Safe and Sound –
Exposure Control for Workers in Music and Entertainment

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Introduction

The Directive of the European Parliament 2003/10/EC concerns itself with the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). It refers to all workers and expressly to those in the music and entertainment industry. The basic principles of noise control are implemented in the Directive. This includes the general obligation for noise reduction at source as well as the priority of collective protection measures over individual protection measures. When exceeding the exposure action levels of 80 dB(A) and 85 dB(A) measures have to be taken such as the application of hearing protection, health surveillance, the marking of noisy workplaces and the implementation of a noise reduction program. Moreover, taking into account the attenuation that is accomplished by hearing protection, an upper exposure level has to be set at 87dB(A). The action levels and the exposure level refer to the physical parameter of the daily noise exposure level $L_{EX,8h}$ as defined in ISO 1999.

Many of these provisions seem to be inappropriate, hard to implement in the entertainment sector or to work as an restriction of the freedom in arts. The peculiarity of sound in this sector is that it is intended and indispensable but harmful at the same time. Sound is not an unwanted secondary effect but to some extent it is expected by the audience. As for the musicians it is actually the main product of their work. Nevertheless it is this special product that can directly put a risk on their most important instrument, namely their ears.

Sound Exposure

The scope of affected employees covers musicians and performers, disk jockeys, technical or service staff, security, first aiders, ushers etc. These people are frequently exposed to sound levels loud enough to cause hearing impairment. A rather harmless pleasure for consumers during one evening therefore becomes an occupational hazard for employees due to their repeated exposure over years.

It appears that it is the professional musicians who are mostly and directly affected by music sound. The average sound pressure levels of a single acoustic instrument measured close to the ear of the musician during individual training is within the range of 80-95 dB(A) [1, 2]. For a musician playing in an ensemble the individual sound level is characterized by the sound of his own instrument, the sound field of the instruments in his proximity and the reflections given by the room acoustics. For orchestra musicians the typical average sound pressure level L_{Aeq} during rehearsals or performances is within the range of 85-95 dB(A). Maximum sound levels may even reach the pain threshold. The highest levels have been measured with the brass, woodwind and percussion players and the musicians positioned in front of these instruments [2, 3, 4, 5]. On the other hand the peak sound pressure levels of acoustic instruments are hardly critical for causing acute hearing losses.

Player	Average $L_{A,eq}$ dB(A)	Maximum $L_{AS,max}$ dB(A)	Peak $L_{pC,peak}$ dB(C)
Percussion	93	120	132
Brass	93	108-116	115-129
Woodwind	92	99-109	111-119
Violin, Viola	89	107-109	121-122
Cello, Bass	87	99-100	111-119
Choir	92	-	-
Conductor	84	-	-

Table 1: *Sound pressure levels in orchestras [2, 4]*

The average noise exposure of workers with a markedly varying daily noise exposure is characterized by the weekly noise exposure level $L_{EX,40h}$. Depending on the instrument and the position within an orchestra, the weekly exposure levels of orchestra musicians are within the range of 85-95 dB(A) and thus almost comparable to the noise industrial workers are exposed to [2]. Exposure levels lower than 85 dB(A) have been calculated. But one has to bear in mind, however, that these values can only come about when individual training and warm-up playing are not taken into account and by averaging the sound exposure to a yearly exposure level including off-season periods [3, 6].

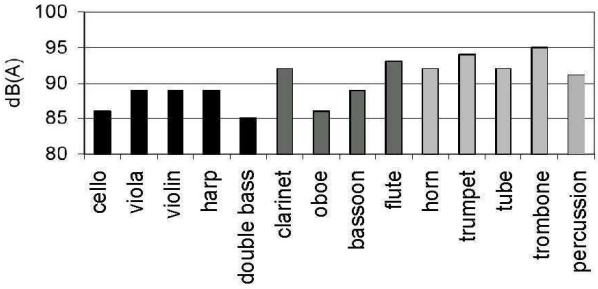

Figure 1: *Weekly noise exposure level of orchestra musicians [2]*

In the entertainment sector the working conditions are most diverse and often handled flexible. Thus the noise exposure of workers covers a wider range. As an example for this branch the following table displays the daily exposure levels for workers in British music clubs [7].

Job	Range $L_{EX,\ 8h}$ - dB(A)	Average $L_{EX,\ 8h}$ - dB(A)
Bar staff	89-99	92
Floor staff	90-100	93
DJ	93-99	96
Security	-	96

Table 2: *Daily noise exposure level of workers in music clubs [7]*

Options for Exposure Control

Relevant sound levels are mostly intended and essential in the music and entertainment sector. Nevertheless, at many workplaces exposure reduction will have to be considered in order to comply with the Directive. The classical way of noise control consists of noise reduction at source, on the transmission path, by organizational measures and finally by the application of hearing protection. This ranking in the choice of measures is given in the Directive which is but difficult to realize in the entertainment sector. So in practical live we have the risk that for reasons of simplification this priority in noise control measures is turned upside down. As a result noise control starts with the application of hearing protection. But this would hardly improve the protection of workers and would not comply with the aim of the Directive.

Noise control at source seems to be counterproductive - but an impressive sensation of any music is primarily related to its dynamic and secondly to the average sound level. The question of what sound level is intended should be considered by event organizers.

However, there exists no general solution for the choice of the suitable measures of sound reduction in the music and entertainment sector. Most often only a combination of several individually chosen measures can yield a practicable exposure control. Some examples for different sectors are given in the following.

Musicians

For orchestra musicians a large amount of the individual exposure results from their own instrument but playing in big ensembles increases the exposure. Moreover certain conditions of room acoustics and the positioning of the musicians can be disadvantageous.

In a typical orchestra arrangement the woodwind and brass players almost play in the direction of their colleagues in front of them. This results from the way of holding these instruments, their collimated sound radiation and an ensemble setup on small rising steps. Positioning theses musicians on higher risers of most suitable one meter height or more can improve the situation and enhance the high frequency radiation to the audience. Increasing the distance between the musicians e.g. by deeper steps provides a simple option for sound reduction. Further repositioning within an orchestra can be useful to avoid hot spots within the ensemble. Several lines of loud instruments one after another produce a loud area proximate in front. Experiments show that repositioning the musicians primarily changes the sound at the position of the conductor but much less within the auditorium.

If the sound level at the ear of musicians is dominated by other instruments in their proximity, sound screens can give some protection. But currently the discussions and opinions about sound screens are often conflictive which might result from different experiences. There are diverse types of sound screens and ideas on how they should be designed. Generally there are two types of screens, acoustically reflective screens and acoustically absorbent screens. Hybrid types can combine these functions. Purely reflective screens often made of perspex give an acoustic shield in the high and mid frequencies but their reflections may increase the exposure of the musicians close-by. So e.g. string players may receive some protection from the sound of brass players behind. But the brass players to some amount will play against a kind of reflecting wall and receive an additional sound exposure. Just as well the string players will percept unfamiliar parts of their own sound now reflected at the screen in their back. Absorbent screens avoid this effects but too much absorption changes the sound impression of the musician and the conductor which even might result in an exhausting overplaying of the musician. The suitable adapted combination of acoustically absorbing and reflecting surfaces is essential for the design of the screen. In either case all types of screens get less effective with decreasing size especially at lower frequencies. Moreover the visual transparency of screens is important at some applications. Modern micro-perforated materials can be absorbent and transparent simultaneously. Finally proper consultancy in the application of screens is most important because misapplication may impair the situation within an ensemble.

In orchestra pits there are three sound level increasing factors: tightness, sound reflecting walls and overhangs. The consequences are high sound levels, multiple reflections, inhomogeneous sound fields and resonances especially at low frequencies. While enlarging the pits is mostly no option, room acoustic improvements can reduce the reflections from the walls and the overhang. Dedicated absorbent elements based on the principle of membrane absorbers are effective at middle and lower frequencies without occupying a plenty of volume as classical fibrous absorbers [9]. These arrangements do not only reduce the sound levels but often improve the acoustic transparency and perception between the musicians and thus improve the musical interaction and the orchestral performance. Another constructural measure could be to open the orchestra pit acoustically e.g. by designing the balustrade or parts of the overhang acoustically transparent but optically intransparent.

This avoids reflections within the pit and brings the sound to the audience. Constructural modifications should particularly be considered at refurbishments and new building.

Typically, musicians using electrically amplified instruments have more control on their instrument setup and often work in a more flexible work environment than orchestra musicians. A well reconsidered stage setup can limit the sound levels e.g. by positioning musicians away from and behind PA speakers or by a thoroughly chosen number and position of monitor speakers. Carefully directed monitor and instrument amplifier speakers yield a clearer sound and a better feedback to the individual musician without raising the overall sound level.

In-Ear monitors offer an alternative approach for on-stage monitoring. In-ear monitors consist of custom-fit ear plugs with built-in miniature monitor speakers and a wireless transmitter receiver system one can wear on a belt. These systems may substitute monitor loudspeakers and can help to reduce the exposure on the stage. But the users have to take care of the volume setting or have to use systems with a limiter function. Otherwise high sound levels of more than 110 dB may reach the ear drum. The ear plugs should fit properly to avoid background sound to leak in. An improper fit may cause the user to turn up the volume to overcome the undesired background sound.

Noise rest periods are crucial for the hearing conservation. The human ear needs a substantial rest to recover from a temporary threshold shift e.g. 10 - 16 hours after a loud session or a concert. These facts have to be considered in the work schedule for all kind of musicians, workers and labor conditions.

Preventive measures, technical or organizational, are often easier to apply during rehearsals than during performance. So separate considerations on sound control measures for the arrangements of rehearsals, including individual rehearsals, are an extra opportunity for an effective exposure reduction.

Workers in Entertainment Venues

Noise reduction in discotheques or clubs seems to be limited by the consumer's preference to attend loud venues. But studies show that about the half of adolescent visitors of discotheques have the perception that discotheques are more loud than pleasant and that they would accept sound level limits [10, 11]. Another problem are the limited options for separating workers from loud areas. So the aim in discotheques and clubs is to restrict high sound levels in areas where it is wanted and needed e.g. on the dance floors. The fundamental design elements to realize this are physical separation, adequate absorption and suitable sound equipment.

Bars should be positioned away from the dance floor and quieter areas (chill-out-rooms) should be arranged. Acoustic screening can protect work areas or off-duty areas from noise sources. Absorbent materials on ceilings and walls lower the sound level in these areas and avoid the reflection of sound energy from the dance floor to other areas. Dedicated sound equipment should have directed loudspeakers aiming at the dance floor and e.g. not at the bar. It should consist of multiple loudspeakers to provide a uniform sound field without hot spots. Loudspeakers should not be placed on the ground so that people might get too close to them. Lifted or hanging constructions can prevent this. Anti-vibration mounts of speakers avoid that vibration energy is induced in the building structure and thus spread through the whole building. Equipment with low distortion and proper equalizer settings achieve an improved sound quality with a subjective more intense sound perception but objective lower sound levels. Monitoring of sound levels or the use of sound limiter systems help to control the average level during an event.

Hearing Protection

When the options for sound reduction at the sound source and on the transmission path to the worker are exhausted, the use of suitable personal hearing protection might be indispensable - for artists, technical workers and service staff. Nevertheless there are reservations against hearing protection in all groups of affected workers.

Musicians often refuse even ear plugs with a flat frequency response. An unsatisfactory sound impression as well as restrictions in instrument control and interaction within the orchestra are complained. These problems predominantly result from the occlusion effect which influences the perception of bone conduction and thus changes the sound of the own instrument at the ear of the player. Brass-, woodwind- and players of other instruments which induce a lot of structure-borne sound into the jaw or skull are highly affected. Individual consulting on the choice and application of hearing protection is the issue to adapt to playing with ear plugs [1, 5]. Hearing Protection should be a topic in musician's education as a matter of course.

Workers in the service sector criticize the restrictions in communication under hearing protection. But the speech intelligibility primarily depends on the ratio of speech level to background level which is not influenced by hearing protection. Hearing protection with a flat frequency response improves the situation for these workers as well.

Conclusions

For workers in the music- and entertainment industry the noise exposure is an occupational hazard and exceeds the action values or exposure limits given in the Directive 2003/10/EC. But musicians and other workers in this sector need their hearing at least as much or probably even more than any other workers. So the peculiarity of this sector is not the question if exposure control makes sense but what are the suitable measures and methods to achive it. The challenge is to consider that hearing damage may be caused by sound but that the performance of music, live or recorded, is a significant more complex and subjective process than can be expressed in decibel. For example the auditor's subjective perception of loudness depends on characteristics such as the time structure, the dynamic and frequency spectrum of music. The goal is to optimize any performance with respect to an impressive sensation for the audience not necessarily by increasing the average sound pressure levels.

Exposure control is possible but only the choice of highly individually adapted measures of exposure control can realize hearing conservation and ensure a performance product that satisfies the consumer's request. A key issue to achieve this will be information and training in a way which addresses the experts working in this sector. Only the professionals themselves, most of them affected personally, are able to put these ideas into practice.

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