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A NATURAL SOUND LOUDNESS ESTIMATION METHOD AS A PERSPECTIVE TOOL FOR HEARING AID FITTING IN PATIENTS WITH DEAD COCHLEAR REGIONS

Dorota HOJAN–JEZIERSKA[(1)], Ewa SKRODZKA[(2)], Edward HOJAN[(2)]

[(1)]Poznań University of Medical Sciences, Department of Biophysics
A. Fredry 10, 61-701 Poznań, Poland

[(2)]Adam Mickiewicz University, Institute of Acoustics
Umultowska 85, 61-614 Poznań, Poland
e-mail: hojanaku@interia.pl

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Hearing aids fitted with the use of classical methods (POGO, NAL, Berger ect.) often do not bring the expected benefit to hearing impaired people with "dead regions", (DRs). For such patients we propose an alternative method of hearing aids fitting, based on perception of natural sounds – The Natural Sounds Loudness Estimation (NSLE) method. Our aim was to check whether patients with such a complicated hearing loss were able to follow loudness changes in the sound material. Four persons (seven ears) with diagnosed DRs were examined. Only one of them was not able to perform the loudness estimation test with satisfactory precision (calculated as a correlation coefficient between sound pressure changes on an original sound track and subjectively perceived changes in loudness). Next, the parameters necessary to proper hearing aid fitting were calculated using the NSLE. Estimated insertion gains (IGs) were generally lower than those predicted by three classical methods used for comparison. Our conclusion is that the NSLE method may be a good option for hearing aids fitting in the case of people with DRs.

Keywords: hearing aid fitting, dead regions, NSLE.

1. Introduction

People with hearing disorders often complain about the quality of sound produced by hearing aids they use and difficulties in speech intelligibility in noisy conditions. Thus, hearing aids are not often effective and helpful devices and their usefulness is limited. In majority of situations it is not possible to obtain speech intelligibility "as it was before", especially in the case of serious hearing problems of sensorineural origin. Thus, the main aim of the audiologist is to fit the hearing aid in such a way as to obtain the best possible speech improvement for a given hearing loss, or in other words, to optimise the hearing aid fitting procedure. Optimisation means: proper diagnosis of the impairment, taking advantage of modern hearing instruments (multi-channel, digital) and a choice of an adequate hearing aid fitting method. In our work we concentrated attention on the latter factor in the aspect of DRs.

By definition, the areas of the basilar membrane where inner hair cells are completely non-functioning or even missing and/or neurones innervating those places are non-functioning or degenerated, are called "dead regions" [1]. A "dead region" is defined in terms of the characteristic frequencies of the inner hair cells and/or neurones immediately adjacent to the dead region. Basilar membrane vibrations in such regions are not transduced and do not lead to action potentials in the auditory nerve. It is usually not possible to predict the occurrence of DRs on the base of a tonal audiogram [2] and specific methods of diagnosis must be used (psychophysical tuning curves (PTCs), threshold equalizing noise method (the TEN test), [2]). Classical hearing aid fitting methods which ignore the presence of DRs are often unsuccessful and hearing aids fitted using such methods do not improve or sometimes worsen the life comfort of hearing impaired people.

2. Natural sound loudness estimation (NSLE) method

The NSLE method belongs to the class of interactive procedures based on perception of natural signals, similarly to A-Life or Scaladapt methods. The method was proposed by HOJAN, GEERS and JEZIERSKA [3]. The method combines the assumptions of the Würzburger Hörfeld Skalierung (WHS) scaling field method concerning the subjective evaluation of the loudness of synthetic stationary signals on a category scale and the Stevens' postulate of an absolute coupling between the sensation values assessed on a category scale and the magnitude of perceived by the listener. This relation is the same for normal and hearing impaired patients. The NSLE method enables estimation of a hearing threshold taking into account relation between the amplitude changes of the signal in dB [SPL] and subjective estimation of the signal on a category scale of perceived loudness. In the next step the insertion gain (IG) of the hearing instrument can be calculated. Details of the NSLE method can be found in [3].

3. Results and discussion

We investigated many persons (with high-frequency hearing loss and steeply sloping audiogram, which potentially may have DRs) and only for four of them the TEN test gave a positive result. Then, the NSLE test was performed for those patients. The testing signal was a fragment, 188 s in duration, Fugue of J. S. Bach. Based on results of the NSLE test the hearing thresholds, IGs and the parameters necessary to fitting were estimated.

The hearing threshold estimated from the NSLE, the TEN test results (indicating occurrence of the DRs) and results of tonal audiometry (for comparison) for three subjects are shown in Fig. 1. It should be noted that the hearing threshold estimated from the NSLE is in all cases well above the threshold obtained from tonal audiometry.

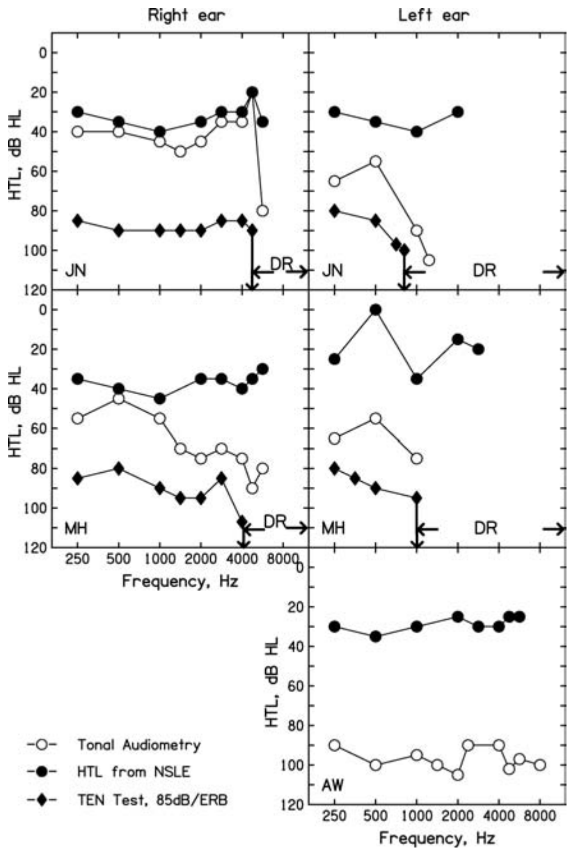

Fig. 1. Hearing thresholds determined with the use of tonal audiometry, the NSLE method and the TEN test.

We decided to calculate IGs and all parameters necessary to hearing aid fitting for *Siemens Artis SP* and *Siemens Cielo SP* hearing aids. The *Siemens Artis SP* is a digital hearing aid with 12 frequency channels available for independent amplification. Similar calculation were performed for *Siemens Cielo SP* hearing aid with six frequency channels. Results of the NSLE expressed as a correlation coefficient between sound pressure changes on the original sound track and perceived changes in loudness are shown in the first row of Table 1. As can be seen in Table 1, subject MG achieved the worse result, while the other ones did the loudness estimation test fairly well. Subject MG was excluded from further investigation. Subject AW had an cochlear implant in the right ear, so that ear was not tested directly. For that subject the measurements were possible to perform only for the left ear with the behind the ear (BTE) hearing aid, due to profound hearing loss.

Additionally, in the second row of Table 1, reaction time (obligatory parameter for the NSLE method) is shown. In rows 3–5 averaged values for the activation levels of the Automatic Gain Control – Output type (AGCO) in dB SPL, compression coefficients for the AGCO and activation levels for the Peak Clipping system (PC) in dB SPL are shown.

Table 1. Results of the NSLE expressed as a correlation coefficient and details for hearing aid fitting predicted from the NSLE.

		Subject			
		JN	MH	AW + BTE	MG (excluded from investigation)
Correlation coefficient for NSLE	Right ear	+0.76	+0.88	–	−0.21
	Left ear	+0.67	+0.87	+0.72	−0.21
Reaction time [ms]	Right ear	416	281	–	350
	Left ear	420	762	588	619
Activation level for AGCO [dB SPL]	Right ear	40.0	84.7	–	
	Left ear	82.5	73.7	78.6	
Compression coefficient for AGCO	Right ear	0.82	1.91	–	
	Left ear	1.1	1.5	1.36	
Activation level for PC [dB SPL]	Right ear	75.7	108.9	–	
	Left ear	110.0	104.3	110.0	

The compression coefficient of 0.82 obtained for the right ear of subject JN should be treated as an artifact and excluded from the parameter set, as a value of less than 1 means expansion, not compression. Parameters listed in rows 3–5 were also known for 12 frequency bands of *Artis SP* and 6 frequency bands *Cielo SP* but because they were very detailed, we did not present them in this paper.

To obtain further insight into the hearing loss of investigated patients we performed the speech audiometry test. Phonetically balanced Polish language discrimination test and detection test based on numbers NLA-93 [6] were presented monaurally via headphones. An example result of the speech audiometry test is shown in Fig. 2, for subject MH. The data in figure confirm the expected difficulties in speech intelligibility. It should be noticed that in a numerical test (redundant, easy test) the subject was able to obtain 100% of intelligibility provided the amplification was sufficient. However, results for one-syllable word test (difficult, low-redundant) performed for the left ear confirmed

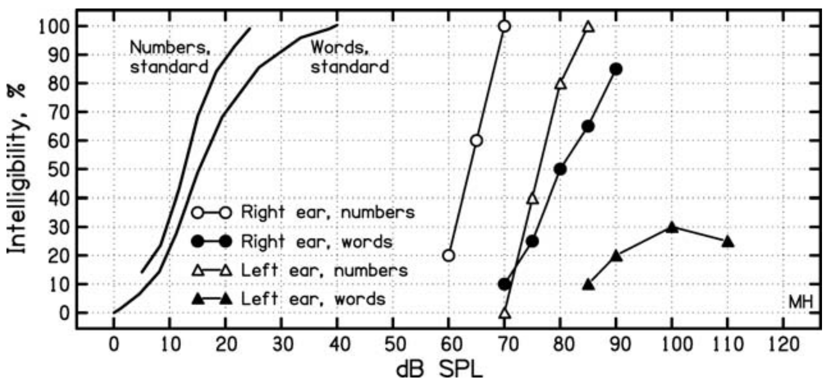

Fig. 2. Speech audiometry results.

profound hearing loss of cochlear origin [7] and significant difficulties in speech intelligibility. Similar results (not presented in Fig. 2) were obtained for subjects AW and JN.

Next step was to calculate insertion gains (IGs) based on the NSLE results. The results for *Artis SP* and *Cielo SP* were similar, so in Fig. 3 we present only those for *Artis SP*. The IGs (for *Siemens Artis SP*) calculated for subjects JN, MH and AW, predicted by the NSLE, were compared to the gains predicted by other commonly used hearing aid fitting methods (POGO II, DSL i/o, NAL NL-1), Fig. 3.

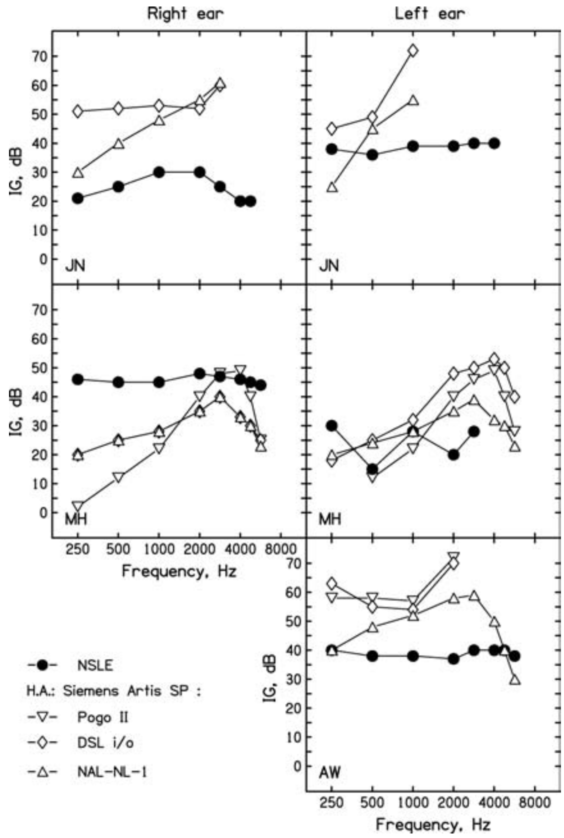

Fig. 3. Insertion gain predicted by the NSLE method and three classical methods.

The Pogo II method was not applied to subject JN because it is dedicated to profound hearing losses (for average hearing loss greater than 65 dB HL) and is not applicable to the hearing loss of subject JN. Two other classical methods (NAL-NL-1 and DSL i/o) are by definition dedicated for medium hearing losses (for average hearing loss smaller than 65 dB HL). Those methods were used for estimation of the IG for subjects MH, JN and AW. However, in the case of subject AW, we are aware of the deep hearing loss and from classical point of view the Pogo II method should be the best for this subject. We must admit that in the case of application to deep hearing loss the NSLE method needs further investigation.

Our aim was to compare IGs predicted from the NSLE and those predicted from classical methods. Generally, the gain calculated from the NSLE method was lower than the gains predicted by classical methods, except for the case of the left ear of subject MH. This general observation is in agreement with published reports and our previous work [2, 4–5]; the reports published in the literature postulate significant reduction of the IG in the frequency interval covered by the DR. The report mentioned above [5] was based on vowel-consonant-vowel (VCV) material. Our results confirm the need of IG reduction in the case when the sound material is more complex. At the moment we are not able to explain why the IG predicted by the classical methods for the left ear of the subject MH were lower than the IG predicted by NSLE. To answer this question and verify our calculations further experiments are in progress.

4. Conclusions

- In the case when no significant improvement in speech intelligibility is obtained after hearing aid fitting made with the use of a classical method, a detailed cross checking analysis of all available audiological data is postulated.
- When the occurrence of a dead region is possible, the TEN test must be done.
- Results presented in this article show that hearing aid fitting for patients with dead regions, based on the NSLE procedure is a promising and powerful method leading improved speech intelligibility.
- Further work is in progress. At present we are testing the usefulness of multichannel digital hearing aids for DRs patients to determine the optimal number of processing channels and clarify the problems raised in this work.

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