ACCEPTABLE LEVEL OF ACOUSTIC DISTURBANCES TO SPEECH SIGNAL AS A MEASURE OF SUCCESSFUL HEARING AID FITTING

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Abstract

A method has been established to measure the maximum acceptable background noise level (BNL) for a listener, while listening to speech at the most comfortable listening level (MCL). The acceptable noise level (ANL) is the difference between BNL and MCL.

The ANL procedure was used to measure acceptance of noise in the presence of speech at MCL, that was stated as 65 dB for normal-hearing listeners. There were two groups of normal-hearing listeners treated in two ways.

In the first stage of the study, a group of 16 students were exposed to the list of words at the level of 65 dB SPL (MCL). The level of "babble" noise was increased up to the moment when the person declared discomfort. At such level of "babble" noise (BNLX%) the acceptable noise level ANLX%, and the speech intelligibility X% were determined.

The aim of the second stage of experiment (for a group of 36 students) was to establish a level of "babble" noise BNLX% (and then the acceptable noise level ANLX%,) at the level of speech intelligibility X% determined in the first task.

It was found that the X% determined at the state of discomfort equals 61% for ANL=(19±2) dB. The ANL estimated at the X%=61% is very similar and equals (18±2) dB.

Background

Noise disturbs same activity of live, is related to a subjective assessment of the annoyance [1].

Nabelek, Tucker, Letowski [2] have proposed to use the level of background noise tolerated by a hearing impaired person during a conversation, the so-called Acceptable Noise Level (ANL) for prediction of successful use of a hearing aid; it is well known that the hearing impaired persons have much different levels of readiness to use hearing aids. The value of *ANL*[dB] is calculated as the difference between the so-called maximum comfort in speech perception in silence (*MCL*) and the level of "babble noise [3]" (*BNL*) tolerated by a hearing impaired person in free field conditions, i.e. the level at which a given person is able to follow the narration without stress or tiredness:

$$ANL = MCL \text{ [dB SPL]} - BNL \text{ [db SPL]} \quad (1)$$

The lower the *ANL* values, the higher the probability of acceptance of hearing aid [5,6].

ANL is unchanged at repeated measurements for persons of normal hearing [7] and at least for 3 months for persons with hearing impairment [8]. *ANL* is not dependent on binaural or monaural amplification for most listeners [8], it is improved when directional microphones or algorithms reducing the acoustic noise are used [9,10]. An attempt was made to use the *ANL* values for direct evaluation of the quality of hearing aid adjustment [11,12].

It was assumed that the difference $\Delta(ANL)$ between *ANL* determined with and without a hearing aid could be a measure of the quality of the hearing aid fit:

$$\Delta(ANL) = \mathrm{ANL}_{\text{with hearing aid}} - \mathrm{ANL}_{\text{without hearing aid}} \text{ [dB]} \quad (2)$$

One of the parameters directly describing the successful fitting (quality of hearing aid fitting) of hearing aids commonly used hitherto has been the gain in speech intelligibility (≥20%) in free field obtained as a result of hearing aid use [12]. Experimental study [11,12] has shown that the gain of ≥20% is attained for $\Delta(ANL)$ greater or equal 2 dB.

Because a measurement of the background noise tolerated by a hearing impaired person during a conversation is easy and rather fast, it is proposed to be used as a method for the testing of quality of hearing aid fitting. In contrast to e.g. the APHAB procedure of direct speech intelligibility, measurements of the shift in the hearing loss threshold without and with the hearing aid which are time- and work-consuming, measurement of $\Delta(ANL)$ measurement take about 5 minutes and is well accepted by the subjects.

The basic notion for a future procedure for the evaluation of hearing aid fitting quality is the acceptable noise level defined after Nabelek, by formula (1).

As follows from the hitherto experience of the authors the acceptable noise level must be defined unambiguously. The lack of numerical definition of this notion can be a source of disagreement in evaluation of $\Delta(ANL)$ at different laboratories, which prevents a reliable comparison of results. Its unambiguous definition is necessary to employ this parameter for evaluation of successful fitting of hearing aids.

Material and methods

To make the definition of the acceptable noise level more reliable and unambiguous it is proposed to introduce a new term – the acceptable noise level at the level of speech intelligibility of X% ($ANL_{x\%}$ [dB]) defined on the basis of formula 3

$$ANL_{x\%} = MCL \text{ [dB SPL]} - BNL_{x\%} \text{ [dB SPL]} \qquad (3)$$

where:

MCL – is the maximum comfort of speech perception in silence, $BNL_{x\%}$ – is the maximum admissible level of "babble" noise at the speech intelligibility of X%.

On the basis of this definition it is possible to determine the accepted noise level at any level of speech intelligibility, e.g. 10, 30 or 80%. To be able to apply this parameter for evaluation of the quality of hearing aid fitting, the changes $\Delta(ANL)$ [dB] between *ANL* determined with and without a hearing aid are expressed by formula 4:

$$\Delta(ANL)_{x\%} = (\mathrm{ANL}_{\text{with hearing aid}})_{x\%} \text{ [dB]} - (\mathrm{ANL}_{\text{without hearing aid}})_{x\%} \text{ [dB]} \quad (4)$$

where: $(\mathrm{ANL}_{\text{with hearing aid}})_{x\%}$ and $(\mathrm{ANL}_{\text{without hearing aid}})_{x\%}$ are defined by formula 3.

In this paper an attempt to determine the acceptable noise level at a speech intelligibility level X% for normal hearing persons was made.

Procedure of measurement

Measurements were made in free acoustic field; background noise level in the experiment room was ≤30 dB SPL. The distance between the subject and the source of sound was 1m.

In the first stage of the study, a group of 16 students of electroradiology at the Medical University, Poznan, aged 22 to 30, including 9 males and 7 females of audiologically normal hearing, were asked to determine speech intelligibility at a given level of "babble noise" (individual tasks). They were exposed to the list of words at the level of 65 dB SPL (*MCL*) from a loudspeaker. The level of "babble" noise was increased up to the moment when the person declared discomfort. At such level of "babble" noise (*BNLX%*) the acceptable noise level $ANL_{X\%}$, and the speech intelligibility X% were determined.

In the second stage of the study, a group of 36 students of electroradiology at the Medical University, Poznan, aged 22–30, 27 males and 9 females of audiologically normal hearing were asked to take part in the study.

The task was to establish a level of "babble" noise $BNL_{X\%}$ (and then the acceptable noise level $ANL_{X\%}$,) for persons of normal hearing at the level of speech intelligibility X% determined in the first task.

They were exposed to the list of words at the level of 65 dB SPL (*MCL*) from a loudspeaker. The level of "babble" noise was increased up to the decrease in the speech intelligibility to the average level of speech intelligibility X% determined in the first stage of the study.

Results

The results of the first stage of the study are shown in Figure 1.

The mean value of X% and its standard deviation equals (61±8)%.

The value of *BNL* at X%=61% equals 46±2 [dB SPL]. The value of $ANL_{61\%}$ and its standard deviation equals 19±2 [dB].

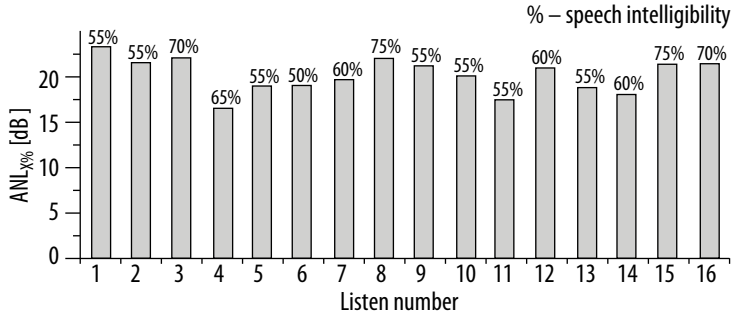

Figure 1. The acceptable noise level ($ANL_{X\%}$) at the speech intelligibility level corresponding to the level of discomfort for individual 16 participants.

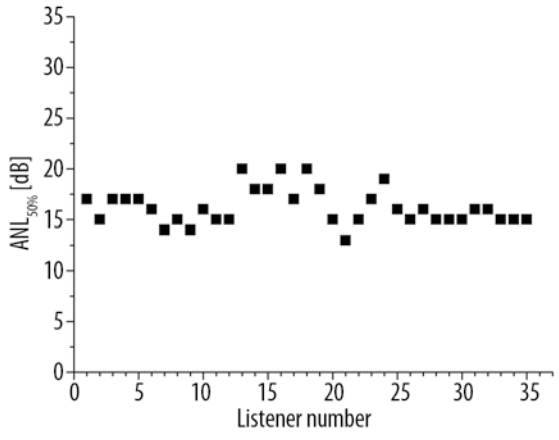

Figure 2. The acceptable noise level ($ANL_{X\%}$) at X%=61% for 36 normal hearing subjects participating in the study.

The results of the second stage of the study are presented in Figure 2.

The value of $ANL_{61\%}$ [dB] changes from 15 dB to 20 dB. The mean value of $ANL_{61\%}$ [dB] and its standard deviation equals 18±2 dB. It corresponds to $BNL_{61\%}$ =47±2 [dB SPL].

Conclusions

1. The *ANL* determined at the state of discomfort is equal to (19±2) dB.
2. The *ANL* estimated at the X%=61% is very similar and equals (18±2) dB.
3. The results obtained have suggested that it is possible to determine more precisely the value of *ANL*.

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