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GAP DETECTION THRESHOLDS IN 1/3-OCTAVE WHITE NOISE CENTERED AT 4 kHz IN CHILDREN 7 – 14 YEARS OF AGE WITH NORMAL HEARING AND WITH VERY HIGH FREQUENCY SLOPING HEARING LOSS

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Gap detection thresholds in 1/3-octave white noise were measured in primary school children aged 7 – 14 with normal hearing and with very high frequency sloping hearing loss. The results show median gap detection thresholds, in the group of normal hearing children of 5.5 ms, while in the group of hearing impaired median gap detection thresholds are five times larger, i.e. 25.5 ms, reaching 50 ms in some cases.

1. Introduction

Large very high frequency sloping hearing loss or the so-called "peculiar hearing loss", JAROSZEWSKI [9], observed in substantial proportion of children tested, ROGOWSKI *et al.* [19], opens a question if it is accompanied by poorer temporal acuity, like in adult subjects, JAROSZEWSKI [11], JAROSZEWSKI *et al.* [12]. While many studies show usually poorer temporal acuity in adult subjects with sensorineural hearing loss e.g. FITZGIBBONS and WIGHTMAN [3], BUUS and FLORENTINE [1], SCHNEIDER *et al.* [20], also with high frequency sensorineural hearing loss e.g. FITZGIBBONS and GORDON-SALLANT [2] or very high frequency sloping hearing loss e.g. JAROSZEWSKI [9], in children such data are not available. However, many studies report data for normal-hearing children e.g. GROSE *et al.* [5], HALL and GROSE [6], TREHUB *et al.* [21 – 23], MORRONGIELLO and TREHUB [17].

It is recognized that in normally hearing children temporal acuity is worse than in adults; e.g. IRWIN *et al.* [7] report gap detection thresholds of 25 ms and 13 ms for children and adults, MORRONGIELLO and TREHUB [17] report 15 ms and 10 ms, while in TREHUB *et al.* [23] report, these thresholds are only 5.6 ms and 5.2 ms respectively. Large differences across studies concern also the age at which children achieve the level of temporal acuity observed in adult subjects. For instance while WIGHTMAN *et al.* [25] and also HALL and GROSE [6] found it to be 5 to 6 years, IRWIN *et al.* [7] and GROSE *et al.* [5] report the age from 9 to 11 years.

Gap detection has been widely used as the determinant of temporal resolution of the hearing system since it was first introduced by PENNER [18] in the investigation of the rate of decay of auditory sensation, e.g. TYLER *et al.* [24], BUUS and FLORENTINE [1], GLASBERG *et al.* [4], IRWIN and MCAULAY [8], JAROSZEWSKI *et al.* [10]. It is still used for that purpose in spite of some controversial data from MOORE and GLASBERG [15], saying that gap detection thresholds are almost identical in normal hearing and hearing impaired, at least for the gaps in the sinusoidal stimuli, MOORE *et al.* [16].

In the present report the gap detection thresholds in band-limited HF noise measured in normal hearing and hearing-impaired children 7 – 14 years of age are presented. The hearing impairment was of the type of very high frequency (12 or 16 kHz) rapidly sloping hearing loss (peculiar hearing loss). In some cases the children experienced also moderate selective V-dip hearing loss and/or low frequency moderate hearing loss of conductive character. The present work is an extension of the earlier reported, JAROSZEWSKI *et al.* [12] in which gap detection thresholds in band-limited noise in young musicians with normal hearing and with peculiar hearing loss were determined. It was found that in young musicians aged 18 to 29 peculiar hearing loss substantially affects temporal acuity, even that in almost all cases normal hearing was preserved at frequencies below 12 kHz.

2. Procedure and equipement

Hearing thresholds were determined with the use of the clinical audiometer Interacoustics AC 40 in the mode of tonal audiometry. An 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 kHz 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 a Telephonics TDH 39P headphones with MX41/AR cushions were used, while in the range of high frequencies (12.0 and 16.0 kHz) a Koss HV PRO with circumaural cushions were used. Data acquisition, its preliminary processing and storage were executed by IBM PC and IABASE 95 program.

A 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 until the 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 responses.

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 the 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 organized 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 the subjects binaurally through a Beyer Dynamic DT 911 headphones at a level of 15 dB SL. The hearing threshold of each subject was determined with the use of the signal of analogous construction as the test signals. An IBM PC running under control of the GAPDET software was used for the generation of the stimuli, their time organization, data acquisition and its preliminary processing. 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, and so did not affect their timbre and had no influence on the results.

The time required to complete the test was 15 min without repetition of the successive pairs of the stimuli and could amount to 30 min or more with the repetition. For some children (approximately 25%) the test turned out to be too long lasting and tiresome and therefore in these cases it was completed in two sessions.

3. Subjects

A group of 43 children selected at random from Warsaw primary schools served as the subjects. In this group 9 children had HL within the limits ±20 dB in both ears at 12 kHz and/or at 16 kHz, and 11 children had HL within ±20 dB in only one (better) ear at 12 kHz and/or at 16 kHz, the other ear being worse. These two groups of 20 children together were recognized as normal hearing.

The remaining 23 children of the group were hearing impaired with rapidly sloping hearing loss. They had HL in excess of 20 dB at 12 kHz and/or at 16 kHz in the better ear and also HL in excess of 20 dB at 12 kHz and/or at 16 kHz in the worse ear. The amount of hearing loss observed in this group reached 89 dB in one ear while it was sometimes over 32 in both. It is assumed that the children were strongly positively motivated since they were paid for their services.

4. Results

The raw data of HL and gap detection threshold are presented in Table 1. Careful examination of these data shows that almost always small gap detection thresholds are associated with normal hearing in both ears or at least in one ear. On the contrary, large gap detection thresholds are found in the subjects with substantial hearing loss usually in both ears. However, in some children large gap detection thresholds are found in spite of very good hearing thresholds (e.g. subject ID 1037). It seems that in this child, the extremely large gap detection threshold measured, resulted from comparatively poorer efficiency in handling computer-operated procedure and since does not necessarily reflect true temporal acuity.

Table 1. Raw numerical data on HL and gap detection threshold in the sample of 43 children tested; ID – subject number, GDT – gap detection threshold, HL – hearing level at 12 or 16 kHz.

ID	HL				GDT
	12k	16k	12k	16k	(ms)
	left ear		right ear		
966	12	20	13	21	23.0
978	21	44	15	26	54.1
991	16	38	5	55	22.7
1037	4	4	−1	−5	191.1
1039	−2	−1	5	−5	13.5
1056	1	55	−4	36	12.3
1186	14	2	14	15	6.7
1187	3	−1	8	24	13.1
1191	39	55	32	55	200.0
1196	52	47	17	42	14.3
1206	2	13	3	4	14.2
1211	22	69	15	35	45.0
1218	15	25	13	29	24.7
1219	7	7	19	22	27.2
1221	−2	−9	6	−3	8.0
1222	13	75	−3	37	19.0
1223	13	17	1	4	6.6
1224	40	53	19	47	31.5
1227	22	75	19	75	25.3
1228	3	9	13	17	6.3
1229	−1	6	3	8	4.0
1231	1	−4	7	8	2.6
1232	89	74	50	43	8.9
1233	25	75	74	75	17.9
1234	−1	7	3	13	5.4
1235	10	1	−7	−10	3.6
1236	3	5	−1	17	5.6
1237	5	7	4	9	3.2
1238	3	13	−4	−2	3.4
1239	12	25	−5	−10	10.3
1240	1	−4	−5	−2	3.3
1241	47	75	38	75	22.5
1242	57	69	> 75	> 75	18.0
1293	34	27	50	40	46.1
1294	3	7	9	1	5.0
1295	13	32	17	75	19.4
1296	8	17	13	30	19.5
1297	7	10	9	23	5.0
1298	4	40	6	28	16.0
1299	12	23	8	19	25.8
1300	19	55	75	>75	25.3
1301	11	39	19	55	13.6

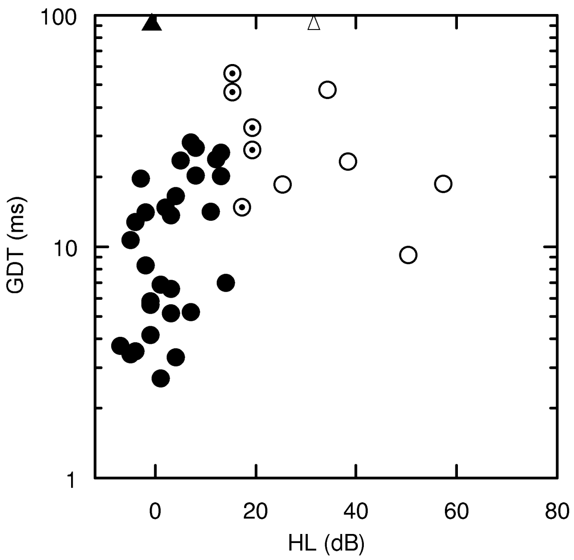

Fig. 1. Scatter diagram of the gap detection threshold at 12 kHz relative to the hearing level in the better ear, in the sample of 43 children; • – HL ≤ 20 dB in both ears, ⊙ – HL > 20 in one ear, ◯ – HL > 20 dB in both ears, ▲, △ – GDT > 100 ms.

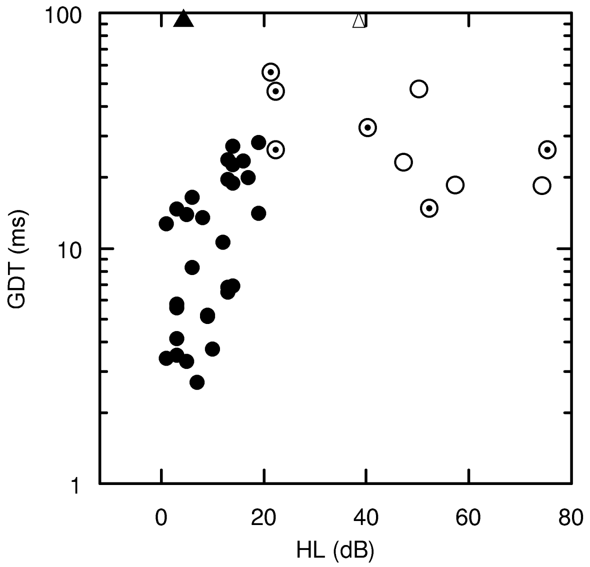

Fig. 2. Scatter diagram of the gap detection threshold at 12 kHz relative to the hearing level in the worse ear, in the sample of 43 children; • – HL ≤ 20 dB in both ears, ⊙ – HL > 20 in one ear, ◯ – HL > 20 dB in both ears, ▲, △ – GDT > 100 ms.

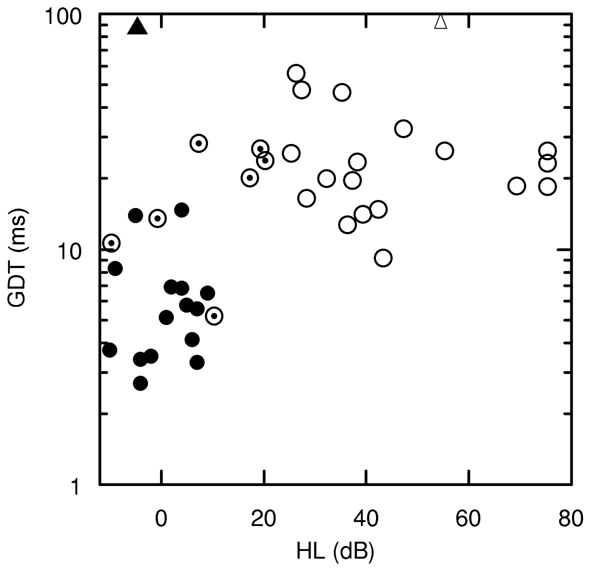

Fig. 3. Scatter diagram of the gap detection threshold at 16 kHz relative to the hearing level in the better ear, in the sample of 43 children; • – HL ≤ 20 dB in both ears, ⊙ – HL > 20 in one ear, ◯ – HL > 20 dB in both ears, ▲, △ – GDT > 100 ms.

The median value of gap detection threshold in the present experiment amounts to 5.5 ms for normal hearing and to 22.5 ms for hearing impaired with both ears impaired, which roughly corresponds to the data reported in the literature. Scatter diagrams of the gap detection thresholds relative to the hearing level at 12 kHz in the better ear and in the worse ear are presented in Fig. 1 and in Fig. 2, correspondingly. Scatter diagrams of the gap detection thresholds relative to the hearing level at 16 kHz in the better and in the worse ear are presented in Fig. 3 and Fig. 4.

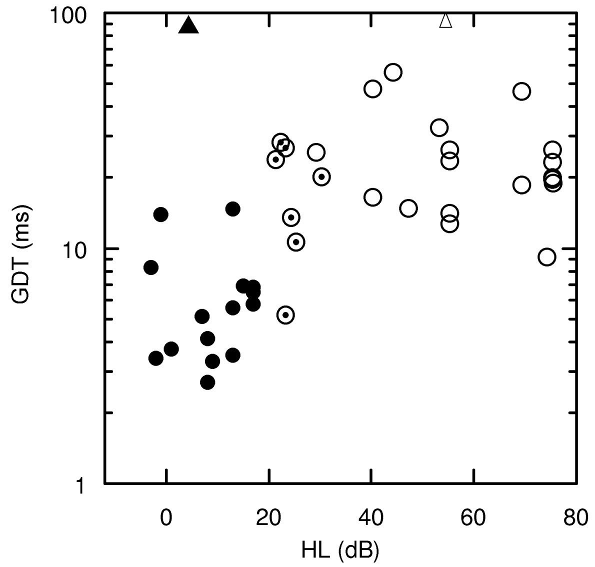

Fig. 4. Scatter diagram of the gap detection threshold at 16 kHz relative to the hearing level in the worse ear, in the sample of 43 children; • – HL $\leq$ 20 dB in both ears, ⊙ – HL > 20 in one ear, ◯ – HL > 20 dB in both ears, ▲, △ – GDT > 100 ms.

5. Discussion

The whole group of 43 children recruited from the population of the pupils in Warsaw primary schools shows very high degree of hearing impairment. Only 20 of the group of 43 were recognized as normal hearing although in 11 cases normal hearing (within ±20 dB) was preserved in only one ear. If normal hearing was recognized in those only who had both ears not impaired, it would give a figure of only 20% normal hearing in the tested sample. This figure is in agreement with the earlier findings, JAROSZEWSKI *et al.* [14], concerning hearing impairments in school children from Warsaw primary schools. Large gap detection thresholds in the hearing impaired children result evidently from that impairment. Procedure induced errors as in case of the subject ID 1037 are recognized as marginal.

6. Conclusion

The net result of the present investigation is that the very high frequency sloping hearing loss found in school children affects temporal resolution in a substantial degree, similarly as in the case of adult subjects, JAROSZEWSKI [11], JAROSZEWSKI *et al.* [13]. While in the case of adult subjects the impairment of temporal acuity can be attributed to the long history of life auditory experience, the same effect in school children seems to indicate quite astonishing similarity and is rather alarming.

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