Current Approaches to Hearing Aid Evaluation

Méthodes actuelles d'évaluation prothétique

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Key words: hearing aid fitting, hearing aid evaluation, gliding fitting, verification

Abstract

Current approaches to hearing aid evaluation are classified and reviewed according to the corresponding level of the auditory pathway at which the method tackles the problem. Following this concept, verification criteria can be described as comparisons of: (1) frequency responses with target responses; (2) SSPL90 contours with LDL contours; (3) unaided/aided/normal loudness growth functions measured by acoustic reflexes, auditory brainstem responses, loudness scaling, etc.; (4) unaided/aided long-term average speech spectrum with MCL contours; (5) unaided/aided articulation indexes; (6) unaided/aided/ normal localization abilities; (7) unaided/aided/normal speech recognition scores in quiet and noise; and (8) unaided/aided self assessment measures. It is concluded that evaluation procedures ranking highest along the ascending auditory pathway are most relevant for everyday hearing conditions. However, for analytic purposes the peripheral approaches turn out to be most useful as they provide criteria on how to improve fittings. Taking the effects of acclimatization and counselling into consideration, the limited value of a single hearing aid evaluation session planned immediately after the fitting becomes evident. Therefore a gliding fitting and evaluation approach is recommended to maximize the benefit of the amplification by hearing aids.

Résumé

Les méthodes actuelles d'évaluation prothétique sont classées et examinées selon le niveau correspondant aux voies auditives supérieures auquel la méthode aborde le problème. Ce concept décrit les critères de vérification comme étant des comparaisons entre : (1) les réponses aux fréquences avec des réponses cibles; (2) les contours SSPL90 avec des contours LDL; (3) les fonctions de croissance normale de l'intensité sonore aidé et non aidée, mesurées par les réflexes acoustiques, le potentiel évoqué auditif, l'échelle de sonorité, etc.; (4) le spectre (à long terme) de la parole avec et sans appareil et des contours MCL; (5) l'index d'articulation avec et sans appareil auditif; (6) la capacité de localisation sonore avec et sans appareil auditif; (7) l'évaluation de l'intelligibilité de la parole (aidée et non aidée) dans des conditions tranquille et bruyante; et (8) les mesures d'auto-évaluation avec et sans appareil auditif. L'auteur conclut que les procédures d'évaluation les plus élevées sur les voies auditives ascendantes sont les meilleures dans les situations d'écoute de tous les jours. Cependant, aux fins de l'analyse, les méthodes périphériques se révèlent les plus utiles car elles fournissent des critères sur la façon d'améliorer les ajustements. Tout en tenant compte des effets de l'adaptation et de la relation d'aide, la valeur limitée d'une seule séance d'évaluation post-ajustement prothétique devient évidente. Par conséquent, l'auteur recommande une méthode graduelle d'ajustement et d'évaluation pour maximiser l'avantage de l'amplification par des prothèses auditives.

Introduction

The problem of hearing aid evaluation is as old as the attempt to optimize hearing aid performance (Carhart, 1946). Both tasks are closely related to each other and therefore the strategies of hearing aid verification are generally based on procedures developed primarily for hearing aid selection and fitting. Today we are faced with a vast variety of fitting and evaluation procedures. The proliferation of fitting and verification approaches may be due to the fact that hearing aid wearers are frequently not fully satisfied with their hearing instruments, although state-of-the-art evaluation procedures are applied. The search for more efficient evaluation procedures continuously creates new approaches.

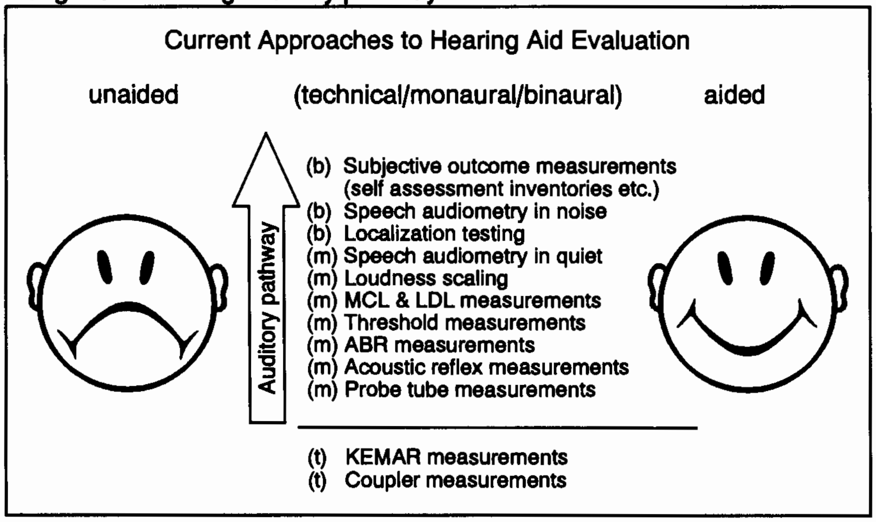
It appears useful to classify the different approaches to hearing aid evaluation according to the level at which that approach assesses the auditory system. Following this concept, current approaches can be arranged along the auditory pathway (Fig. 1). The order is somewhat controversial because several procedures cannot be attributed to a single level. Some of the approaches measure monaural hearing, others the binaural condition, and they cannot be ranked easily. However, Figure 1 gives a fairly good idea to what extent peripheral and central capabilities are involved. Therefore, hearing aid evaluation procedures will be reviewed according to Figure 1, and the advantages and limitations are discussed in this paper. The evaluation criteria will be treated separately from the measurement procedures, as some of them can be applied to different procedures.

Evaluation Procedures

Coupler Measurements

This section comprises coupler, ear simulator, and KEMAR measurements on hearing instruments. These approaches have to be looked at as the lowest evaluation level available. These measures do not include individual factors, such as, middle ear impedance, hearing loss, suprathreshold properties (recruitment of loudness, etc.), and cognitive abilities. Coupler measurements have turned out to be a useful tool for technical checks, maintaining quality standards and for ordering parameters of ITEs. With regard to real ear hearing aid performance, however, the 2cc coupler represents neither the mean nor the individual impedance. The modified Zwislocki and the IEC 711 ear simulators model the average impedance of human ears quite well, but do not allow for different ear canal volumes and body diffraction effects. So KEMAR measurements are highest ranking within this section because the KEMAR simulates the hearing aid performance on an average ear up to the tympanic membrane.

Figure 1. Synopsis of current approaches to hearing aid evaluation ranked along the ascending auditory pathway.



The limitations of coupler measurements and the advent of probe tube measurements in the ear canal are the fundamental reasons that "technical evaluation tools" do not play an important role in hearing aid evaluation any more. In infants, children, and difficult-to-test patients, however, coupler or ear simulator measurements can be used supplementary to real ear measurements to assess relative changes caused by earmold modifications or different amplification settings.

Probe Tube Measurements

The principle of probe microphone measurements can be traced back to the 1940s and 1950s (Wiener & Ross, 1946; Ayers, 1953; Ewertsen et al., 1957). It took about 30 more years until this kind of testing gained clinical importance when the probe microphone in the ear canal was replaced by an external microphone connected to the ear canal by a silicone tube (Lauridsen & Günthersen, 1981; Lauridsen & Birk Nielsen, 1981). Today hearing health care professionals are in general agreement that probe tube measurements provide significant information in hearing aid fitting and verification (Tecca, 1990).

Real ear insertion gain (REIG) is generally considered as one of the major criteria in hearing aid evaluation. It is defined as the frequency by frequency difference in sound pressure level in the ear canal between the aided and unaided condition (Fig. 2, shaded area). In the range of linear operation REIG equals functional gain as determined by the difference between sound-field aided and unaided behavioral thresholds. The concept of probe tube measurements has been extended to real ear maximum output (SSPL90), input-output, and distortion measurements. The results of real ear measurements are compared to one of the criteria discussed below (see Evaluation Criteria) to evaluate the benefit of the hearing aid.

Figure 2. The concept of real ear insertion gain (REIG) measured by a probe tube measurement system.

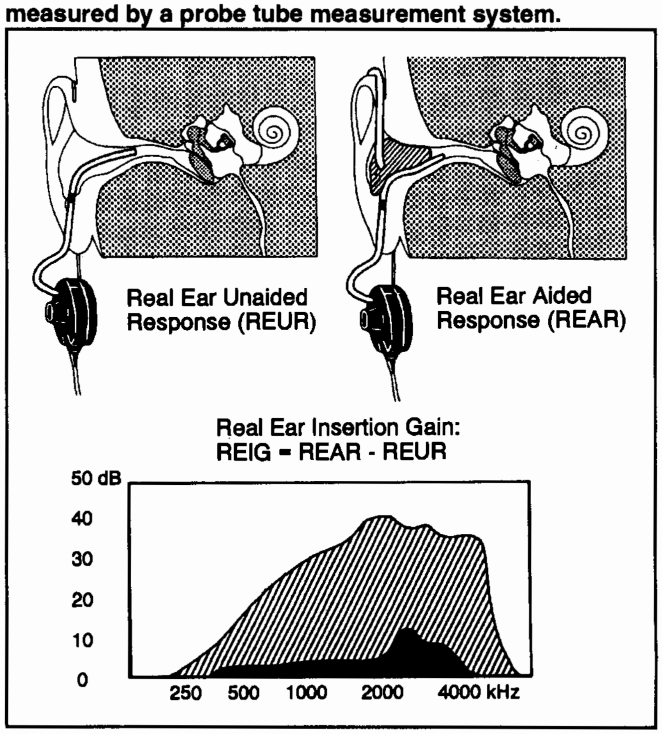


Figure 3. Equipment for simultaneous real ear and acoustic reflex growth measurements.

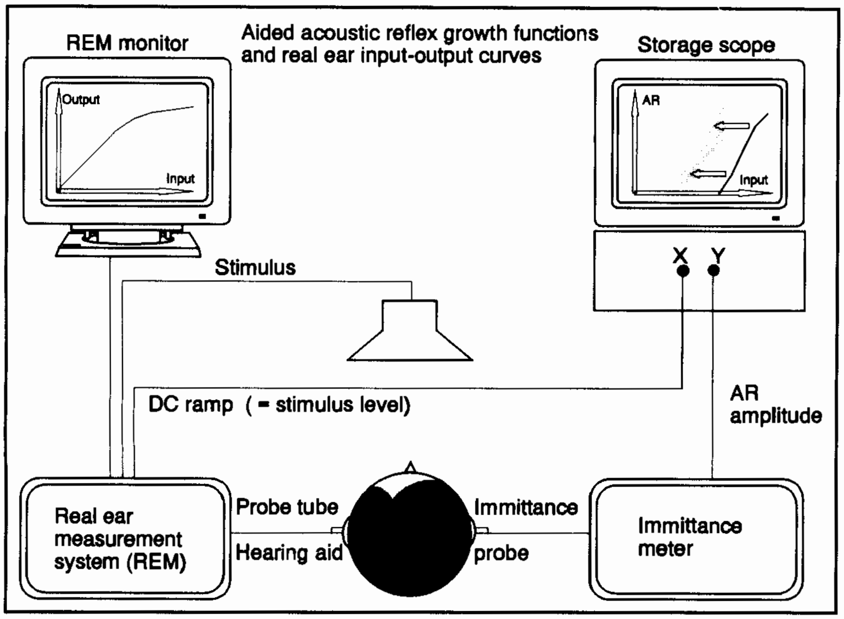
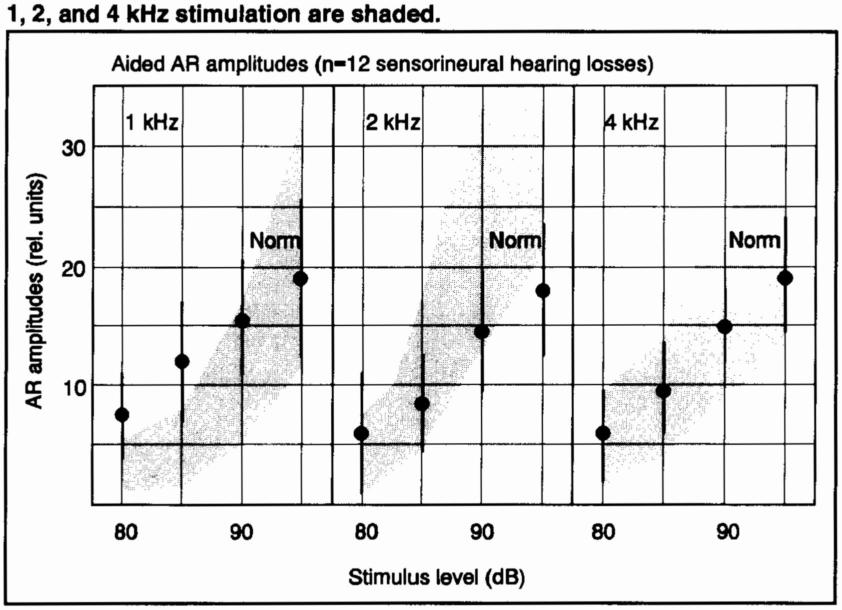


Figure 4. Mean values and standard deviations of aided acoustic reflex growth functions for a group of 12 hearing aid wearers. Normal ranges for 1, 2, and 4 kHz stimulation are shaded.



The advantages of probe tube measurements in hearing aid evaluation are evident and can be summarized as follows: (1) earmold effects (vents, horns, etc.), individual ear canal volume, and middle ear impedance included; and (2) real ear unaided/aided gain, insertion gain, input-output, and distortion measurements feasible. On the other hand, the potential power of probe tube measurements is frequently overestimated because some aspects are not taken into account: (1) reliability is affected by probe placement and decreases with increasing test frequency; (2) real ear hearing aid performance is actually measured, but no target measures are provided; and (3) effects of the middle ear, the cochlea, or the auditory pathway are not included, in particular no information on loudness growth functions or speech recognition is obtained by REM. Therefore the role of probe tube/probe microphone measurements in hearing aid evaluation has to be considered carefully.

Acoustic Reflex Measurements

Real ear gain can also be predicted by comparison of aided/unaided acoustic reflex (AR) thresholds. Rines et al. (1984) found close agreement between behavioral and acoustic reflex measures of functional gain. The advantages of stapedial reflex procedures compared to behavioral measures can be summarized as: (1) feasibility without active co-operation of the patients (children, difficult-to-test patients); (2) applicability during natural and narcotic-induced sleep; and (3) no effect of internal and external noise on aided threshold measurements in frequency regions of normal or near-normal hearing.

Compared to probe tube measurements the AR approaches represent a more central assessment. In relation to behavioral measurements, however, AR approaches test at a lower level of the auditory pathway. Acoustic reflexes, for example, can be present, although the patient does not perceive the stimulus, if the lesion is localized above the level of the acoustic reflex arc. In babies and young children ARs frequently cannot be observed due to middle ear problems. Unaided AR thresholds cannot be determined in patients with severe to profound hearing losses.

The advantages and limitations of an AR approach are described in detail elsewhere (Kiessling, 1987a). In combination with a slightly modified probe tube measurement system, simultaneous evaluation on (1) the ear canal level (REM) and (2) the brainstem level (AR) is feasible (Fig. 3). The signal-to-noise ratio can be improved by AR response averaging. In this case the storage scope in Figure 3 has to be replaced by a computer equipped with AD converter. Whether or not AR growth functions are actually correlated to the loudness function, they have proven to be clinically useful for verifying hearing aid performance by aided reflex growth functions in difficult-to-test patients. We have shown (Kiessling, 1980) that normalization of AR growth curves for speech

Figure 5. Functional gain compared to insertion gain measured with three different probe tube measurement systems.

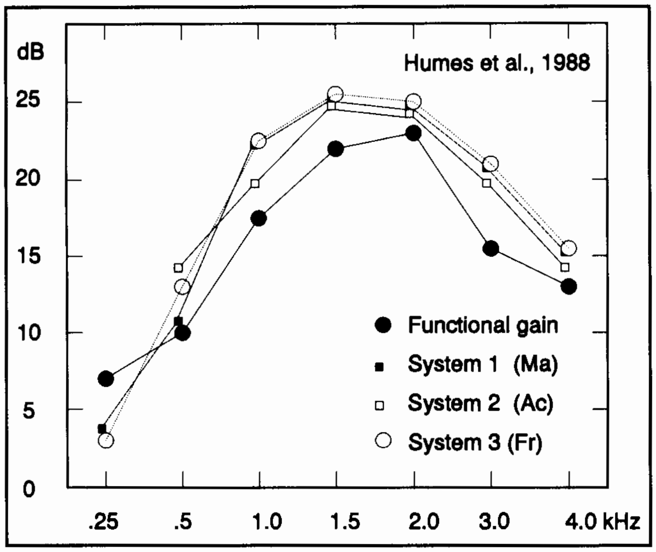
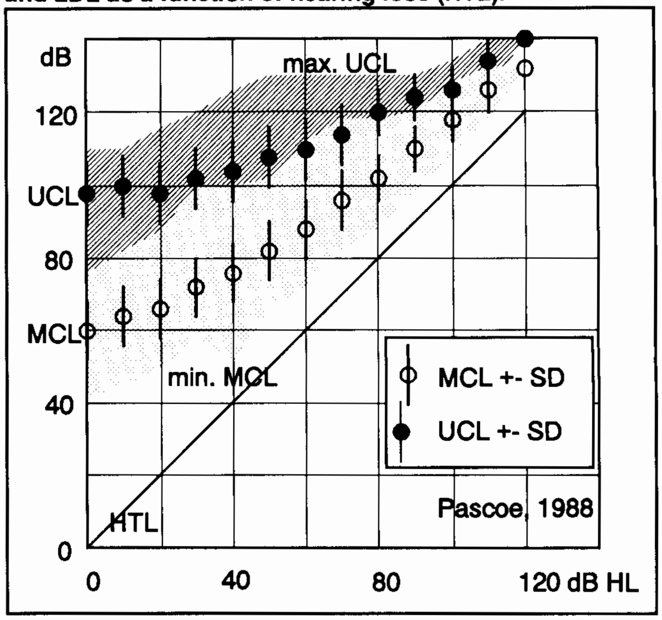


Figure 6. Mean values and standard deviations of MCL and LDL as a function of hearing loss (HTL).



and/or narrow band noises seem to be fairly good criteria for hearing aid evaluation (Fig. 4).

Auditory Brainstem Response Measurements

If no subjective procedures can be employed in young or uncooperative patients, hearing aid evaluation may be performed on the brainstem level by measurement of unaided/aided auditory brainstem responses (ABR). (For a comprehensive review, see Hall & Ruth [1985] or Mahony [1985]). Typically, intensity-latency functions are used as the evaluation criteria (Hecox, 1983; Gerling, 1991). Other authors have reported on procedures based upon ABR thresholds (Kileny, 1983) or intensity-amplitude functions (Kiessling, 1982).

The major problem in eliciting an aided ABR is the alteration of the stimulus shape processed by a hearing instrument. This effect varies greatly from hearing aid to hearing aid due to variability in the electroacoustic parameters among aids. In addition, the evaluation of compression aids is strongly affected by the stimulus repetition rate. For these reasons, ABR measurements have not found broad acceptance in clinical hearing aid evaluation, although it would be desirable to have another powerful method for difficult-to-test patients available.

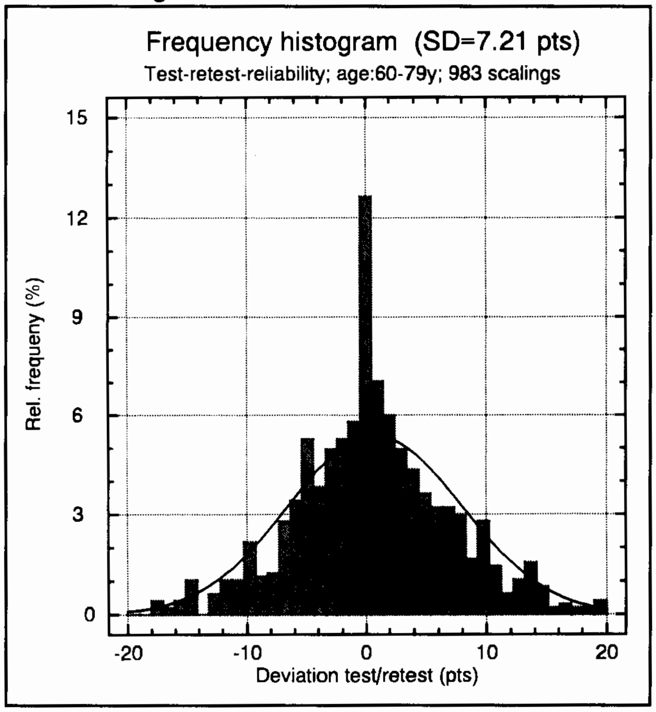
Threshold Measurements

Unaided/aided threshold measurement is the classical approach to assess real ear gain, commonly called functional gain. It can be calculated from the difference of aided/unaided thresholds. Unaided thresholds are usually determined by headphone measurements, whereas aided thresholds are measured under sound field conditions (Dillon & Walker, 1982; Walker et al., 1984a).

As probe tube measurements became more popular, functional gain measurements lost importance. Functional gain, however, provides important information on perception abilities not available by probe tube measurements because real ear measurements do not say anything about the auditory signal processing beyond the tympanic membrane, that is, insertion gain measurements may indicate a certain amplification even in completely deaf patients. On the other hand, aided thresholds may be masked by internal noise of the hearing aid or external noise present in the sound field (Pascoe, 1988a). Furthermore the reliability of threshold measurements is affected by the patient's ability to cooperate. Several studies have shown (Mason & Popelka, 1986; Tecca & Woodford, 1987; Dalsgaard, 1988; Humes et al., 1988) that functional gain determined by behavioral measurements and insertion gain measured with probe tube systems are in good agreement over the linear range of the hearing aid (Fig. 5).

Functional gain is used primarily to evaluate frequency by frequency that part of the long-term average speech spectrum shifted into the audible range of the hearing aid wearer. According to this concept most prescription methods are tailored to place the average speech spectrum into the most comfortable loudness range (Berger et al., 1989; Byrne & Dillon, 1986; Cox, 1988; Humes, 1988; Libby, 1986; McCandless & Lyregaard, 1983; Popelka, 1988; Pascoe, 1988b).

Figure 7. Test-retest reliability of loudness scaling in a group of elderly patients (age 60-79 years) with sensorineural hearing losses.



MCL and LDL Measurements

Whereas threshold based prescription formulas assume a functional relationship between pure tone hearing losses and most comfortable levels, individual determination of most comfortable levels (MCL) and of loudness discomfort levels (LDL) represent the next step up on the evaluation ladder. Pascoe (1988b) has shown a close correlation between mean threshold, MCL, and LDL values. However, individual MCL and LDL (or UCL, uncomfortable loudness) contours can differ up to 25 dB from the mean values (Fig. 6). This observation suggests the importance of determining suprathreshold loudness measures for each hearing aid candidate instead of using threshold based procedures. On the other hand, pure tone hearing losses can be obtained more easily than MCL or LDL measures.

The importance of appropriate maximum power output (MPO) or SSPL90 shaping has been outlined by many authors (Skinner et al., 1982; Walker et al., 1984b, Hawkins, 1984; Hawkins, 1986; Seewald, 1988; Stuart et al., 1991). Recently the role of LDL determination for SSPL90 setting and evaluation was reviewed by Mueller and Hawkins (1990). They concluded that LDL measurements provide more accuracy than LDL estimation from the pure tone hearing loss if the best instructional set, the most valid stimuli, and the best delivery system are used.

To avoid sound field calibration problems and corrections for different types of hearing aids we suggest that MCL and UCL be measured with a linear test hearing aid under free field conditions when the sound pressure level in the ear canal is monitored by a probe tube measurement system (Kiessling, 1987b; Kiessling, 1987c). This procedure is called in situ audiometry (ISA) and is feasible with different commercially available REM systems. The evaluation of a large number of fittings revealed that the best fitting is obtained by matching the frequency response to a MCL derived target response. The target response can be predicted from the MCL contour using a linear correction function of the type

$$\text{REAR} = a(f) * \text{MCL} + b_1(f),$$

where a(f) is the slope and $b_1(f)$ is a frequency-specific additive term,

or less precisely using an simple additive correction of the type

$$\text{REAR} = \text{MCL} + b_2(f).$$

The additive correction value $b_2(f)$ is -4 dB at 500 Hz and +5 to +8 dB at 1000 Hz and above.

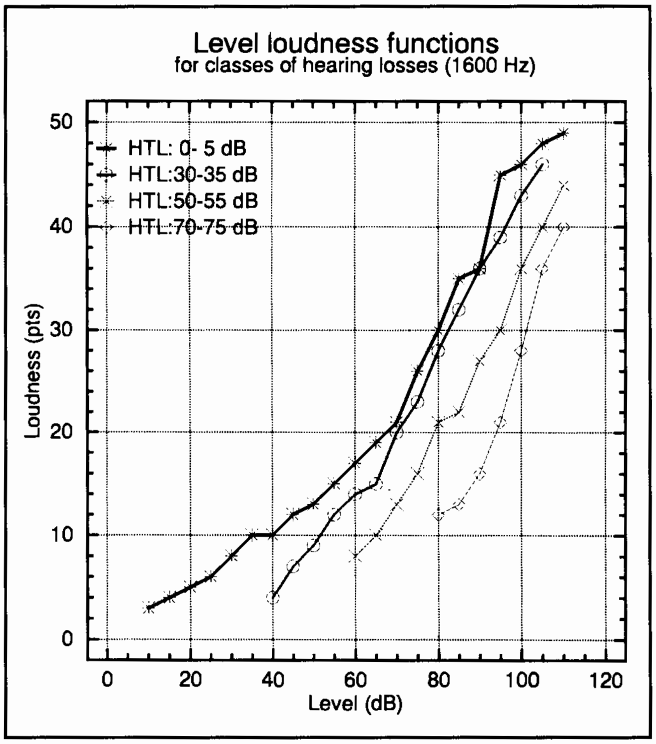
Loudness Scaling

Complementary to MCL/LDL measurement, loudness scaling of narrow band stimuli offers another attractive approach to hearing aid evaluation (Hellbrück & Moser, 1985; Pascoe, 1988b). Although the question of whether loudness scaling is feasible in a clinical population remains unresolved, there is growing evidence that its reliability is sufficient.

We have investigated the application of loudness scaling (on a 50 point scale) to hearing aid fitting and evaluation. It was found that the test-retest reliability decreases slightly with increasing age, but elderly hearing aid users are still able to scale with sufficient reliability. The distribution of test-retest deviations (Fig. 7) exhibits a standard deviation of 7.21 points on a 50 point scale for patients age 60 to 79. Other factors, such as gender, hearing loss, and stimulation frequency, have no significant influence on the test-retest reliability. For hearing aid evaluation purposes, aided level loudness functions can be compared to the normal loudness growth functions. Averaged level loudness functions for different classes of hearing losses are given in Figure 8 for 1600 Hz narrow band noise stimulation. Interestingly, the recruitment effect present at low frequencies (e.g., 500 Hz) disappears with increasing stimulation frequency. At 4000 Hz the slopes of the loudness growth functions are very similar for classes of different hearing losses.

From a set of level loudness functions for different test frequencies, equal-loudness contours can be calculated for

Figure 8. Level loudness functions for classes of hearing loss. Stimulation is accomplished by 1600 Hz narrow band noise.



the unaided/aided conditions. In terms of this approach, an appropriate amplification is indicated by "blowing up" the residual dynamic range to place the speech energy spectrum between the hearing threshold and the equal loudness contour for uncomfortable hearing. For future developments it might be most preferable to combine the concept of loudness scaling with the principle of in situ audiometry (see MCL and LDL Measurements) to establish a reliable, frequency specific, and suprathreshold evaluation procedure.

Speech Audiometry in Quiet and Noise

As speech signals are most important for the majority of hearing aid users, speech audiometry is a traditional evaluation approach. Aided speech testing in quiet gives a good estimate of the monaural benefit. The benefit of binaural fittings, however, can be assessed by speech audiometry under noisy conditions. Unfortunately speech audiometry evaluation procedures cannot be applied worldwide in a standardized way due to the differences of the test material available in different languages. Although standardized or commonly used speech test material is available in most languages (Martin, 1987), many problems still need to be solved.

The biggest problem of speech based hearing aid evaluation is the choice of appropriate speech and noise signals. This issue is very complex. For the selection of the speech material, the following aspects have to be taken into account: (1) words vs. sentences; (2) complete sentences vs. sentences with key words of high/low predictability (Kalikow et al., 1977); (3) speech material with open responses vs. rhyme test material; (4) female vs. male speaker; and (5) trained vs. untrained speaker. Selection of appropriate noise signals is also not straightforward, and various questions must be answered: Should the noise have the same spectrum as the speech material rather than a spectrum representing a situation? Which is most important for the individual patient (babble, factory, street, car, etc.)? How can we determine the most important noise condition for an individual? In the utmost case, tape recordings of typical everyday noises for each hearing aid user should be considered. Is modulated or unmodulated noise favourable? Should the noise be artificially created or should it be composed of natural signals? Which directions are preferable for the presentation of speech and noise?

Most of these questions cannot be answered definitively today, and more research has to be done to optimize and probably standardize the test conditions for hearing aid evaluation. Certainly there is no single, uniform signal/noise condition that is optimal for all hearing aid users (Sotscheck, 1985; von Wedel, 1986; Fastl, 1987; Kollmeier & Müller, 1988). So presumably we will end up with a set of test conditions for different purposes. For instance, rhyme test material seems to be a powerful tool for analytical approaches by doing transformation analyses or by the evaluation of confusion matrices (Miller & Nicely, 1955; Wang & Bilger, 1973; Dreschler, 1986). An analysis of prevalent confusions may yield practical information on how to improve the hearing aid performance. On the other hand, the social hearing handicap (unaided/aided) may be predicted most reliably by testing sentence recognition under noisy conditions. Last but not least, we must be aware of the limited accuracy of speech recognition scores, which is a function of the number of items per list (Green, 1987).

Localization Testing

Localization is one of the major abilities of binaural hearing and can be used to evaluate binaural hearing aid fittings. The test stimuli (noise or speech) are generally presented by a set of loudspeakers arranged around the test person. This allows for an evaluation of the benefit of binaural fittings or demonstrates the deficits of monaural fittings in patients with binaural hearing impairments.

Various evaluation criteria have been described in the literature (Jeffres & Taylor, 1961; Berg & Hunig, 1990; Pröschel & Döring, 1990), but no standardized test procedure has been

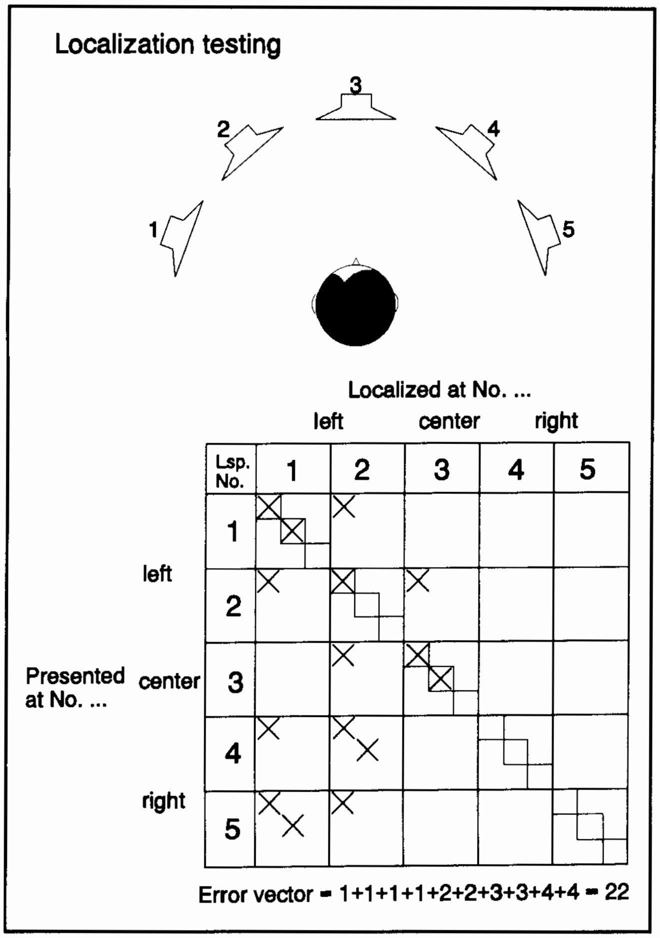


Figure 9. Localization testing by evaluation of the error vector defined as the sum of the error components. The error vector can be normalized considering the number of loudspeakers and the number of presentations per direction.

developed at this time. For clinical purposes the concept of "error vectors" suggested by Berg and Hünig (1990) seems appropriate. We use modified equipment with 5 loudspeakers and an evaluation form (see Fig. 9). The absolute error vector optionally can be transferred to a normalized measure taking the number of loudspeakers and the number of presentations into consideration.

Subjective Outcome Measurements

Subjective outcome measurements can be regarded as the most comprehensive approach to hearing aid evaluation. In contrast to most other evaluation procedures, subjective outcome measures cover the whole range of everyday listening conditions. Numerous inventories have been developed to evaluate the unaided/aided social hearing. Ewertsen et al. (1973) developed the so-called Social Hearing Handicap Index (SHHI). A German version of the SHHI was established by von Wedel et al. (1983). Schow and Nerbonne (1982) suggested a 10 item inventory for the Self-Assessment of Communication (SAC) and its companion form (SOAC), which is available for use with significant others. Ventry and Weinstein (1982) proposed a 25 item questionnaire (HHIE: Hearing Handicap Inventory for the Elderly) followed by a 10 item screening version of the HHIE called the HHIE-S.

Efficient tools for the assessment of the unaided/aided hearing handicap are available today in many languages. Nevertheless, subjective outcome measures are rarely used to assess the benefit of amplification because: (1) the patients tend to underestimate their hearing problems in a clinical setting and (2) the self-assessment results do not enable a determined improvement of fittings. The advent of hearing aid features like Datalogging™ available in the Memory Mate™ opened new dimensions for analytical evaluation approaches. Ringdahl et al. (1988) have shown that objective data collected by Datalogging™ give a more reliable impression about the hearing aid use than subjective judgements. These data (total on time, on time use in each memory, number of switchings) can be used as a basis for a systematic fine adjustment in the period after the hearing aid fitting.

Evaluation Criteria

An essential criterium for hearing aid evaluation can be defined as placing the long-term average speech spectrum into the range of most comfortable hearing. According to this goal, some fitting formulas (POGO, NAL, etc.) predict target responses from pure tone thresholds. The targets are compared to insertion gain responses measured either by a probe tube system or functional gain measures. Some formulas (e.g., POGO) also estimate the maximum power output on the basis of the pure tone audiogram to "squeeze" the output signal into the residual dynamic range of the hearing aid user. More sophisticated evaluation procedures (CID, MSU, ISA, etc.) also take MCL and LDL contours into account to allow an individual shaping of the SSPL90 and the output dynamic range of the hearing instrument.

The unaided/aided articulation index (AI) provides a useful evaluation criterium. As the definition of the AI given by ANSI (1969) is quite complex, the AI never became popular for clinical use until simplified calculation rules were developed. Mueller and Killion (1990) created a count-the-dot audiogram form to quantify the audible part of the average speech spectrum (Fig. 10). The density of the dots represents the importance function of nonsense monosyllabic words. Pavlovic (1989; 1991) modified the count-the-dot approach of Mueller and Killion by introducing an importance function of everyday speech, and he made suggestions to calculate the AI from pure tone thresholds. An example is given in Figure

Figure 10. Assessment of the articulation index by a count-the-dot-audiogram form.

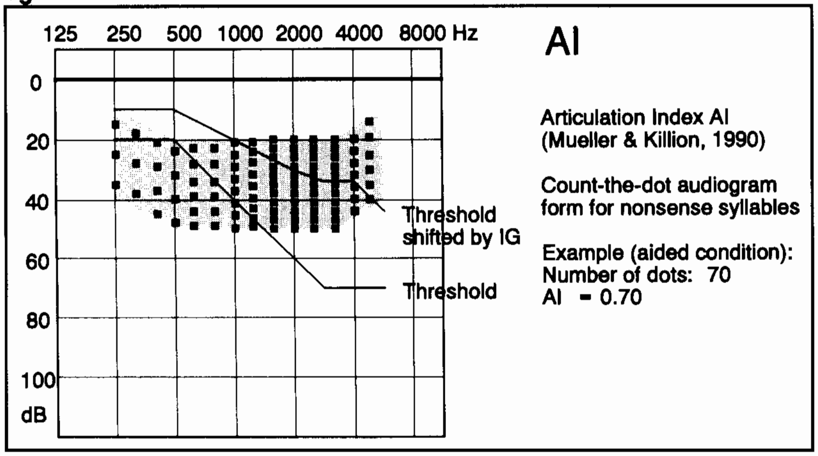


Figure 11. Assessment of the articulation index.

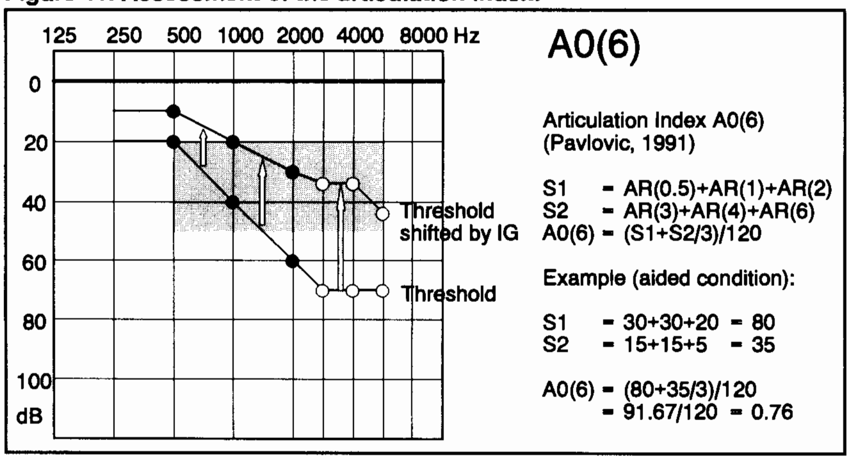
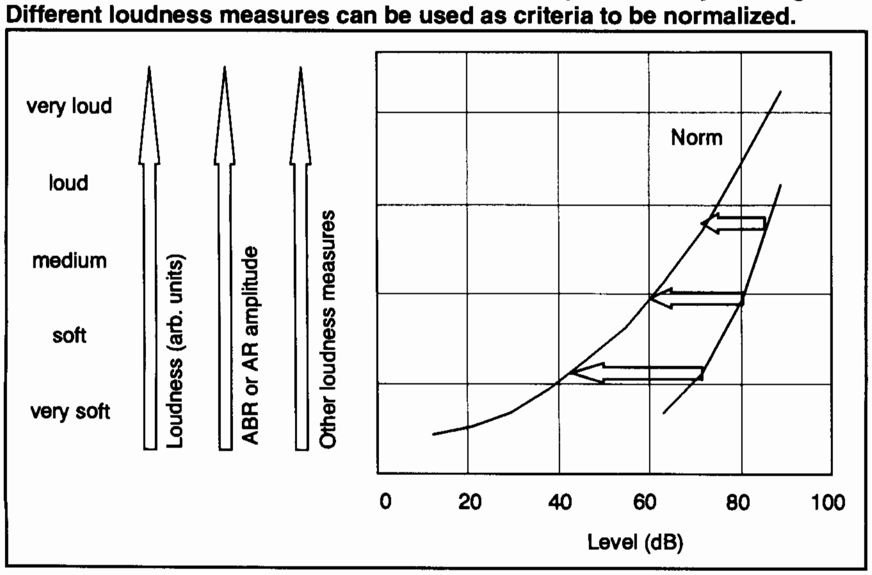


Figure 12. Generalized concept of appropriate amplification by hearing aids. Different loudness measures can be used as criteria to be normalized.



11 of how to calculate the aided AI by shifting the unaided threshold by the insertion/functional gain.

Other evaluation approaches may be based on input-output functions. Growth functions of acoustic reflexes, auditory brainstem responses, loudness scaling, or any other loudness measure can be employed as evaluation criteria. In terms of this concept, pathological growth functions are shifted towards the normal range by hearing aid amplification (Fig. 12). Verification procedures compare pathological to normal growth curves. This can be done either for broad band signals or separately for the major speech frequencies if the loudness measure provides frequency specific data.

All criteria mentioned above are necessary, but not necessarily sufficient prerequisites for adequate speech recognition and for a positive acceptance of the hearing aid by the user. Speech audiometric evaluation tackles the problem on a higher level, but yields less information for analytical purposes. The aided recognition score at normal speech levels (e.g., 65 dB) may be employed as criterium for speech audiometric evaluations. The expected benefit of amplification can be estimated by shifting the unaided speech recognition function into the range of normal speech levels (Fig. 13). An increased maximum aided score compared to the maximum unaided score can be expected in patients with frequency dependent hearing losses. The reason for this extra benefit is the fact that appropriate frequency response shaping generally enables better performance than the broad band response of the audiometer (upward spread of masking in high frequency losses) (Keller, 1980). The error vector (see Fig. 9) may be used as an evaluation criterium for localization tests. Most self-assessment inventories provide a normal range (e.g., SAC: 20%) to be used as a criterium for subjective quality judgements.

Conclusion

This review reveals that a broad choice of hearing aid evaluation procedures is available today. From the theoretical point of view, it appears most favourable to verify hearing aid fittings as extensively as possible. However, in a clinical setting this goal cannot be achieved because of several limiting factors, for example, time consumption, manpower, and patient's ability to cooperate. The problem therefore is to make the right choice for each patient.

The higher along the ascending auditory pathway an evaluation procedure tackles the problem, the more relevant it is for everyday hearing conditions. For analytic purposes the peripheral approaches are more useful because they provide criteria on how to improve a fitting. Therefore it is recommended to monitor the fitting parameters on two different levels — first, on a mid-level to get guidance for systematical intervention. For this purpose it appears most promising to combine loudness scaling with real ear measurement and monitoring of the actual sound pressure level, similar to in situ audiometry. This kind of fitting and verification approach can be denoted as in situ loudness scaling. Second, the overall benefit should be estimated by a high ranking evaluation tool (e.g., speech audiometry in noise and as an option by subjective outcome measures) to assess the social aided hearing.

Following this strategy, however, one has to be aware of the limited value of hearing aid evaluation procedures, particularly immediately after the fitting. Common experience of hearing health care professionals and systematic clinical studies (Watson & Knudsen, 1940; Humes, 1988; Gatehouse, 1988) have shown that the benefit increases as soon as the auditory system gets used to the amplification provided by a hearing aid. This period of acclimatization typically takes weeks, in some cases up to three months (Gatehouse, 1988). Adaptive fine adjustment and counselling (Brooks, 1979) have shown considerable enhancement effects on the hearing aid benefit.

As these factors (acclimatization, fine adjustment, counselling) affect each other in a time-dependent complex way, hearing aid evaluation should be handled as a gliding procedure. Figure 14 demonstrates the concept of "gliding" fitting and evaluation. In this example the benefit is increased by boosting the high frequency gain step by step. In conclusion, a hearing instrument has to be fitted to the individual hearing impairment, but the auditory system also has to accustom itself to the amplification.

Figure 13. Example for an estimation of aided speech recognition scores from the unaided speech recognition function.

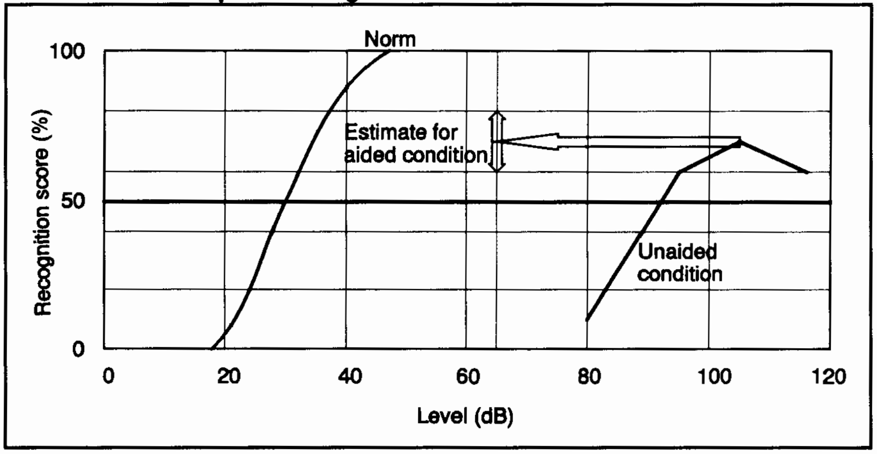
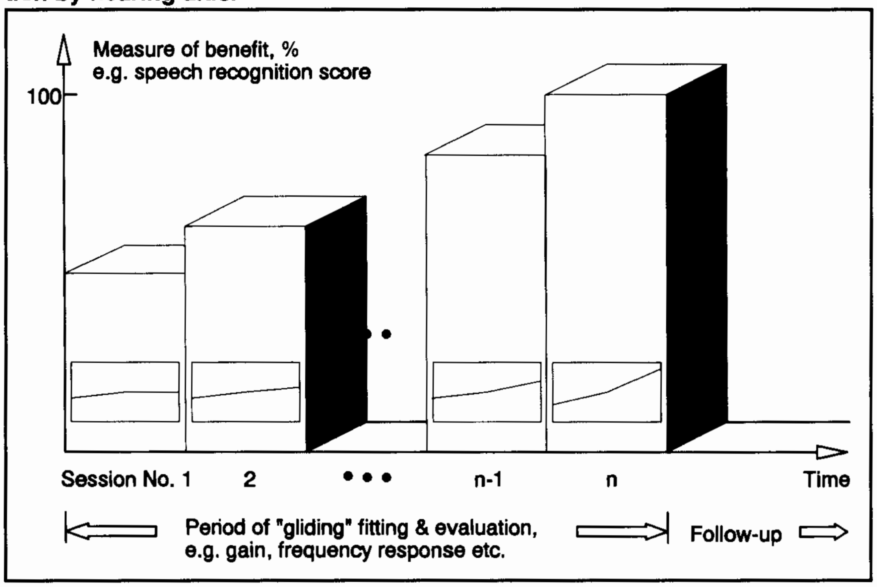


Figure 14. Gliding hearing aid fitting and evaluation is recommended (e.g., high frequency gain enhancement) to maximize the benefit of the amplification by hearing aids.



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