

# Orchestra Musicians and the Protection of Hearing – Balancing Overprotection and Hearing Damage

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## Introduction

The stigma surrounding hearing damage and hearing protection among professional musicians is slowly declining. But what is the current situation for ensembles, and which challenges still lie ahead? This contribution aims to keep the discussion going by combining the perspectives of room acoustic consultants with that of practicing musicians. It examines the interplay between room acoustics, hearing protection, and the everyday professional realities of musicians. This study highlights concrete opportunities for action by all parties involved.

## Motivation

A large surge of interest in the topic of hearing protection for orchestral musicians was triggered by the court decision in *Goldscheider vs. the Royal Opera House London* (hereinafter ROH) [1]. During the rehearsals of Wagner's *Das Rheingold* and *Die Walküre* in the orchestra pit of the ROH, the claimant and viola player Mr. Goldscheider was seated in front of the brass section. Following previous complaints, multiple musicians, including the claimant, were equipped with noise dosimeters, which recorded a sound exposure of  $L_{eq} = 92$  dB(A) during the three-hour rehearsal. After the rehearsal, Mr. Goldscheider was diagnosed with acoustic trauma, hearing impairments, and a balance disorder, ultimately ending his career as a musician. According to the court documents, the ROH provided the musicians with both custom-molded earplugs offering 9 dB attenuation and foam earplugs providing up to 28 dB attenuation. The orchestra seating arrangement was changed the day after the incident as a consequence of the dosimeter recording evaluation. This is the first court decision in Europe holding an orchestra administration liable for hearing damage to musicians associated with concerts or rehearsals. It started industry-wide discussions both about the orchestra as workplace and the accountability of orchestra administrations.

## Short Literature review

In general, the acceptance of using hearing protection is rising among musicians. Following Greasley *et al.* [3, p. 17-18], two thirds of the ca. 500 interviewed musicians in the UK do (sometimes) use hearing protection, while over 80% think that hearing protection *should* be worn. The authors document the tensions of the musicians between applying the hearing protection and a negative perception of their own and their colleagues' sound [3, p. 19]. One of the consequences is, that already 19% of the musicians under 30 years old report being diagnosed with

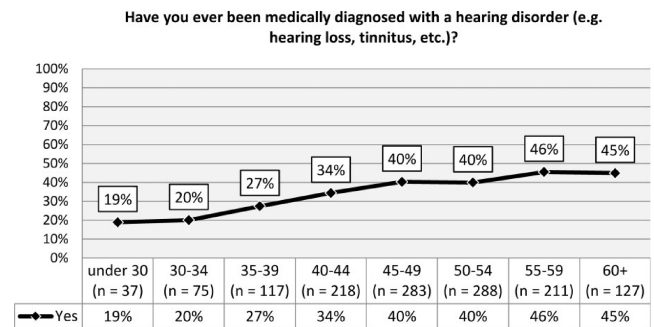


Figure 1: Diagnosed hearing disorder after Gembris *et al.* [2]

a hearing disorder, according to a large cross-sectional study of 2536 musicians from 133 professional orchestras in Germany by Gembris *et al.* [2]. With rising age of the musicians, the fraction increases further above 40% (see figure 1).

Most industrialized countries have implemented regulations for protection against workplace noise. In Europe, these are defined by Directive 2003/10/EC [4] and implemented in Germany through the LärmVibrationsArbSchV [5]. These regulations define lower and upper exposure action values of  $L_{eq} = [80; 85]$  dB(A). An exposure limit value of 87 dB(A) shall not be exceeded, with the effect of hearing protection duly taken into account [4]. For peak sound pressure levels, the corresponding values are 135, 137, and 140 dB(C).

Concerning the sound levels present for both musicians and workers in symphonic orchestras and amplified music venues, a large literature review has been conducted by Trompette and Venet [6]. They summarize that the noise exposure of all orchestra musicians exceeds at least the lower exposure action value. In addition, they outline the consensus to break down the noise exposure into four main components of decreasing importance:

1. The dynamic of the music piece.
2. The sound power of the own instrument.
3. The number of musicians and their seating layout
4. The room acoustic conditions (volume, reverb, ...)

The previous literature review evaluating  $L_{eq}$  measurements is supplemented by the annual exposure tables compiled by the Swiss *suva* over long-term measurements [7]. They indicate (discretized)  $L_{ex,2000}$  levels spanning the working lives of over 3000 professional Swiss

**Table 1:** Yearly sound exposure values  $L_{\text{ex},2000'}$  in dB(A) and equivalent sound level  $L_{\text{eq}}$  at the workplace (without exposition time) of orchestra musicians in dB(A). After suva [7].

Musician	$L_{\text{ex},2000'}$	$L_{\text{eq}}$
Near brass and percussion	90	90
Violin, viola	90	90
Cello, double bass	86	86
Flute	90	90
Woodwind	90	90
Brass	95	95
Harp	90	90
Percussionist	90	95
Conductor	83	86

musicians and music teachers (see table 1). Except for the conductor, all values fall into the range  $85 \text{ dB(A)} \leq L_{\text{ex},2000'} \leq 95 \text{ dB(A)}$ .

## Context and Influencing Factors

The conflict between management and musicians regarding sound exposure in orchestras is neither new nor resolved. In the following, the authors highlight the existing constraints around this topic from their perspective.

### Room Acoustics

Although there is mutual agreement in the literature that no room acoustic condition can provide the required attenuation of sound exposure on its own, it is still rewarding to investigate the ensemble playing of musicians within certain room acoustic conditions. A recent publication by Gade showed that an orchestra can reduce their overall level by 2 dB if provided with appropriate room acoustic conditions [8]. Although, to date, these results are not confirmed by a strict scientific test design, these results underline the importance of good ensemble conditions as opposed to a simple reduction of reverberation time or room feedback suggested in various workplace safety guidelines. Especially, as any decrease in room feedback may force musicians to (over-)compensate by playing louder. In conclusion, the importance of the sound power of the musician derived earlier as a main component of noise exposure [6] seems to be coupled (partly) with the stage acoustics. Interlinked with this discussion is the size and volume of the rooms used to both rehearse and perform music. Musicians need to rehearse with the same dynamic in their usually significantly smaller rehearsal rooms. ISO 23591 provides many helpful guidelines on the design of *safe* rehearsal rooms but falls short on orchestra pits and clear statements about the required area per musician [9]. The space between musicians defines directly the possible geometrical spread of sound intensity. Trompette and Venet identify  $1.7 \text{ m}^2 - 2.2 \text{ m}^2$  per musician as common recommendation in the literature [6, p. 42].

With respect to the audience, a certain loudness is expected at their listening position in the auditorium [10]. The literature agrees on a forte level of around 85 – 90 dB(A) [9, 11]. Another strategy for reducing on-stage loudness therefore is to optimize sound projection

from the stage to the audience to minimize the sound level difference between stage and audience. When the hall supports projection well, musicians can play at lower sound levels on stage while still producing a powerful fortissimo in the hall and simultaneously gain greater flexibility in softer dynamics.

### Music program

It appears to have always been in the interest of humanity to create louder instruments with a greater dynamic and tonal range. At the same time, concert halls and ensembles have grown in size to accommodate larger audiences, reinforcing the demand for greater projection and sound power. These developments culminated in the large and intense compositions of the late Romantic period expressing both strong emotion and power. With respect to potential hearing damage, it is often these compositions (and their instrumentation) that are highlighted in noise exposure studies. However, these compositions continue to be most in demand among audiences, conductors, and musicians. Unfortunately, the authors cannot provide a music-historical derivation of this hypothesis.

### Personal Hearing Protection

Using personal hearing protection is challenging for many musicians, as it places them in a dilemma between delivering the highest possible performance and protecting their hearing. Accordingly, a general consensus has emerged in the noise protection literature that playing with hearing protection should be practiced from the very beginning of a musician's career, both to improve self-assurance when playing with protection and to postpone potential hearing disorders to a higher age [3, 6, 12, 13]. It is estimated that older musicians will need up to a year to adjust [12]. Unluckily, these recommendations have not yet been established broadly among musicians and even less in professional music schools and higher education.

Wearing noise protection only situationally has two main caveats: first, the musician needs to mark the right moments to apply hearing protection in the score, which is not always possible or successful. Second, both acclimatization and recovery effects might irritate the musician. It is recommended to wear hearing protection consequently during individual and ensemble rehearsals, allowing for less attenuation during the critical performance during concerts [12]. The tragic case of Mr. Goldscheider underlines these aspects. The 9 dB attenuation filters provided by the ROH had been insufficient for the particularly loud seating arrangement, but the alternatively used 29 dB foam filters caused both overprotection and bad spectral attenuation for the softer passages [1]. In addition, the loud rehearsals had been shortly after one another.

In general, musicians require a mostly constant attenuation across all frequencies to maintain the tonal balance of the music. Currently, this spectrally flat attenuation can be achieved with attenuation levels of up to 15 dB, highlighting the importance of *moderate* filters. The minimal attenuation for certified personal hearing

protection is currently defined as [12 dB; 11 dB; 9 dB] for the respective high, mid, and low frequency range (HML) according to DIN EN 352-1 [14]. The currently available Elacin ER-9© hearing protection is the product closest to the minimal attenuation values on the IFA positive list with HML = [14 dB; 12 dB; 13 dB] [15, 16]. Applying this product to a typical equivalent sound level in the brass section of  $L_{eq} = [90 \text{ dB(A)}; 130 \text{ dB(C)}]$  [6, table VII] yields an approximate sound level at the ear of 73.3 dB(A). Applying it to the string section with  $L_{eq} = [84 \text{ dB(A)}; 123 \text{ dB(C)}]$  [6, table VII] yields an approximated sound level at the ear of 67.4 dB(A). In conclusion, even the minimally available, DIN EN 352-1 compliant hearing protection is rated as overprotection with levels far below  $L_{eq} = 80 \text{ dB(A)}$  if applied consequently for both the loudest and softest instrument sections [12, section 5.a)]. This leaves the musicians with no other choice than removing their hearing protection in softer passages introducing all caveats discussed above. Using only the minimally compliant DIN EN 352-1 attenuation would lead to a well matched level of 82.6 dB(A) at the ear for musicians of the string section. Of course, this is provided that the protection fits correctly and stronger attenuation might be necessary for special situations.

Musicians suffering from the occlusion effect often use their hearing protection only sparingly. The higher the sound level transmitted by air is attenuated by hearing protection, the more dominant is the bone conducted sound path, resulting in a drastic change of tonality. There is passive hearing protection with extra vents, which compromises between occlusion and attenuation. Due to the increasing popularity of headphones for the general public, there is significant research effort being made to minimize the occlusion effect in combination with active sound reproduction through the headphones (not necessarily in combination with active sound cancellation). If the earpiece can provide sufficient attenuation itself, this strategy allows less sound pressure to be created at the eardrum and thus protect the musician. Combined with an identical attenuation of both ears to maintain the relative level differences and an external trigger to set the sound reduction by the musician, this technology allows overcoming most currently existing downsides. An already existing and commercially successful alternative is the Hearwig©, a specially designed headrest, which allows the musician to adjust the attenuation by shifting their torso [17].

## Organizational Measures

In agreement with the EU directive, the STOP principle should be applied with respect to noise protection. It defines the order of actions as Substitution, Technical improvement, Organizational change, and Personal protection. Naturally, substitution of an orchestra is not applicable. As personal protection has been discussed, the two outstanding aspects will be briefly introduced below.

### Planning

As derived earlier, the instrumentation and musical dynamics of the piece has the strongest influence on the

IFA Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung

Musiker-Schallleistungsrechner

Belastung zu hoch | Summe der Punkte: 117  
Gesamtpegel  $L_{eq,Woche}$ : 85,7 dB(A)

Fehlermeldungen unterhalb der Tabelle in roter Schrift

Zelle	Tätigkeit	$L_{eq}$ (dB(A))	Mit Gehörschützer	GS 1 oder GS 2	Dauer in Stunden	Punkte	Prozent der Gesamtbelastung
1	Einzel-Üben	96	Ja	2	84	3	5
2	Proben	96	Ja	1	82	12	13
3	Aufführungen	96	Nein		96	3	81
4	Unterrichten	91	Ja	1	77	3	1
5			Nein				
6			Nein				
7			Nein				
8			Nein				
9			Nein				
10			Nein				
11			Nein				
12			Nein				

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Stand: 08/2024

Quelleinstrumente: 1. Studie v. T. Böhm, SUVA; 2. Schallpegel-Tabelle Musik, SUVA

Datenquelle Gehörschützer: Gehörschützer-Datenbank des IFA

Eine Belastung von 100 Punkten entspricht einer Belastung von 85 dB(A) in einer Woche (7 Tage) - doppelte Punktzahl bedeutet doppeltes Gehörschädigungsrisiko. Der Gesamtpegel entspricht der Wochenbelastung. Ziel ist eine Exposition bis maximal 85 dB(A), d.h. maximal 100 Punkte.

**Figure 2:** Planning tool to anticipate weekly sound exposure of orchestra musicians. The Excel© tool stores the measurement data to 50 hearing protection products. The entries in red exceed the weekly exposure level. Screenshot, IFA [15]

sound exposure of musicians. Insurance companies suggest taking the sound level of the repertoire into account when planning a season or week (see figure 2) [12, 13]. A vehicle for a user-friendly implementation could be the existing orchestra management software. The cast per piece is already stored by and could be combined with the sound power levels suggested by ISO 23591 [9], weighted according to the overall dynamic range of the piece. In addition, regeneration times after loud rehearsals or concerts could be suggested automatically [18].

### Stage Acoustics

On-stage hearing for musicians is a multi-dimensional puzzle, involving *hearing oneself*, *hearing others* and *hearing the room*, requiring an appropriate balance between these three aspects so that they do not excessively mask each other [19]. Many stage acoustics do not provide a sufficient number of helpful reflections to support the ensemble play in between instrument groups as well as the feedback towards the musician. Improving the ensemble play allows each musicians to better control their instrument both in performance and rehearsal spaces [8].

### Seating Arrangement

The space between musicians directly defines the possible geometrical spread of sound intensity. Trompette and Venet identify  $1.7 \text{ m}^2 - 2.2 \text{ m}^2$  per musician as a common recommendation in the literature [6, p. 42]. Naturally, a situation-specific compromise needs to be sought to allow a good cross-communication and ensemble play.

### Sound Barriers

Unfortunately, the currently often-used commercial plexiglas screens cannot provide a sufficient sound reduction. Measurements by the German PTB state a maximum attenuation of 2 dB [18]. In addition, the sound is not absorbed but only re-directed without much control. Experimenting with sound absorbing, non-transparent barriers might lead to satisfactory results, especially in orchestra pits where the space constraints are highest. It is on the acousticians to consult their clients about these shortcomings and suggest customized alternatives.

### Level Monitoring

The monitoring of sound levels either using dosimeters or fixed microphones is recommended. It serves multi-

ple purposes: Firstly, it documents both exposure and level to allow for an objective discussion and planning for both the musicians and the orchestra administration. Second, it can help generate trust and acknowledgement between all parties. Especially systems that allow direct monitoring enable the administration to take action before exposure levels are exceeded. This can be a change in seating arrangement, breaks, or an order to use hearing protection for specific sections. Due to advances in technology, direct monitoring solutions increasingly exist both for dosimeters, single- and multi-microphone arrangements.

## Conclusion

In conclusion, hearing protection for orchestra musicians remains a complex balance between preventing hearing damage and preserving musical performance. Despite advances in technology and research, there is no single solution, and a combination of strategies is required to minimize risk. Careful repertoire planning is most likely the biggest leverage on musicians' sound exposure. Personal hearing protection using custom-molded earplugs is effective but requires early practice, correct fit, and situational awareness. The currently available products lead to overprotection for soft instruments, forcing the musicians to apply them only situationally. Room acoustics and stage design can reduce on-stage sound levels through adequate spacing between musicians, optimized stage projection, and cross-communication. Commercial solutions, such as direct sound monitoring systems, offer practical means to implement protection and enable orchestra administrations to plan rehearsals and performances more safely. Noise barriers and customized acoustic solutions should complement personal protection, particularly in constrained spaces like orchestra pits. Education and collaboration between musicians, management, and acousticians remain essential to ensure adherence and effectiveness. Ultimately, the goal of all parties involved is to protect musicians' hearing while preserving the artistic integrity of orchestral performance.

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