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Sound exposure of musicians in a pit orchestra

A. Boasson, R.A. Metkemeijer and J.H. Granneman
Adviesbureau Peutz & Associés B.V.
PO Box 696, 2700 AR Zoetermeer, The Netherlands

Abstract

Musicians of orchestra are exposed to high sound levels, that depend on the specific location and instrumental group within the orchestra. Noise induced hearing loss strongly relates to the average daily dose influenced by different circumstances. For one year the sound level distribution for all representative members of a professional pit orchestra have been determined by measurements during most activities. Long term hearing effects of the derived daily doses are expected to be limited, and only for certain groups in the orchestra. Besides hearing loss, annoyance and functional limitations due to high sound exposure for certain orchestra members caused by instruments of colleagues is an important practical issue. Solving the latter problem will also reduce the risk for hearing loss to an acceptable level.

1. Introduction

The Dutch government wishes to make an agreement with the Central Organization of Symphonic Orchestra's about the way to control the occupational sound exposure of musicians of member orchestra's. Besides a literature investigation (see references) a long time sound survey in an orchestra was carried out to be able to assess the situation of orchestral musicians and to recommend practicable measures. Apart from permanent occupational hearing loss (NIPTS: noise induced permanent threshold shift) certain parts of the performance create temporary hearing loss (TTS: temporary threshold shift). This affects the labor conditions of musicians in a negative way. Although no general limits exist for this latter effect, it is felt that an integral solution for both problems should be aimed at.

2. Research Strategy

It is well known that high sound levels occur within orchestra. To be able to assess the risk for permanent hearing loss it is important to determine these sound levels as accurate as possible. The sound exposure depends strongly on the repertoire, the configuration of the orchestra, specific location and instrumental group, duration of rehearsals and performances. Only if the sound levels are measured during a long period of time a representative result can be achieved. For this reason sound measurements have been carried out during almost all the activities in one year of the Dutch Ballet Orchestra (DBO). Different music pieces and orchestral settings have been considered (rehearsals and performances) and measuring locations as much as practically possible. Besides availability for this survey the DBO was

selected because the occurring sound levels are expected to be higher than in other orchestral settings because of the relatively small rehearsal room and the orchestral pit (worst case).

3. Measurements

In one year during almost all activities sound levels were determined at 18 varying locations. Every time 8 positions were actually measured. Each year consists of about 18 projects with different repertoire and number of musicians. Measurements were carried out during 178 of the 258 activities between 19th of Jan 1998 and 2d of March 1999. Twenty representative groups of musicians have been considered. By comparison of measurement results at varying positions within the orchestra the sound levels at every position have been derived. Thus, the sound levels are determined from directly measured sound levels, values derived from measurement results under comparable circumstances and calculated values for adjacent musicians. Table 1 shows an example of survey results: for different groups of musicians the equivalent sound levels related to the whole performance/rehearsal as well as its duration are given.

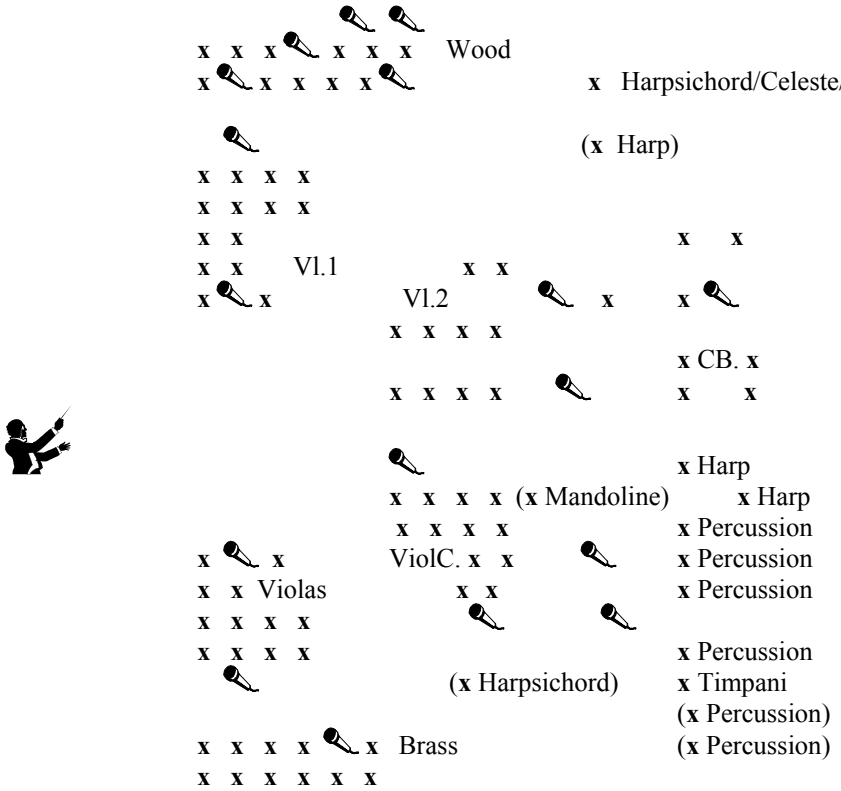
Table 1: Example of sound levels near DBO-musicians.

Equivalent sound levels in dB(A)*; duration in minutes between brackets					
Instrumental group**	**23-1-'98 rehearsal**	**26-1-'98 rehearsal**	**29-1-'98 rehearsal O**	**29-1-'98 rehearsal A**	**30-1-'98 galaconcert**
First violins f	**78.2** (173)	**72.9** (188)	79.4 (173)	**80.4** (160)	**81.8** (159)
First violins b	**75.8** (173)	**73.4** (188)	**82.0** (167)	**81.6** (160)	**79.8** (159)
Sec. violins f	80.8 (173)	**74.4** (188)	**83.3** (173)	80.8 (160)	80.8 (159)
Sec. violins b	**77.9** (173)	**84.8** (188)	80.5 (167)	**74.4** (168)	**77.9** (191)
Violas f	**76.2** (173)	76.2 (188)	76.2 (173)	76.2 (160)	76.2 (159)
Violas b	**82.0** (173)	**75.4** (188)	**82.8** (173)	**84.1** (170)	**84.7** (188)
Violoncelli f	*76.2* (173)	*76.2* (188)	*76.2* (173)	*76.2* (160)	76.2 (159)
Violoncelli b	**73.9** (173)	**72.9** (189)	**82.8** (167)	**81.5** (160)	**82.3** (185)
Double bass	82.0 (173)	82.0 (189)	**82.2** (173)	**81.7** (160)	82.0 (159)
Harp	⇔	81.7 (188)	**81.7** (167)	81.7 (160)	81.7 (159)
Flute/clarinet	*84.6* (30)	*84.6* (140)	*84.6* (173)	*84.6* (160)	*84.6* (159)
Oboe/bassoon	83.6 (30)	83.6 (140)	83.6 (173)	**83.4** (160)	**83.7** (159)
Brass	87.4 (30)	**86.3** (140)	87.4 (173)	**88.3** (170)	87.4 (159)
Horns	*88.4* (30)	*88.4* (140)	*88.4* (173)	*88.4* (160)	*88.4* (159)
Percussion	⇔	**86.3** (140)	**84.6** (171)	85.5 (160)	85.5 (159)
Timpani	⇔	**86.3** (140)	**84.6** (173)	85.5 (160)	85.5 (159)
Harpsichord	⇔	⇔	81.7 (173)	**81.7** (160)	81.7 (159)
Piano	⇔	82.2 (188)	**82.2** (173)	82.2 (160)	82.2 (159)

* Bold numbers: measurement results; normal numbers: derived from comparable measurements; italic numbers: calculated from measurement results at adjacent positions; ⇔ = musicians not present;
** f = front, b = back.

An example of measuring positions in a specific orchestral setting is shown in figure 1.

FIGURE 1 Measurement positions in specific orchestral setting



4. Daily dose

For each project the average sound levels has been derived. Taking into account the yearly number of projects and activities and the duration of each activity the average daily dose on a yearly base of each group of musicians has been derived; see table 2.

Table 2: Average daily dose on a yearly base (260 working days) in dB(A)

Instrumental group	average daily dose in dB(A)	Instrumental group	average daily dose in dB(A)
First violins f	78	Flute/clarinet	83
First violins b	80	Oboe/bassoon	82
Second violins f	79	Brass	86
Second violins b	81	Horns	86
Violas f	79	Percussion	84
Violas b	84	Timpani	83
Violoncelli f	79	Piano	80
Violoncelli b	81	Celeste	81
Double bass	80	Harmonium	70
Harp	81	Harpsichord	74

5. Assessment

Dutch labor legislation states that sound reducing provisions are obliged if equivalent levels during working activities exceed 85 dB(A), unless it can be shown that the average daily dose does not exceed 80 dB(A). As can be seen from table 2 the latter sound limit is exceeded for different groups of musicians. According to this legislation one should basically regard the sound levels during each concert or rehearsal. However it appears that the sound levels differ from project to project significantly, depending on the specific group of musicians. Since the risk for hearing damage depends on the sound exposure during several years, an average daily dose on a yearly base is a reasonable approach.
It is interesting to compare the exceeding of the daily dose limit of 80 dB(A) with the NIPTS as can be expected from ISO 1999. Table 3 shows these NIPTS values for an example of groups of musicians related to an exposure time of 10 and 30 years respectively. These NIPTS values are moderate compared with the threshold shift related to age.

Table 3: NIPTS in dB conform ISO 1999 after 10 respectively 30 years of exposure

Instrumental group	**daily dose**	**500 Hz**	**1000 Hz**	**2000 Hz**	**3000 Hz**	**4000 Hz**	**6000 Hz**
First violins b	80	0/0	0/0	0/0	0/1	1/2	0/0
Sec. violins b	81	0/0	0/0	0/0	0/1	2/2	1/1
Violas b	84	0/0	0/0	0/0	2/3	4/5	2/3
Violoncelli b	81	0/0	0/0	0/1	0/1	2/2	1/1
Flute/clarinet	83	0/0	0/0	0/0	2/2	3/4	2/2
Brass	86	0/0	0/0	½	3/5	5/7	¾
Percussion	84	0/0	0/0	0/1	2/3	4/5	2/3
Timpani	83	0/0	0/0	0/0	2/2	3/4	2/2

6. Considered measures

Based on the sound measurements and computer model calculations potential effects of certain ‘physical’ sound reducing measures are evaluated.

- To increase the distance between brass/percussion/woodwinds and strings from 1,5 m to 3 m will reduce the equivalent sound levels of musicians directly before these groups with 1,5 a 2,5 dB. An additional doubling of distance will mainly reduce peak levels but not so much the equivalent sound levels. However, such an increase of distance is not feasible in a pit situation and will furthermore influence the ensemble conditions in a negative way. One could consider to locate brass in one row instead of two rows after each other and to increase the distance with the musicians group before it.
- To locate trumpets and trombones higher. Because of the directional properties of these instruments the peak sound levels of musicians in front of them can be reduced by approximately 3 dB (assuming all these instruments are directed in a similar way). The influence on the average daily dose is moderate, possibly 1 dB. Furthermore it disturbs the balance in the orchestra which demands adaptation of playing habits.
- For woodwinds a similar measure could be considered, although the effect is slightly less because of different directional characteristics of these instruments.

- One could consider a screen directly behind the head of musicians which are exposed to high sound levels. Peak levels could be reduced by 3 à 10 dB for brass depending on the specific orchestral configuration. The effect on the average daily dose are expected to be 2 a 5 dB. It will be clear that such screens influence the orchestral balance significantly which might not be acceptable for the conductor and/or musicians behind such screens.

Besides these 'physical' solutions one could consider organisational measures such as distribute playing hours over more musicians, rotation of positions of musicians, the choice of the repertoire related to the contribution to the average daily dose. Although these organisational solutions look a little academic, they are seriously considered, especially because it involves a limited number of musicians.

Up till now personal hearing protecting aids appear not to provide a practical solution for the majority of musicians. Main causes of that are the influence of such devices on the perception of the music sound, occlusion and bone conduction effects. In general devices which are positioned in the auditory duct are not acceptable. However, one could consider designing an active sound reducing device outside the auditory duct. Because problems occur in frequency bands from 500 Hz and up such a solution does not seem impossible. The technical possibility to adapt the characteristics of such a device to specific demands makes it worth while to initiate further research on it.

7. Ongoing research: extrapolation to symphony orchestra

By measurements differences between the sound levels in pit orchestra and symphony orchestra on stage have been determined, taking into account differences in room acoustical characteristics, orchestral setting and configuration, repertoire, rehearsal circumstances. During the same music piece sound levels in a pit respectively on stage were measured on 14 locations simultaneously. Room acoustical circumstances as well as distances between musicians appear to be relevant. From comparison of these measurement results the following appears.

The equivalent sound levels in the front groups of musicians (first and second violins, violas, violoncellos, double basses, woodwinds) are 1 à 2 dB higher in the pit than on stage because of shorter distances between musicians. The equivalent sound levels of brass work (trumpets, trombones, tubas, horns) are 2 à 3 dB higher in the pit than on stage due to the partially closed ceiling above these musicians. Another effect of this ceiling is that the contributions of these instruments to sound levels at the front musicians is lower in the pit than on stage. The same is valid for percussion. Thus, in the orchestra pit musicians at the front are exposed to equivalent sound levels that are comparable to those on stage; under and near the closed part of the pit 2 à 4 dB higher sound levels occur than on stage.

Although research is still ongoing it can be expected that in symphony orchestra on stage average sound levels occur which are 1 à 3 dB higher than in the DBO in pits mainly due to the higher number of musicians and different repertoire. The highest difference regards brass. On the other hand the duration of performances are in general shorter which leads to a 0.5 à 1.5 dB lower average daily dose. In table 4 the average daily dose for orchestra on stage are given (indicative values) related to repertoire, orchestra configuration and number of musicians.

Table 4: Average daily dose on a yearly base in dB(A); DBO research transferred to orchestra on stage (indicative values)

Instrumental group	DBO research	stage orchestra	Instrumental group	DBO research	stage orchestra
First violins f	78	79	Double bass	80	81
First violins b	80	80	Harp	81	81
Sec. violins f	79	80	Flute/clarinet	83	84
Sec. violins b	81	82	Oboe/bassoon	82	83
Violas f	79	80	Brass	86	87
Violas b	84	83	Horns	86	87
Violoncelli f	79	80	Percussion	84	85
Violoncelli b	81	82	Timpani	83	84

8. Conclusions and recommendations

An extensive sound survey has been carried out with measurements during almost all activities of a pit orchestra in one year. From this daily doses of musicians have been determined. Some groups of musicians are exposed to a yearly average daily dose around or lower than 80 dB(A), for instance the first violins, second violins (front and middle), alt violins in front, cello's in front. For 5 groups of musicians the daily dose is slightly above 80 dB(A) for instance: the second violins back, violoncellos back, harpsichord. For other groups of musicians the daily dose is significantly higher than 80 dB(A) for instance; violas back, wood flute/clarinet, horns, brass.

Research is still going to derive expected sound exposure values for symphony orchestra based on the results of the DBO.

Taking into account the exceeding of the limit of 80 dB(A) this research study confirms the conclusions from different other research studies that the risk for hearing loss of musicians due to orchestral activities is relatively low. However, high sound levels during certain parts of music are a main cause of complaints by musicians. These high sound levels during short periods of time lead to temporary threshold shifts that influence the working conditions of musicians in a negative way. It can be concluded that provisions in the orchestra only seem necessary on positions around the woodwind and brass sections and percussion of the orchestra. Besides physical sound reducing measures or specific ear protection devices, one should seriously consider organisational measures.

References

1. Doswell Royster, J., Larry H. Royster & C. Killion Mead: Sound exposures and hearing thresholds of symphony orchestra musicians. J. Acoust. Soc. Am. 89 (6) p. 2793-2803 (1991).
2. Marshall Chassin, M.: Musicians and the Prevention of Hearing Loss. Singular Publishing Group, Inc. San Diego - London (1996).
3. Meyer, J.: The Sound of the Orchestra. J. Audio Eng. Soc., Vol. 41, No. 4, p.203-213 (1993).
4. Schäcke, G.: Schalldruckpegel im Orchestergraben eines Opernhauses. Zbl Arbeitsmed 36 p. 58-64 (1986).