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SOUND PRESSURE LEVELS IN EMISSION OF PERCUSSION INSTRUMENTS DURING TRAINING SESSIONS

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Sounds of selected percussion instruments played in individual training sessions of students-percussion players were recorded and analysed. In statistical signal analysis the "impulsiveness" in terms of $L_{\max} - L_{\text{eq}}$ and in terms of kurtosis, as an alternative measure were determined. Signal recording and spectral analysis were performed in the frequency range up to 96 kHz.

1. Introduction

The effects of exposure to sounds of percussion instruments were observed already in early investigations pertaining to the hearing damage risk in musicians, e.g. JAHTO and HELLMAN [8], GRYCZYŃSKA and CZYŻEWSKI [6], AXELSSON and LINDGREN [1]. These observations were next confirmed by the data from KARLSSON *et al.* [10], OSTRI *et al.* [11] and recently by the data from remarkable work by FEARN [5]. However, also conflicting data were reported, e.g. WESTMORE and EVERSDEN [15], JOHNSON *et al.* [9], in which no correspondence was found between the instrument type and hearing loss.

It should be noted, that in all the investigations cited, except for that by JOHNSON *et al.* [9], hearing thresholds were determined in the frequency range from 0.25 or 0.5 kHz to 8 kHz only. Also, hearing losses up to 30 dB (without correction for the loss specific for the given age) were, as it seems, underestimated, KARLSSON *et al.* [10], ROYSTER *et al.* [13]. Selective hearing loss (V-dip type) of the order of 20 dB at 4 or 6 kHz (KARLSSON *et al.* [10]) or high frequency sloping hearing loss reaching 28 dB (over 10 dB after correction for age, ROYSTER *et al.* [13]) should not be neglected either.

In a remarkable work by FEARN [5] percussion players were identified as exposed to probably the highest peak sound pressure levels in music exposures, reaching 140 – 146 dB or even 148 dB (depending on instrument type, room characteristics etc.) and thus experiencing the highest risk of hearing damage. In the examined sample of musicians aged 16 – 30, Fearn found hearing loss over 15 dB at 4 kHz or 20 dB at 6 kHz in 46% of percussion players, while in musicians playing brass, woodwinds and strings the proportion with hearing loss was significantly lower. It should be noted according to FEARN [5], that extreme sound pressure levels are present in the orchestra in the neighbourhood of percussion and brass section. In these places, often second violins, violas and violoncellos are situated, sometimes also woodwinds. Hence, the effects of exposure to percussion sounds pertain to a high degree also to other musicians, a fact which very often is disregarded. SCHACKE [14] in turn, found supernormal hearing loss in 60% in a sample of percussion players examined.

Examination of the hearing thresholds in young percussion players in the frequency range up to 16 kHz presented in the earlier paper, ROGOWSKI *et al.* [12] estimated the specific high frequency sloping hearing loss as 24 dB higher on the average than in musicians who were less exposed to percussion sounds. In that paper a preliminary analysis of the selected xylophone sounds is given; an instrument that is recognised as very annoying by percussion players themselves. In some selected xylophone sounds the determined rise time was lower than 10 μs, with the resultant very high frequency components, HAMERNIK *et al.* [7].

It may be worthwhile to note that small rise times and high values of the sound pressure level in acoustic pulses may result in a hearing loss of specific character. Such loss is often moderate in the range of low and mid frequencies and reaches the largest values in the frequency range between 8 and 20 kHz, i.e. in the range where normal audiometric examination is executed only occasionally, FAUSTI *et al.* [4].

Earlier observations (ROGOWSKI *et al.* [12]) indicated the need of performing the analysis of the emission of percussion instruments in the frequency range up to 96 kHz. Preliminary results of that analysis are given in the present report.

2. Procedure and apparatus

The analysis was performed on the sounds of selected percussion instruments, namely: xylophone, snare drum, A-Due cymbals, tube bells, orchestral bells, kettledrum and a set of drums. The measurements were carried out in the practice rooms of the Academy of Music. Music selections typical for practice sessions isolated sounds and orchestral music selections played with various different drumsticks were recorded.

Sound signal was picked up from the acoustic field using 1/4″ condenser microphone Brüel & Kjær type 4135 with follower Brüel & Kjær type 2669. The microphone was situated on a tripod near the instrument at a distance corresponding to the position of the head of the musician. This signal, amplified in a Brüel & Kjær amplifier type 2690 "NEXUS" was sampled at frequency 192 kHz with the use of 12-bit A/D converter Quatech DAQ1201 and recorded on a hard drive of a class IBM PC. Spectral analysis of the recorded signals was performed with the use of the MATLAB program procedures. Statistical analysis and computation of kurtosis was done using WaveStat program prepared by the second author. Kurtosis is a ratio of the fourth moment of the distribution to the square of the second moment (DWEYER [2]). It is a measure of the "peakedness" of the distribution and was used as a measure of impulsiveness (ERDREICH [3]).

3. Results

The results of spectral analysis of short (120 s) music selections played on a xylophone, marimba, snare drum and cymbals are presented in Fig. 1. The spectra were calculated using Hanning window 1024 samples long and 50% overlapping. The distribution of the instantaneous sound pressures for the same music selections are represented in Fig. 2. The results of statistical analysis of music selection played on eight percussion instruments are given in Table 1. In case of xylophone the results are for two different kinds of drumsticks.

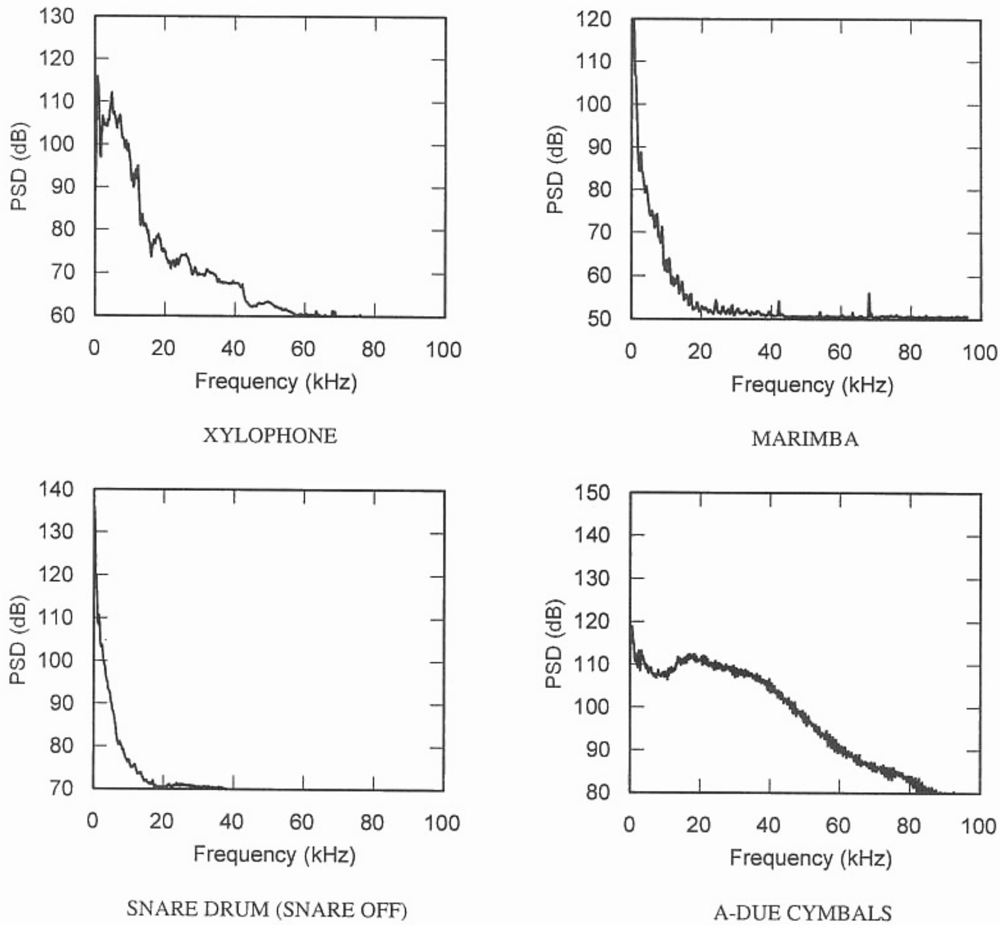
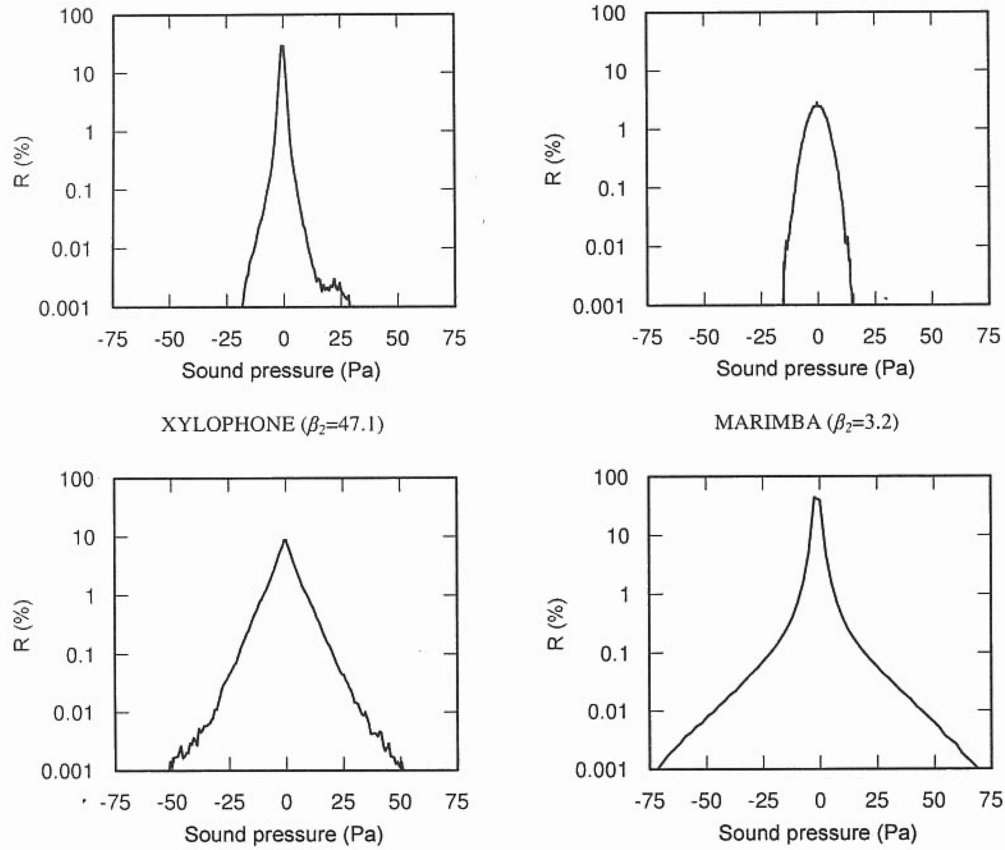


Fig. 1. Power spectral density spectra of the sound samples of four percussion instruments: xylophone, marimba, snare drum and A-Due cymbals.

Normalised functions of the effective frequency band for the four music instruments i.e. xylophone, marimba, snare drum and cymbals are represented in Fig. 3. Figure 4 presents initial phase of the sound G7 played on a xylophone with the use of plastic and



XYLOPHONE (β_2=47.1) MARIMBA (β_2=3.2)

SNARE DRUM (NO SPRING) (β_2=8.2) A-DUE CYMBALS (β_2=67.1)

Fig. 2. The distribution of instantaneous pressure for sample sounds of four percussion instruments: xylophone, marimba, snare drum and A-Due cymbals; in parentheses the values of kurtosis.

Table 1. Statistical parameters of selected sample sounds of percussion instruments tested.

No.	Musical instrument	L_{peak} (dB)	L_1 (dB)	L_{eq} (dB)	I (dB)	CF (dB)	β_2
1	Orchestral bells	119.5	99.0	87.4	11.6	32.1	81.5
2	Tubular bells "Premier"	118.2	109.0	99.4	9.6	18.8	4.4
3	Kettledrum "Ludwig"	125.0	117.2	107.5	9.7	17.5	4.7
4	Xylophone "Musser Kelon 51"$^{(*)}$	126.2	108.4	97.3	11.1	28.9	47.1
5	Xylophone "Musser Kelon 51"$^{(**)}$	126.0	107.7	96.8	10.9	29.2	37.4
6	Marimba "One" Ron Samuels	117.8	113.9	105.6	8.3	12.2	3.2
7	Cymbals A-Due	136.7	119.5	106.3	13.2	30.4	67.1
8	Snare drum "Yamaha" (snare off)	130.8	120.8	110.2	10.6	20.6	8.2
9	Snare drum "Yamaha" (snare on)	127.5	117.9	106.5	11.4	21.0	9.3
10	Drums	132.8	124.3	114.8	9.5	18.0	4.4

$^{(*)}$ — plastic sticks; $^{(**)}$ — wooden sticks; CF — crest factor.

wooden drumsticks. Significant differences in the rise time for so produced sounds with practically constant peak values are evident.

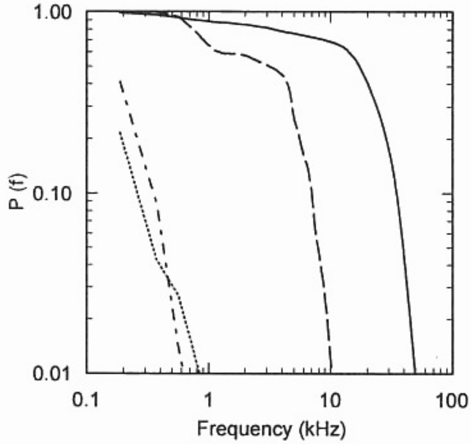


Fig. 3. Normalised effective frequency bands for sample sound of: xylophone — dashed line, marimba — dashed-dotted line, snare drum — dotted line and cymbals — solid line.

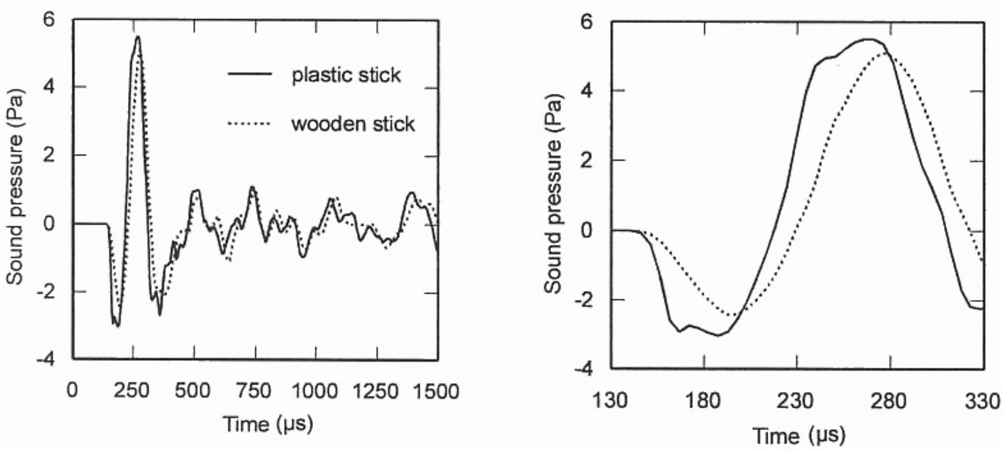


Fig. 4. Isolated G7 xylophone sound; temporal course of acoustic pressure for wooden and plastic drumsticks.

4. Discussion and conclusion

The analysis shows dangerously high sound pressure levels in sounds emitted by percussion instruments during individual practice sessions in classrooms of the Academy. Equivalent sound pressure levels for drums, snare drum, kettle-drums, marimba and cymbals reach 105 – 115 dB while peak sound pressure levels are in excess of 136 dB.

The characteristic of percussion sounds is significant impulsiveness which in terms of $I(L_1 - L_{eq})$ and $I(L_{peak} - L_{eq})$ amounts to 8.3 – 13.2 and 12.2 – 32.1 dB correspondingly. The values of kurtosis of the distribution of instantaneous sound pressure values differentiate the tested group of percussion instruments. Large kurtosis was found for xylophone, cymbals, and orchestral bells i.e. instruments without resonators.

The spectral analysis shows the presence of significant values of spectral power density in the range of supersonic frequencies for xylophone and for cymbals. In the case of cymbals the amount of energy emitted in the frequency range between 18 and 100 kHz equals the energy emitted in the auditory range.

In cymbals and particularly in xylophone sounds very small rise times were found amounting in some cases to only few microseconds. As it seems only kurtosis as a measure of impulsiveness is sensitive to this parameter. As mentioned, the xylophone with its rapid sound onset, is recognised by musicians as an instrument, which exerts a very heavy load on the hearing system.

According to the working hypothesis rapid sound onsets and relatively large sound pressure levels in xylophone may underlay the unpleasant effect of "blocked ears" in percussion players and may result in specific hearing loss in the frequency range between 8 – 16 kHz.

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