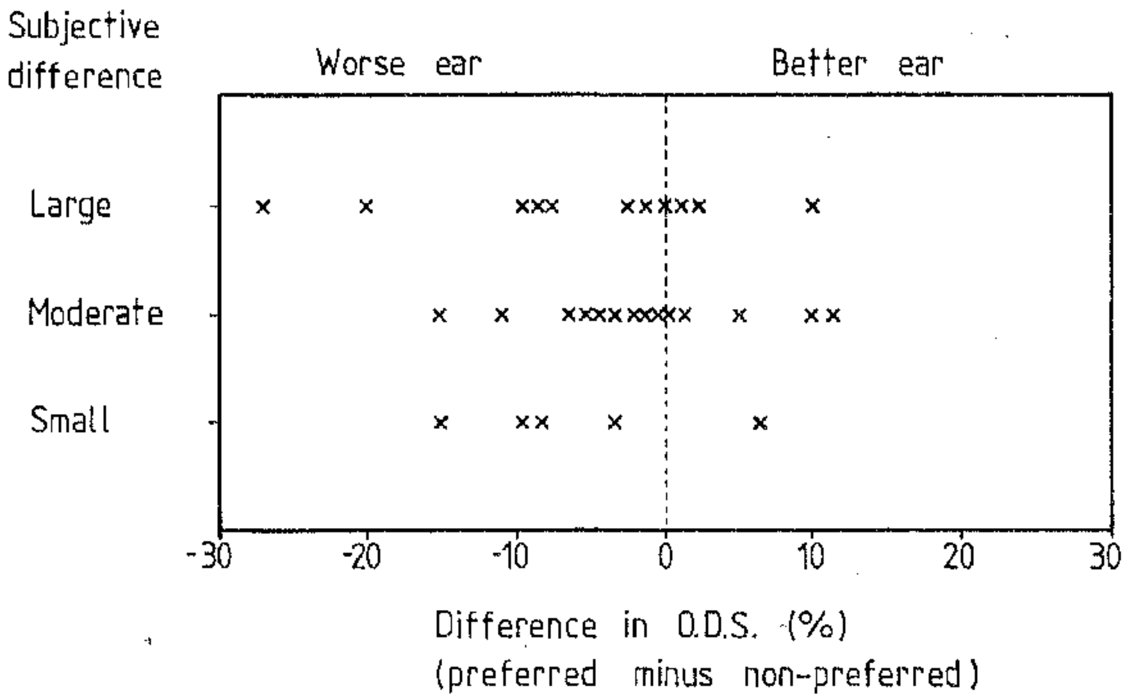

Figure 4.5. Subjective difference between ears in aided hearing versus difference in Optimal Discrimination Score.

Subjects with preference for practical reasons

There was no correlation between subjects' preference for practical reasons and the SFA, HPLE or ODS. 8 individuals had speech frequency asymmetry of 10 dB or more: 5 preferred their aid in the poorer hearing ear and 3 in the better hearing ear.

11 subjects chose to wear their aid in their right ear and 9 in their left ear. Of the 10 who found the aid easier to manipulate in one ear, 8 chose the right ear. 3 subjects found the right ear mould more comfortable and 4 found the left more comfortable. 3 chose the left ear because they used the telephone in the right ear.

Hours of use

Table 4.2 shows the mean number of hours for which subjects were estimated to use their hearing aids, with subjects grouped according to the reasons for their preference.

Reason for preference	Mean use (hrs/day)	1 S.D.	No. of subjects
Hearing:			
preferred ear	8.0	4.3	30
non-preferred ear	7.3	4.3	30
Practical:			
preferred ear	6.0	3.4	20
non-preferred ear	6.2	3.6	20
No preference:			
both ears	3.7	3.0	8

Table 4.2. Mean daily hours of hearing aid use.

The level of use in those subjects with no preference for side of hearing aid use was significantly lower than in those with a preference ($p < 0.05$ using the chi-square test). Other differences between groups in table 4.2 are not statistically significant ($p > 0.05$).

DISCUSSION

Many patients are dissatisfied with their hearing aids (Boothman et al. 1980). It seems reasonable to expect that the proportion would be reduced if the correct decision on side of hearing aid provision were always made. But on what basis do we make this decision? There are three ways of reaching a decision: we can let the patient choose, we can test his performance with an aid in either ear (see chapter 5), or we can have a provision strategy which is based on scientific study.

How much weight can be attached to patients' preference in this study? The subjects had 10 weeks experience of a hearing aid in each ear before they were asked to make a choice. This experience was in their usual environment, not in the strange surroundings of an audiology clinic. It would have been difficult to convince these patients that their choice was wrong, and that they should wear their aid in the ear opposite to the one they preferred. It could be argued that many patients have the preconceived idea that a hearing aid should be fitted in their "deaf" ear. But if their opinion is unchanged after 10 weeks trial in each ear, then perhaps there is a sound basis for their opinion. Also, the subjects of this study used their hearing aids for 7 hours per day on average; this is a high level of use compared to other reports (Stephens 1977), and supports the view that the subjects' preference is based on considerable experience.

Certain audiometric criteria were used to select the subjects of this study, but these criteria include the great majority of patients being prescribed a hearing aid for the first time. The results cannot be extrapolated to those with more severe losses. Within these criteria, however, there is a wide spread of speech frequency hearing losses (figure 4.1).

It is commonly held, though not proven, that individuals with conductive hearing loss benefit more from a hearing aid than those with sensorineural loss (Hodgson 1981). It is reasoned that ears with a conductive loss can tolerate more amplification without causing discomfort and have relatively normal frequency resolution, whereas ears with sensorineural loss may have poor speech discrimination and cannot tolerate as much amplification because of recruitment. There is no reason to suppose that the results of this study are affected by this theory. There were no subjects whose poorer hearing ear had an air-bone gap and better bone conduction thresholds than the other ear; this would be the only type of patient in whom a preference for the poorer hearing ear could be so explained.

Though the hearing losses in this study were almost all sensorineural or mixed, there is no theoretical reason why these results should not be equally applicable to pure conductive losses.

52% of patients asserted that they could hear better with their aid in one ear. In most cases this was the poorer hearing ear. In this group, those with asymmetry between ears of 10 dB or more, in their speech frequency average or in their half-peak level elevation, invariably preferred the poorer ear. Some of those with asymmetry of less than 10 dB preferred the better ear. Several subjects with little measurable hearing difference between ears reported a large difference in their aided hearing ability. The audiometric thresholds were averaged over three recordings, so they should be more accurate than a single recording. At first sight, it is surprising that 63% of subjects with a difference in their aided hearing preferred the ear with the poorer speech discrimination score, as this is contrary to the standard practice of fitting the ear with the better discrimination. However, the optimal discrimination score tends to fall as the hearing loss increases, so this is to be expected when their preference is for the poorer hearing ear. Though one of the criteria for admission to this study was a difference in ODS between ears of less than 30 %, no patient was excluded because of this criterion. Large differences in ODS are uncommon within the pure-tone limits of this study.

In this study, the half-peak level elevation was the best single predictor of preference in those with an aided hearing difference. The regression equation using the half-peak level elevation and the optimal discrimination score was the best overall predictor of preference. Though the equation looks complicated, the calculations are easily done on a pocket calculator. This equation has been used for several months in the Audiology Clinic of Glasgow Royal Infirmary with little difficulty.

It is important, however, to remember that only 87% of subject's preferences (based on hearing difference) were correctly predicted by this equation. 2 of the 4 incorrectly predicted reported a large difference in their aided hearing, and the other 2 reported a moderate difference. This represents a major disagreement between clinical recommendation and patient's preference. The only way of satisfying these exceptions is to routinely provide bilateral ear moulds in order to allow the patient to choose the side of hearing aid use at leisure in his normal environment.

One alternative strategy would also appear reasonable, that is to fit the poorer hearing ear if there is asymmetry (measured by pure tones or speech) of 10 dB or more, and to provide bilateral ear moulds if the hearing loss is symmetrical. This strategy would have been acceptable to all of the subjects who reported a difference in their aided hearing ability, and also to those with no preference for side of use. But 20 (34%) of the subjects in this study had a preference for practical reasons. 8 of these subjects had asymmetric hearing and 3 preferred the better hearing ear, though they denied any hearing difference. There was no apparent way of predicting which individuals would find a difference in their aided hearing and which would have a purely practical preference. Therefore the only way to satisfy these exceptions is to routinely provide bilateral ear moulds in asymmetric hearing as well. The typical cost to the N.H.S. of an ear mould is four pounds; this seems a small price to pay for the chance of greater patient satisfaction.

If we consider the 20 individuals with a practical preference, there is no evidence to support the idea that a right-handed individual will prefer an aid in his right ear. Even if the 7 whose choice was due to a more comfortably fitting ear mould are disregarded, 5 out of 13 subjects preferred the left ear for practical reasons. There was no apparent way to predict these preferences. All patients had adequate control of hand and arm movements to manage an ear level hearing aid in either ear. The data collected in this study on reasons for practical preference were basic; this aspect requires further investigation in the future.

The high mean level of use can be attributed to the individual attention paid to these patients; Ward (1981) reported that hearing aid use was increased by routine follow up of new hearing aid users. The mean hours of use in his experimental group was 6.7. The amount of use was assessed at interview. Subjective assessment at interview has been shown to be a valid method of estimating hearing aid use. Haggard et al. (1981) compared subjective assessment with objective assessment made by inserting an electronic timing device in the hearing aid. He reported good correlation between the two.

It is interesting that the level of use was the same in both preferred and non-preferred ears, whether the subject reported better hearing or simply a practical preference. It has been shown that hearing aid use is related to need or disability (Carstairs 1973, Ewertson 1974) rather than benefit - it seems reasonable to assume that better hearing ability indicates greater subjective benefit - and these findings tend to confirm this. A possible explanation of the significantly lower level of use in those with no preference is that they did not wear their aid sufficiently often to make a valid judgment, but were reluctant to admit this.

CONCLUSIONS

A patient's preference for side of hearing aid use cannot be reliably predicted. It is recommended that bilateral ear moulds should be routinely provided for bilateral mild to moderate hearing loss. If it is decided that only one ear mould should be provided, this should be fitted in the poorer hearing ear. The poorer hearing ear should be identified from the half-peak level elevation of a speech audiogram.

Hearing aid use does not appear to be related to the amount of reported benefit.

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CHAPTER 5

ASSESSMENT OF HEARING AID BENEFIT

INTRODUCTION

One of the major aims in audiology in the past three decades has been the development of reliable, accurate tests of hearing aid benefit. That so many tests are currently used is evidence of the failure to achieve this aim.

Different methods of assessing benefit have been reported, from free-field pure-tone audiometry (Shulberg, 1980) to brainstem electrical responses (Kileny, 1982). Most tests, however, employ speech signals. The earlier tests used monosyllables, such as the Northwestern University Auditory Test No. 6 (NU6) (e.g. Beattie and Edgerton, 1976). These tests are still in common use. More recently, the Synthetic Sentence Identification (SSI) has been recommended (Jerger and Hayes, 1976). Comparisons of the NU6 with the SSI (Orchik and Roddy, 1980), and of the SSI and CID W22 word lists (Gerber and Fisher, 1979) showed no difference in the efficacy of these tests at measuring benefit. Audiovisual tests have also been used (Haggard et al., 1981a) but have not yet been shown to have an advantage over auditory tests. All of these tests show a higher score with an appropriate hearing aid, but their sensitivity and accuracy are inadequate to differentiate between different aids, unless one aid is totally unsuitable (Walden et al., 1983).

Hearing aid benefit has also been assessed by questionnaire (Tannahill, 1979; Walden et al., 1984), but again the sensitivity is poor.

Though these tests appear to be of little value in the individual patient, they have been applied to groups of subjects to successfully demonstrate differences between aids (Thompson and Lassman, 1969).

The aims of this study were to assess the efficacy of an audiovisual test for measuring hearing aid benefit, and to investigate differences in benefit achieved by using a hearing aid in either ear. It was hoped that either the difference in benefit in each ear would be large enough to measure or differences would become apparent over a number of subjects.

In view of the results of this study, a pilot study was done to investigate other methods of assessing hearing aid benefit and to relate this to patients' preference.

METHOD

This chapter presents further data on the subjects in chapter 4. The methods described here are complementary to those in the preceding chapter.

Hearing questionnaire

The hearing questionnaire (appendix 3) was completed on three occasions by each subject to represent their subjective disability with no hearing aid and with a hearing aid in either ear. Only the first 14 questions were included. The questionnaire was given to each subject on their first visit to the Audiology Clinic. The questions were then modified so that they referred to disability when using a hearing aid. This revised questionnaire was posted to each subject at the end of the trial period of wearing each shell mould. The completed questionnaire was collected when the subject was reviewed.

FADAST

Objective assessment of benefit from hearing aid use was made with FADAST, the Four-alternative Auditory Disability And Speech-reading Test, which is an audio-visual test of speech perception (Summerfield and Foster, 1983). A single word is presented, which the subject has to identify from a set of four words distinguished by two different vowels and two different consonants (e.g. pin, tin, pen, ten). The four words appear as subtitles on a television screen. 100 test items are presented from 25 such sets of words. The visual acuity of subjects was regarded as adequate if they could read the subtitles.

The signal was presented at 58 dBA. A broadband background noise was also presented at 58 dBA. The signal and the noise were played through a loudspeaker on top of the television which was 2 metres in front of the subject. Details of equipment and calibration can be found in appendix 6.

In a preliminary study to assess the repeatability of FADAST, 9 hearing-impaired individuals were tested unaided twice in immediate succession.

The subjects of the preference study were tested without their hearing aid on their second visit, and with their hearing aid on their third and fourth visits. When tested with their aid, subjects were first told to adjust the aid to a comfortable listening level. They were allowed to re-adjust this during a practice list of 10 items. Subjects were instructed to guess if they did not recognise the correct answer. Responses were recorded by an observer.

FAAF

Subsequent to this study, 7 subjects returned for further tests. These subjects were selected because they had asymmetric pure-tone thresholds and had reported that they could hear better with their aid in one ear. This time, the FAAF test (Four Alternative Auditory Feature) was used (Foster and Haggard, 1979). This test is similar to FADAST without a visual stimulus. Test items are one of four words distinguished by consonant change only (e.g. rose, rove, rode, robe). The test list consists of 80 presentations from 20 sets of words. Five different orderings of the test list were available. The subject marks his answers on an answer sheet which lists the four alternatives for each presentation.

The signal was presented free-field at 55 dBA with speech-shaped background noise at 50 dBA. The signal source was located 2 metres in front of or to either side of the subject (figure 5.1). The noise source was 2 metres in front of the subject. Subjects were tested in three conditions: unaided and with their hearing aid in either ear. Three tests were done in each condition, with the signal from each of the three sites. The sequence of the nine tests was random, and all five test lists were used. Before testing with their aid, each subject was told to adjust his aid to a comfortable level while listening to recorded speech presented at similar sound pressure levels and with the same background noise.

Details of equipment and calibration are in appendix 7.

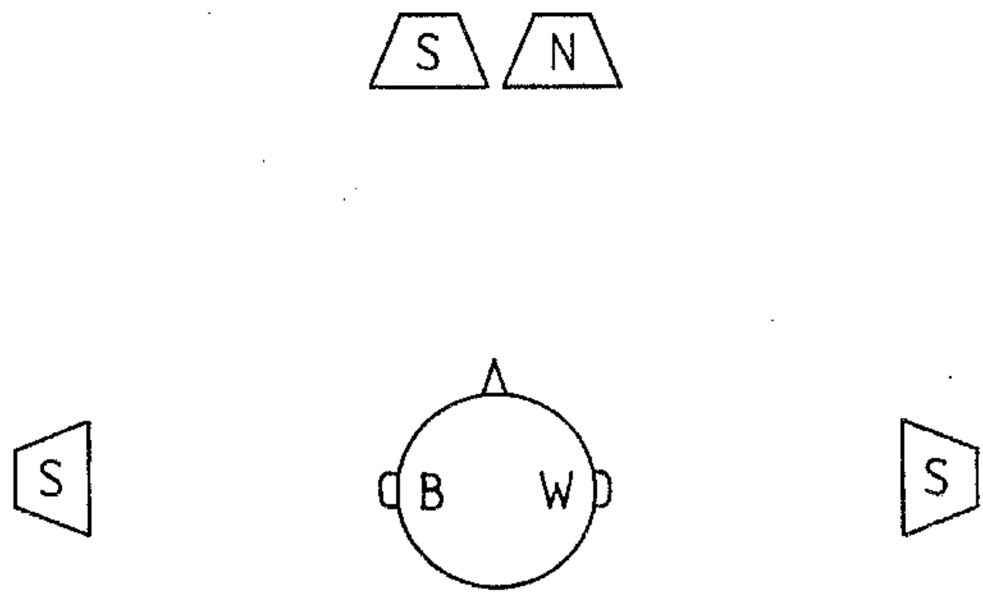

Figure 5.1. Arrangement of loudspeakers for FAAF tests.

B = Better ear

W = Worse ear

S = Signal (only one source per test)

N = Noise

RESULTS

Hearing questionnaire

A composite score was calculated by marking an answer as 0 if it indicated no disability, 1 if it indicated a mild disability, and 2 for more marked disability (and also 3 if the question offered 4 options). The unaided scores for questions 1 and 2 (hearing a watch ticking in either ear) were halved as only one of them was answered in the aided questionnaires. The questions about telephone use (numbers 8 and 9) were omitted because most patients used the telephone in the unaided ear or removed their hearing aid first. Thus 11 questions made up the composite score.

52 subjects completed the questionnaire three times. Table 5.1 shows the scores with patients grouped according to their reasons for preferring their aid in one ear.

Results were analysed with Student's t test. The differences between aided and unaided scores for those with a practical or hearing preference are statistically significant ($p < 0.02$). There is no significant difference ($p > 0.05$) between scores with the aid in the preferred or non-preferred ear. Those with no preference appear to have less unaided disability than those with a preference, but the difference is not significant; neither is the difference between aided and unaided scores in this group.

Preference	n	Aided ear	score	1 S.D.
Hearing	26	neither	10.8	4.1
		preferred	6.2	2.5
		non-preferred	7.0	3.8
Practical	19	neither	11.4	5.6
		preferred	6.8	4.0
		non-preferred	7.4	4.7
None	7	neither	7.0	5.1
		right	5.1	3.1
		left	5.9	3.0

Table 5.1. Mean scores from hearing questionnaire with standard deviations.

There was no significant correlation between the unaided hearing disability scores and pure-tone or speech audiometric indices (figure 5.2); neither was there any correlation between the change in disability score due to aid use and audiometric indices.

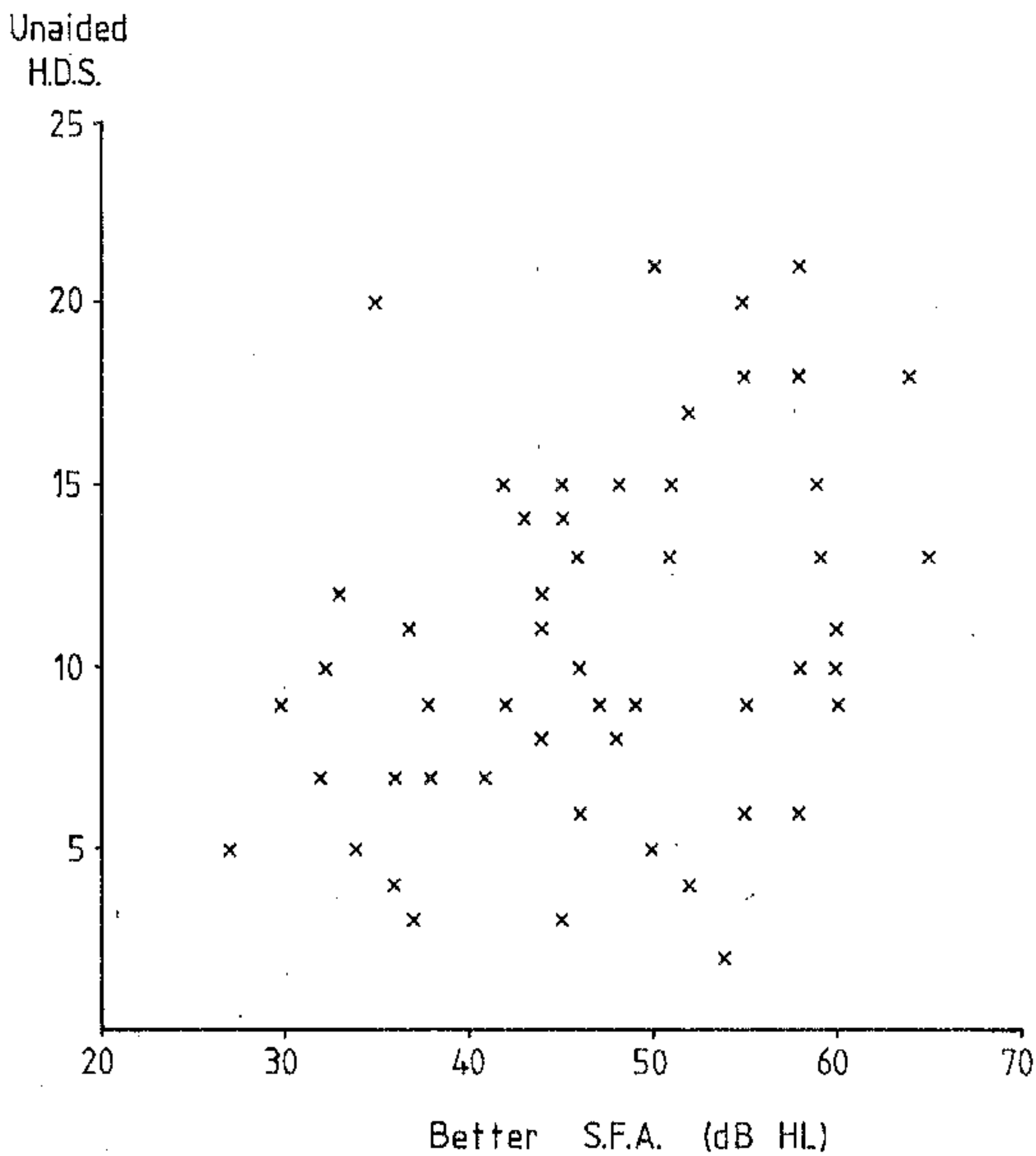

Figure 5.2. Unaided Hearing Disability Score (HDS) and better ear SFA.

FADAST

FADAST scores increased by an average of 3 % on immediate re-testing of 9 individuals (table 5.2). The standard deviation of the change was 2.9 %. There appears to be a small practice effect, but this should be compensated for by the two month interval between tests in this study.

First test	Re-test	Change
85	82	-3
70	70	0
74	74	0
95	96	1
63	65	2
69	73	4
52	57	5
62	68	6
66	77	11

Table 5.2. Repeatability of FADAST.

52 subjects completed FADAST in the three conditions. The mean SFA in the better hearing ear was 46 dB HL and in the worse hearing ear was 56 dB HL. 3 subjects were unable to do FADAST, 2 because of visual acuity inadequate to read the subtitles and one who was only semi-literate. The other 3 excluded were the first 3 subjects admitted to the study; they were tested with a pilot version of FADAST which was not comparable.

There was a strong inverse linear relationship between unaided FADAST scores and the SFA in the better hearing ear (figure 5.3). The correlation coefficient was -0.72. There were no significant non-linear components. Figure 5.3 also shows that FADAST has a good dynamic range, and that there were no ceiling or floor effects in this group of subjects.

The mean FADAST scores for the 52 subjects were 71.8 % with no hearing aid, 81.9 % with the aid in the better hearing ear and 80.1 % with the aid in the worse hearing ear (as defined by the SFA). The difference between the two aided scores was not significant ($p > 0.05$). Analysis by the method of extremes, however, showed that more subjects had higher scores with their aid in their better hearing ear ($p < 0.05$).

The aided FADAST scores for each subject were compared, with the better and worse ears defined by the HPLE. Figure 5.4 shows the change in FADAST scores with a hearing aid in either ear for subjects with asymmetry of more than 5 dB in their HPLEs.

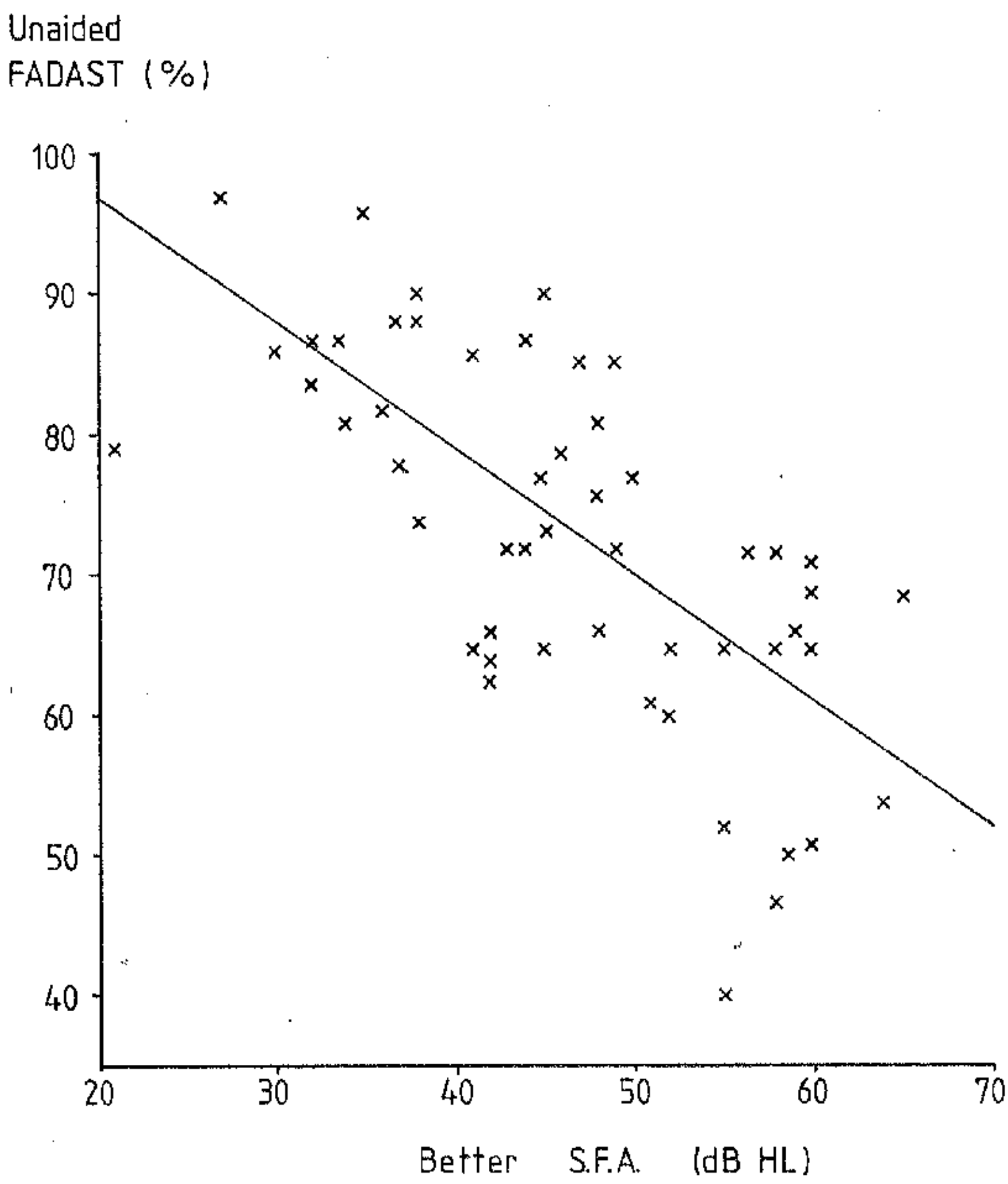

Figure 5.3. Unaided FADAST score and better ear SFA.

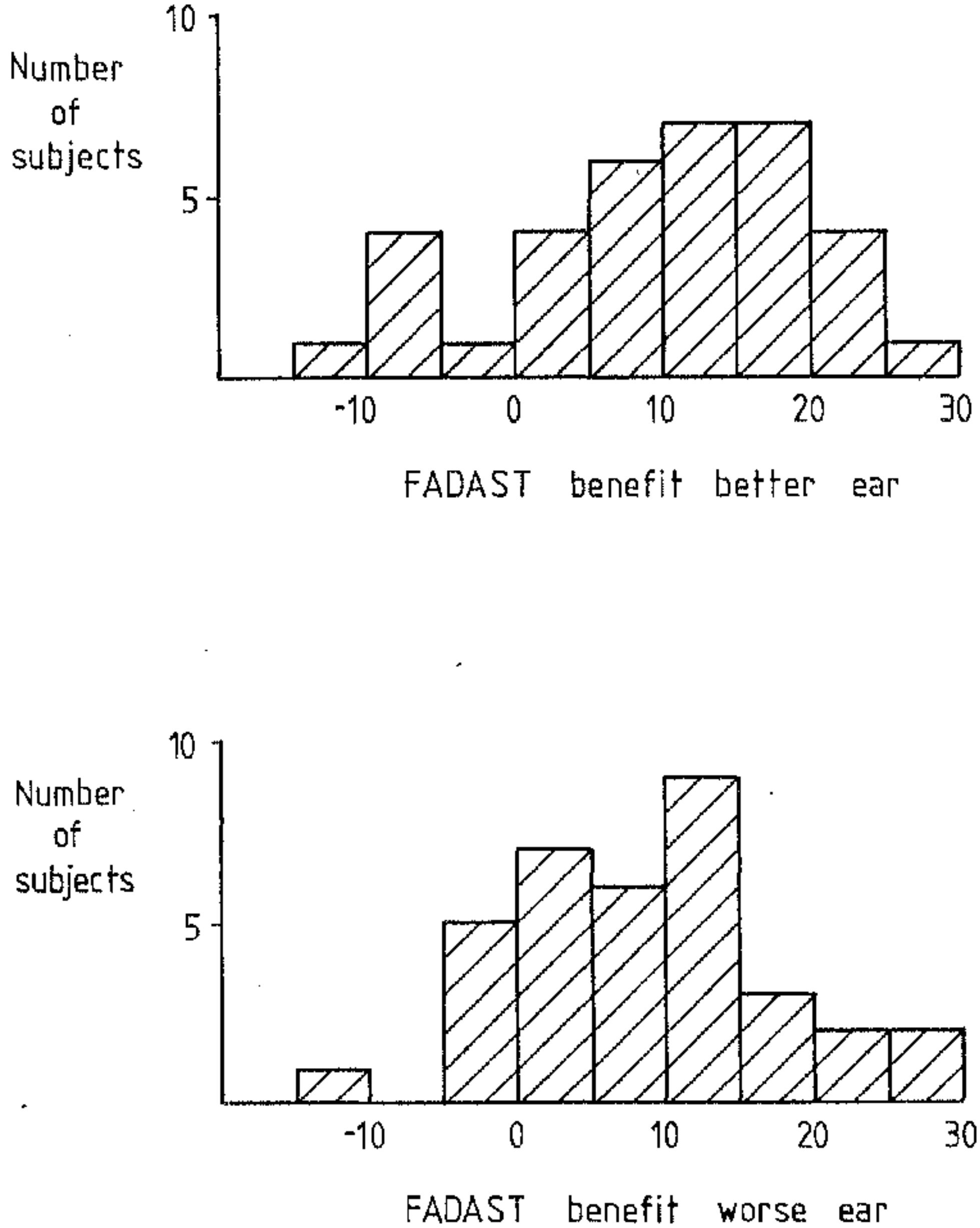

Figure 5.4. Aided minus unaided FADAST scores for subjects with asymmetry of > 5 dB in their HPLEs.

A difference of more than 5 % in FADAST scores was taken as significant (table 5.2). 16 subjects had a significantly higher score with their better ear aided while 9 had a significantly higher score with their worse ear aided (as defined by the HPLE). In the previous chapter, it was shown that all those subjects who reported a preference because of hearing and had asymmetry of more than 10 dB in their HPLEs preferred their aid in their worse hearing ear; 6 of those subjects had a significantly higher FADAST score with their better ear aided and 2 with their worse ear aided. Neither of these figures are statistically significant ($p > 0.05$).

No correlation was found between FADAST scores and subjects' preference for side of hearing aid use, irrespective of the reasons for their preference.

While these results are not conclusive, subjects appeared to get more benefit from a hearing aid in their better hearing ear. Test results certainly did not support the subjects' preference for the poorer hearing ear.

FAAF

The conflict between preference and measured benefit suggested that overall hearing ability was not the most important influence in preference. An alternative hypothesis was that patients' preference was governed by the desire to alleviate their greatest disability, which occurred when sounds came from the side of their poorer hearing ear. To test this hypothesis, hearing ability had to be assessed with the signal in different locations. It was not practical to use FADAST because its video component obviously could not be moved, and spatial separation of video and audio signals might have been confusing to some subjects.

The 7 subjects who did FAAF tests had mean SFAs of 42 and 67 dB HL in their better and worse hearing ears.

Table 5.3 shows the results of the FAAF tests with the signal in front of the subject; FADAST results are repeated for comparison. The differences between the FAAF results were not statistically significant because of the small number of patients, but their similarity to FADAST scores was reassuring. The results of FAAF tests with the signal to one side were not comparable with those where the signal was in front of the subject because the noise source was always in front of the subject. Spatial separation of signal and noise has been shown to alter the difficulty of speech tests (Lawrence and Franks, 1978).

Condition	FAAF	FADAST
Unaided	62.4	71.8
Aid in better ear	68.7	81.9
Aid in worse ear	67.0	80.1

Table 5.3. FAAF scores (%) with the signal in front of the subject and FADAST scores (%).

Table 5.4 presents the results of FAAF tests with the signal to either side of the subject. With no hearing aid, the subjects scored better when the signal came from the side of the better hearing ear due to the head shadow effect. The highest score was achieved with the aid in the better hearing ear and the signal on the same side. With the aid in the poorer hearing ear, scores were higher than unaided scores. However, the worst score of all was achieved with the aid in the better hearing ear and the signal to the other side.

	Location of FAAF signal	
Condition	Better ear	Worse ear
Unaided	70.7	67.3
Aid in better ear	74.8	66.0
Aid in worse ear	73.2	71.3

Table 5.4. FAAF scores (%) with the signal to either side of the subject.

Benefit and equivalent SFA

The better hearing ear is the major determinant of disability. Though the SFA measures impairment rather than disability, it can be used as an approximate guide to disability. The relationship between FADAST scores and the better SFA (figure 5.3) can be used to convert aided FADAST scores to the equivalent SFA. The aided FADAST score is plotted on the graph in figure 5.3 and the SFA corresponding to this is found. Instead of reporting that a subject had an aided FADAST score of 88 (a statement meaningless to those unfamiliar with FADAST), it can be stated that a subject had a residual disability when wearing a hearing aid equivalent to that expected in an individual with a SFA of 30 dB HL. This allows hearing aid benefit to be presented in terms familiar to all clinicians.

Table 5.5 shows the difference between unaided better ear SFA and the equivalent aided SFA with the aid in each ear for subjects whose better ear SFA was between 30 and 59 dB HL. These figures demonstrate that the reduction in hearing impairment achieved by the use of a hearing aid is often very small. In several subjects, the aided SFA was worse than the unaided SFA. The more severely impaired subjects had a significantly greater decrease in impairment than those with milder losses ($p < 0.05$).

	Unaided better ear SFA (db HL)		
	30 - 39	40 - 49	50 - 59
Number of subjects	12	19	13
<u>Aid in better ear</u>			
Worse by > 10 dB (eq)	0	0	0
Worse by 1-10 dB (eq)	2	2	1
Better by 0-10 dB (eq)	7	8	3
Better by 11-20 dB (eq)	3	7	7
Better by > 20 dB (eq)	0	2	2
Mean improvement dB(eq)	5.1	11.1	18.2
1 standard deviation	8.0	9.3	11.1
<u>Aid in worse ear</u>			
Worse by > 10 dB (eq)	0	1	0
Worse by 1-10 dB (eq)	1	4	1
Better by 0-10 dB (eq)	8	11	2
Better by 11-20 dB (eq)	3	2	6
Better by > 20 dB (eq)	0	1	4
Mean improvement dB(eq)	6.1	5.9	16.2
1 standard deviation	5.1	10.0	9.1

Table 5.5. Equivalent change in better ear SFA from wearing a hearing aid in either ear.

Table 5.6 uses the same data but shows the aided threshold rather than benefit. Very few individuals had an aided threshold better than 30 dB HL -- a level that is commonly taken to represent socially acceptable hearing.

	Unaided better ear SFA (db HL)					
	30 - 39		40 - 49		50 - 59	
Number of subjects	12		19		13	
Aided ear	B	W	B	W	B	W
Aided SFA (dB eq.)						
< 30	7	7	6	4	3	2
30 - 39	3	5	7	5	4	4
40 - 49	2	0	5	7	4	6
50 - 59	0	0	1	3	2	1

Table 5.6. Aided hearing threshold expressed as equivalent SFA for aid in better (B) and worse (W) hearing ears.

DISCUSSION

An audiovisual test was chosen for this study because it is similar to face-to-face conversation and because one of the common situations in which hearing aids are used is watching television.

It is likely that there are larger potential differences in benefit between aiding better and worse ears than there are between two different aids for the same ear. FADAST was not sufficiently accurate to detect these reliably in individual subjects, so it is unlikely that FADAST would detect significant differences between two aids. However, FADAST did demonstrate a large difference between aided and unaided listening conditions.

When the subjects were considered as a group, they appeared to get more benefit from their hearing aid when it was in their better hearing ear. Certainly, neither FADAST nor the hearing questionnaire agreed with the subjects' reported side of maximum benefit. This is not the first study to find a conflict between preference and benefit. Thompson and Lassman (1970) found that a group of subjects appeared to get more benefit from a high-frequency hearing aid than from a more conventional, broad-frequency aid with little amplification above 4 kHz, yet the subjects preferred to use the conventional aid.

Why do patients prefer their aid in their poorer hearing ear? The most obvious reason is that this arrangement allows them to receive binaural cues. Binaural advantage is not limited to situations where there is spatial separation of signal and noise and each ear receives a different signal - dichotic listening situations. It also occurs, and is probably just as large, in a diotic listening situation where each ear receives the same stimulus (Kaplan and Pickett, 1981; Davis and Haggard, 1982). FADAST was presented diotically. If binaural advantage were the reason, FADAST scores should have favoured the worse ear.

An alternative hypothesis is that patients wish to minimise their disability in the most disadvantageous listening situations - when the sound comes from the side of their poorer hearing ear - even at the expense of not achieving the maximum possible benefit in more favourable conditions. This would be an example of a minimax strategy: one accepts a small penalty (in this case, less than maximum benefit in easy listening conditions) to insure against a possible large penalty (inability to hear in difficult situations). House insurance can be taken as an analogy: a small outlay prevents a possible large loss. The FAAF results support this hypothesis, though they are not conclusive.

When a signal was presented to the better hearing ear, a hearing aid was of benefit irrespective of which ear it was in; however, when a signal was presented to the worse ear, the situation causing the greatest disability, a hearing aid in the better hearing ear was of no benefit while an aid in the worse ear was of considerable benefit.

Patients' interpretation of benefit may be very different from what is usually measured by tests of benefit. Haggard et al. (1981a) found that patients often reported much more benefit than was shown by tests. Perhaps we should revise our concepts of benefit before we can develop more relevant tests to measure it. It would be rash, however, to assume that overall benefit can be measured. In this study, both FADAST and the hearing questionnaire showed benefit from a hearing aid. Yet unaided FADAST scores and FADAST benefit scores were closely related to hearing impairment, while no such correlation was found with the hearing questionnaire results. This suggests that they measure different aspects of disability and benefit.

The FAAF study was adjourned because subjects found it laborious to do nine full word lists. It is planned to recommence the study using a computer-controlled adaptive procedure to determine the signal-to-noise ratio at which 50 % of tests are answered correctly.

This will greatly reduce the time required and may increase the sensitivity of the test. The location of the background noise source will be changed to avoid the problems of varying spatial separation of signal and noise.

The conversion of benefit scores to equivalent SFA shows that there is a large residual disability when using a hearing aid. Patients often say they are of great benefit - and they undoubtedly are, in comparison to not using an aid. But they do not restore normal hearing. Orchik and Roddy (1980) previously showed that aided test scores were far below normal scores. Conversion of scores to equivalent SFA shows just how large the residual deficit is. This method of converting benefit scores can be applied to any test which has a quantifiable relationship with pure-tone thresholds in the unaided condition. It should be used solely for convenience to provide a familiar scale to enable comprehension of results. It is not suggested as a disability scale. It was shown in chapter 2 that disability was poorly related to pure-tone thresholds.

These results also show that present NHS hearing aids are of more benefit to those with greater hearing impairment, as indeed they are designed to be. They are of very little help to the mildly impaired. It has been suggested that audiological services should be expanded to cope with the large number of hearing impaired individuals who have not previously sought management (Haggard et al.,1981b). These individuals tend to have mild hearing loss and have less disability than the present clinic population (see chapter 2); the present range of NHS hearing aids would be of little benefit to these individuals.

CONCLUSION

Hearing aid benefit can be demonstrated by audiovisual tests or by questionnaire, but the results of these do not agree with patients' preference. It is concluded that benefit is multi-dimensional and that further investigation is required.

A simple method of presenting results of tests of hearing aid benefit is demonstrated. This method shows that there is a large potential for improvement in present NHS hearing aids, and that these aids are unlikely to be of much benefit to individuals with mild hearing loss.

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CHAPTER 6

CONCLUSION

The conclusions of this thesis may conveniently be divided into those which are relevant to current clinical practice and those which may influence future research.

As far as clinical practice in the average otolaryngology clinic is concerned, the most important conclusion is that the preferred side of hearing aid use cannot be reliably predicted. Routine provision of bilateral ear moulds would be a small change in clinical practice which could lead to a significant increase in patient satisfaction.

The clinician should consider whether he thinks it is worthwhile making adjustments to the ear mould system when prescribing a hearing aid. If he does not consider it worthwhile, pure-tone audiometry does not appear to have any significant advantages over voice testing in decisions on hearing aid provision. Patients present because of disability which does not correlate well with pure-tone thresholds. Is pure-tone audiometry done for a reason other than tradition? Perhaps the time spent on hearing aid fitting could be significantly and profitably increased by the re-allocation of the time usually spent on audiometry.

High on the list of research aims should be the development of a valid test of disability - a way of quantifying patients' symptoms. This would automatically provide a valid measure of benefit - the difference between aided and unaided disability. Such a test will require careful thought about the location as well as the nature of the signal. The spatial variation of the FAAF experiment looks promising, but requires further evaluation. It is more likely, however, that a valid test of disability will require a more sophisticated signal, such as synthetic sentences.

For the present, the most reliable indicator of overall benefit is the patient's opinion.

APPENDICES

APPENDIX 1

DEFINITIONS

Conductive hearing loss

A mean air-bone gap at 0.5, 1 and 2 kHz of 15 dB or more.

Sensorineural hearing loss

A mean bone conduction threshold at 0.5, 1, 2 and 4 kHz worse than 25 dB HL.

Mixed hearing loss

A combined sensorineural and conductive hearing loss.

APPENDIX 2

AUDIOMETRIC METHODS

Pure-tone audiometry

Pure-tone thresholds were assessed in a commercial, sound-reduced room with ambient noise levels at which thresholds of 0 dB HL could be measured for a normal hearing person. Equipment was calibrated to ISO 389 and thresholds were measured using a standard method (British Society of Audiology, 1981) at the frequencies 500, 1000, 2000, 4000 and 8000 Hz for air conduction, and 500, 1000, 2000 and 4000 Hz for bone conduction. Masking was applied to the contralateral ear where required using a shadow method (Coles and Priede, 1970).

Speech audiometry

AB(s) short isophonemic word lists (Boothroyd, 1968) were played from a tape recording via an audiometer and headphones. Tests were conducted in a sound-reduced room. The method used was a shortened version (Gatehouse, 1984) of the ISVR method (Priede and Coles, 1976).

The test procedure was:

(1) Estimate the Half Peak Level (HPL) by adding the calibration factor (see below) to the average of the best two pure-tone thresholds at 500, 1000 and 2000 Hz.

(2) First word list at estimated HPL plus 5 dB. If phoneme score greater than 50 %, go to (3); if not, increase intensity by 10 dB and repeat (2).

(3) Next word list 15 dB below (2). If score less than 50 %, go to (4); otherwise decrease intensity by 10 dB and repeat.

(4) Estimate the intensity of 50 % score from (2) and (3) and test at 40 dB above this, or at maximum output of audiometer, or at loudness discomfort level, whichever is less.

(5) If a sigmoid curve cannot be easily fitted, more word lists are done at appropriate intensities.

The indices recorded were the Optimal Discrimination Score (ODS), which was the score from test (4), and the Half Peak Level Elevation (HPLE), which was the HPL minus the calibration factor. The HPL was the intensity level at which the subject scored half his ODS. The calibration factor was the HPL measured for normal young adults on the test equipment used.

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APPENDIX 3

HEARING QUESTIONNAIRE

(1) Can you hear a watch ticking when it is held close to your left ear?

1. Clearly
2. Not very well
3. Not at all

(2) Can you hear a watch ticking when it is held close to your right ear?

1. Not at all
2. Not very well
3. Clearly

(3) Can you usually hear the water boiling in a pan when you are in the same room?

1. Easily
2. With some difficulty
3. With great difficulty

(4) Can you usually hear the water running when you turn on a tap?

1. With great difficulty
2. With some difficulty
3. Easily

(5) Can you usually hear the bleeps of a nearby pelican crossing?

1. Easily
2. With some difficulty
3. With great difficulty

(6) When you are in the street, can you usually hear the siren of a passing ambulance, police car or fire engine?

1. Not at all
2. With great difficulty
3. With some difficulty
4. Easily

(7) Can you follow the television news when the volume is turned up only enough to suit other people?

1. Easily
2. With some difficulty
3. With great difficulty
4. Not at all

(8) Can you make out what people are saying on the telephone with the earpiece to your <u>left</u> ear?

1. Not at all
2. With great difficulty
3. With some difficulty
4. Easily
5. Do not use the telephone

(9) Can you make out what people are saying on the telephone with the earpiece to your <u>right</u> ear?

1. Easily
2. With some difficulty
3. With great difficulty
4. Not at all
5. Do not use the telephone

(10) Can you follow what is being said on the radio news when the volume is turned up only enough to suit other people?

1. Not at all
2. With great difficulty
3. With some difficulty
4. Easily

(11) Do you turn your head the wrong way when someone calls to you?

1. Never
2. Seldom
3. Sometimes
4. Often

(12) If you are in a group of people and someone you can't see starts to speak, are you able to tell where the person is sitting?

1. Usually
2. Sometimes
3. Not usually

(13) How difficult do you usually find it to follow somebody's conversation when other people are talking close by?

1. Great difficulty
2. Some difficulty
3. No difficulty

(14) When talking in the quiet to someone you know to be a clear speaker, how much difficulty do you have in understanding what they are saying?

1. No difficulty
2. Some difficulty
3. Great difficulty

(15) How often does any hearing problem you may have restrict enjoyment in your social and personal life?

1. Never
2. Seldom
3. Sometimes
4. Often

(16) Do you get a feeling of being cut off from things because of difficulty in hearing?

1. Often
2. Sometimes
3. Seldom
4. Never

(17) Do any hearing difficulties you may have lead to embarrassment?

1. Never
2. Seldom
3. Sometimes
4. Often

APPENDIX 4

HEARING QUESTIONNAIRE : ANSWERS

41 complainers (C) and 33 non-complainers (NC) with a BEA between 25 and 39 dB HL completed the Hearing Questionnaire. Their answers are presented below; figures are percentages of the total answers.

(1) Can you hear a watch ticking when it is held close to your left ear?

	C	NC
Clearly	17	30
Not very well	32	64
Not at all	51	6

(2) Can you hear a watch ticking when it is held close to your right ear?

	C	NC
Clearly	38	9
Not very well	45	55
Not at all	18	36

(3) Can you usually hear the water boiling in a pan when you are in the same room?

	C	NC
Easily	37	69
With some difficulty	46	28
With great difficulty	17	3

(4) Can you usually hear the water running when you turn on a tap?

	C	NC
Easily	76	97
With some difficulty	24	3

(5) Can you usually hear the bleeps of a nearby pelican crossing?

	C	NC
Easily	63	85
With some difficulty	29	9
With great difficulty	7	6

(6) When you are in the street, can you usually hear the siren of a passing ambulance, police car or fire engine?

	C	NC
Easily	93	100
With some difficulty	7	0

(7) Can you follow the television news when the volume is turned up only enough to suit other people?

	C	NC
Easily	20	44
With some difficulty	51	47
With great difficulty	29	9

(8) Can you make out what people are saying on the telephone with the earpiece to your left ear?

	C	NC
Easily/with difficulty	80	97
Not at all	20	3

(9) Can you make out what people are saying on the telephone with the earpiece to your right ear?

	C	NC
Easily/with difficulty	90	100
Not at all	10	0

(10) Can you follow what is being said on the radio news when the volume is turned up only enough to suit other people?

	C	NC
Easily	10	38
With difficulty	90	62

(11) Do you ever turn your head the wrong way when someone calls to you?

	C	NC
Never/seldom	51	77
Sometimes/often	49	23

(12) If you are in a group of people and someone you can't see starts to speak, are you able to tell where the person is sitting?

	C	NC
Usually/sometimes	66	91
Not usually	34	9

(13) How difficult do you usually find it to follow somebody's conversation when other people are talking close by?

	C	NC
No difficulty	2	21
Some difficulty	44	64
Great difficulty	54	15

(14) When talking in the quiet to someone you know to be a clear speaker, how much difficulty do you have in understanding what they are saying?

	C	NC
No difficulty	44	73
Some difficulty	56	27

(15) How often does any hearing problem you may have restrict enjoyment in your social and personal life?

	C	NC
Never/seldom	8	70
Sometimes/often	92	30

(16) Do you get a feeling of being cut off from things because of difficulty in hearing?

	C	NC
Never/seldom	24	64
Sometimes	39	33
Often	37	3

(17) Do any hearing difficulties you may have lead to embarrassment?

	C	NC
Never/seldom	23	58
Sometimes	56	39
Often	21	3

APPENDIX 5

LIFESTYLE QUESTIONNAIRE

(1) Do you live on your own? Yes

No

(2) During a normal week, how many hours do you spend on the following activities?

(a) Watching TV

(b) Listening to radio or record player

(c) In a pub or club

(3) During a normal month, how many times do you do the following?

(a) Attend meetings, talks or church

(b) Go to bingo, cinema or other entertainment

(4) During a normal week, how many times do you use the telephone?

(a) At work

(b) At home

(5) Do you know anyone who has a hearing aid? Yes

No

APPENDIX 6

FADAST EQUIPMENT AND CALIBRATION

FADAST was recorded on a Sony U-matic video cassette with the test words on one audio channel and a broadband noise on the other. 1 kHz calibration tones were recorded on each channel.

The tape was played on a Sony U-matic video recorder. The video signal appeared on a 19 inch video monitor. The audio signals were led via an audio-mixer to a high fidelity amplifier and a single loudspeaker placed on top of the monitor.

Equipment was calibrated acoustically each week using the calibration tones and a sound-level meter. At this time, the voltage across the terminals of the loudspeaker was measured for each calibration tone. The voltage reading was used for electrical calibration of the equipment each day.

APPENDIX 7

FAAF EQUIPMENT AND CALIBRATION

FAAF lists were recorded on one channel of open-reel tape with a speech-shaped background noise on another channel. 1 kHz calibration tones were recorded on each channel.

The tape was played on a reel-to-reel tape recorder. The signals were led separately via an audio-mixer and an amplifier to individual loudspeakers.

Equipment was calibrated acoustically each week and electrically each day (see FADAST, appendix 6).

APPENDIX 8

HEARING AID FREQUENCY OUTPUTS

The frequency response to a 60 dB input for the currently available BE 10 series hearing aids with the tone control set at "Normal" is shown in figure 6.1.

Acoustic filters

In the study of side of hearing aid provision (chapters 4 and 5), acoustic filters were inserted in the connecting tubing between aid and ear mould. A 680 ohms filter was sited approximately 2 cm from the ear mould and a 1500 ohms filter 3 cm from the mould. The alteration in the frequency response of a BE 14 fitted with this ear mould system is shown in figure 6.2. The main effect is to smooth the response with some reduction in low frequency gain.

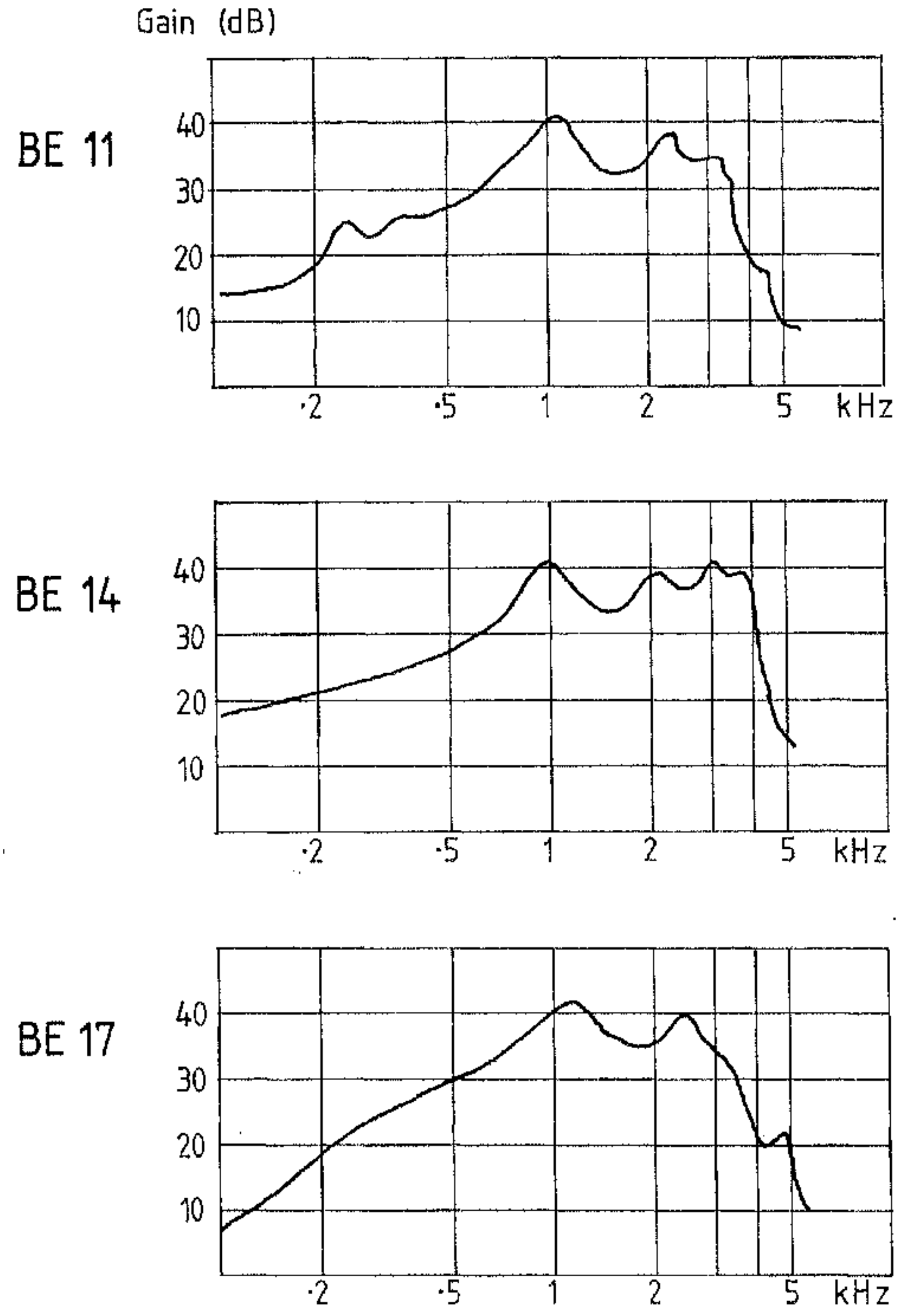

Figure 6.1. Frequency response of NHS hearing aids.

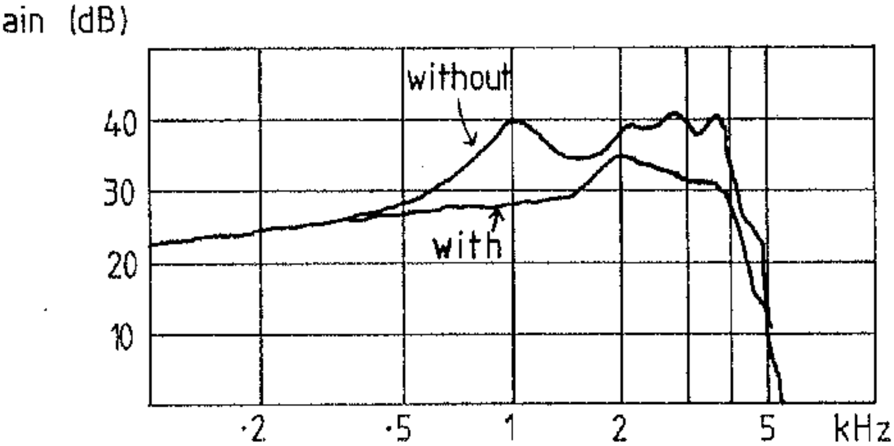

Figure 6.2. Frequency response of a BE 14 with and without acoustic filters.