Proceedings of the Institute of Acoustics

WHAT IS AN 'ACOUSTICALLY CORRECT' PERFORMANCE? - MUSIC AND THE NOISE AT WORK REGULATIONS

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1. INTRODUCTION

The Noise At Work Regulations (NAWR) [1] require a noise assessment to be made when an employee is likely to be exposed at the first action level or above. A review by the Medical Research Council in 1985 [2] concluded that the risk of hearing damage to 'classical' musicians is slight, but material for some. Recent studies have shown that some musicians are exposed to levels exceeding the second action level on the concert platform [3],[4] and that violinists (and violists) may have up to 6dB difference in hearing between left and right ears [4], which is attributable to the playing of the violin and would appear to indicate that professional musicians hearing is affected by their playing.

The author is investigating noise exposure of employees during performances. Early results illustrate some of the issues.

2. TYPES OF PERFORMANCE

The above studies looked at a small selection of repertoire played by a symphony orchestra on a concert platform. This paper considers musicians playing orchestral instruments outside the typical orchestral concert. For staged performances, musicians often play in semi-enclosed orchestra pits where conditions are often more cramped than on the concert platform, which may cause an increase in sound levels. Many musicians are not part of a regular orchestra, especially those providing music for occasional theatrical performances, such as the traditional Christmas pantomime. The workload amongst freelance musicians varies considerably, with some constantly in demand and others only occasionally getting orchestral work. In addition to conventional orchestral music, there are many other music groupings, such as dance or concert bands, and many musicians also teach.

3. MEASUREMENTS

3.1 Relative exposure.

Undisturbed field measurements are preferred in Noise Guide 3 [5]. In a musical ensemble each musician will be exposed to sound (we will refer to music as sound rather than noise!) from their own instrument and from the other instruments. Depending on seating and the acoustics of the playing area, the sound field near the musicians can be measured, but the musician is usually very close to his/her own instrument. To compare free field measurements and personal dose, measurements were made of a trumpet player sitting approx. 1m behind

and slightly to the left of a viola player in an orchestra of approx. 80 musicians during a 'run through' of a work which lasted 3 hours including breaks. Both musicians wore logging dosemeters with the microphone clipped to their collar. The violists' microphone was on the right collar, to allow him to play, and pointing backwards, towards the trumpet. A sound level meter was also set up, about 0.3m from the viola players left ear, at ear height. Results are shown in Table 1.

3.2 'Modern' music.

A contemporary composer's music was No.1 in the Classic FM CD chart when his music was performed at a concert hall in London. The instrumentation was piano, string quartet, electric bass, 2 soprano saxes (doubling alto), baritone sax doubling piccolo and bass trombone doubling euphonium with additional trumpet and french horn for a few numbers. The musicians are leading players active in a variety of music fields, for whom the music was written. They were amplified and each musician had a monitor speaker, largely because of the variety of levels of the instruments. A logging dosemeter was worn by the piccolo player for the second half of the rehearsal and the first half of the performance. A normal dosemeter was worn by the soprano saxophone for the second half of the rehearsal and the 'cello for the first half of the performance. Results are shown in Table 2.

3.2 Amateur 'Concert Band'

Many musicians play for a number of years before becoming professional and not all musicians are playing in top orchestras. As an example of general music making, dosemeters were worn by a trumpet and piccolo player in a regular rehearsal of a local amateur 'concert band' with approximately 30 brass and woodwind players. Results are shown in Table 3.

4. RESULTS.

Table 1.	Relative levels			
Instrument	Meter	Duration(mins)	Leq(dB)	Lepd*(dB)
Trumpet	Dosemeter	180	96.5	92.3
Viola	Dosemeter	180	92.6	88.4
Viola	Sound level meter	180	89.6	85.4

Table 2.	Modern music				
Session	Instrument	Duration(mins)	Leq(dB)	Lepd*(dB)	Lepw*(dB)
Rehearsal	Piccolo/Bari	105	104	98.5	91.5
Rehearsal	Soprano/Alto	105	106	99	92
Performance	Piccolo/Bari	60	103.2	94	87
Performance	'Cello	60	93.5	85	78

Table 3.	Concert Band		
Instrument	Duration(mins)	Leq(dB)	Lepd*(dB)
Piccolo	120	97.5	91.5
Trumpet	120	97.0	91.0

* Lepd and Lepw are calculated according to NAWR assuming each measurement is the only noisy activity during the specified period, eg 1 session per day or week.

5. Interpretation of results.

5.1 Relative measurements.

Table 1 shows a significant difference between the free field and dosemeter measurements for the violist. This indicates that in the right ear, the players own instrument was roughly as loud as the sound from other instruments. From Royster [4] the viola may be 6dB louder in the left ear than the right ear. The dosemeter levels suggest that the trumpeter received more than twice the dose of the violist (right ear). The measurements for the viola suggest that self-exposure (i.e. the musicians own instrument) is the main factor, rather than other instruments. If self-exposure dominates, as musicians are usually in the near field of their own instrument, the playing environment may not be important, except that in these measurements, the trumpet and viola were on the same level, whereas on a concert platform the trumpet is usually raised above the violas. As trumpets must be played pointing at least slightly down, the violists may be more exposed on a concert platform, although the trumpet may also have to play louder for the same effect.

5.2 The modern music measurement

These measurements show the high sound levels that can be produced by today's players. It is easy to 'blame' the amplification for the high levels, but short Leq's observed during warm up, away from the amplification, were similar to those during rehearsal. Although only part of the rehearsal and performance were measured, these portions showed some musicians exceeding the allowed weekly dosage before the performance began! The 'cello levels are not dissimilar to the 'orchestral' viola.

5.3 Amateur band.

The amateur band measurements show similar exposure levels to the relative measurements. This may be co-incidence, with professional musicians making much more sound, but playing for proportionately less time in an orchestra than a concert band, but indicates that the levels measured in the first experiment were not exceptional.

6. Application of the Noise At Work Regulations.

Unlike almost all other employees, the sound musicians produce is the work that they do, not a byproduct of their work, especially if self exposure dominates. Unlike electronic music,

where musicians may be able to play to a click track, or controlled monitor signal fed through headphones, orchestral musicians are trained to perform by listening to a live ensemble, with a considerable dynamic range of listening. However, if the NAWR regulations are to be complied with, the sound must be reduced when the second action level is exceeded.

Reducing noise at source is the preferred method. Some musicians have suggested the current fashion of using 'period' instruments may reduce orchestral levels and that this could be a solution. However, 'period' instruments do not offer a solution to dance and concert bands, or contemporary music. Another way would be to restrict performances of certain works. Restricting sound levels of acoustic instruments is unlikely to be a practical solution.
Reducing the transmission path may be impractical if self-exposure dominates the exposure.
Reducing the period of exposure is the most practical solution to limiting exposure. This could result in the available work being more evenly spread among musicians, which may be considered beneficial. However, it would also limit the ability of musicians playing louder instruments to work to impractical levels, (such as one performance or rehearsal per week!) and would probably mean that leading players would have to choose between teaching or playing, which would reduce the high level of training available at present. This option may also reduce the quality of orchestras, which depends regular playing together.
Rotation of musicians may be a possibility in some cases, but is unlikely to be a solution where the music is written for specific performers, or where a small number of performances are given by an orchestra which must have regular experience of playing together, which is the vast majority of music performed in the UK.
Use of ear defenders is a last resort. Although this option is a solution in some cases (and the Musicians Union recommend one make to their members) these are generally worn during 'pop' music where the dynamic range is not as wide as in 'orchestral' music. Some musicians do wear ear defenders whilst playing classical music, but these are usually string players worried by brass or percussion, not the people measured as being most exposed, the brass players themselves.
Instrument manufacturers should presumably provide warning information for instruments such as trumpets and piccolos. Perhaps warning notices should be attached to scores of new music!

The regulations do not cover people who are not at work, so the amateur band is not at risk of breaking the law.

The requirements of NAWR are limited by the test of being 'reasonably practical'. In considering what is reasonably practical, (and also in considering granting an exemption to weekly averaging[8]) an important consideration is likely to be the risk of hearing damage to the persons affected.

7.Risk of Hearing Damage.

Royster [4] found that orchestral musicians had higher hearing thresholds than a typical

population sample, not exposed to industrial noise. However, none of the musicians would be considered to have a hearing handicap by applying BS5330 [9] to Royster's results, as summarised in Table 4. The differences of the measured HTL $_{(1,2,3)}$ from an otologically normal non-exposed sample according to BS6951[10] and from the figures quoted by Robinson in HSE research [11] for a typical population exposed to the first action level since 18 years of age, are also shown, with a positive difference indicating a greater hearing threshold. The latter is an approximate comparison, as Robinson quotes figures for specific ages at 38, 48 and 58 where Royster has averaged across 10 year age bands. The linear average L_{epd}'s for instrument groups are given, although this sample is not the same as the HTL sample.

Table 4	Risk of hearing damage for an American Symphony Orchestra					
Group	Sample number	Mean age(yrs)	$HTL_{(1,2,3)}$ measured	$\Delta HTL_{(1,2,3)}$ ref BS6951	$\Delta HTL_{(1,2,3)}$ 1st Action	Mean L_{epd}
Total	59	52.4	14.5	4.3		85.5
Males	46	53.2	15.7	4.3		
Females	13	49.5	10.5	3.7		
Age 30-39	12	35.3	8.2	3.8	-3.3	
Age 40-49	12	46.3	11.9	6.0	-4.4	
Age 50-59	13	55.1	15.9	6.2	-7.1	
Age 60-69	14	64.6	20.2	4.4		
Age 70+	6	72.8	18.8	-3.1		
Violin & Viola	27	54.9	15.9	4.8		84.1
Horn & Trumpet	7	46.7	11.1	4.5		91.2
Clarinet, Flute, Bassoon & Percussion	12	48.3	14.1	5.7		86.7
Cello, Bass, Harp & Piano	13	53.9	11.5	1.4		80.6

These figures do not suggest that musicians hearing is more at risk than a typical population exposed to industrial noise at the first action level, even though the brass are exposed above the second action level. This is also borne out by the high average age of a world class orchestra.

Musicians may not form a 'typical population' for a number of reasons, which may affect hearing levels. Many start playing at 10 years of age, and those likely to become professionals may rehearse regularly at levels comparable to professional playing, as the measurements of an amateur band have shown. Orchestral musicians may take special care of their hearing outside their working environment. Employees exposed to the limit of the NAWR are free to attend discos or pop concerts where they may be exposed to an event Leq of 107dB [10] (at which an Lepd of 90dB will be received in 10 minutes!) The physical effort required to play instruments at loud levels may effectively regulate against excessive exposure long term, unlike electronic instruments. Most importantly, most musicians do not do the same thing every day for 40 years, and have periods in which

their exposure is very little. The NAWR require assessment over periods of 1 day or, with written exemption, 1 week. Both the British [7] and International [11] standards for assessment of risk of hearing damage allow the exposure to be averaged over periods up to one year.

8.Subjective comments.

In the course of taking measurements, many discussions have taken place. Musicians were generally concerned about their hearing and aware that they may be at risk. In orchestras, noise complaints generally came from the string players, although the above measurements show that they are not the most at risk. Perhaps this is a classic example of 'one persons music is another persons noise'. Opinions also varied as to which pieces were the loudest.

9. Conclusions.

Measurements have shown that musicians are exposed to high sound levels, with some exceeding the weekly exposure in half a performance. Other data suggests that musicians exposed above the daily action levels may not be at risk of hearing damage. Application of the legislation could restrict the ability of some musicians to work, or some pieces to be performed and reduce the quality of leading orchestras. However, ignoring the problem may fail to protect the hearing of people who depend on their hearing for their living.

Earlier this year two items hit the headlines: the Arts Councils' attempt to create a 'super-orchestra' and a Headteachers' decision not to allow pupils to see 'Romeo & Julliet' because it was not 'politically correct'. If the NAWR were applied as written, could we find that London orchestras will become 'diluted' by not being able to perform together frequently, or certain works (maybe even Prokofiev's Romeo & Julliet, which is quite loud!) will not be performed because they are not 'acoustically correct'?

10. References:

[1] Noise At Work Regulations 1989 HMSO
[2] Medical Research Council: 'Damage to hearing arising from leisure noise' p34-7 HSE (1985)
[3] D McBride & others: 'Hearing Music' BMJ 305 p1561-3 (1992)
[4] J Royster & others: 'Sound exposures ..musicians' JASA 89 p2793-802 (1991)
[5] HSE: 'Noise Guides 3-8' HMSO(1990)
[6] HSE: private communication 1994
[7] BS5330 'Estimating the risk of hearing handicap due to noise exposure' (1976)
[8] BS6951 'Threshold of hearing .. for otolologically normal persons' (1988)
[9] D Robinson: 'Noise Exposure and hearing: A new look at the experimental data' HSE (1987)
[10] HSC: 'Guide to Health, Safety and Welfare at Pop Concerts..' (1993)
[11] ISO1999: 'Determination of occupational noise exposures and .. hearing impairment' (1990)