Scaling of Loudness by Children Using the NSLE Method

D. Hojan-Jezierska¹, O. M. Stieler²,³

¹ Department of Biophysics, Poznan University of Medical Sciences, Fredry 10, PL 61-701
² Institute of Acoustics, Adam Mickiewicz University, Umultowska 85, PL 61-614
³ Department of Otolaryngology University of Medical Sciences, Przybyszewskiego 49, PL 60-349 Poznan, Poland

Abstract

Experience in adjustment of hearing aids indicated the need of using diagnostics method based on environmental and music signals, while a comprehensive representation of hearing perception is affected by many factors. Therefore, effective methods based on the use of environmental sounds are under intense development. An earlier study in a group of adults with correct and impaired hearing has proved the diagnostic value of the method for evaluation of hearing ability of children with the use of a music signal. The possibility of application of the loudness scaling by the NSLE (Natural Sound Loudness Estimation) method as hearing tests in children age 7-15 has been studied. The ability of subjective determination of changes in the signal loudness, (changing in time) on a category scale has been tested.

Keywords: Loudness scaling, category unit, subjective response

Introduction

Clinical study of the hearing aid fitting has indicated the need of using methods other than those of classical pure tone audiometry [1]. The use of methods based on natural signal perception permit a simultaneous testing of the majority of psychoacoustic characteristics of the hearing process, determining the quality of perception. The NSLE (Natural Sound Loudness Estimation), method combines the assumptions of the Würzburger Hörfeld Skalierung (WHS) - scaling field method, concerning a subjective evaluation of the loudness of synthetic-stationary signals on a category scale and the Stevens thesis of an absolutely coupling between the values of the category scale assessment and subjective sensation, the same for the normal and impaired hearing patients.

Experimental procedures

The subjects were 12 normally hearing children age 7-15, elementary school pupils. In the experiments the relation between the amplitude changes of the signal in dB [SPL] and a subjective estimation of the signal loudness in a category scale of subjective perception of loudness was studied. The testing signal was a fragment of the h-moll fugue of Jan Sebastian Bach, 188 seconds of duration [1]. The average time dynamic change was 0,9 dB s⁻¹; Lₐₐᵥ=71 dB. The same signal was earlier applied in the tests of the adults in the aim to compare the results [2]. The children were asked to follow the changes in the signal level and indicate the corresponding values describing a subjective sensation of loudness on the category scale on a computer monitor. The experiment was performed at the hearing sound of most comfortable Level (MCL). The subject’s indications [KU – category unit] were automatically recorded and stored in computer memory and then compared with changes in the acoustic sound pressure level of the signal [dB SPL]. The preliminary procedure of testing the response time (reaction time) of the child allowed assigning of a common zero point of both curves. The amplitude pressure values, changed in the time domain, were first stored in a computer memory and then sampled at
the frequency of 41.4 kHz. Correlation between loudness scaling and sound pressure level values of musical sounds in the process of fitting was estimated by average correlations coefficient R [2,3]. In sequence, each part of the signal was submitted to the following processes: the calculation of the FFT (Fast Fourier Transform) from 4096 samples reflecting the momentary values of the sound level pressures at the 98.9 ms time intervals, the division of the frequency range within which the FFT analysis was conducted; e.g. 4 defined sub-ranges. Spectral analysis of the 98.9 ms temporal numbers of each sample, in which the maximum of the total energy of the signal was concentrated in a certain frequency range. The curves have been compared using the SPSS software for Windows (LSD and Duncan -Statistic-Tests for p<0.05). The above procedure was illustrated by a few examples. This short demonstration was followed by a repeated explanation of the measuring procedure.

Results

An example response of one of the subjects J. O. (7 year old), Fig. 1a, illustrates the category evaluation of loudness perceived by children. The results of their loudness perception, thin lines [KU], are confronted with the lines illustrating the acoustic sound pressure level [dB SPL], bold lines. The curve illustrating the category evaluation by the subject relatively well corresponds to the changes in the acoustic pressure of the signal. From the data it is possible to calculate the loudness examination on the categorical scale as a function of the changes in the acoustic level of the signal, for the entire frequency range, Fig. 1 b. Mean value of the correlation coefficients R = 0.78 between the subject’s response and the signal loudness (p< 0.05) changes obtained in the group of 12 children.

Fig. 1. (a) The examples values of categorial evaluation of the signal loudness [KU] by J. O. (7 years old ); (b) Category evaluation of signal loudness as the function of its sound pressure level for the entire frequency range
Conclusions

The results of the study performed for the group of normally hearing children aged 7-15 have also indicated the following facts:

- A good correlation between the changes in the acoustic sound pressure level and the subjective evaluation of the signal loudness implies relationship between these parameters for children, too.
- Children have great capacity of perception and scaling of the loudness of music sounds.
- Determination of the response time does not give a comprehensive characteristics of a child as a patient (properly, especially with hearing problems) as the child’s attention is more easily distracted during test.
- In general, the results of the study suggest that the NSLE method could be used as a diagnostic hearing test for children; in future, perhaps, the method could be used as a tool for the optimum adjustment of the hearing aid, too. Preliminary trials definitely improve the accuracy of the scaling of loudness. The first attempts of applying the NSLE method to test hearing capacity in children with normal hearing have indicated that the children were able the scale the loudness of acoustic signals of the time changing amplitude, which means that in future the method could be used as a tool for the optimum adjustment of the hearing aid, as well as for adults.

References