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GAP DETECTION THRESHOLDS IN YOUNG MUSICIANS WITH NORMAL HEARING AND WITH VERY HIGH FREQUENCY SLOPING HEARING LOSS IN 1/3-OCTAVE WHITE NOISE CENTERED AT 4 kHz

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Gap detection thresholds in 1/3-octave white noise centred at 4 kHz were determined in young musicians with normal hearing preserved and with very high frequency sloping hearing loss. The thresholds were determined in the control group of 20 with normal hearing, i.e. flat audiogram up to 16 kHz, and in the experimental group of 15 with high frequency sloping hearing loss exceeding 30 dB at 12 kHz or at 16 kHz, the so called peculiar hearing loss. A group of 7 older subjects exhibiting also peculiar hearing loss was included for comparison. The results show gap detection thresholds in the normal hearing subjects ranging from 1 ms to 6 ms, which are in good agreement with the earlier data from the present authors. However, few examples of higher gap detection thresholds (11, 26 ms) in normal hearing were also observed. For the experimental group with high frequency sloping hearing loss at 12 kHz or at 16 kHz, the gap detection thresholds found were on the average significantly higher ranging from 6 ms to 26 ms. In the group of older subjects gap detection thresholds were on the average still significantly higher.

1. Introduction

Temporal acuity or temporal resolution of the hearing system provides ability to follow rapid changes of the signal with time. Simple and quite often used measure of temporal resolution is the gap detection threshold in continuous stimulus or between two bounding stimuli. This measure was introduced by Penner, see PENNER [13], for the determination of the decay time of auditory sensation.

Numerous investigations show that the gap detection threshold is larger in the subjects with sensorineural hearing loss i.e. these subjects can detect only larger gaps, e.g. TYLER *et al.* [17], BUUS and FLORENTINE [1], GLASBERG *et al.* [2], IRWIN and MCAULAY [4], JAROSZEWSKI *et al.* [5]. However, it was also reported that the gap detection thresholds are almost identical in normal hearing and hearing-impaired, at least for the gaps in the sinusoidal stimulus, e.g. MOORE and GLASBERG [9], MOORE *et al.* [10].

Gap detection threshold is larger in elderly subjects as reported by for example SCHNEIDER *et al.* [15], SCHNEIDER and HAMSTRA [14], NING-JI HE *et al.* [12] and

Snell [16]. However, also in that respect controversial data were reported, e.g. Moore *et al.* [11]. Typical gap detection thresholds in noise in normal hearing subjects and for presentation level above 30 dB SL amount from 2 to 3 ms up to approximately 10 ms, e.g. Moore [8], Green [3], Glasberg *et al.* [2]. In cases of hearing loss of 30 – 70 dB the gap detection thresholds are usually but not always larger and fall in the range from approximately 10 to 30 ms, e.g. Glasberg *et al.* [2], Jaroszewski *et al.* [7].

In the present report gap detection thresholds in noise, found in the subjects with normal hearing and with very high frequency rapidly sloping hearing loss (the so called peculiar hearing loss) are presented. This work was undertaken to find out if the peculiar hearing loss present in some young musicians (largely playing percussion and brass wind instruments, e.g. Jaroszewski [5], Rogowski *et al.* [6], Jaroszewski *et al.* [7]), affects temporal acuity of the hearing system. No data referring to this particular question could be found in the literature.

2. Procedure and equipment

Hearing thresholds were determined with the use of the clinical audiometer Interacoustics AC 40 in the mode of tonal audiometry. The intermittent signal 250/250 ms was used at 11 standard audiometric frequencies i.e. 0.125, 0.250, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, and 8.0 Hz and at two frequencies above this band i.e. 12.0 and 16.0 kHz. Signal level was adjusted manually with the use of an electronic attenuator set at 1 dB step. In the range of low (standard) frequencies Telephonics TDH 39P headphones with MX41/AR cushions were used, while in the range of high frequencies (12 and 16 kHz) Koss HV PRO with circumaural cushions were used. Data acquisition, its preliminary processing and storage were executed by IBM PC and IABASE 95 program.

Simple closed block two alternative forced choice (2AFC) procedure was used to determine gap detection thresholds. The paradigm consisted of two observation intervals lasting 2 s each, separated by 500 ms interstimulus interval. After presentation of one pair of stimuli an answer interval of the duration of 2 s followed. Such sequence of the stimuli was repeated endlessly until listener indicated the interval containing the gap. The closed block of stimuli consisted of 20 repetitions of 5 pairs containing different gap durations i.e. of 100 pairs. Each of the five pairs containing the gap was presented 10 times in the first and 10 times in the second observation interval. The succession of the pairs containing different gaps and the occurrence of gaps in the successive test trials was random. Gap detection threshold was determined for each subject from individual psychometric function as the gap duration corresponding to 75 percent correct.

The filtered 1/3-octave band noise centered at 4 kHz was used to determine gap detection thresholds. A sample of noise was transferred into digital form and linear onset and decay functions were introduced at the beginning and at the end. The onset and the decay duration were 20 ms and 1 ms correspondingly. By reversing time succession and phase a second signal was obtained with onset time 1 ms and decay time 20 ms. Each trial consisted thus of two samples of noise separated by a gap of the duration of 2, 4, 8, 16 or 32 ms. The samples of noise were so organised that the onset time of the first and the decay of the second were 20 ms each while flanks of the gap measured 1 ms.

The stimuli were presented to subjects binaurally through the Beyer Dynamic DT 911 headphones at a level of 15 dB SL. The hearing threshold of each subject was determined with the use of signal of analogical construction as the test signals. The generation of the stimuli, their time organisation, data acquisition and its preliminary processing were performed by an IBM PC running under control of the GAPDET program. A 16-bit MultiSound Fiji TurtleBeach transducer was used for digital to analog signal conversion.

Since the level of signal presentation was low, the spectral components resulting from the presence of the gap in the test signal were below the threshold of hearing of the subjects, did not affect their timbre and had no influence on the results.

3. Subjects

A group of 42 subjects participated in the experiment. 35 of them were young active musicians playing various instruments and these were aged 18 to 29, while the remaining 7 subjects were either musicians or not musicians and were aged from 28 to 69. In the group of 35 young musicians 15 were playing percussion or brass wind instruments and were so selected purposely on the grounds of the data from the earlier experiments, e.g. JAROSZEWSKI [5], JAROSZEWSKI *et al.* [7], ROGOWSKI *et al.* [6]. The remaining twenty musicians were less exposed.

Twenty young musicians of the test group were qualified as normal hearing and fifteen young musicians as hearing-impaired, on the grounds of the data from audiometric examination. As a criterion the value of hearing loss at frequencies of 12 kHz and 16 kHz only was used in selection (flat audiogram up to 16 kHz and hearing loss exceeding 30 dB at 12 kHz or at 16 kHz correspondingly). Hearing loss at these frequencies, called peculiar hearing loss earlier, is characterised by large values and very steep sloping between the range where normal hearing was preserved and the range of loss. The group of elder hearing-impaired subjects with the peculiar hearing loss was included to enable comparison of gap detection thresholds between subjects with the same hearing loss but of the different age.

4. Results and discussion

The examples of gap detection threshold psychometric functions for some subjects, selected from the three groups of subjects i.e. young normal hearing, young hearing-impaired and elder hearing-impaired are presented in Fig. 1. The results of the gap detection thresholds in 1/3-octave noise centered at 4 kHz are presented in Fig. 2 and in Fig. 3 as scatter diagrams. The gap detection thresholds related to the value of hearing loss at 16 kHz are given in Fig. 2, while the same data related to the hearing loss at 12 kHz are shown in Fig. 3. The value of hearing loss in the figures pertains always to the ear with larger loss.

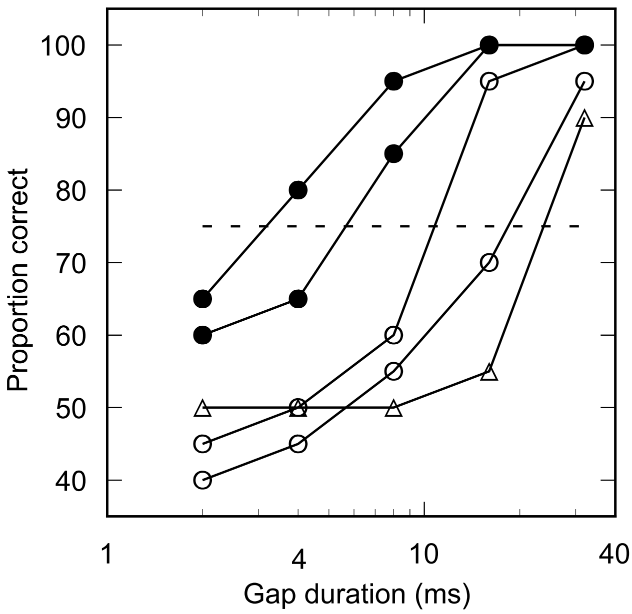

Fig. 1. The examples of gap detection threshold psychometric functions for some subjects selected from the three groups of subjects: young normal hearing (•), young hearing-impaired (○) and elder hearing-impaired (∆).

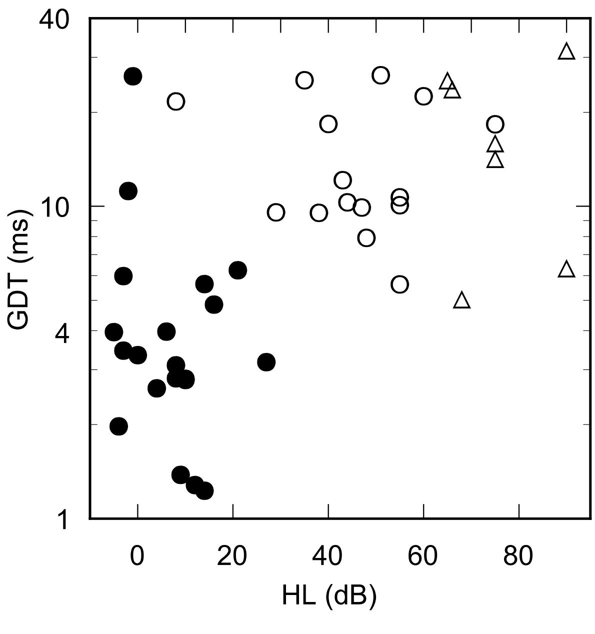

Fig. 2. The gap detection thresholds related to the value of hearing loss at 16 kHz in the better ear for the control group (•), experimental group (○) and the group of elder hearing-impaired subjects (∆).

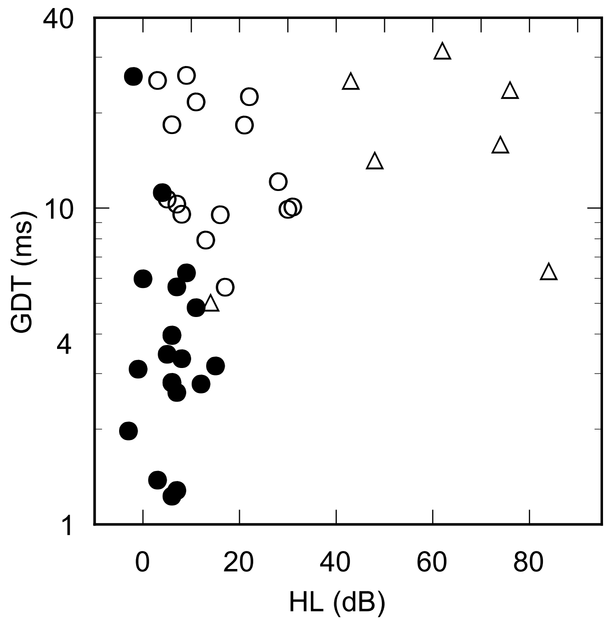

Fig. 3. The gap detection thresholds related to the value of hearing loss at 12 kHz in the better ear for the control group (•), experimental group (○) and the group of elder hearing-impaired subjects (Δ).

In both groups of young musicians tested a rather strong relation is observed between the values of the peculiar hearing loss at 12 and at 16 kHz and the gap detection thresholds. While the gap detection thresholds in normal hearing young musicians fall in the range from 1.3 to 6.2 ms, in hearing-impaired with peculiar hearing loss the gap detection thresholds amount from 5.6 to 26.3 ms. Large gap detection thresholds, but comparable to those observed in hearing-impaired young musicians was observed in the group of elder subjects with peculiar hearing loss (5.0 – 31.5 ms).

The results of the present investigation indicate, that the peculiar hearing loss which pertains to frequencies outside of the range of the standard routine audiometric testing (from 125 Hz to 8 kHz), significantly affects operation of the hearing system in time domain, decreasing its ability to follow rapid changes of the signal with time. It should be noted that the earlier published data on the relation between gap detection thresholds and hearing loss pertained exclusively to the wide band hearing loss, mostly in excess of $1\,{}^1\!/_2$ octave and in the range below 8 kHz.

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