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Methods for hearing aid selection and fitting

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METHODS FOR HEARING AID SELECTION AND FITTING

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CHAPTER I

Introduction

1.1 Acquisition of a hearing aid in Mexico

In Mexico there are three ways by which people obtain hearing aids. These are:

1.1.1 Through and ear, nose and throat doctor (ENT)
1.1.2 Through an audiologist
1.1.3 Through a hearing aid dealer.

1.1.1. Through an ENT

Many otolaryngologists have in their offices an audiometer with which they can assess the hearing status of their patients by air and bone conduction. If the doctor decides that there is nothing medically wrong with the patient and that what is needed is some prosthetic device to help him/her understand speech, there are two possible ways to treat the situation:

1) to send the patient to an audiologist, and

2) to refer the patient to a hearing aid dealer.

After taking either option, very few doctors will continue seeing the patient unless some medical aspect of hearing loss appears.

1.1.2 Through an audiologist

Most referals to an audiologist for a hearing aid evaluation come from ENT doctors or from word-of-mouth recommendations among clientele.

The battery of tests administered by the audiologist - to select a hearing aid - depend upon factors such as patient age, nature of hearing loss, whether or not the patient has language, equipment available, etcetera. The most commonly employed battery consists of:

1) air and bone conduction;
2) speech testing using nonsense monosyllables for speech reception threshold (SRT) and two-syllable words for discrimination;
3) typanometry, acoustic reflex, brain stem electric responses(BSER), as well as measuring threshold of discomfort for speech (rarely used).

After any one test battery has been administered, the audiologist is able to make the decision as to whether or not the patient is a hearing aid candidate. A patient who is a candidate for an aid may reflect the type of test setting, where the test is being conducted, and varies according to whether the service is public or private. Different places employ different criteria, e.g., some select an aid for hearing losses that have a pure tone average of 35 dB HL in the better ear, while others will not select an aid unless the pure tone average is worse than 60 dB HL in the better ear.

Once it has been determined that the patient needs an aid, the selection procedure begins. First, the audiologist, based on knowledge of hearing aid stock available, will select a couple of aids which may be best suited to the patient's needs. During this preselection the audiologist will decide if an ear-level or box type aid is preferable, and whether or not to try one or two aids, perhaps one with a "Y" cord. The use of a "Y" cord in Mexico is very common whenever both ears have a similar level of loss and configuration type. If the patient is a child, the selection of a second hearing aid is recommended only after the child has learned to tolerate the first aid and if such a purchase is economically feasible.

The evaluation procedure used most frequently by audiologists in Mexico, first proposed by Hallowell Davis in 1948, is the "Social Adequacy Index for Hearing". It consists of presenting to the unaided ear in the field 10 two-syllable words at three different hearing levels (45,65,80 dB HL respectively) and obtaining the per cent correct discrimimation at each intensity. If the patient scores 100 per cent on the three tirals, then he does not need an aid. If 100 per cent is not scored, then the patient is a hearing aid candidate. The social adequacy index for hearing" is then determined for each hearing aid selected, or from among hearing aid variables. The ideal is to have the patient score 100 per cent correct discrimination, or as close to that figure as is possible.

Once a hearing aid is selected, the patient is then referred to a hearing aid dealer who sells that particular brand (as not all dealers carry all brands available in Mexico) with written specifications as to what aid should be purchased, recommended volume settings, as well as whether peak clipping or automatic gain control are needed. The dealer then takes earmold impression(s) and makes the mold or molds according to specifications (if any).

Upon obtaining a hearing aid and earmold the patient returns to the audiologist for final instructions. Normally such instructions are verbal - concerning the use of the aid, battery replacement, and the like - and often include a written schedule which recommends graded use of the hearing aid. That is, during the first week of use the aid is to be worn only for half an hour morning and evening in a quiet environment; the time increment and environmental settings are increased weekly. With elderly patients it may take up to a month before use is the street is advised, with the very young and infants the same goals may not be achieved for two to three months. It is hoped that through such procedures better adaptation to the aid will be realized.

1.1.3 Through a hearing aid dealer

Often individuals with hearing loss will go directly to a hearing aid dealer for help after stopping in a dealership or looking one up in the yellow pages. In most reputable hearing aid agencies, trained technicians will test the prospective client's hearing by air and bone conduction, speech test and discomfort. The procedures used are rather unorthodox, but they have learned from experience some that do the job, and are therefore acceptable for their clients. As an example, one way to set the $SSPL_{90}$ of the aid would be by sending the patient outside to a noisy street. If the aid "bothers" the client they will lower the saturation level until they get a comfortable fit.

In some of the dealerships they do use the "Social Adequacy Index for Hearing" to assess the improvement given by different hearing aids.

1.2 Some results.

In 1981 Martha Rosette[1], Chief Audiologist in the Hospital Infantil de Mexico, did a retrospective study of over seven years work which involved 3671 cases of hearing loss in children. From all possible cases, 650 children were selected as hearing aid candidates. Based on selection criteria of pure tone average worse than 60 dB HL in the better ear obtained by pure tone audiometry or with BSER with thresholds (wave V becomes apparent) that become evident with levels higher than 60 dB HL.

In patients with language, the "Social Adequacy Index of Hearing" was used to determine the need for an aid. The number of cases and their age range are as follows:

Age in years	Number of children
0-1	55
2-4	212
5-8	213
9-15	146
>15	23

Out of the 650 patients, 46% (N=305) for whom a hearing aid was selected, actually bought the aid and came back to get the instructions for its use. Only 17% (N-113) of the children are actually receiving special education and have periodic audiological controls.

Some of the problems of this particular population have much to do with ignorance, poverty and superstition. These problems are further compounded by the relatively exorbitant $400-$700 cost of hearing aids, not including maintenance, and the constant lack of schools and teachers concerned with the education of the deaf.

In light of the aforementioned problems, it becomes apparent that we are unable to judge how many patients are lost due to the fitting procedure, or how many simply fail to return again for many other possible reasons in this particular setting.

Studies of this nature are sorely needed and are the only feedback the audiologist has to be able to evaluate realistically techniques used. The author hopes professionals in Mexico can be encouraged to produce similar statistical studies based on data "hidden" in their case files.

1.3 Discussion and Conclusions.

Through observations of various audiological settings and procedures used in Mexico City, it became apparent that many audiologists are following some of the trends in hearing aid selection. The following are a few points about which we in Mexico should be more conceintious:

a) Calibration of equipment. According to the American Speech and Hearing Association (ASHA)[2] the audiometer should be electroacoustically measured every 3 months and real ear checking of the equipment should be done almost daily - at least once a week.

b) Speech testing. When obtaining the articulation curve for a given patient, the per cent of correct discrimination at each level is obtained when the patient gives 3-out-of-6 or 4-out-of-8 correct answers, and then the tester proceeds to the next level.

The problem inherent in testing in the above manner is explained by Olsen and Matkin:

> "A major criticism of the use of lists shorter than 50 words has been the absence of phonetic or phonemic balance in such lists."[3]

Also worth mention is the lack of information available on the difficulty or ease of different test materials. Audiologists should be more aware/careful of why any particular list of words is used, whether we are presenting the material live voice or in a tape, voice qualities of the speaker in either situation, and the quality of electronic reproducing equipment used. If more attention is paid to these small details, not only will we make our test procedures more reliable, but the test results will therefore be more comparable to those obtained elsewhere.

c) Social Adequacy Index of Hearing. H. Davis comments:

> "The social adequacy index of hearing was conceived as the probability of hearing correctly a word of everyday speech, averaged across all words and all conditions...in practice the idea did not work out very well. One reason is that phonetic balanced (PB) recordings never have been standardized well enough to measure a man's discrimination with anything like the accuracy with which we measure his threshold level."[4]

As Davis states further, these ideas are "of theoretical interest" but more standardization in addition to more research is greatly needed.

Most of the techniques used in the past to prescribe an aid have been revised and the procedures updated. New ideas have been emerging in an attempt to keep pace with technical improvements of the hearing aid industry, as well as motivation within the industry to provide the best hearing aid available for the patients' needs and income.

In the following chapters I shall review some of the pre-selection procedures as well as some of the most common methods of selecting an aid used in the United States of America. The way these techniques are classified was designed by D.P. Pascoe[5] and is employed herein because of clarity in highlighting differences throughout.

CHAPTER II

Preselection Procedures

2.1 Candidacy for a hearing aid.

2.1.1 Motivation

As clinicians we always must be aware of why the patient is visiting us. All audiologists have dealt with patients who come into the office claiming they hear very well, but their spouses complain that they don't. Other patients claim that their hearing is fine, but rather that the problem lies in the people who do not speak clearly, especially the younger generation who "just mumble". Some patients can be shown what they are missing and therefore will change their attitude towards the aid - many may become successful users. A very different situation occurs with patients who seek help because they are conscious of what a hearing loss is making them miss.

The attitude of the hearing aid candidate, as well as dependency on hearing in professional and private life are important factors that will contribute to the success in adaptation to a hearing aid.

2.1.2. Degree of loss

As mentioned in the first chapter, different audiological settings have different criteria as to what level of loss will require or benefit from a hearing aid. W.R. Hodgson[6] offers the following guidelines to the relationship between hearing loss and need for amplification based on pure tone average (PTA) or SRT in the better ear:

Hearing loss in dB(re:ANSI 1969)	Need for Amplification
0-25	None
25-40	Part time
40-55	Frequent
55-80	Area of greatest satisfaction
80+	Great need - partial help

This classification applies when the loss is gradual and bilateral; sharply falling losses or unilateral losses create other problems and therefore have to be handled differently.

Actually, hearing level cannot determine candidacy for an aid. The problems many patients experience in communication should be the guide as to whether or not an aid is to be worn.

2.1.3. Communication

Accurate understanding of speech may be more important for some people than for others. The person who leads an active professional and/or social life will depend on hearing to a greater degree than the retired man who just wants to be able to hear the television more clearly. Ultimately, it is the patient who has to decide whether or not to wear an aid. If the patient feels he needs an aid it is incumbent upon the audiologist to prescribe the aid best suited to the patient's needs.

Along with the improvements in size and fidelity of hearing aids, there is a concomitant trend to manufacture less powerful aids. Presently the mildest hearing aid marketed has gains of 20-25 dB and $SSPL_{90}$ of 95-105. Pascoe (op. cit.) classifies aids according to their $SSPL_{90}$ in the following manner:

95-105 dB	very mild
106-115	mild
116-125	moderate
126-135	powerful
133+	too powerful, suited for only mixed losses

He also states:

> "The tendency in the past ten years is bringing us to prescribe hearing aids for milder hearing losses. The hearing aid industry is helping us by creating less powerful aids better suited for this new population."[7]

2.2 Monaural vs. Binaural

> "Whenever possible binaural hearing should be re-attained or restored...the better hearing a patient has, the more need he will have of good quality sound this means not only spectral but spatial quality. Spatial quality is unconcious, it gives the feeling of being surrounded by sound, a feeling of being alive, a feeling of movement."[8]

The problem with binaural amplification is usually patient attitudes, i.e., one who does not understand why two aids are needed if there is only a small loss. Secondly, a very real problem if often found in the economic realm. Here the limiting factor is the patient's ability to afford an aid and the cost of maintenance

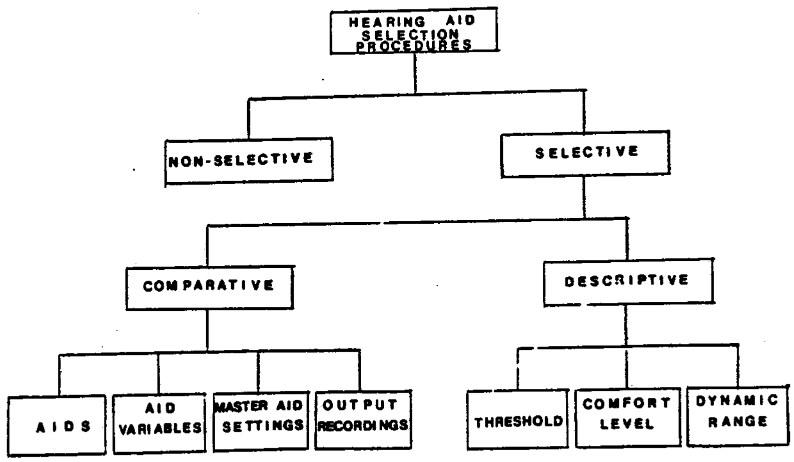
2.3 Ear Selection

Two aided ears are not always better than one, i.e., if one ear has a very poor discrimination it may be distorting the sound quality rather than enhancing it. Binaural hearing enhances localization and sounds natural, but it is not always possible. When only one ear is to be aided, there are two main factors which should be taken into account when selecting an aid - dynamic range and slope of the loss. If the two ears differ in their UCL, the ear with the wider dynamic range should be aided. Patients with sharply falling audiograms are more difficult to fit than those with audiograms which are graudally sloping.

The selection of frequency response and gain are going to be discussed in detail in the next chapter.

CHAPTER 3

Selection methods for hearing aids have been classified in different ways. Pascoe[9] offers the following diagram to compare data - "looking at it from as many angles as possible in order to appreciate the clinical implications of each procedure":



(from Pascoe 1980:218, Figure 1)

Most methods and their variables fit into this classification. In this chapter I review some methods that belong in each category listed above.

3.1 Non-selective procedures.

In 1946 Davis et al.[10] published some studies that are known as the Harvard Report. This report provides a series of tentative specifications of needed characteristics of hearing aids. Davis lists seven specifications for the "ideal" hearing aid:

1. Frequency characteristics:Range - The response should be as flat as possible. Low cut off frequency is between 200-300 Hz and high cut off should be preferable at 4000 Hz, no lower than 3000 Hz.

2. Frequency characteristics:Slope - The slope should be

flat or should rise towards the high frequencies with a slope of not more than 1 dB per octave. An adjustable tone control should provide an alternative slope rising at between 6 and 7 dB per octave.

3. Limitation of maximum acoustic output - The output of the aid should be limited so that it does not reach the discomfort threshold. The way to limit the output is by peak clipping or by using compression.

4. Saturation level control - the instantaneous acoustic output should be controlled and the following levels are permissible:

	Maximum instantaneous output
Beginner	114 dB SPL
Low Power	120 dB SPL
Standard	126 dB SPL
High Power	132 dB SPL

5. Sensitivity and freedom from internal noise - The aid should be sensitive and free from noise to make a 'normal' ear hear speech at a level no more than 10 dB above the unaided threshold.

6. Acoustic gain - A minimum of two, if not three, aid models should be produced; for severe hearing losses, a maximum gain for speech of 80 dB should be provided, for mild cases 30-40 dB of gain is enough. The cases that fall between the extremes could be helped by adjusting the volume control.

7. Gain control - The aid must have a gain control that has numerous intermediate positions and a range of 40 dB.

In their general comments Davis *et al.* state that the problem of individual fitting will almost disappear and the only selection that has to be made is that for acoustic gain and limitation of maximum output level.

Discussion:

The ideas of the Harvard report began a new era in the hearing aid fitting and manufacturing practice. Nowadays we still want many of the characteristics of hearing aids related to smoothness and bandwidth. However, since Pascoe (1975) the idea of functional high frequency gain, instead of the ritual coupler gain, has awakened many professionals to seek what the patient is actually hearing of speech in the high frequencies. To assess better this frequency range, the Pascoe High Frequency Word List (HF) will reveal differences in the patient's ability to use his aid not only in the quiet situations but also in situations where there is noise. The problem with PB word lists is that they do not adequately disclose high frequency loss.

3.2 Selective Procedures

The term selective amplification means amplification which varies in amount at different speech frequencies.[12] We can select an aid whose response is best suited to a specific patient by comparing (i.e. among aids or among aid variables), or by describing the response desired, basing our selection criteria on the patient's threshold, comfort level or dynamic range.

3.2.1. Comparative Methods

3.2.1.1 Comparisons among aids

Carhart[13] described a procedure to evaluate hearing aids that is now called the Carhart Method. This procedure for testing has seven steps:

1. Initial audiologic evaluation - otoscopy, puretone air and bone conduction, SRT, and discrimination scores (PB lists).

2. Corroborating the results - unaided SRT, unaided discrimination and unaided tolerance limit.

3. Set the aid at 'comfort level' - with a 40 dB HL input; the aid should be comfortable.

4. Set the aid at full volume and obtain again aided thresholds and tolerance limit.

5. Adjust the instrument to the 50 dB HL comfort level and obtain signal to noise ratios. Regarding this step Carhart states:

> "Since ordinary listening situations include varying degrees of background noise, it is pertinent to estimate the effectiveness with which each hearing aid performs for the patient in the presence of noise." (1946:784)

In his laboratory Carhart used two kinds of noise - one a combination of thermal hiss and static pulses, and the other a sawtooth noise. The levels at which the noise is presented and the patient's responses will vary in every case. Some patients will show more difficulty with all hearing aids and therefore will require more extensive counseling as well as the help of auditory training to learn what to expect from the aid.

6. Set the aid again to the 40 dB HL comfort level. Obtain aided thresholds and compare them with the ones previously obtained in Step 2. A PB-50 discrimination test is administered

at 25 dB re aided threshold.

7. Steps 2 through 6 are repeated with the second and third aids to be tried.

This procedure yields seven scores on each hearing aid and covers four dimensions: sensitivity, tolerance, efficiency in noise, and sound discrimination. In selecting an aid Carhart considered as many criteria as possible. Sometimes an aid was strongly indicated by a single criteria as being the best choice. At times, with patients with whom performance was equivalent - the selection was made through other factors such as aesthetic preferences, weight, and so on.

Hodgson (1977) states about Carhart's procedure that "it was thorough and intensive. It got the patient involved in decision making regarding the selection procedure."(p.135).

Discussion

The Carhart procedure is very carefully planned, but is very time consuming. For this reason it has been shortened to audiologic evaluation, counseling the patient about his expectations from a hearing aid, measurements of speech gain, measurements of intelligibility through various hearing aids in quiet and recommendation of a specific aid.

In the speech discrimination scores, differences of more than 8 per cent were taken by Carhart as "indicating sufficient distinction in instrument's performance". (1946:788) Hodgson (1977:137) states that "it is probable that small differences in discrimination scores obtained with different hearing aids may be more apparent than real." The study of Shore, Bilger and

Hirsh[14] concludes that the reliability of discrimination scores is not good enough to warrent their use in selecting the best hearing aid for a typical patient for whom big differences in scores will not be found. More time should be devoted to the difficult-to-fit patient.

3.2.1.2 Comparing aid variables

A very different approach to hearing aid selection is proposed by Resnick and Becker[15] . Their rationale is that the audiologist can tell the patient about his hearing loss, about aids in general and what to expect from an aid, but not which aid to purchase. In this context the audiologist is viewed as "the authority on hearing problems not hearing aids".(1963:696) Their system works on the premis that the audiologist and the hearing aid dealer can work together to the benefit of the aid user. Their method consists of five steps:

1. Complete audiological assessment;
2. Counseling the patients on problems and avenues of aural rehabilitation;
3. Referring the patient to a specific hearing aid dealer. The dealer is contacted by telephone and the audiogram, SRT and discrimination scores are read to him;
4. The dealer fitting the patient with the instrument;
5. The patient returning to the audiologist for aided evaluation.

The system has been working for many years. Hearing aid dealers are experts at fitting their products. They can spend much time making adjustments in the internal settings of their aids for optimum results. The audiologists are pleased to be able to spend their time in other testing and counseling situations.

Discussion

Depending on the type of audiological setting, many patients would be benefitted if this procedure was carried out correctly; particularly in those places that have to see many patients and each has limited time with the audiologist. In such instances the patient would be better fitted by the hearing aid dealer who can spend more time with him.

3.2.1.3 Master hearing aid settings

A master hearing aid is an instrument which simulates most of the characteristics of hearing aids. Usually the maximum gain, maximum power output and frequency response characteristics can be varied. The patient is fitted with the master hearing aid and the characteristics chosen to be examined are selected from a set of controls. The quality of sound provided to the patient is great since size is not a concern with a master aid. Bandwidth, filters, satuation levels and distortion levels produced by these instruments is excellent and not comparable with what the patient is actually going to obtain from a personal aid.

In trying to avoid this problem, Levitt[16] (1978) made a pocket-size Wearable Master Hearing Aid (WMHA). The dimensions of which are 5.5 x 3.25 x 1 inches. It has two channels for binaural amplification with a variety of plug-in units to modify the frequency response, compression and/or peak clipping, gain, maximum power output and other relevant variables. His procedure consists of:

Stage 1: Baseline audiometric data. Puretone thresholds, SRT, speech discrimination, level of comfort, level of discomfort and otoadmittance measures; tympanometry, static admittance and reflex thresholds.

Stage 2: Fixed experimental design. The purpose of this stage is to obtain a good initial estimate of the optimum setting of the WMHA.

Stage 3: This stage is designed to provide an efficient yet practical way of adjusting the aid.

Stage 4: Final comparisons. Scores of patients were tested as to discrimination with the best WMHA setting vs. the patient's own hearing aid, with a nonsense syllable test in quiet, and with signal to noise ratios (S/N) of +10 and +20 dB.

With a few exceptions the scores for the WMHA at its estimated optimum setting were higher than those for the subect's own aid. Comparing the performance of the WMHA and the patient's own using different speech material show also an increased performance with the WMHA.

Discussion

One big advantage of the master hearing aid settings selection is that it is a good, feasible way of trying several different variables simultaneously. This procedure has not been widely accepted because of the difficulty in handling many controls, especially since systematic procedures have not yet been standardized.

A disadvantage of the procedure is that all the circuitry available in a master aid is not available in models for purchase by patients. In those models currently marketed, only a given number of circuit boards will produce a limited number of frequency responses. Manufacturers try to "customize" such circuitry but this is not always possible. especially for very steeply falling high frequency losses.

A workable compromise is the wearable master hearing aid.

Perhaps in the future the techniques to handle a master hearing aid will be standardized and obtained responses will be sent to manufacturers, who in turn can custom-make an aid for specific patients. Then we will not have to compromise so greatly between ideal and real hearing aids.

3.2.1.4 Output recordings

This method of hearing aid selection includes the recording of hearing aid outputs onto magnetic tape. The listener then compares the responses of two aid simultaneously.

Zerlin[17] used running speech in the presence of realistic noise for comparison material. The speaker was a native English speaker reading a 30-second passage from Readers' Digest, and the noises were recorded sounds of a busy cafeteria during the lunch hour. When the two signals were presented at a S/N of +5 dB the effect was likened to trying to understand a speaker over the constant babble and clatter in a cafeteria. For his research Zerlin used six aids of moderate gain (50dB). To calibrate the gain he put into the aid a filtered noise band (300-4000 Hz) input at a level of 65 dB SPL, then the gain of the aid was set so that the output level read 50 dB higher than the input. When the noise was discounted, he presented to the aid the running speech at a level of 65 dB SPL adding the cafeteria noise at a level of 60 dB SPL. In addition to the running speech, short lists of the CID W-22 monosyllable words were recorded through the aids in quiet.

Patients listened through TDH-39 earphones and had the two-position selector switch so they could listen alternatively to either of the pair of recordings. It was suggested to the patients to choose on the basis of intelligibility of speech in noise. When the two intelligibilities were judged to be the same, the choice should be based on the relative comfort with which he could listen to both aids. After a 30-second listening period, the tape was stopped and the listener asked for his/her preference. Following the paried comparisons, the listener heard a 25-word list of monosyllables and an intelligibility score was obtained for each aid.

The results show "that five out of six aids yielded about the same average intelligibility score (between 66 and 71 per cent); clearly then, with one exception, electroacoustic differences among these aids do not manifest themselves when measured by intelligibility test scores...on the other hand the preference judgement is indeed the superior method for discriminating among hearing aids". (1962:372-372).

Discussion

Zerlin's findings about the use of discrimination scores to judge hearing aids coincides with the findings of Shore et al. (1960). An advantage to this method of comparison is that it allows rapid comparison among aids while other techniques make the comparison difficult because the patient very soon adapts to the distorted signal and thus the signal "seems" to improve through time. When the patient is subsequently using another aid, he tends to forget the sound qualities of the first.

A big disadvantage is that the recorded signals will be imprinted in a linear device and changes in the playback level will not affect the distortion of the system. A hearing aid tends to be nonlinear at its higher output levels and as gain is increased more distortion products are introduced into the output. Therefore, at high levels taped aid response is not an entirely accurate representation of what the aid is really going to do.

3.2.2 Descriptive methods

Sandlin[18] proposes the term nonverbal procedures for those that do not use speech testing for their evaluations.

> "The descriptive or nonverbal procedures assume that there is a relatively precise acoustical transformation that must be applied to the desired sound input levels, so that the resulting outputs can be optimally received by the intended listener."
>
> (Pascoe 1980:219)

The desired sound input is shaped according to three main methods of description: 1) threshold of audibility; 2) comfort level; and 3) dynamic range.

3.2.2.1 Threshold

Berger *et al.*[19] have a very rapid procedure for hearing aid prescription. After the audiological evaluation has been completed, the audiologist decides whether or not the patient needs an aid and if so, in which ear(s). Then he determines what the aided response should be for optimum understanding of speech, and finally, the amplifier and earmold characteristics that give the desired response.

To determine what the aided response should be Berger et al. offer the following formula:

$$\frac{\text{HTL at 500 Hz} + 10}{2} \qquad \frac{\text{HTL at 1000 Hz} + 10}{2}$$

$$\frac{\text{HTL at 2000 Hz} + 10}{1.5} \qquad \frac{\text{HTL at 3000 Hz} + 10}{1.7}$$

$$\frac{\text{HTL at 4000 Hz} + 10}{2}$$ (1979:19)

The above are applicable to any aid. The 10 dB represents a reserve gain. Maximum gain is defined as operating gain plus reserve gain. To assess the threshold of discomfort, Berger et al. use puretones and then convert HL to SPL by adding 11 dB at 500 Hz, 7 dB at 1000 Hz and 9 dB at 2000-4000 Hz. To set the $SSPL_{90}$ he employs:

500 Hz:UCL in Hz + 11dB or 115 dBSPL
1000 Hz:UCL in Hz + 7 dB
2000 Hz:UCL in Hz + 9 dB
4000 Hz:UCL in Hz + 9 dB (1979:28)

3.2.2.2 Comfort levels

Watson and Knudsen[20] report a selection criterion based on the most comfortable equal loudness curve. Their method consists of obtaining pure tone air and bone conduction thresholds. Then they determine the most comfortable loudness curve. For air conduction they select the frequency at which the air-bone gap is the smallest; then for that frequency the most comfortable listening level for the reference tone is obtained. Subsequently frequencies above and below are compared and an equal loudness contour is obtained.

The amount of amplification in dB at each frequency is derived by plugging the data into the following formula:

$$\text{Amplification} = HL - \left[(MCL-HL)_{\text{ref. freq.}} \right] - \left[(MCL - HL)_{\text{test freq.}} + K \right]$$

HL = hearing level at threshold
MCL = most comfortable level
K = constant, controlled by gain control and the patient

Watson and Knudsen recommend using this selection procedure mainly with those patients that show sharply sloping audiograms.

Victoreen[21] uses sound pressure (SP) charts (SPL charts). He bases his method on speech at 72 dB SP being a comfortable level for the normal ear. To the patients he presents wave trains (tonal-like pulses with different duration and number of cycles) in the field with the aid on and the patients are requested to tell the audiologist if the sound is soft or loud. Where the patient changes from saying the sound is soft to saying it is loud, is known as the break point. The break point should be associated with the 72 dB SP input level. Upward or downward changes will be controlled by the aid's gain control. To obtain the saturation level, Victoreen measures the uncomfortable level (UCL) and then assertains what input caused it. He writes that the SP limit should be 130 dB.

Discussion

By basing selection on the MCL the aid hopefully will be comfortable. This is particularly true if we use the Victoreen method. Another big advantage of the Victoreen procedure is that all testing is done in the field. With the patients earmold this will give us good results without calibration errors.

3.2.2.3 Dynamic range

Shapiro[22] has dealt with prescribing hearing aids through measurement of the patient's dynamic range. In his procedure, he uses pulsed narrow bands of noise centered at 250, 500, 1000, 2000, 3000, and 4000 Hz. He measures the patient's threshold of discomfort by asking the patient to indicate when the sound becomes "annoying" without being painful. The MCL is obtained by asking the patient to set the noise level at an intensity which would be most comfortable for long-term listening.

From the MCL's at 1000, 2000, 3000, and 4000 Hz subtract 60 dB to derive the gain for each frequency. The gain at 500 Hz is obtained by subtracting 10 dB from the gain at 1000 Hz. Ten dB is added to the values obtained to provide for additional reserve gain. The saturation level is determined by averaging the thresholds of discomfort and 500, 1000, and 2000 Hz. According to these results, the audiologist specifies the response characteristics of the hearing aid most suited to the data. The patient then goes to a hearing aid dealer, who will match the requested specifictions to an aid for the patient.

From the stock of aids, Shapiro selects one which matches the responses desired. To evaluate the effectiveness, he obtains a speech articulation function for half of the W-22 lists at 35,50, and 65 dB HL. The aid is considered to provide appropriate amplification "if the speech discrimination at 50 dB HL is within normal limits; equals or exceeds the unaided speech discrimination; and there is no decrease in discrimination at 65 dB HL". (1976:168)

A procedure employing the concept of usage of dynamic range and long-term average spectrum of speech was suggested by Pascoe[23]. The main idea of the Pascoe method is to bring the speech spectrum up to the patient's most comfortable level (MCL), without reaching the patient's uncomfortable level (UCL), through the use of frequency-selective amplification.

In order to accomplish the above, Pascoe initially measures the dynamic range of the patient's hearing by using pulsing pure tones. Through earphones the patient grades each signal according to its sensation along a 9-point scale; 0=no sound; 1=too soft; 2=soft; 3=soft but clear; 4=just right (OK); 5=OK; 6=OK; 7=a little loud but OK; 8=loud; 9=too loud (uncomfortable). Tones are presented in ascending 10 dB steps. When approaching the higher levels, 5 dB intervals are used in order not to overshoot the "too loud" level. The tone is then decreased in 10 dB steps until the threshold is reached; finally to ascend once more in 5 dB steps. This procedure is followed for at least three frequencies. It is important to test any frequency where a "knee" in the audiogram is found (Pascoe 1981).

Once the dynamic range is obtained, a cross frequency equal intensity search at a comfortable intensity and at a higher intensity is performed. This will highlight the patient's response consistency.

When results from two ears are secured, a binaural single frequency, single level comparision is also useful to illustrate the consistensy of the responses. This point is particularly important at those frequencies where both ears were different.

To conclude the battery of tests, the audiologist should do live voice dynamic range measurements controlling the intensity with the VU meter and asking the patient to score the intensity of the voice, saying "1 - 2 - 3," with the procedure used before.

Second, Pascoe calculates the "desired functional gain", i.e., the gain needed to amplify conversational speech in specific frequency regions. The objective is to amplify the speech spectrum so that it will conform to the contour of the patient's MCL at the MCL level precisely. At this stage it is very important to maintain the shape of Pascoe's perceived levels of speech - a 'two-humped' curve with the first peak at ± 500 Hz, the second at ± 2000 Hz and with a depression in the 1000 Hz area. The levels of speech input across frequencies are:

Frq Hz	250	500	1000	1500	2000	3000	4000	6000
dB HL	40	55	49	50	54	52	52	40

(1981)

The third step is deciding on the aid's $SSPL_{90}$, which should be following the contour of the patient's UCL without surpassing it. The use of compression is recommended if the area between MCL and UCL is 20 dB or less.

The fourth step is selecting a test aid whose coupler response follows the configuration chosen. Here the audiologist seeks to have the aid's coupler slope match the desired slope in dB per octave in areas of 500 and 2000 Hz at least.

Fifth the patient's aided and unaided threshold to one third octave band noise in the field is measured; using a speaker at a zero degree azimuth at the level of the subject's ear, while the head is 2.5 m from the speaker. The untested ear should be plugged and muffed.

Sixth the functional gain is obtained by subtracting unaided from aided thresholds.

Seventh the desired speech levels are calculated by subtracting MCL from HTL and then dividing the result by different quantities across frequencies:

HL	250	500	1000	1500	2000	3000	4000	6000
	1/2	1	8/10	7/10	9/10	9/10	9/10	1/2

Eighth the functional gain obtained is compared to the ideal curve. On the basis of the comparison the audiologist can determine the frequency where the aid's response should be changed.

Ninth, once the functional gain is known, within the smallest limits of error, it is compared to the coupler gains and functional vs. coupler correction is obtained.

Tenth, the recommendation to the patient includes the following data: ear to be aided; type of aid; functional gain at level used; coupler gain in dB with a 60 dB SPL input (2cc coupler); coupler $SSPL_{90}$; earmold type; and which other features should be included - such as automatic gain control, variable $SSPL_{90}$, telephone switch and so on.

Eleventh the patient buys an aid and is subsequently encouraged very strongly to return for a free hearing aid check wherein Steps 5 and 6 are repeated. Also during that session, counseling about aural rehabilitation is given.

Discussion

The Pascoe method of hearing aid prescription has the disadvantage that the evaluation takes at least two hours per ear - much too long for many audiological settings. The advantages are that the audiologist knows precisely what is wanted, what the aid is doing for the patient, what it could be doing and where the possible faults of the obtained frequency response are. Here the audiologist determines what if anything can be changed, or where compromise is necessary between what is desired and what is possible.

CHAPTER 4

Conclusions: Summary

Different audiological settings employ different methods of selecting hearing aids. Many are obviously well-chosen for the patients wear their aids. The problem we audiologists encounter is knowing when an aid is delivering the maximum benefits to the patient. It should be kept in mind that our aim is not only to help the patient hear better, but also to make that experience as pleasurable as possible.

A summary of the principles in hearing aid prescription from Pascoe (1981) is:

1. Binaural hearing should be attained or restored;
2. Effective band width should be as wide as possible;
3. The dynamic range for each patient should be assessed;
4. Frequency response should balance the high and low bands of sound to equal loundess or comfort;

5. Maximum pressure output should be as low as possible;

6. Compression is needed when the dynamic range is narrow, i.e., less than 20 dB between MCL and UCL;

7. Bone vs. air conduction - basically we should always send the signal by air.

8. Directional vs. nondirectional - the effects of the microphone placement has not been studied in depth, so the patient can try either and see how he likes it.

Hopefully, if we follow these principles we shall be getting good, comfortable fittings.

Many audiologists will find than an eclectic approach suites them best and most will respect the test results of others who understand the complexities of hearing aid evaluation procedures.

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