Safe and Sound

Guide to Hearing Conservation in the Music and Entertainment Industry

baua:
Bundesanstalt für Arbeitsschutz
und Arbeitsmedizin

Research on health and safety at work

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Bundesanstalt für Arbeitsschutz
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Contents

Foreword

This guide includes information and recommendations for the avoidance of hearing damage in workers in the music and entertainment sector. It is aimed at employers and workers whose activity is connected with music – played live or reproduced – and it therefore relates to a wide variety of workplaces, such as theatres, discotheques, clubs, studios, music schools or at concerts. The guide has been drawn up in collaboration with a working group comprising specialists from associations in the music and entertainment industry, accident insurers and occupational safety and health institutions. It serves to help achieve a level of protection with respect to hazard due to noise, such as is specified for all workers by the German Noise and Vibration Occupational Safety and Health Ordinance.

The typical forms of noise-related hearing damage arise successively due to excessively frequent, too loud sound exposure. Since our hearing does not have any effective warning system, such incurable hearing damage normally goes unnoticed at first. The core topics of this guide are therefore the conscious handling of sound exposure, i.e. the exposure time and loudness, as well as the early detection of hearing impairment. Throughout a professional career, good hearing is for most workers in this sector a basic prerequisite for the performance of their work. The information, instructions and suggestions given in this guide are intended in particular to help limit exposure due to music to a level which is acceptable in health terms without adversely affecting the enjoyment of the music. The suitable procedure for an individual case mainly depends on the respective activity, the function and the area of responsibility within the sector – the type of music is initially not so crucial. An overview given in chapter 4 of this guide shows which basic strategy is appropriate for which occupational group. In chapters 1–3 basic terms in acoustics, the specific hearing hazards in this sector and the most important statutory requirements are explained. Chapters 5 and 6 give detailed instructions for reducing exposure and implementing occupational health care.

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– Health Department of the City of Münster
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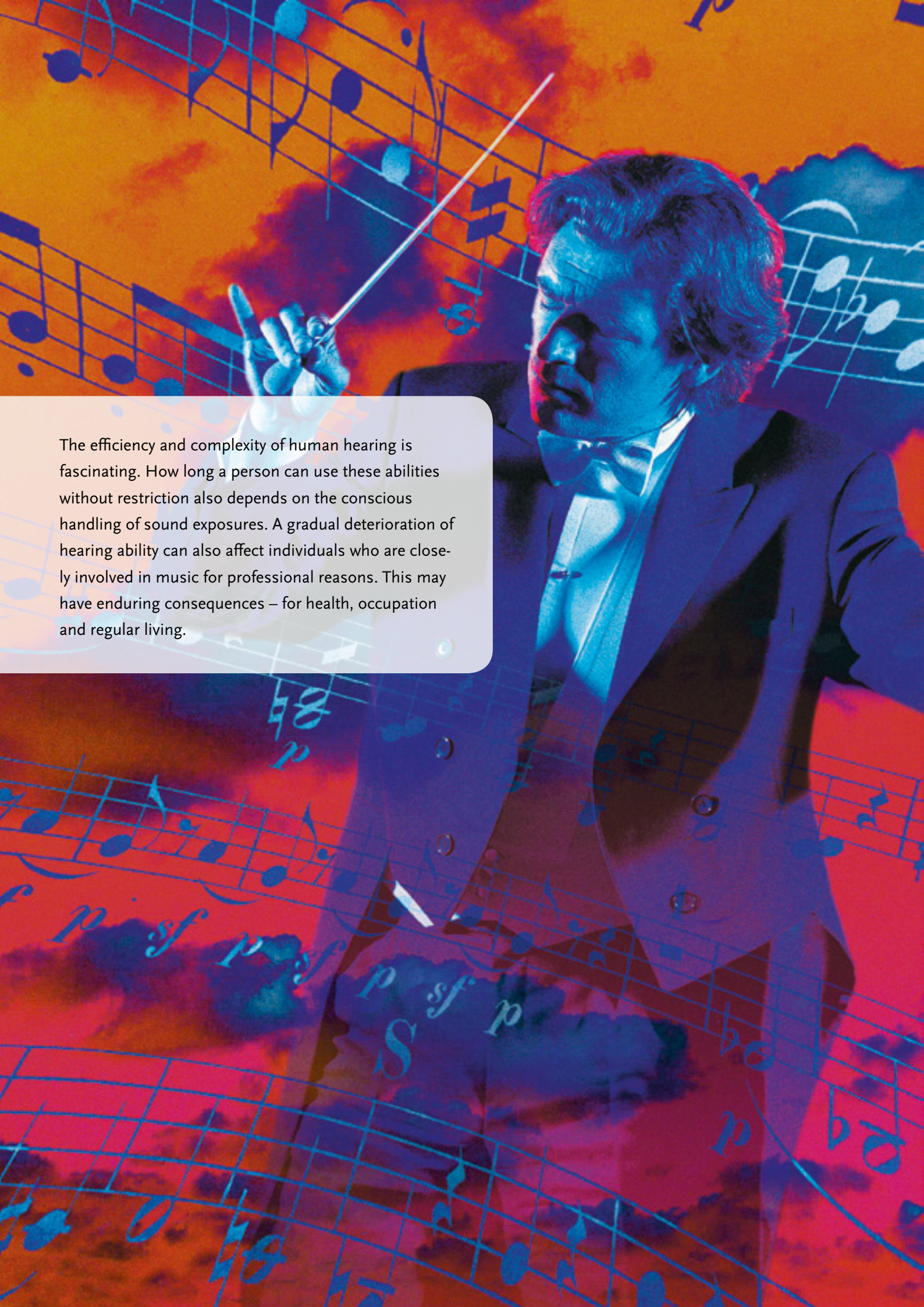


The efficiency and complexity of human hearing is fascinating. How long a person can use these abilities without restriction also depends on the conscious handling of sound exposures. A gradual deterioration of hearing ability can also affect individuals who are closely involved in music for professional reasons. This may have enduring consequences – for health, occupation and regular living.

1
Acoustics and Hearing

Introduction and definitions

What musician has not experienced it at least once? The concert was a resounding success, the audience was enthusiastic, the reviews in the press look as though they will be full of praise. But despite all this the feeling of pleasure at the success is not completely unadulterated. In the course of the performance a whistling in the ear, at first merely annoying then increasingly disturbing, became evident. Hours after the performance it had not gone away, but rather had become stronger and more irritating. With a bit of luck the nightmare will have disappeared in a few days.

If you overdo it too many times, a temporary disturbance can become a chronic tinnitus. This and other hearing disorders not only adversely affect the well-being of the persons concerned, but can also jeopardise their professional success. Although about 75% of musicians constantly worry about the health of their hearing, many know extremely little about the relationship between sound, acoustics and the development of hearing damage. Anyone who understands how we hear will recognise possible risks and can dispense with such concerns. Knowledge and care go hand in hand.

1.1 Hearing

Sound

The term sound describes pressure fluctuations in air which are superimposed on normal static air pressure. These pressure fluctuations cause the eardrum to vibrate, are transformed into nerve signals in the inner ear, are compared in the brain with known patterns and are recognised as speech or music.

Sound is the generic physical term, regardless of any subjective evaluation.

Noise

In general the term noise is used to describe sound which is undesirable or deleterious to health. But even low-level noises can be disturbing. Think of a fly that does not allow us to get to sleep. The brain classifies sensations into pleasant and unpleasant ones. The term noise is only applied to sound events which are a nuisance or which cause harm.

Sound can be harmful to health. This guide is devoted primarily to measures to prevent hearing damage. But we should not forget that in the long term noise not only has a damaging effect on the ear, but that it can, for example, also adversely affect blood pressure or concentration. Music sometimes has to be loud in order to achieve the desired effect. And yet music and, for example, traffic noise are identical in physical terms: sound.

Ear

The outer ear and auditory canal form a bell which is optimised for sound waves within a certain pitch range. Via the eardrum and the ossicles the sound waves pass into the cochlear. There the sound is broken down according to pitch. About 20,000 auditory cells transform the sound into nerve impulses. These impulses are transmitted via parallel "data lines" – the auditory nerve – to the brain.

The hearing has astonishing abilities, most of which we are not aware of, but which we nevertheless take for granted.

Frequency range

Between the lowest and highest perceptible tone there are for a young person with good hearing about ten octaves: 16 to 16,000 Hz (see Frequency). One octave signifies the interval between one tone and the tone of double frequency. By way of comparison: our eye can only perceive light waves in a range which is equivalent approximately to one octave.

Frequency resolution

The frequency resolution of human hearing is about 1/30 of a semitone.

Sensitivity

We can just about perceive sound when it represents a fast periodic change in air pressure of 1/5,000,000,000 of normal air pressure. If our ear were a little more sensitive, we would perceive – without the presence of sound – the natural movement of air particles as a constant interfering noise.

Loudness range

The softest, just perceptible tone at about 2,000 Hz has a sound pressure of 20 µPa (Pa = Pascal: unit for the pressure; 20 µPa = 20 Pa/1,000,000 has been laid down as a reference value). The loudest tone which causes the first sensation of pain exhibits 20,000,000 µPa, and it is thus 1 million time greater.

Scales with the same accuracy would have to display the weight of a single letter just as precisely as that of a heavy goods vehicle – without being damaged.

Sound source location

Sound waves coming from the right are heard first by the right ear. The time differential between perception by the right ear and perception by the left ear is evaluated by the brain in order to locate the sound source. This works up to a time differential of 1/100,000 seconds. If our eye were able to process signals in such small intervals, we would be able to watch how the television or computer screen builds up an image line by line.

If noises come from above or below, the timbre changes. This can be attributed to the special form of the auricle, the auditory canal and the reflections and diffraction phenomena on the upper body and head. Our brain exploits these effects, which also help to locate the sound source. The sound just perceived is compared with acoustic impressions from our brain's archive.

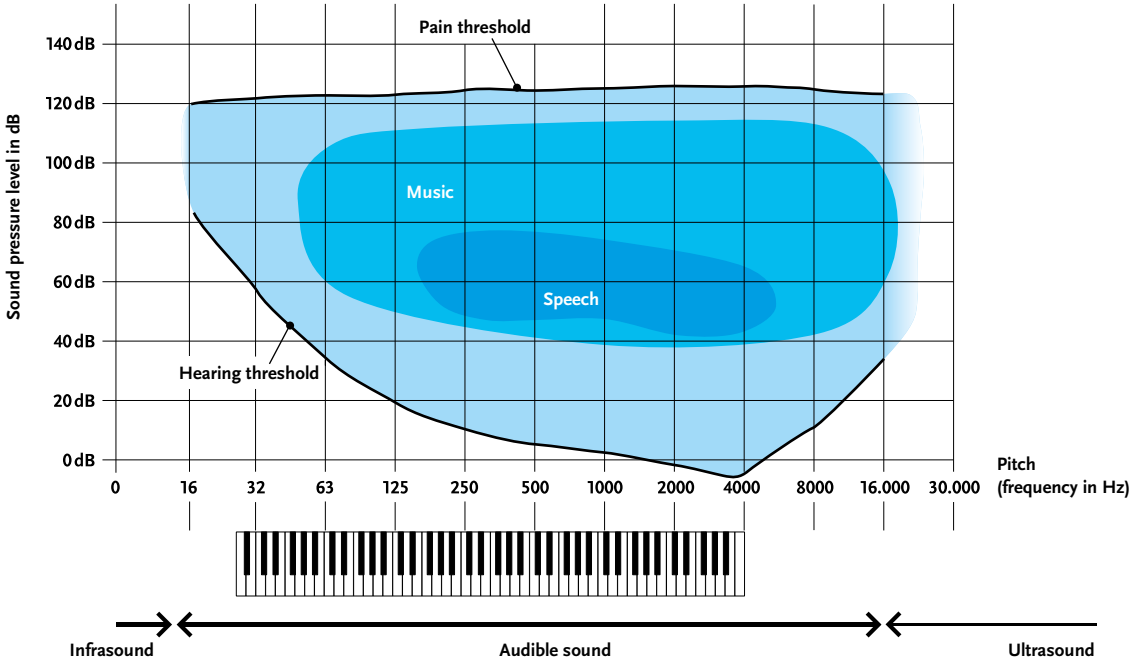
Now you can also see why you cannot immediately locate noises you have never heard before or why children tend to have greater difficulty than adults in identifying the origin of a noise: the noise in question has not yet been stored in the archive.

Directional spatial hearing

If a number of people in a group are speaking at the same time and equally loudly, we are able to concentrate on one speaker and understand exactly what he is saying. This is one of the outstanding abilities of our hearing, and one which we understandably use in many everyday situations.

Auditory sensation area

In the picture the human hearing ability is represented as an "auditory sensation area". The hearing threshold shown in the diagram below describes the range at which noises of a certain frequency can just be perceived. The hearing threshold is obtained as a mean value of a large number of measurements conducted on subjects with normal hearing. The upper curve at sound levels around 120 dB is the so-called pain threshold at which an acoustic signal is experienced as being painful. Also marked in the auditory sensation area are the range of speech communication, the so-called speech field and the area of musical information. Noise-induced hearing impairments concern initially only the high frequencies and hence more the consonants when hearing speech. Hearing losses in the speech field contribute to the social disablement of the hearing-impaired.



Explosion trauma

Experience has shown that sound peaks of very high loudness are especially harmful to the ear. Sound peaks caused, for example, by firearms and explosions can cause acute damage to the ear. In such cases one talks of an acute noise trauma. In an enclosed room with major acoustic reflection on the walls the risk of damage is even greater than in the open because more sound energy has an effective impact on the ear!

1.2 Sound

Frequency

Of special importance for the hearing sensation is pitch or frequency, in other words the number of pressure fluctuations during a second. It is measured in Hz (= 1/s). A healthy ear can perceive acoustic oscillations from 16 Hz to 16,000 Hz (= 16 kHz). Below this one speaks of infrasound, above it ultrasound. Such frequencies are not audible to most people.

Loudness

Sound pressure level

The effects of sound (including music) on the human body depend mainly on the sound pressure. The greater the sound pressure, the higher the perceived loudness. The ear can process extraordinarily different sound pressures. The hearing threshold and pain limit are different by 6 orders of magnitude! (hearing threshold 20 µPa; pain limit 20,000,000 µPa). In order to show this large value range in terms of a manageable range, the sound

Sound level Decibels dB pressure is simplified as sound pressure level: sound pressure Lp, measured in decibels (dB). (Hearing threshold at 0 dB, pain limit at 120 dB).

Sound event	Typical sound level in dB(A)	Sound event	Speech communication
	140	jet engine (at a distance of 30 m)	
	120–130	pain limit	
	110	pneumatic drill	
rock concert	105–120	drop forge	(from 105 dB) no communication possible
dance floor in a discotheque	95–105	circular hand saw	communication only possible with considerable vocal effort
music in the orchestra pit	85–100		
	85–90	city traffic, trucks	communication difficult even when shouting
chamber music in a small hall (at listener)	75–85		
phone dialling tone	80	lathe	communication possible with raised voice
piano played at moderate loudness (at listener)	70	interior noise, car	(up to 70 dB) conversation possible at normal loudness
	50–60	normal conversation	
	45–55	office noise	
	40	library	
	30	quiet environment, night-time, whispering	
hearing threshold	0	hearing threshold	

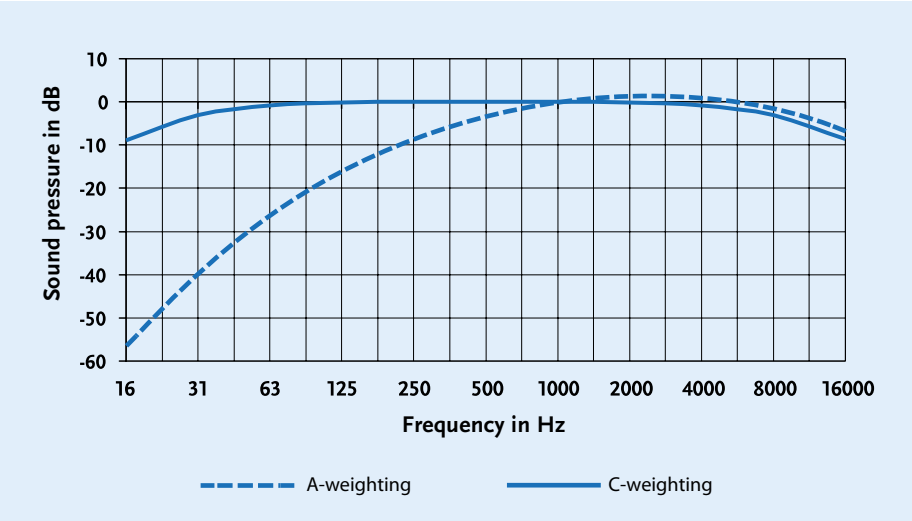
The weighting curve (A) shown in the figure corresponds approximately to the sensitivity of the human ear as a function of frequency. In this presentation "0 dB" means optimum hearing, and negative values characterise a lower sensitivity of the ear for these frequencies.

Frequencies in the range of 1–4 kHz are perceived best, and high and low tones as being less loud.

A-weighting

C-weighting

The sensitivity of the ear, which is highly dependent on the pitch, is taken into account in the measurement of sound by a filter, the so-called A-weighting. With high sound levels, this pitch-dependent perception changes and it is taken into account more precisely by a so-called C-weighting.



Level addition

3 dB rule

Sound levels in dB are unfamiliar, logarithmic variables for which the familiar addition rules do not apply. Hence the following remarks on the often used 3dB rule:

With a doubling of the sound energy, the sound level rises by 3 dB. Example: Two equally loud instruments each with 85 dB together yield 88 dB.

The crucial factors for risk or damage to the ear are the sound intensity and the duration of exposure.

A doubling of the exposure time doubles the risk.

A rise in the sound level of 3 dB also doubles the exposure and hence the risk.

Vice versa a lowering of the level by 3 dB has the same effect as a halving of the exposure time.

A sound event with a level of 88 dB therefore has double the intensity of a sound event with 85 dB. If we continue the calculation we find that 115 dB means a 1,000 times higher exposure than 85 dB.

Our ear can just about make out a difference of approx. 2–3 dB between two noises. Only a rise of 10 dB between two noises do we perceive as a doubling of loudness. However, this is the equivalent of ten times the sound intensity and hence of the hearing exposure!

Hearing sensation with increase in sound level

Hearing sensation	Increase in sound level	Sound power of the number of identical sound sources
4 x as loud	+ 20 dB	x 100
2 x as loud	+ 10 dB	x 10
substantially louder	+ 6 dB	x 4
audibly louder	+ 3 dB	x 2
just louder	+ 1 dB	x 1,25
		x 1

The effects of sound on people range from disturbances of one's peace (from 30 dB(A)) through vegetative reactions (from 65 dB(A)) to damage to the inner ear (over 85 dB(A)).

There is a widespread misconception that a person can assess on the basis of his or her subjective (pain) sensation whether a sound is dangerous or not. This is quite wrong! The pain threshold (for pains in the eardrum) is between 120 and 140 dB(A). Repeated sound exposures to only 85 dB(A) over eights hours a day for a period of more than 10 years can lead to permanent hearing damage. You do not have to experience pain before damage occurs. At the damage location, in the inner ear, (unfortunately) no pain sensation is generated.

Equivalent continuous sound pressure level L_{eq}

The equivalent continuous sound pressure level L_{eq} represents a special average value of sound pressure levels over the period of a measurement. It provides information on how loud a sound event was on average during the measuring time. This value alone does not initially reveal anything about a possible risk to hearing. To assess a hearing loss risk it must also be taken into account how long a person is exposed to the sound emission. A sound exposure is therefore described by a daily noise exposure level $L_{EX,8h}$. This is an equivalent continuous sound pressure level which relates to a work period of 8 hours. It replaces the weighting level previously used in Germany.

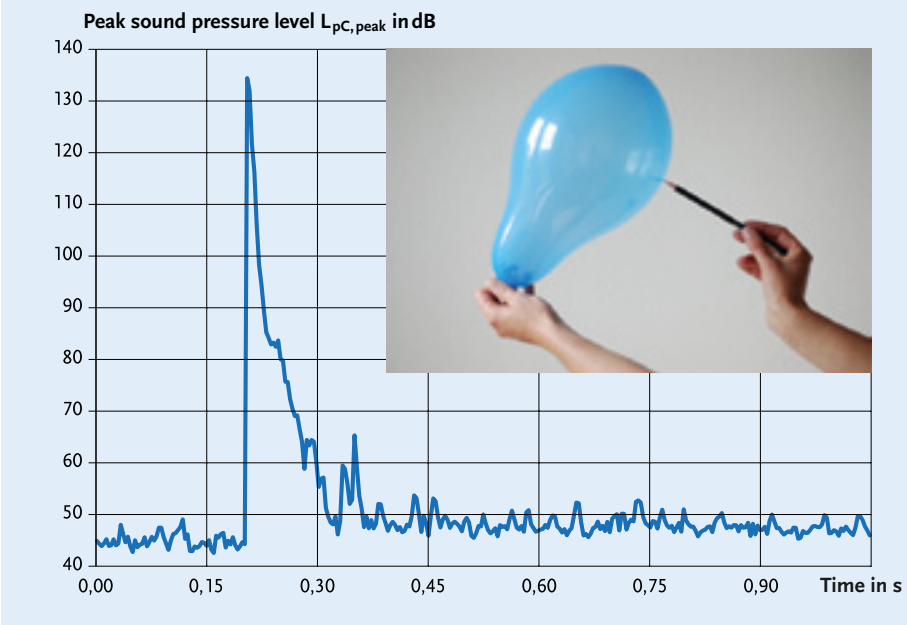
Daily noise exposure level $L_{EX,\,8h}$

Weekly noise exposure level $L_{EX,\,40h}$

If the sound exposure fluctuates very considerably from day to day, with the weekly noise exposure level $L_{EX,40h}$ it is possible to determine the sound exposure on average over a working time of one week. It relates to a work period of 40 hours. Extreme fluctuations can, for example, arise for many musicians, for whom days of rehearsals, days of performance and times without sound exposure may alternate irregularly. The weekly noise exposure level can be referred to in approved exceptional cases in order to assess the exposure. Impulsive sound

Impulsive sound

Impulsive sound, occasionally also called sound peaks, arises when two objects strike one another (e.g. as in the case of drums or cymbals). Sound peaks are very brief sound events. The crack of a toy gun lasts, for example, only about 0.0005 seconds.



Time curve of the peak sound pressure level $L_{pC,\,peak}$ for a bursting balloon at a distance of 1 m

1.3 Hearing damage

Hearing threshold

The lowest sound pressure the ear can just perceive is called the hearing threshold. It differs a little from person to person. As an average hearing threshold at 1 kHz a sound pressure of 20 µPa has been fixed historically (According to more recent studies this value is twice as high). This corresponds to a sound pressure level of 0 dB!

The hearing threshold depends very much on the frequency and with most pitches it is above this value, but with others below it (see Auditory sensation area).

TTS

Sound levels above 75 dB may result in a temporary threshold shift (TTS).

A **temporary threshold shift** is a temporary reduction in hearing which normally occurs after the impact of a very high sound level. After a loud concert or if a person has been in the vicinity of loud machines for an extended period, there is perhaps the experience of additional after-effects which may accompany a temporary threshold shift: damped hearing, ringing or whistling in the ear, or even a certain feeling of numbness.

The good news is that the ears mostly recover after such a temporary threshold shift and these effects disappear again provided the ears are granted adequate respite. The bad news is that frequent, excessively loud sound exposure will, in the final analysis, lead to a permanent hearing threshold shift.

PTS

Regular noise impact over years can result in a permanent shift in the hearing threshold.

A **permanent threshold shift** is a lasting hearing impairment. If the ears are frequently exposed to a barrage of sound and the warning signs and symptoms are ignored, one day the damped hearing and perhaps the additional ringing in the ears will no longer disappear. The technical term of this is permanent threshold shift, PTS.

Forms and causes of hearing impairment

Depending on the location of the hearing disorder, a distinction can be drawn between two basic forms of such disorder: sound conduction disorders and sound sensation disorders

(sensory hearing impairment). Sound conduction disorders are due mainly to tubular ventilation disorders, middle ear infections, otosclerosis, and rarely to deformities. An important feature of sound conduction disorders is the fact that audible impressions are of lower intensity, but they are essentially undistorted. The hearing loss is mostly in the slight to moderate range and can easily be corrected by operative measures or with the support of apparatus. This form of hearing impairment is due to excessive sound exposures. In the case of most sound sensation disorders, on the other hand, the cause is a disturbance of the conversion of the sound from a pressure wave to nerve impulses in the inner ear. This is why the outcome is not only a reduction in intensity of the audible information, but at the same time a distortion and selective failures within the frequency spectrum. In addition to this there occur frequently, alongside the restricted dynamic range, also patho-physiologically relevant phenomena such as hearing fatigue, and so such hearing disturbances must in principle be classified as more serious. Noise-related hearing impairment is a classic form of sound sensation hearing impairment and is therefore relevant for musicians, for example. Other causes are in-born, not infrequently inherited forms or also inner ear hearing impairment due to a serious infection, such as bacterial meningitis or accident damage (petrosal bone fracture) or the frequently occurring generative hearing impairment, i.e. progressive inner ear hearing impairment with no evident cause.
Noise-related hearing impairment

Noise-related hearing impairment

Sound-induced hearing damage arises from excessively great and excessively long sound impact.

Hearing losses due to noise-related damage are based on damage to the inner ear. Such losses are irreversible, i.e. incurable. Hearing aids are also not capable to revive the damaged areas of the inner ear. Even state-of-the-art hearing aids can only attempt to use the still functioning frequency ranges of the damaged ear in order to restore a certain speech communication by boosting the loudness – often with an inadequate result. This means that the enjoyment of hi-fi or precise music-making is rendered considerably more difficult or even impossible.

Hearing threshold shift

To have poor hearing means that ever greater sound pressures are required to enable the ear to perceive something. A sound-induced hearing reduction begins with a lowering of the hearing threshold in the range above 4,000 Hz and leads initially “only” to a major deterioration of the sound texture, which above all impairs the hearing of music. Since this happens very slowly, the individual concerned becomes accustomed to it. Hearing reduction spreads to lower frequencies and is often only noticed when speech intelligibility is impaired.

Before you think: “My ears must be very good because I have worked successfully in the orchestra for 20 years and my hearing is simply good”, just consider that your hearing may already be damaged and you are not even aware of it. The only model for finding this out is to undergo a hearing test.

Noise-induced hearing damage arises mostly over a period of 10 years and more. Such hearing damage develops sluggishly and mostly unnoticed by the person affected. But it can no longer be cured.

Musicians with impaired hearing must concentrate more in the orchestra than their colleagues with healthy hearing. As hearing damage progresses it becomes more difficult to follow in a mixture of parts a particular part one wishes to hear. The ear locates an

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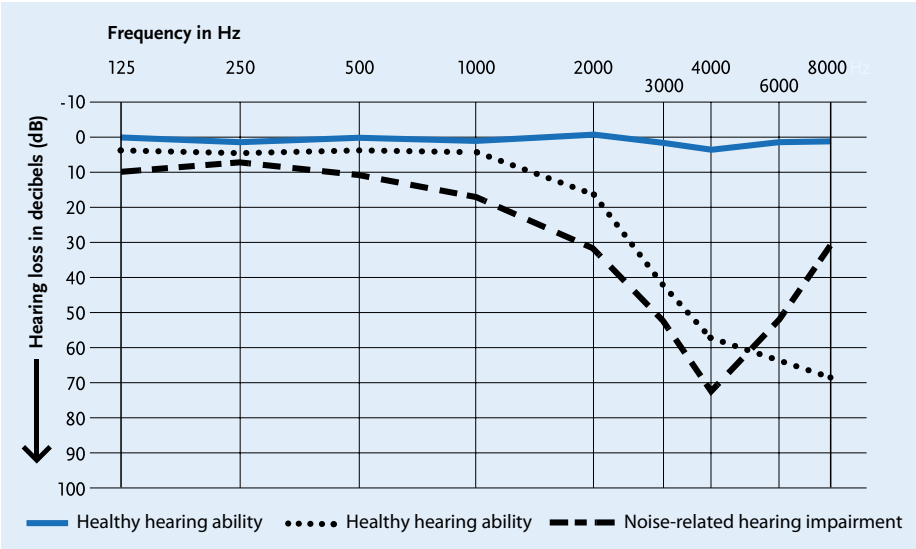
orchestra part spatially in the high tone range, which is most damaged by noise. If the low tone range, which is actually easier to hear, is also masked by the simultaneous presence of additional sound around the person affected, so-called interfering sound, the latter will find it extremely difficult or even impossible to conduct a conversation. This interference is called the "cocktail party effect". Impeccable directional hearing is also important in an orchestra. The enhanced concentration, combined with uncertain intonation and impaired precision in hitting cues, is experienced by many musicians as additional stress. Even a slight inner ear hearing impairment together with a tinnitus can in individual cases limit the possibilities for exercising one's profession.

Sound-induced hearing damage can also express itself in the form of other symptoms or can be accompanied by them. Typical examples here tinnitus, hyperacusis and diplacusis.

Audiometry

Audiometry is a method for determining hearing ability. For this purpose the ear's hearing threshold is determined in a quiet environment for a series of pure tones and compared with the hearing threshold of a healthy ear.



Audiogram

The hearing threshold shift as compared to a healthy ear is displayed graphically by means of the frequencies. The picture shows the pure tone audiogram for incipient noise-induced hearing damage. In this presentation "0 dB" signifies normal hearing, the values plotted downward characterise poorer (damped) perception of these frequencies by the ear.

Tinnitus

Tinnitus is normally described as a ringing, whistling or hissing in the ear which is also audible in the absence of any external sound. This is a frequent side effect of excessive sound exposure.

Hyperacusis

In the case of hyperacusis (pathological oversensitivity to noise) the person affected experiences most sound as normal, but a sound which is a little louder seems to be too loud and is painful. This oversensitivity can also be limited to specific noises or tones and is perceived especially by flautists as a burden. Hyperacusis is a fairly frequent symptom with sound-induced hearing damage.

Diplacusis

Diplacusis (hearing double tones) is a fairly rare symptom, but one which can be very disturbing to musicians, singers, sound engineers and music lovers as well. Hearing double tones is an abnormal sensation of sound, either in terms of time or pitch. With two-sided

double tone hearing, the individual hears the same tone in the two ears differently. With one-sided double tone hearing a single tone is perceived as a number of tones in one ear.

Characteristics of a hearing disturbance

The effect of a hearing disturbance, separately or in any combination and dimension, covers four mutually independent parameters, which are typically named repeatedly by hearing-impaired persons in everyday communication:

1. The **loss of intensity** causes a partial weakening or a failure of loudness perception ("I hear things as too quiet").
2. **Frequency loss** means that the aforementioned loss of intensity can be different at the various hearing frequencies ("in everyday situations I can actually hear well – only I cannot hear birds twittering any more").
3. **Dynamic loss** means that the loss of intensity occurs differently at the various sound levels. In the case of inner ear disorders, the perception range for quiet sounds normally fails, even without any change in that for loud sounds ("I have hearing problems in particular when people speak softly and mumble"). At the same time hearing impairment can also involve an enhanced noise sensitivity (so-called recruitment) ("why are you shouting? I'm not deaf!").
4. **Phase loss** is a disorder of the time resolution capacity ("please talk more slowly and then I will be able to understand you").

1.4 Sound exposure

Exposure time

The duration of the sound's impact, the exposure time, is made up of all sound impacts during a day. This also includes short noise impacts lasting one minute or even less.

Noise dose

A noise-induced hearing impairment develops all the faster and all the more strongly, the louder the sound is and the longer it impacts on the ear. For this reason the exposure time and the sound intensity are taken to form a noise dose – the daily noise exposure level (chapter 1.2). Hearing damage arises when the daily dose assumes excessively great dimensions over extended periods. All damaging sound events which have an impact on our hearing over our lifetime accumulate. If the sum of these impacts exceeds the critical level, hearing damage occurs. Rehearsals and performances as well as recreation behaviour have to be adjusted in the light of this fact. In particular care must be taken to ensure that one's hearing is granted rest breaks. It is assumed that after a high noise impact at least 10, or even better 16 hours without noise are necessary to enable the hearing to recuperate.

In the case of persons with healthy hearing it can hardly be assumed that hearing damage will develop if the duration of noise exposure with a daily noise exposure level of 90 dB does not exceed 6 years, 87 dB 10 years and 85 dB 15 years.

But it is natural that not every ear is the same. Many people have the good fortune to have been born with robust ears and are less susceptible to hearing damage.

The effect of continuous noise on the ear is a dose effect. For shorter exposure times higher noise levels are tolerable. Noise-related damage develops over the course of many years. To prevent this, the exposure must be restricted. When estimating the daily or weekly dose – in other words the exposure level – the 3 dB rule applies once more: a halving of the exposure time has the same effect as a reduction of level by 3 dB. The following value pairs for sound level and exposure time yield the same exposure level of 85 dB(A)

Sound level L_{eq} in dB(A)	Exposure time in hours	Daily noise exposure level $L_{EX,8h}$ in dB(A)
85	8	85
88	4	85
91	2	85
94	1	85
97	½	85
100	½	85

Action values

If the exposure attains certain action values, protective measures must be taken. These are primarily of a technical or organisational nature and must, where relevant, be supplemented by the use of hearing protectors.

Peak levels $L_{pC,\ peak}$

The highest short-duration level reached by a noise in a certain period, e.g. with an impulse, is the peak level $L_{pC,\ peak}$. Very high level peaks can cause acute damage to the ear. There are therefore also action and maximum allowable values for the peak level.

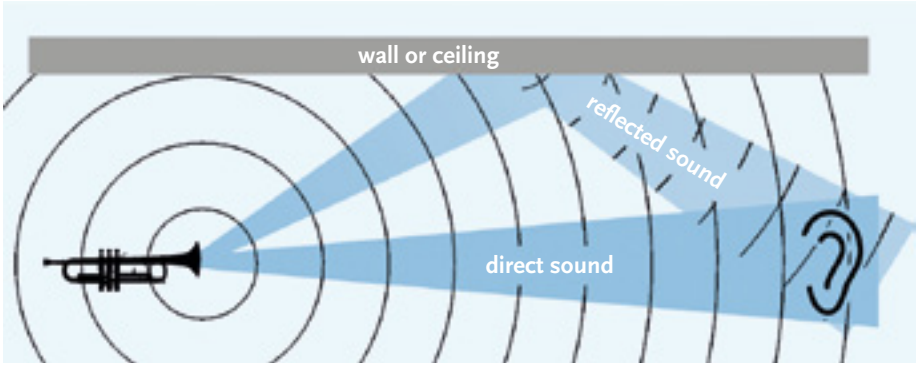
Direct sound

For orchestral musicians the direct sound which reaches the ear directly from the neighbouring instrument or one's own is crucial.

Room acoustics

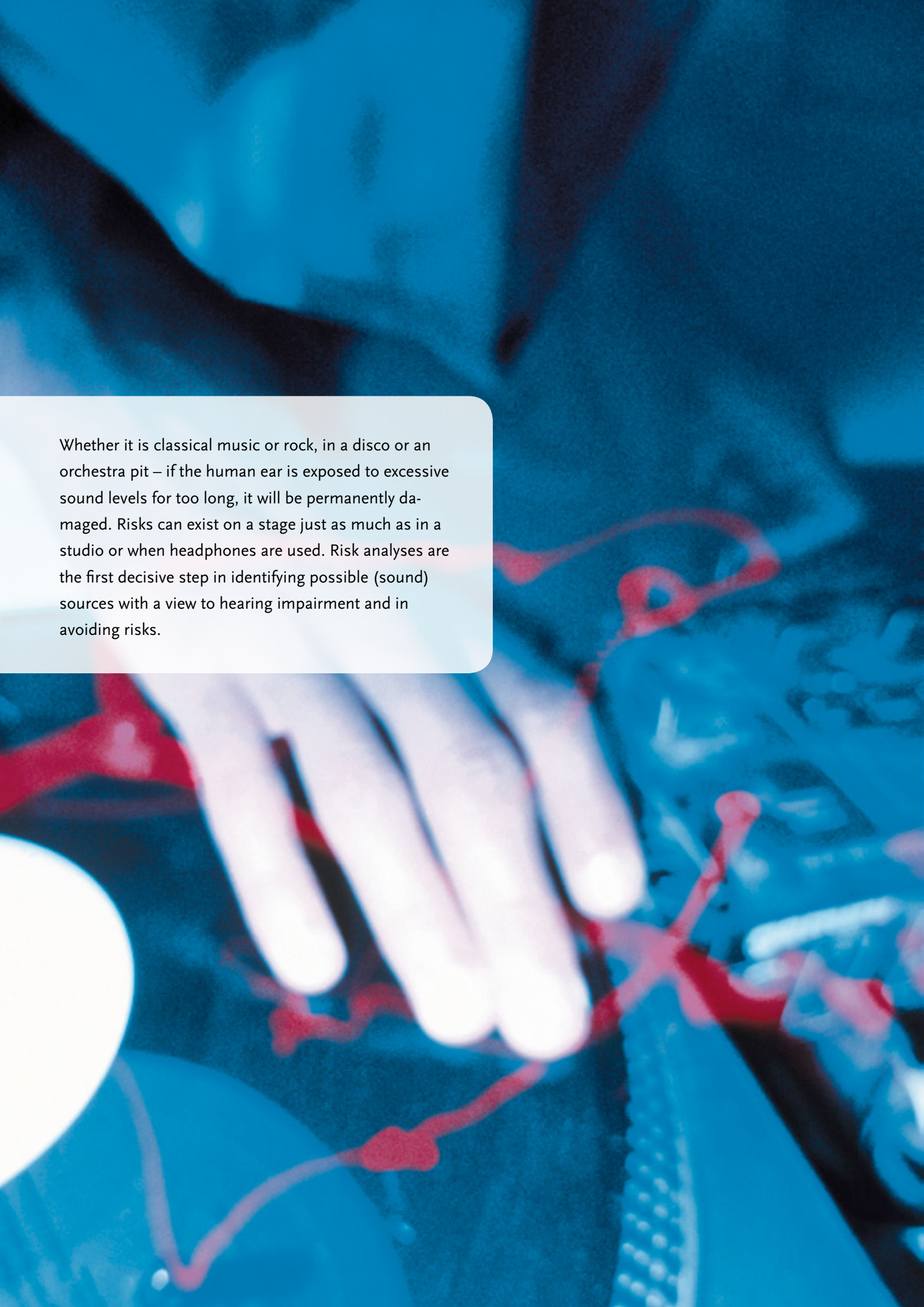
The loudness at the ear depends, however, not only on the instrument or in general on the sound source. The sound reflected off the walls of the room increases the noise level in addition. The reflected noise is normally substantially quieter.

Reflected sound



The sound level falls in the open by 6 dB with a doubling of the distance to the sound source. In rooms this only applies close to the sound source, and then the sound level remains largely constant because of the sound reflections.

Confined spatial conditions reduce the distances between the ear and the neighbouring instruments. With this the sound level rises. For this reason the conditions in the orchestra are particularly unfavourable when the musicians sit very close together, for example in the orchestra pit.



Whether it is classical music or rock, in a disco or an orchestra pit – if the human ear is exposed to excessive sound levels for too long, it will be permanently damaged. Risks can exist on a stage just as much as in a studio or when headphones are used. Risk analyses are the first decisive step in identifying possible (sound) sources with a view to hearing impairment and in avoiding risks.

2
Sound Sources and Risks in the Music and Entertainment Sector

Subjective sound sensation is an individual matter, but is also situation-dependent, differs considerably and hence yields no adequate information as to when it could be critically loud. There is therefore no alternative to an expert and objective risk assessment. Even so all those involved can consider whether the sound exposures in their surroundings could be a problem. In this chapter the most important "musical" sound sources and related sound levels and sound exposures are described.

When is it too loud?

You get an initial indication of high sound exposures if
- the sound is louder than busy big city traffic,
- you have to raise your voice to speak to someone standing directly next to you,
- you feel at the end of the working day that you can only hear in damped or distorted form or if you have a ringing or whistling in your ears,
- at the end of the working day you have to turn the loudness of your stereo or television up to the point that it is too loud for others.

2.1 Orchestras and other ensembles

Part of what makes performances by symphony orchestras and other large ensembles so impressive is the loudness of a large number of musicians playing at the same time. But high loudness levels also involve risks for the hearing ability of, for instance, artists or conductors.

The sound levels may differ considerably according to the position in the ensemble.

Distance in the ensemble

Artists sitting in front of a group of brass instruments are exposed to a greater risk than others. Artists sitting close to kettle drums or percussion instruments are just as much at risk. Drums, cymbals, glockenspiel and other percussion instruments can generate such high sound levels that one's ears can ring afterwards.

Brass or percussion instruments are not the only ones that can damage your hearing ability, however. Most instruments have the potential to generate high sound levels. If the distances between the musicians in a group are too small, their hearing may be at risk.

Working in an orchestra pit

Orchestra pits are often very confined and mainly enclosed spaces. The dense positioning of the occupants means that the musicians are often "playing directly into one another's ears'. Thanks to the enclosed nature of the space, little sound gets to the listeners, which is why it is often necessary to play more loudly or to employ electronic amplification.

Note: The less sound that leaves the orchestra pit, the louder it is for the musicians.

Louder instruments

Orchestral music has become steadily louder in the course of the past few centuries, which can be seen from the modifications in instrument design. As music moved from aristocratic courts and salons to larger public places of performance, the designs of the instruments developed such that they become suitable for larger rooms. Brass and woodwind instruments became heavier and louder. Percussionists use larger drums and cymbals. String musicians moved from gut strings to metal strings to make sure they remained audible among the other instruments.

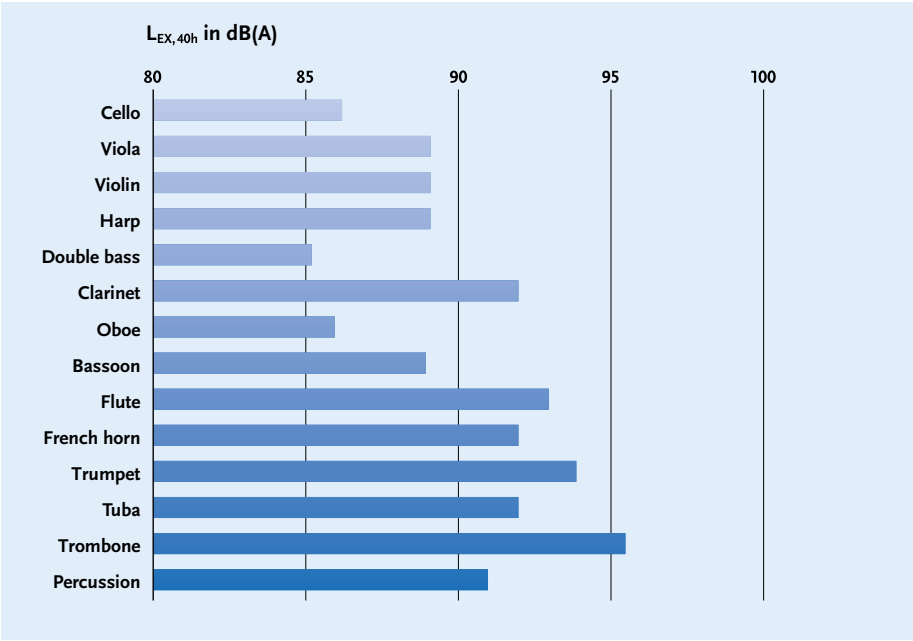
For the ears the loudness is crucial – not the style of music

Many people think classical music – and also many forms of jazz – is culturally superior and noble, while they regard rock music as the musical form of expression of those who are socially inferior. If anyone should worry about their hearing, it is the metalhead types with their enormous loudspeaker towers, isn't it? Do not fall for this widespread misconception!

When it comes to hearing damage, it is mainly the sound level and exposure time – in other words exposure level (chapter 1) – that is crucial. Classical and jazz musicians can be just as much at risk. Studies show that – regardless of a sound limitation strategy – the still harmless sound dose can also be exceeded in the case of orchestral musicians.

Sound exposure among orchestral musicians

The graphic below shows the typical values for the weekly exposure level of various orchestral musicians. These values are a measure for the total sound dose to which a musician is exposed in the course of an average working week. They are obtained from the present sound pressure level in various situations and the duration of the corresponding activities. The values were determined during the usual activities such as performance, rehearsal, warm-up and individual practice sessions – all are in the range which represents a potential risk of hearing damage.



Typical weekly exposure level of various orchestral musicians (T. Billeter, B.Hohmann: Fortschritte der Akustik 27 2001)

2.2 Acoustic instruments

It is possible with nearly all instruments, including the human voice, to generate sound levels which may endanger the hearing of artists or other persons in the immediate vicinity. This chapter highlights a number of some features specific to individual instruments.

Trumpets and trombones

Trumpets and trombones can be very loud. In performances of especially loud works, peak levels of 115 dB(C) have been measured for brass instruments.

The bells of these instruments generate a highly directional sound, especially at higher frequencies – frequently also in the direction of other musicians located in front of the brass section.

Flutes and piccolos

Flutes and piccolos tend to cause a greater hearing loss in the musician's right ear, which results from the instruments' position. Then the left ear can hear harmonics of higher frequencies better than the right ear and musicians may feel this asymmetry as a distortion.

Stringed bow instruments

Violins and violas generate sound levels above 80 dB(A) at the musician's left ear, many peak levels being above 110 dB(C). In the case of violinists and viola players, the left ear is subjected to a greater exposure because it is this ear that is always closer to the resonator.

Cellos and double basses are generally quieter than violins and violas and are further removed from the ear.

Percussion instruments

Percussion instruments such as drums, tom-toms, congas, bongos, cymbals, gongs, rattles, triangles, wooden drums, vibraphones and xylophones, can generate impulsive sound.

Keyboard instruments

A large grand piano can generate sound levels above 100 dB(A). Upright pianos attain sound levels of 95 dB(A). Cembalos are quieter than pianos and have a smaller dynamic range. In the case of organists, the sound exposure depends to a particularly high degree

on the individual circumstances. If, for example, certain registers are positioned at ear level, sound levels in excess of 100 dB(A) can arise.

Sound levels of individual instruments

Of course instruments can be played with varying loudness, and most of them provide a dynamic range of 40 to 50 dB – this is what makes music so varied. The table below shows reference values for the typical sound levels (equivalent continuous sound pressure level L_{eq} at the musician's ear) of individual acoustic instruments, such as arise for example during warm-up or practice.

Average sound level of individual acoustic instruments (B. Hohmann: Musik und Hörschaden, 2009)

Instrument	Typical average sound level L_{eq} in dB(A)
upright piano, grand piano, organ	80
cello, double bass	80
violin, viola	86
Flute	86
clarinet, oboe	90
saxophone, trumpet, trombone	95
percussion, drums	95

Music teachers

The sound exposure for a music teacher depends on various factors and is influenced by the distance and from the positioning of the student, the room acoustics and the repertoire.

Exposure level for music teachers (source: SUVA sound level table)

Music teacher at music colleges for the instrument	Typical exposure level $L_{EX,\ 40h}$ in dB(A)
violin, viola	84
cello, double bass	80
flute, piccolo	86
oboe, bassoon	83
clarinet	86
saxophone	90
brass instruments	90
percussion, drums	90
harp	80
upright piano, organ	80
song	90

Singers

Professional singers can generate surprisingly high sound levels of up to 110 dB(A). But such extreme loudness levels are of course invariably only attained for short periods. On the other hand the average sound levels (equivalent continuous sound pressure level L_{eq}) for a single singer during practice are, according to the situation, 75 dB(A), and during speech exercises up to 109 dB(A) during rehearsal.

When singing in an ensemble or choir, the voices of the singers in the immediate vicinity can in addition be louder than one's own voice.

If one considers all the common singing situations and activities of singers, sound exposures with the following typical exposure levels are obtained overall:

Singing	Typical exposure level $L_{EX,\,40h}$ in dB(A)
male singer (soloist)	95
female singer (soloist)	95
choral singer	86
prompter (opera)	83

Exposure level for vocalists (source: SUVA sound level table)

2.3 Electrical instruments

The advantage of electrical instruments and electronic amplification is that they provide extensive control over the loudness. The other side of the coin is that the amplification can easily get out of control, sometimes literally at the throwing of a switch. Rock may be "music for the neck down" as Rolling Stones Keith Richards, guitarist so appropriately called it, but this music also involves risks for the part of the body above the neck.

And with electrical amplification the timbre or dynamics are not necessarily linked with playing at full loudness. Normally it is possible to arrange the sound in such a way that your ears are protected to some extent without any worsening of the performance.

Percussion

If you ask musicians in small ensembles, many will say straight away that they have to play loudly to be heard above the percussion. Most rock and pop drummers will say that hitting the drums hard is an essential part of their music or their job. Whatever the truth is, there are at any rate a number of strategies for preserving the hearing ability which drummers and other musicians can try out.

Guitars

Percussionists are not the only musicians who insist that high loudness levels are an inseparable element of their music. Electrical guitarists – especially those who love extreme distortion – will probably object that they have to turn the loudness up in order to get the right sound. The fact is that guitar amplifiers make a major contribution to the timbre. Often such amplifiers do not, however, make it possible to generate a certain sound texture irrespective of the loudness. Sometimes a smaller amplifier sounds more "authentic" at the limit of its output than a larger amplifier working at under its full output – the answer is to try it out. In any case the loudness should be determined by the musician and not by the possibilities of the amplifier.

Electric bass guitars

Electric bass players have a tough job getting heard in a mix of electronically mixed music because the human ear does not hear low frequencies as well as middle and high ones. The temptation is therefore to set the bass amplifiers louder than would be necessary to achieve a balanced sound texture. In enclosed rooms with unfavourable acoustics this can give rise to unpleasant and burdensome effects, such as humming room resonances.

Keyboards, samplers and record players

Upright pianos, organs, synthesizers, samplers and record players cover a far wider range of frequencies than most other electrical instruments. If you want to hold your own with drums, guitars or a loud mix, you will put your ears and those of your colleagues at risk.

Note: In general it is important when handling amplified instruments that you find a balance between the perception of your own instrument and the whole sound texture produced by all the musicians. The crux of the matter is that any unnecessarily loud instrument will force the other artists to increase their own loudness, which will make the overall sound on the stage or in the rehearsal room louder – and this cycle will only end at the pain barrier. A considered way of handling amplifiers is helpful – not only with respect to the loudness, but also for the sound texture as a whole. Every style of music is conducive if the musicians do not play against one another but with one another.

Exposure level for musicians (source: SUVA sound level table)

Light music orchestra, big band	Typical exposure level $L_{EX,\,40h}$ in dB(A)
conductor	86
brass players	95
percussionists	95
musicians with electrically amplified music (pop/rock/jazz)	100

2.4 Loudspeakers and monitors

The basic problem with many sound systems is that they can generate sound levels which are beyond the exposure limits of the human ear. Rock and pop music played live regularly attains sound levels of 100 to 115 dB(A). Directly in front of loudspeakers the sound level can reach 120 to 140 dB(A). But music played in discotheques, for example, can often generate 100 dB(A) and more.

On the stage

Musicians and singers use monitoring loudspeakers to hear themselves and others. Other sound systems emit the sound to the audience (and to personnel such as sound and lighting engineers as well as event personnel). Normally the loudspeaker systems are all the bigger, the bigger the venue.

Many musicians and sound engineers immediately turn the system right up instead of starting off quietly and then increasing the loudness in accordance with the needs of the situation. Loud music is mainly synonymous with badly sounding music, however, especially for those in the audience who are unfortunate enough to sit closer to the loudspeakers than to the musicians or sound engineers. Music lives from dynamics, in other words form the alternation of loud and quiet passages. The listener becomes accustomed to music which is constantly loud and is no longer impressed by it.

In the studio

To be loud, music does not have to be live. When recording in the studio many artists like to play at high loudness levels. The reproduction on monitors in the control room can also be loud. Artists, producers or engineers may insist on high monitor levels when tracks are being mixed.

The obvious danger is, of course, that – if you repeatedly record or mix at high sound levels for many years – you will damage your most important instruments, namely your ears. In an environment where transparency and precision is crucial for the production of good music, this would be fatal.

Headphones

Headphones are useful in the studio, for the mixing of live music and for speech communication during a live performance. The main advantage of headphones for musical purposes is that you can adapt the mix for yourself individually – no-one has to hear what you hear. On the other hand, headphones – whether used for music or speech communication – can damage your hearing if you turn the loudness up high, for example to drown out background noise. Where there is undesirable background noise it is therefore to be recommended that you do not work with open headphone systems, but with closed systems which have high sound insulation to the outside (chapter 5.3). But even without background noise, you will unconsciously hear more loudly with headphones than when playing over loudspeakers because the sound is no longer felt in your gut.

In-ear monitors

In-ear monitors are earplugs with built-in miniature loudspeakers. The earplugs dampen external sound and so the wearer can monitor the sound more precisely at lower loudness.

Despite the reduction of background noises, in-ear monitors can generate high sound levels of 120 dB(A) at the eardrum. If not properly inserted and used, in-ear monitors can therefore be just as dangerous as monitoring loudspeakers, perhaps even more so. If applied with care, however, they offer a good alternative to classic monitoring loudspeakers (chapter 5.3). To avoid a feeling of being shut-off at live performances, audience noises can also be mixed in.

Exposure level of workers in discotheques (HSE Research Report 026)

Discotheques, clubs	Typical exposure level $L_{EX,40h}$ in dB(A)
bar staff	92
service floor staff	93
DJ	96
security	96

2.5 Venues

You should not only pay attention to what you play, but also where you are playing it. Room size, room layout and construction materials can have a major effect on the sound level you are producing.

Electronically amplified music and room acoustics

Sound engineers who work with electronically amplified music generally prefer rooms where there is little reverberation. The reason for this is that the artists or engineers themselves want to be able to mix in the desired reverberation and thus have a better control over the overall result.

Unfortunately the walls of many venues, such as clubs, sports halls and multipurpose halls, are made of concrete or other hard, smooth materials which hardly absorb sound and prolong the reverberation times. In a “hard” room sound can be reflected to and fro for several seconds after it has left the stage; this raises the sound pressure level in the

room and makes it difficult to achieve effective control over the sound texture. Electronic amplification does great things in terms of adding reverberation, but does not do much to suppress reverberation. The same applies to rehearsal rooms. Unfavourable, sound-hard surfaces give rise to a considerable increase in the sound level as compared to a heavily damped room (up to 10 dB is possible) and to an "opaque" sound texture. Here "dryer" room acoustics are an advantage.

Considering alternative stage designs

If you are preparing a rehearsal or a performance at a venue where there is no fixed stage or performance area, you should gear your planning not only to visual and aesthetic considerations. When planning think also about the impact of sound on artists and others. Many of the preventive strategies proposed in chapter 5 are possibly not suitable for your venues. During rehearsal and practice times use the opportunities you have to arrange the structures and premises.

2.6 Other sound exposures

In addition to music, sound is generated in particular by tools, machines and technical equipment. Other sound, such as that from (blank) guns or explosives, will be called industrial sound from now on.

Live performances

Risks due to the impact of sound arise less frequently when the music is not a central element of the performance. Even so, performers, staff and other workers in theatres and at live performances sometimes find themselves exposed to industrial sound at dangerous levels if they have to work in the vicinity of machines, technical equipment or sound effect devices.

When a stage or support structures are being set up, high sound levels may arise. Carpenters or other craftsmen may possibly be working near power saws, drills and other loud tools. The use of special effects such as shots or explosions can also generate dangerous sound exposures.

Industrial sound

Electric drills, power generators, fans and other power tools and equipment generate continuous sound. You should therefore make sure when purchasing machines and devices that they generate comparatively little sound. Since machine manufacturers have to comply with the requirements of the EC Machinery Directive, they are obliged to provide a noise emission declaration in the operating manual and, from December 2009, also in advertising brochures. The noise emission values given there should therefore be compared when evaluating the offers from different manufacturers, thus enabling you to select a machine which has the lowest noise emission values.

You may possibly be working in environments with industrial impulsive sound, including among others hammer blows, shots, explosions and other sudden sound impulses. Impulsive sound lasts only a very short time (less than one second), but it can still damage someone's hearing, especially at very high levels.

Background noise

Background noise is sound in your surroundings which does not consist of music, dialogues or sound effects. Background noise, such as audience noises or machine noise, can be a problem because it increases the overall sound level in your surroundings and in turn is supposed to be masked by higher levels from the sound system. In many working situations, however, you may have only little opportunity to affect the background noise in your surroundings. Then hearing protectors may help to protect your ears.

2.7 Sound exposures in leisure situations

The risk of hearing loss does not end every day after work. You can also damage your hearing at home, in town or on holiday. It is therefore also important to consider sound exposures in leisure time because sound-induced hearing loss is cumulative: The hearing "remembers" for every all hearing-impairing sound it is exposed to at some time.

Anyone who is exposed to high sound levels in his job must give his hearing adequate opportunity to regenerate in his leisure time. No-one can relieve you of this responsibility for your own health.

How much is too much?

The sound exposure in your leisure time may differ considerably, according to where you live, where you spend your free time or holiday and what hobbies you have. Basically it is your job to think about how much sound you can subject your ears to in your free time. You do not have to be too pedantic in this; simply apply common sense and do not deceive yourself about the nature and duration of your leisure activities.

Audio and video entertainment devices

Audio and video entertainment devices today have added features such as extra bass or surround sound and provide improved – and louder – sound options for home, car hi-fi, TV, PC loudspeaker and stereo systems. Portable audio devices can be dangerous if you turn the headphone volume up to drown out background noise, such as traffic noise.

Concerts and clubs

If you are a lover of live music, clubs or discotheques, then your total exposure to sound may rise considerably, depending on how often and where you go. In small clubs it may be just as loud as in discotheques or at concerts in large halls.

Cinemas

When it comes to cinemas we do not immediately think of high loudness levels, but technological progress and the general Hollywood tendency to what is "bigger, brighter and louder' has led to a situation where the sound level in many action films is as much as 110 dB(A).

Sporting events

It is well known that car races are very loud events. Other sporting events, such as football and basketball, can also be a burden on your hearing. The danger comes not only from the spectator noise. Side programmes or music in the break also increase the sound exposure.

Machine tools

In the home and the garden, electric drills, saws, lawnmowers, leaf blowers, lawn trimmers and similar devices, for example, can produce dangerously loud sound.

2.8 Risk assessment

The main basis for the preservation of hearing is the skilled determination of the risk. The employer therefore has to establish first whether the workers are or may be exposed to noise. The diagram shown here is intended as an aid to achieving this:

- Is it possible to preclude a risk for all workers?
  - Sound levels may damage hearing if:
  - the sound is louder than busy big city traffic.
  - you have to raise your voice to talk to someone standing right next to you.
  - you have the impression at the end of the working day that what you hear is damped or distorted, or if you hear singing or whistling in your ears.

- If it is not possible after an initial estimation to preclude a risk, a more extensive risk assessment must be conducted. Its objective is in particular to establish whether action values are reached or exceeded. For this the noise exposure for a representative working day (or in exceptional cases a working week) must be determined for all workers. The following must be considered:
  - the group of individuals affected,
  - the typical, averaged sound level,
  - the exposure time.

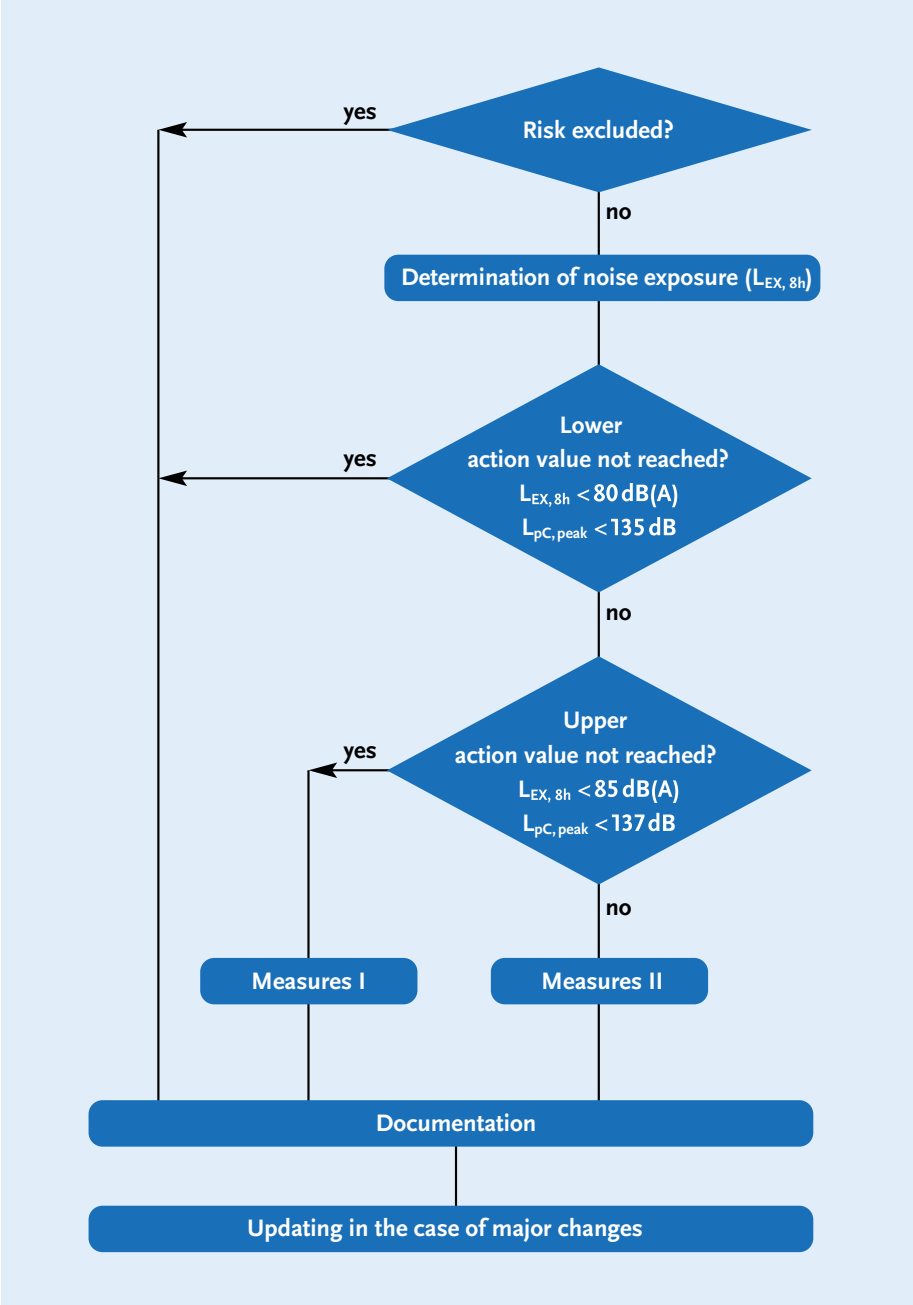
- The individual exposure can be determined with reference to known values common for the particular sector for sound levels at the workplace or to noise exposure values for workers, or it can be determined by own measurements.

- Should measures be conducted? For the majority of workers in the music and entertainment sector the exposure exceeds both action values and it is necessary to apply noise control measures. This applies both with respect to most musicians and to numerous workers in the fields of music reproduction. It may therefore often be appropriate to take sound reduction measures first and then to check by measurement whether, for example, the upper action values are no longer exceeded and what protective measures must be taken (chapter 3).

- Weekly dose: If the noise exposure fluctuates considerably from one working day to the other, a weekly noise exposure level $L_{EX,40h}$ can be used for the risk assessment in exceptional cases with permission from the competent authority (chapter 3). The use of the weekly noise exposure level instead of the daily one in the risk assessment may be appropriate, for example, if the working week consists of three days or less or the fluctuations in the daily noise exposure level are more than 5 dB(A).

- Risk assessments must be conducted by skilled personnel (e.g. a specialist for occupational safety and health, company doctor or an external service).

- Documentation: The results of the risk assessment must be documented and then updated when there are changes in the working conditions.



Risk assessment

The statutory regulations at European and national levels make clear: Anyone who is exposed regularly or continuously to noise for occupational reasons must be protected. By means of risk assessment, by limitation of exposure and by means of information and preventive care. An individual solution relating to the workplace is not always easy to find – but it is still the indispensable prerequisite for the enduring health of one‘s hearing.

3
Statutory Regulations

In this chapter you will find in summarised form the main subject matters of the European Directive 2003/10/EC on the "Minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise)" or the corresponding German ordinance. This directive was incorporated in German law in the form of the Ordinance on protection of workers from risks due to noise and vibrations (Noise and Vibration Occupational Safety and Health Ordinance – LärmVibration ArbSchV).

For the sake of clarity in presenting the basic principles, there are no detailed quotations from these regulations.

Occupational safety and health and music – Is this new?

Occupational safety and health and music

No, even previously the music and entertainment sector was not without statutory regulation in terms of noise control at the workplace. Up to 15 February 2003 workers were safeguarded against the risk of noise on the basis of the European Directive 86/188/EEC, which was implemented in Germany primarily through the accident prevention regulations governing noise (BGV B3) and occupational health care (BGV A4). In the past the music and entertainment sector was thus by no means exempted from regulations for reducing risk due to noise. Subsequently the European Directive 2003/10/EC came into force, and this was followed as from 6 March 2007 by its implementation in German law through the Noise and Vibration Occupational Safety and Health Ordinance.

New features as against previous regulations are the lowering of the action values from which, if exceeded, measures have to be taken to reduce sound exposure.

What is unchanged is the general mandatory requirement to minimise sound exposure with the preventive goal of reducing the risk to health and safety, and in particular of avoiding noise-related hearing impairment. Other physiological or mental noise effects are not dealt with separately in the regulations. The principle of minimising the risks by reducing noise at the source and on the transmission route as far as possible has also been preserved. Only once technical and organisational protective measures have been taken can the remaining risks be excluded with the use of hearing protectors.

The basic requirements of the directive with respect to the preventive goal of hearing conservation are:
– determination and evaluation of risks
– avoidance and reduction of exposure

– information and instruction of workers
– health surveillance and preventive care (audiometric testing)

The structure of the directive is based in particular on the following terms:

Noise exposure levels and action values

Which activities and measures are to be applied to achieve the preventive goals will be determined according to the level of the sound dose to which the workers are exposed in their work. It is characterised for the working time of one day by the daily noise exposure level $L_{EX,8h}$ (chapter 1). In addition to the general minimisation requirement, certain preventive measures are necessary as the exposure level increases when so-called action values are exceeded. Action values exist both for the exposure level $L_{EX,8h}$ and for the peak sound pressure level $L_{pC,\ peak}$ (chapter 1).

Lower action value

The lower action value is $L_{EX,8h}$ = 80dB(A) for the daily noise exposure level and $L_{pC,\ peak}$ = 135 dB for the peak sound pressure level. When one of these two values is exceeded, the following protective measures must be considered:

– **Information and instruction of workers**
  The workers receive information and instruction on the risks due to noise exposure.
– **Hearing protectors**
  The employer provides appropriate hearing protectors.
– **Occupational health care**
  The workers are offered health surveillance of the hearing function (audiometric testing).

Upper action value

The upper action value is $L_{EX,8h}$ = 85 dB(A) for the daily noise exposure level and $L_{pC,\ peak}$ = 137 dB for the peak sound pressure level. If one of these two values is exceeded, the following additional protective measures must be considered:

– **Noise reduction programme**
  Elaboration and implementation of a programme with technical and organisational measures for the reduction of noise exposure by the employer. This takes account, among other things, of work processes and work equipment, as well as the design and layout of workshops and workplaces, and technical and work-organisational noise reduction. It must be provided for that workers and/or their representatives are given a hearing and are actively involved.
– **Markings**
  Working areas are marked and access to working areas is restricted if technically possible.
– **Hearing protectors**
  The use of hearing protectors must be monitored. When selecting hearing protectors, the workers and/or their representatives must be given a hearing and actively involved. Hearing protectors must be selected in such a way that the maximum allowable exposure values $L_{EX,8h}$ = 85 dB(A) and $L_{pC,\ peak}$ = 137 dB are not exceeded. The obligation on the part of workers to use hearing protectors is also governed by the German Occupational Safety and Health Act.
– **Occupational health care**
  Regular occupational medical examinations (audiometric tests), including initial examinations and follow-up examinations, must be arranged for by the employer.

Note: In the case of activities during which the noise exposure fluctuates considerably from one working day to the next, a weekly noise exposure level $L_{EX,40h}$ can be applied. But this is subject to permission from the competent authority, which may issue this if

measurements have shown compliance with the maximum exposure level $L_{EX,\,40h}$ = 85 dB(A) and the measure to minimise the risk has been taken.

Note: When using acoustic instruments, peak sound pressure levels above $L_{pC,\,peak}$ = 137 dB tend to be improbable, but a daily or weekly exposure level of 85 dB(A) is soon exceeded for professional musicians – without the application of noise control measures.

Table of action values and protective measures

Measures	Lower action values $L_{EX,8h}$: 80 dB(A) $L_{pC,peak}$: 135 dB(A)	Upper action values $L_{EX,8h}$: 85 dB(A) $L_{pC,peak}$: 137 dB(A)	Noise and Vibration German Occupational Safety and Health Ordinance
Information and instruction	≥		§ 11
Provision of hearing protectors	>		§ 8(1)
Offer of regular audiometric examinations	>		§ 14(3)
Organisation of regular audiometric examinations		≥	§ 14(1)
Health records		≥	§ 13(6)
Wearing of hearing protectors		≥	§ 8(3)
Noise reduction programme		>	§ 7(5)
Marking of noise areas		≥	§ 7(4)

Many specifications in these regulations appear at first not to have much to do with the music and entertainment sector and difficult to implement accordingly. This is surely the result of the fact that the EU Directive 2003/10/EC is geared in particular to noise control for workers in industrial production and the crafts. On the other hand the directive lays down basic principles of preventive hearing care which have proven themselves in numerous, very different areas of the world of work. There are hardly any alternatives to these – unless one does without them, which would involve a reduction in the level of protection. Pertinent implementation of the regulations requires well though-out individual solutions geared to the respective workplaces. The following chapters of this guide are intended to provide employers and workers affected in the entertainment industry with ideas for the development of such individually realisable sound control strategies.

The right strategy for a specific case in effectively protecting against hearing damage is one that is geared to the circumstances of the relevant professional profiles and fields of activity. For stage designers the procedure will be different from that for a DJ, a producer or the catering staff. What is crucial is that a bundle of measures can be put together for each one. Five basic strategies are given below.

Just as the professional profiles in the music and entertainment industry are highly varied, so the measures taken to help avoid sound exposure which is harmful to hearing should be individually tailored. Concrete strategies are intended to highlight to all potentially concerned individuals and actors – employers and workers, organisers, promoters, musicians, performers, service staff etc. – constructive possibilities for action and behaviour in order to preclude the risk from noise.

4
Strategies of Exposure Limitation

4.1 Workplaces in the music and entertainment sector – Who is at risk?

This guide relates to workplaces in the music and entertainment industry at which music or noises are the principal product or part of a performance. For example in:
– concert halls
– theatres
– open-air stages
– discotheques
– clubs
– bars
– sound studios
– music colleges

Below a number of activities in the music and entertainment industry are listed which frequently involve sound exposures which are hazardous to one's hearing.

Professions in the music and entertainment sector		
Musicians	Theatrical directors	Stage hands
Conductors	Choreographs	Roadies
Singers	Sound designers	Music teachers
DJs	Light designers	Serving personnel
Actors	Stage designers	Bar, kitchen personnel
Dancers	Special effect designers	Catering personnel
Composers	Producers	Box office personnel
Managers	Sound engineers	Security personnel
Technical directors	Audio and video engineers	Paramedics
Artistic directors	Lighting engineers	Technical personnel

4.2 What strategy and for whom?

Criteria for the selection of the strategy

In this chapter and in chapter 5 procedures for limiting the sound exposure of workers are described. In view of the large number of different activities in the music and entertainment field, individual approaches are always necessary for the specific case. Since not all conceivable workplaces in this sector can be considered in detail, five basic strategies are presented in the following. Which of these strategies is the suitable one depends mainly on the function you occupy in the music and entertainment sector (e.g. employer, worker) and the nature of your activity. The five strategies therefore address different occupational groups within the entertainment sector.

For example, it is certainly appropriate in many areas to consider optimising the room acoustics. This could concern an orchestra pit, a rehearsal room or the area of a discotheque. But these matters are the responsibility of the employer and are certainly appropriate mainly when his workers are employed primarily at the same venue.

The choice of a suitable strategy is therefore made in accordance with the next table after the following questions have been answered:
– Are you an employer or a worker?
– Do you employ artists or technical/service personnel?
– Are your employees employed in a single location?

Strategies of Exposure Limitation					
Occupational group	Employer	Employer of artists	Employer of service personnel	Employer	Workers
	operator of a venue or event organiser			suppliers, operators of sound systems	in artistic or service domain
	stationary	non-stationary	non-stationary		
Example	– manager of a bar, discotheque – theatre manager – concert organiser	person responsible for performance – bandleader – orchestral management – ensemble management	provider of – catering – security – first aid	Loan of or trade in sound systems sound engineering at venues	– performing artists – musicians – music teachers – service personnel – technicians
Strategy	**1**	**2**	**3**	**4**	**5**

Strategy 1
Employer and organiser or promoter of a music performance, operator of a venue

Who?

You are an employer and you are organising a music event. Normally you employ actors and musicians or you engage an orchestra or promoter, for example. In a typical case you are the manager of a theatre, club or discotheque. You may possibly also employ service personnel who are not directly involved in musical performances, such as waiters/waitresses or box office personnel.

What has to be done?

As employer and organiser you should
- ensure that your health and safety strategy protects workers from any noise impact that is hazardous to health
- make this strategy clear to your workers or promoters
- keep yourself informed about regulations and technical standards
- keep yourself informed about the content of the present guide and make its subject matter clear to your workers
- occasionally provide your workers or new personnel with suitable information on the risk due to noise

Risk assessment and sound level

You can apply the following procedure in order to identify health risks due to sound exposure:
- Establish the situations and areas where high sound levels may be experienced. Rule of thumb: if persons one metre away from one another can only communicate by raising their voice, the sound level will mostly be above 85 dB.
- Have the sound level measurements conducted by a skilled person during a typical event
- Determine the exposure level for performers, technical personnel and service personnel

Exposure limitation

If the exposure level to which your workers is subject is too high, check to what extent a reduction of the sound is already possible at source, e.g. by
- reduction of the sound level of your performance where practicable (consultation with promoters and specialists for occupational safety and health).
- (contractual) stipulation of noise levels which promoters and performers may not exceed.
- reduction of stage sound system to a practicable extent
- reduction of the loudness of individual instruments, e.g. drums, or use of smaller amplifiers to lower the sound level on stage.
- checking whether an upper limit already exists for the sound level generated as a result of environmental protection regulations (e.g. Ordinance on Places of Assembly). Take account of these when making contractual arrangements with your partners.
- compliance with technical standards and liability regulations towards the audience with respect to excessive sound systems which can be harmful to health (e.g. DIN 15905-5, duty of care).

Sound level reduction

Reduce the sound level by structural and technical measures
- enlargement of the distance between the non-performing workers and the stage or loudspeakers in order to reduce the direct sound exposure in the personnel's working areas
- installation of loudspeakers directly above the dance floor
- reduction of the sound level of those loudspeakers located close to workers
- installation of sound level limiters in amplifier systems
- appropriate acoustic shielding of service areas, such as offices, kitchen, recreation rooms and administrative areas, by the use of walls and doors with suitable sound insulation
- sound baffles in the proximity of the bars, the kitchen or other service areas
- enhancement of transmission losses through enlargement of the absorption of rooms with the use of acoustically active ceilings, walls and linings
- musicians can use special sound-absorbing baffles to protect themselves from the sound of other musicians and to improve their perception of their own instrument
- musicians' practice rooms should be of appropriate size and have suitable acoustic properties (chapter 5).
- by the appropriate design of concert stages and orchestra pits, the exposure of musicians to sound can be reduced and the sound quality in the auditorium improved
- obtain specialist assistance from acoustic experts

Note: When renovations are being carried out, plan with acoustic experts and architects how the acoustic properties of venues or practice rooms can be optimised in a proper fashion.

Consider organisational measures for exposure reduction:
- marking of areas in which peak levels of 137 dB(C) may be exceeded and prohibited access for persons who are not wearing suitable hearing protectors
- reduction of the exposure level by shortening the time in which workers are exposed to high sound levels. This can be achieved by reassigning the (service) personnel in rotation from noise areas into quieter areas.
- indication also to temporary labour agencies that they have an obligation with regard to the health and safety of workers

Use the other technical and organisational possibilities for exposure limitation as described in further detail in chapter 5 of this guide.

Obligations

Alongside the obligations described in chapter 3, you should in particular
- inform your workers about their sound exposure and possible risks, preventive audiometric examinations and the availability and use of hearing protectors
- mark noise areas
- organise preventive audiometric examinations (from $L_{EX,8h} \geq 85$ dB(A))
- provide your employees with suitable hearing protectors if the sound exposure cannot be reduced sufficiently by technical and organisational measures. This applies both to performers and musicians and to technical or service personnel. There are special hearing protectors for musicians with which the frequency range can be attenuated evenly. Consider offering your audience hearing protectors.

Note: The provision of hearing protectors does not release you from your obligation to minimise the sound exposure by taking sound reducing measures.

Strategy 2
Employer of musicians and performers not employed in a single location

Who?

You are an employer and
- you conduct a band, an orchestra or another ensemble and employ the relevant musicians and performers
- you organise music events and engage performers
- you are engaged by an organiser to make music or provide musical performances
- you employ freelance artists

Permanently employed musicians and performers should note the remarks under Strategy 5.

What has to be done?

As an employer you should in general
- draw up a health and safety strategy to give protection against sound which is harmful to health and put it into practice,
- be familiar with statutory regulations and the state of the art, and fulfil your obligations with respect to occupational safety and health,
- be familiar with the subject matter of the present guide and follow the recommendations,
- discuss these topics with the performers, the technical personnel and other workers.

Risk assessment and sound level

You can apply the following procedure in order to identify health risks due to sound exposure:

- First estimate whether the sound level of your performance is within the range that is a health risk. Rule of thumb: if persons one metre away from one another can only communicate by raising their voice, this will probably be the case.
- If necessary determine the sound level of a typical performance under typical conditions by conducting measurements. You can also contact the organiser and take steps together to have the sound level measured and, where relevant, the sound reduced.
- Determine the exposure level for performers and technical personnel
- Conduct a new risk assessment if there have been significant changes to the kind of musical instruments used, the musicians, the amplifiers, the sound system or the performance.
- Clarify with the organiser or manager whether a maximum sound level has been agreed and what sound level is desirable.
- Do not exceed the agreed sound level.
- Inform the organiser before the event of the typical sound level for your performance.
- You can monitor or record the sound level during the event.
- Take account of the regulations and standards regarding protection of the environment and the audience (e.g. DIN 15905-5, duty of care).

Exposure limitation

The possibilities for reducing the sound exposure for your workers include

- reduction of the sound levels of your performances as far as practicable,
- reduction of the stage sound emissions to an appropriate level,
- information and training of personnel controlling the sound system (audience and monitors),
- reduction of the loudness of individual instruments (e.g. percussion or certain instrument amplifiers) so as to limit the sound level on the stage,
- use of mobile technical sound reduction measures for musicians (chapter 5.1),
- enlargement of the distance between non-performing workers and the stage or the loudspeakers,
- giving priority to performance venues with good acoustic conditions and requirement of corresponding circumstances from the operator.

The practice rooms of your musicians should be of an appropriate size and have suitable acoustic properties (chapter 5.1).

Use the other technical and organisational possibilities for exposure limitation as described in further detail in chapter 5 of the present guide.

Obligations

Alongside the obligations described in chapter 3 you should pay attention in particular to the following

- instruction of workers concerning their sound exposure and possible risks, preventive audiometric examinations and the availability and use of hearing protectors,
- provision of suitable hearing protectors where the lower action value is exceeded. There are special hearing protectors for musicians with which the frequency range is attenuated evenly.
- organisation of preventive audiometric examinations (from $L_{EX,8h} \geq 85$ dB(A)).

Strategy 3
Employer of service personnel at changing venues

Who?

You are an employer of security, catering or paramedical personnel, stage, sound and lighting engineers or media representatives.

What has to be done?

In general you should
- keep yourself informed about statutory regulations and technical standards, and the obligations regarding health and safety at the workplace
- keep yourself informed about the content of the present guide and comply with its instructions
- discuss these topics with your workers

For every venue you should
- clarify with the organiser whether the workers may be exposed to noise levels which are harmful to health
- find out who is responsible for noise control measures
- find out which noise control strategies are applied and comply with their instructions
- check possibilities for organisational sound reduction measures

Obligations

Your obligations as described in chapter 3 include, among others,
- instruction of workers concerning their exposure to sound and the possible risks, preventive audiometric examinations and the availability and use of hearing protectors
- provision of suitable hearing protectors if the lower action value is exceeded
- organisation of preventive audiometric examinations (from $L_{EX,8h} \geq 85$ dB(A))

Strategy 4
Employer and supplier or operator of sound systems

Who?

You are a supplier or operator of sound systems, e.g. for a night club, a hotel, a concert hall or an open-air concert, or you operate these technical systems at the venue. You are freelance and/or employed personnel who operate such equipment during the event.

What has to be done?

In general you should
- keep yourself informed about statutory regulations and technical standards and the obligations concerning health and safety at the workplace
- provide information on the safe use of installations and systems which you rent out or sell
- keep yourself informed about the content of this guide and comply with its instructions

Information for your customers

Advise the owner or organiser on
- the appropriate area of use for the equipment
- the safe handling of the systems including amplifiers
- circumstances which can result in hearing damage
- the need to monitor the sound level during rehearsal or the event
- areas in which the peak level can exceed 135 dB(C)

The information can be transmitted in oral or written form or, for example, by means of warning signs applied to the technical equipment.

Erection

- Position the loudspeakers as far as possible so that they are not directly facing places where workers assemble.
- Position the loudspeakers in such a way that it is possible to restrict access to areas with peak levels of >137 dB(C).

Operation

- Keep yourself informed about the organiser's or owner's sound control strategies.
- Keep yourself informed about sound levels desired by the organiser and maximum allowable sound levels.
- Facilitate the monitoring or recording of the sound level and keep related information for the organiser.
- Comply with regulations and standards with respect to protection of the environment and the audience (e.g. DIN 15905-5, duty of care).

Obligations

Your obligations, as described in chapter 3, include, among others,

- instruction of workers concerning their sound exposure and possible risks, preventive audiometric examinations and the availability and use of hearing protectors
- provision of suitable hearing protectors for your employees
- organisation of preventive audiometric examinations (from $L_{EX,8h} \geq 85$ dB(A))

Strategy 5
Workers

Who?

You are, for example,

- a performer or musician employed in an orchestra or ensemble
- employed in the light or sound engineering field
- a worker in the catering operations during the event
- a worker and employed at an event as waiter/waitress, bar, security, kitchen or stage personnel, paramedic or media representative

What has to be done?

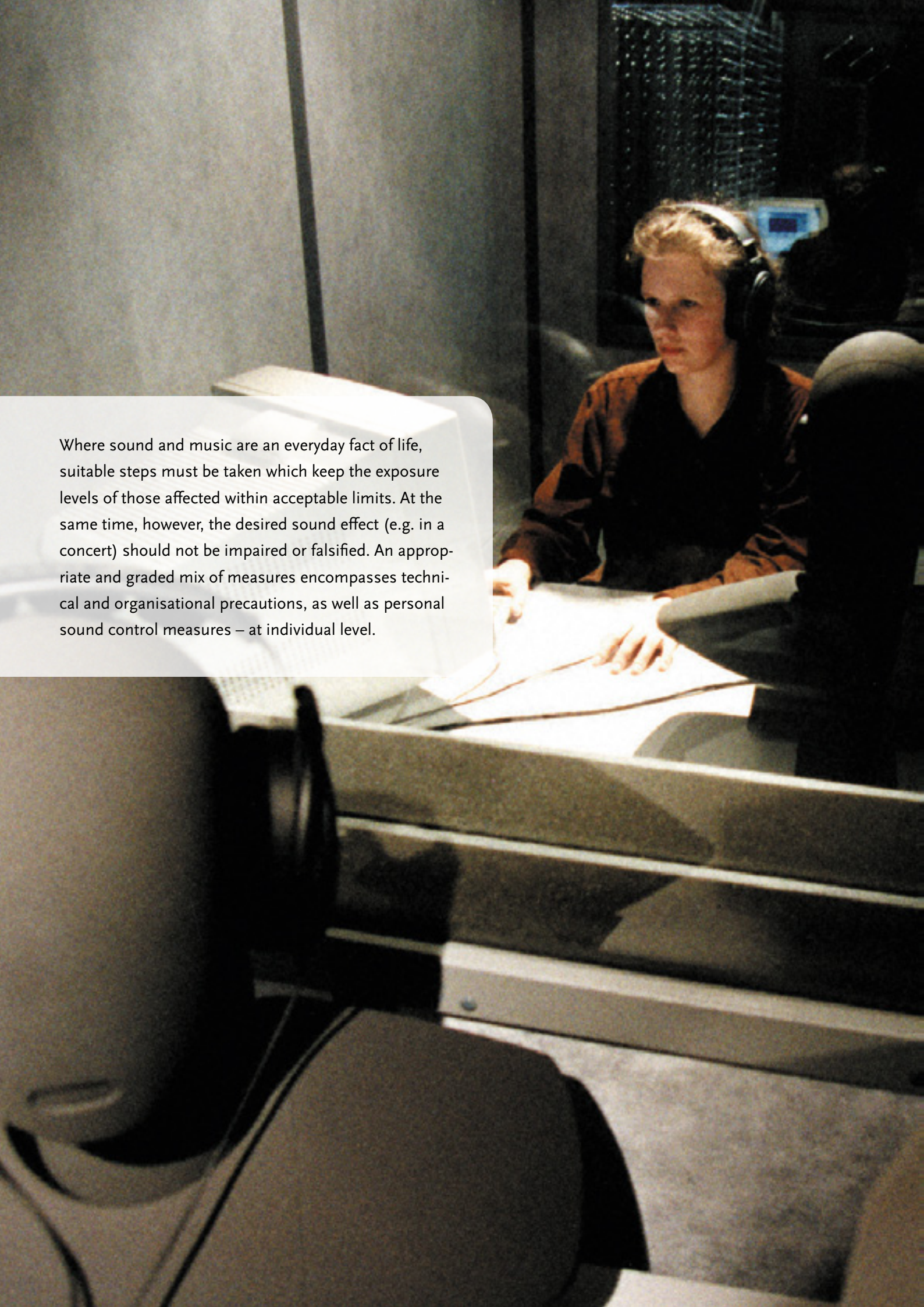
- Keep yourself informed on whether you are exposed to sound levels which are hazardous to health – ask your employer.
- Keep yourself informed about risks and sound control strategies as described in the present guide.
- Consider what sound control measures are applicable in your area.
- Keep yourself informed about what hearing protectors could be suitable for you.

Obligations

Your obligations encompass in particular

- compliance with instructions from the employer or organiser concerning protection against the impact of noise which is hazardous to health
- not rendering sound-reduction measures ineffective
- if necessary, use of hearing protectors
- reporting to the employer on new situations in which noise may arise which is hazardous to health and informing him of any hearing impairment
- taking advantage of preventive audiometric examinations

Note: There are special sound-neutral hearing protectors for musicians which attenuate the audible frequency range evenly (chapter 5.3).



Where sound and music are an everyday fact of life, suitable steps must be taken which keep the exposure levels of those affected within acceptable limits. At the same time, however, the desired sound effect (e.g. in a concert) should not be impaired or falsified. An appropriate and graded mix of measures encompasses technical and organisational precautions, as well as personal sound control measures – at individual level.

5
Exposure Reduction

Reduction of the exposure to sound, whatever the form, basically starts “at the source”, i.e. where the sound is generated. This may affect the orchestra pit just as much as the loudspeaker on stage or in the club. The conditions under which music is presented or performed play a crucial role of course – what are the expectations of the audience, what is the loudness aimed at, what circumstances relating to the room have to be taken into account? Other options for reducing the sound exposure exist on the sound propagation path and on the side of the workers themselves. Basically collective measures such as technical and organisational sound control always have priority over individual measures, such as hearing protectors – and so all those concerned can be effectively and reliably protected.

“Music is often felt to be a disturbance because it always involves noise”, this quotation of Wilhelm Busch is not only applicable to people who are not special lovers of musical activities, but also to active musicians and all those working in the music industry. After all, like machinery noise music can also be damaging if the sound level or duration of impact exceeds certain limits.

5.1 Technical measures

If one wishes to prevent excessive sound levels in the area of music, for practising musicians, organisers, service personnel and disc jockeys, technical measures based on acting on absorption or reflection may help.

These include
- sound baffles or partitions with predominantly sound-absorbing surfaces installed in the sound path
- sound-absorbing linings on the room limiting surfaces, such as walls and ceilings
- deflection of the sound in directions where it is desired or where it can do no harm,
- appropriate orientation of loudspeakers away from workers and the installation of quieter zones – also for musicians on the stage

5.1.1 Sound reduction by absorption and reflection

Direction-dependent sound emission

All sound sources are characterised by the fact that they do not emit sound evenly in all directions, but in preferred directions. This more or less directional sound emission changes in addition with the frequency, i.e. with the pitch. In general it can be said that very low tones such as those of a double bass exhibit an almost spherical sound emission, in other words they are emitted at equal strength in nearly every direction. Very high tones or sound fractions, e.g. those of a trumpet, on the other hand, are often emitted in tightly bundled form.

Taking an example such directional dependencies will now be highlighted. Let us assume there are two musicians standing next to one another in a large meadow, a trumpeter and a double bass player, and they are making music together. If you walked around these musicians you would notice that the timbre and loudness of the music will change considerably as you do so. You would notice this particularly with the trumpet, which sounds much louder and brighter or sharper in front of the trumpet mouth than behind or next to the trumpeter. The reason for this is the particularly marked bundling of the high-frequency sound components in the direction of the bell axis. In the case of the double bass these differences are not so pronounced because the sound-forming low frequencies are emitted with equal intensity in nearly every direction.

In the case of the open air situation, the sound of the musical instruments passes along the direct route to the listener's ear. This changes immediately when the event takes place in a room, whatever the size! Now the sound waves of the instruments also hit the room boundary surfaces (wall, ceiling and floor), are partly reflected there and hence reach the listener by indirect routes. This causes changes both in the timbre and in the loudness as compared to the open air situation, and so one says "the room is playing along with the instruments"!

When the sound waves hit the room boundary surfaces the consequences may vary. On the one hand the sound may be reflected completely, as one would expect of a light ray on a mirror surface, and on the other it could also be completely swallowed up, in other words absorbed. In practice only a portion of the impacting sound waves are reflected and the rest is absorbed. Reflection and absorption depend on the nature of the surface. The harder and smoother the surface, the greater the reflection, while soft, fibrous and porous materials are more absorbent. And so the sound reaches the listeners directly from the instrument as well as via reflections on the walls. The sound level in rooms is therefore always substantially higher than in the open air.

Note: The higher the absorption in a room, the lower the sound level, and all the quieter the sound event!

Sound-absorbing wall and ceiling linings can reduce the sound level in the room by as much as 10 dB. On the other hand musical performances need reflection to a certain extent in order to achieve a living sound.

5.1.2 Measures for musicians

Of course as a musician you can also wear hearing protectors, but this involves certain disadvantages, which we will examine elsewhere. In this section there will be a discussion of technical measures which can give rise to a reduction of the sound level.

The aim of these technical measures is to reduce the sound exposure experienced by the musicians affected without tonal losses. This means that the musical product, in other words the sound at the ear of both the listener and the musician, is not falsified.

5.1.2.1 Room-acoustic measures for musicians

The room-acoustic measures include partitions between the musicians, e.g. in the orchestra, or the application of sound-absorbing materials to the room boundary surfaces, as well as the consideration of directional sound emission from loudspeakers and musical instruments. In order to understand the way such technical measures act, the main room-acoustic effects will first be examined more closely below.

These considerations apply to all rooms where music is practised, performed or reproduced. They include concert halls or other venues, clubs, orchestra pits and rehearsal rooms in theatres as well as tuning rooms for the individual instrument groups. But practice rooms in music colleges or universities are also covered. Here technical measures can reduce the sound exposure of those affected both during erection and renovation.

By assembling reflecting and absorbing materials as technical measures, the intensity of the sound fractions reaching the ear can be reduced. This makes sense, for example, in orchestras, where heavy brass instruments (trombones and trumpets) produce the biggest sound fractions, which are also bundled in the direction of the bell axis. This means that the musicians sitting in front of the heavy brass are subjected to particular sound emissions.

Partitions and sound baffles

If partitions are set up between the rows of musicians, for instance in front of the heavy brass section, they can with be of the absorbing or of the reflecting kind. The effect this produces will vary considerably. If such a partition is reflecting on both sides, the sound of the heavy brass section will be thrown back and this will add to the sound exposure experienced by the trombonists regarding their own sound. On the other hand less sound will go from the heavy brass to the rest of the orchestra and the conductor. This means that the members of the orchestra will hear one another worse and the conductor will call on the heavy brass to play more loudly. In addition the reflections on the front of the partition will increase the sound level at the ears of the musicians sitting directly in front of it with respect to the sound coming from the rest of the members of the orchestra. These sound fractions will in turn not reach the ears of the brass players, and so they will hear their colleague less well. In brief, such a reflecting partition would only have disadvantages.

If the partition is absorbent on both sides, this will be perceived as a reduction of sound level both to the heavy brass section and the musicians sitting front of them. But their reciprocal hearing will be impaired. The conductor may also call on the orchestra to play more loudly, which counteracts the effect of this measure.

It is highly conceivable that only a combination of sound-absorbing and reflecting surface on such partitions can produce the desired result.

Wall and ceiling lining

The situation is similar with regard to reflectors or absorbers mounted on the walls of a room where music is made. The following should be considered here.

Since the sound level increases by as much as 3 dB directly in front of a hard, reflecting wall, musicians sitting close to it should be protected by sound absorbers on the section of wall near to them.

An enlargement of the sound absorption on room boundary surfaces of a music room leads as a matter of course to a reduction of the sound level, but at the same time the reverberation time as a measure of the reverberative nature of the room is also shortened. The room thus takes on a greater acoustic "intimacy", but the volume of sound and the brilliance are adversely affected. Only such absorbers should therefore be selected which are adjusted to suit the particular circumstances and which act in the relevant frequency ranges. It is often beneficial to use low-frequency absorbers which avoid the droning effect of standing waves (resonances).

Technical measures used to date and their problems

It can often be seen in rehearsal rooms and orchestra pits that an attempt is made to ward off excessive sound levels using the simplest means. Often one or more of the following technical measures are used in combination:

a – transparent partitions of acrylic glass (plexiglass) between the groups of instruments,
b – arched or even flat acrylic glass panes of small size behind the heads of musicians exposed to high sound levels (mostly fastened to the chair or arm of the chair),
c – carpets,
d – thin, honeycomb foam panels or "egg boxes" above or next to the percussion (kettle-drums, drums, percussion).

The effects of these measures may differ considerably.

Large, transparent partitions

Re a: Larger transparent partitions of mineral or acrylic glass reflect the sound on both sides in the middle and higher frequency range, but low frequencies or sound fractions are not reflected, or hardly at all. When such partitions are set up, their "shading" effect cannot develop fully in the case of low-frequency instruments, such as kettledrums and double basses.

Owing to the double-sided reflection the musicians sitting behind the partitions are subjected to louder sound than they would be without the partitions, and this is due to their own sound! The musicians sitting in front of the partitions are protected from exposure to the sound from behind, but the portions of sound impacting on them from in front are boosted by such partitions. Furthermore such partitions change the composition of the orchestra sound reaching the conductor, with the danger that he will make the counterproductive demand to play louder.

Small, transparent panels

Re b: Small, transparent panels behind the heads of musicians subject to high sound levels have, like the larger partitions, the effect of reflecting sound on the front and back. Because of their small size, however, this effect is limited to the higher frequency range. A protective effect only arises then with the higher-frequency sound portions, and the lower frequencies are not reflected but curve around these baffles!

Owing to the small distance between the panels and the head – and hence also the ears – of the musicians, the sound portions coming in from the front are boosted by the reflec-

tion. On the one hand, this leads to a greater exposure of the players and, on the other, to a deterioration of their own hearing. This effect is reinforced further if the baffles mounted at head height also curve around the head. This increases the sound level of the sound portions coming from the front due to the focussing effect of the curvature.

Carpets

Re c: Carpets with the thickness of normal fitted carpeting (4–8 mm) display an absorption effect which rises with the frequency. This is only noticeable at very high frequencies (e.g. hissing sounds). In contrast, at middle and low frequencies carpeting has no great effect. By laying a carpet one obtains a somewhat more intimate acoustic "atmosphere" and one avoids scuffing noises on the otherwise hard floor. With carpeting it is practically not possible to achieve any appreciable reduction of sound levels.

Foams

Re d: The acoustic effect of porous materials such as foam depends on the internal structure of the material and the surface texture. Normal foam such as is used for upholstery has practically no sound-absorbing ability, and neither do thin-walled compressed paper structures, such as egg boxes. But because they have a similar appearance to be highly effective foam absorber panels, it is frequently supposed that egg boxes have the same absorbing effect. This is not true, however, but rather thin panels of normal foam and egg boxes have as good as no sound-absorbing effect.

Suggestions for mobile technical measures

Mobile measures

Where the orchestra is on a mobile assignment or where the members or seating arrangements are constantly changing, it is not possible to mount fixed absorbers or reflectors in the room. Here movable structures must be used to help out.

To ensure the adequate effect of acoustic measures, both with regard to absorption and to reflection, the geometrical dimensions may not be too small. For partitions between the musicians the lower limit should be not less than a width of 1 metre, since otherwise the effect will not cover the highest frequency portions of the instrumental sounds. The height of such sound baffles should be so great that the upper edge of the baffle is substantially higher (as far as possible > 50 cm) than the heads of the musicians sitting in front of it. The partitions should also reach down to the floor, i.e. as far as possible they should rest on the floor and be in tight contact with it to prevent any sound from passing round the baffle.

To ensure good visual contact between the musicians and between them and the conductor it is essential for the partitions to be transparent in the upper area. If this upper, transparent zone is also intended to have a sound-absorbing effect, it must not be of normal glass or acrylic glass panes, but should consist of a number of microperforated glass panes. If the absorption is only supposed to be effective on the rear of the partitions, 2 panes with a distance of 3–5 cm between them must be used, the front one being closed and the one behind microperforated. If the partition is intended to absorb sound on both sides, the set-up described must be supplemented by an additional microperforated pane in front of the unperforated one.

To absorb sound below the visual zone, it is possible, for example, to mount acoustic foam absorbers on a hard base plate. But other absorbers, such as mineral wool panels, can be used which are covered by a perforated or slotted metal, wooden or plasterboard panel. Care must always be taken, however, to ensure that the sound of the musicians seated behind the baffles can get to the conductor at sufficient loudness since otherwise his control over the balance of the orchestra' sound may be adversely affected. If there is any doubt, it

is advisable to mount additional reflectors above the heads of the musicians to direct the sound towards the conductor.

Suggestions for permanently installed technical measures

Stationary measures

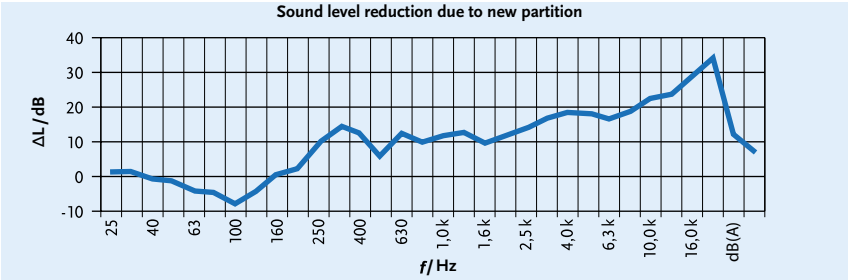
In rooms where the orchestra always has the same or a similar seating arrangement, permanently installed measures can be taken. The same applies with regard to teaching and practice rooms in music colleges or tuning up rooms in theatres. It goes without saying that mobile partitions or sound baffles can and should be used in such rooms. When mounting absorber materials on walls and ceilings, the following must be noted:

1. Walls and ceilings in front of or under which musicians sit after a small distance should, where there are loud instruments such as trumpets, trombones, tubas and percussion instruments, be lined with sound absorbers which preferably absorb the middle and higher frequency ranges. These include flat wall linings consisting under the surface of, for example, mineral fibre, wood fibre or foam. This will reduce the sound levels to which the musicians and their colleagues sitting next to them are exposed to.
2. In order to avoid standing waves (resonances) in the low frequency range – they lead to heavy droning! – low-frequency absorbers should be mounted to the near wall and ceiling surfaces in the area of low-tone instruments (double basses, kettle drums). This mostly involves resonating, thin panels on a cavity with or even without additional damping (panel absorbers). In practice these are, for example, approx. 6 cm thin chipboard panels on a slatted grate backed by a mineral fibre mat or thin metal plates, which are stuck to approx. 10 cm thick foam. These "composite panel resonators" (CPR) are available in sizes of up to 80 x 150 cm and can be suspended like pictures on a wall.

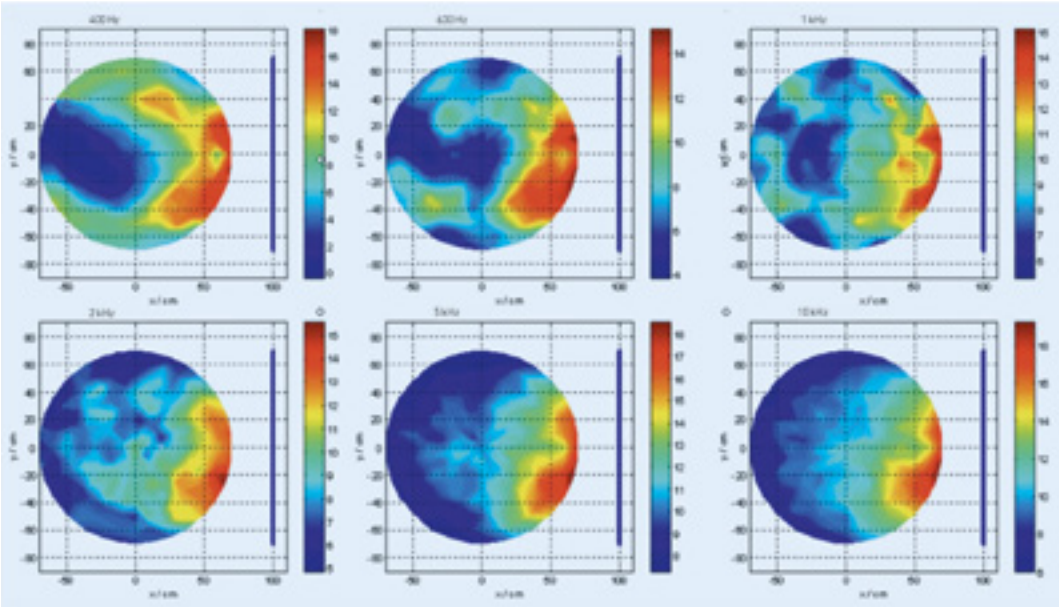
Example of a baffle partition

The picture shows a relatively simple, but effective design of a sound baffle for use in an orchestra. The design consists essentially of a 200 cm high, continuous, 6 mm thick acrylic glass pane whose upper part is bent over at a height of 120 cm and is inclined forward at an angle of 45°. The lower part is covered with sound-absorbing material. Thanks to the inclined upper part of the partition, the sound of the musicians (brass) playing behind it is deflected upward and reaches the conductor and the audience after further reflections on the ceiling or additional reflectors suspended. The dimensions of this partition were selected for a case where the musicians are seated behind it on a 1 metre high platform. The size and form of such a partition must be adjusted to the seating arrangement in each case. The sound control for the musicians (string instruments) sitting in front is all the greater the smaller the distance to the partition. But inadequate distances of < 50 cm may adversely affect the playing. To increase the sound insulation effect a number of these baffles can be joined to one another, the joint being made soundproof with the use of elastic seals.

Sound screen developed in a joint project of PTB, Städtische Bühnen Münster and Unfallkasse NRW.



Level reduction at a distance of 0.5 m in front of the screen



Sound insulation values at different frequencies for a single baffle. What is shown is the sound field (from above) within a horizontal, circular surface at ear height of the seated musician. The centre of the circle is located 1 metre in front of the baffle (blue bar).

5.1.2.2 Acoustic instruments

Enlargement of distance

Enlarging the distances between the musicians offers a simple but effective possibility for reducing the individual sound exposure. In the open air or where the distances are small to the sound source, a reduction of as much as 6 dB can be achieved by doubling the distance.

Note: Musicians should not sit too close together.

Arrangement of the ensemble

If areas of highly excessive sound levels arise in the ensemble, a change in the arrangement may help. For example, with an equal number of musicians sitting in front of a single row of brass players, lower sound levels will arise than when they are sitting in front of a multi-row arrangement.

In the orchestra pit the areas below an overhang should be used as little as possible. Even the loudest instruments can be placed in the open area of the orchestra pit to ensure that their sound is not trapped in the pit, but can reach the audience.

In many ensembles the percussion instruments are the loudest. On the stage or in the rehearsal room an enlargement of the distance to the percussion can help the other musicians.

Steps

Placing the loud registers, such as the brass section, on steps can relieve the burden on the musicians sitting in front of it. But this measure only becomes effective with a step height of one metre or more, and primarily for instruments which emit the sound in a strictly directed fashion. Only in this way, for example, can trumpeters or trombonists play over the heads of their colleagues.

Under confined conditions, such as in the orchestra pit, it is often not possible to install sufficiently high steps. Then there is no point in compromising by installing shallow ones. It is precisely such a measure that will bring the bells of many loud brass instruments to the level of the other musicians' ears. It could be better to have the musicians in front of the brass section sit on slightly elevated pedestals to ensure that the bells of the brass instruments emit sound below ear level.

5.1.2.3 Electrically amplified instruments

Sound systems

Where electrically amplified instruments are used, it is possible in most cases to be more flexible in arranging the working environment than is the case in symphony orchestras. Exploit these possibilities and also take account of the following recommendations in order to avoid any excessive exposure of the musicians to sound.

Monitors

The loudspeakers of a sound system should stand or hang in front of the musicians, in other words at the edge of the stage. This will ensure that the musicians are not subjected to sound from behind or from the side. Once again the principle is that the greater the distance to these sound sources, the lower the sound levels.

The stage monitors should only be "turned up" to the point where the musician concerned can adequately hear his monitor sound.

Monitor and instrument loudspeakers should be aligned directionally or, where relevant, also be mounted in an elevated position. After all, it is a feature of loudspeakers that they emit high frequencies in a bundled form. An appropriate alignment towards the musician can therefore improve the clarity of the sound texture and the perceptions of one's own playing without having to raise the loudness.

In-ear monitoring can offer an ear-friendly alternative to a conventional monitor sound system (chapter 5.3)

5.1.3 Electro-acoustic sound system

One of the aims of operating sound systems should be to concentrate the high sound levels as far as possible on the areas in which they are desired by the consumer. A purpose-optimised sound system and adjusted room acoustics are a basic prerequisite of this.

Dance floor

It has, for example, proven useful to provide sound for dance floors with an even distribution of many low-powered loudspeakers in order to avoid areas with highly excessive sound levels. On no account should loudspeakers stand at the edge of the dance floor, since here it would be possible to come close to them quite arbitrarily. Suspended structures or installation in the ceiling are technically appropriate and render the dangerous areas close to loudspeakers inaccessible.

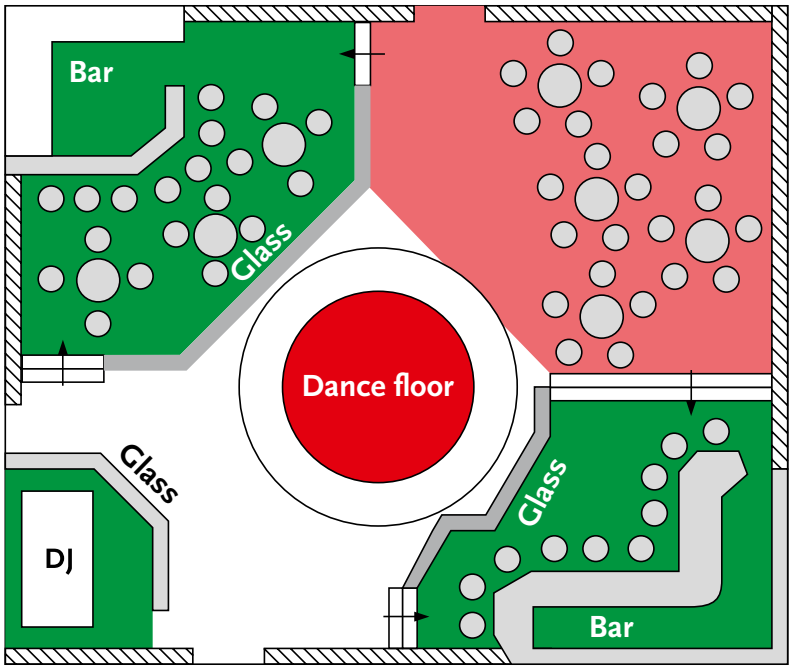
Service areas

Areas where workers are frequently present (bar, beverage outlets, sales stands) should be subjected to sound emissions as little as possible. Here no loudspeakers should be installed as far as possible. If they are installed there their loudness must be turned down as far as possible or they must be turned in other directions in order to avoid excessive sound exposure. It is advantageous to ensure the greatest possible distance between service areas and the loud areas (dance floor, stage). In addition, the walls and ceilings in these areas should be given sound-absorbing linings. Such areas can also be protected by means of baffles, such as partitions, with high sound absorption on the side turned towards the workers.

Limiters

Electronic sound level limiters can be used to control the power of the amplifier and prevent excessive sound exposure.

Disco with quiet areas



5.2 Organisational measures

A reduction of the sound exposure by taking organisational measures relates to the organisation of the activity or the organisation of the time system.

Time-related organisational measures act primarily on the noise exposure level L_{EX}. The exposure due to single, loud events (peak sound pressure level $L_{pC,\,peak}$), in contrast, is normally not affected. When organising work schedules the sound exposure levels to be expected should be taken into account in order to avoid periods with unusually high exposure levels. At music performances, a change of repertoire or premises should also be considered. A halving of the exposure time reduces the exposure level for the relevant activity phase by 3 dB (3 dB rule, chapter 1).

In the preservation of hearing, an adequate regeneration time for the hearing is of major importance, depending on the sound exposure level. Recuperation times must therefore be included in work schedules and any agreements on wages and conditions must be taken into account.

A cyclic change for workers between loud and less sound-exposed working areas or activities can help reduce the individual exposure.

In areas where music is being performed, the exposure reduction possibilities available for rehearsals should be considered. In this respect there is often a greater scope for manoeuvre when it comes to choice of loudness or the use of sound reduction measures.

Exposure reduction possibilities by organisational measures
- harmonisation of work schedules
- planning of recuperation times
- cyclic change of workplace
- rehearsals with reduced loudness or individual registers
- controlled application of sound reduction measures (chapter 5.1) during rehearsals: selection of suitable rooms, e.g. stage instead of rehearsal room, positioning of instruments, enlargement of distances, use of baffles etc.

5.3 Hearing protectors

Under the Occupational Safety and Health Act every employer is obliged to take all necessary measures to preserve the health and hence also the hearing ability of his workers. If the required protection cannot be achieved by measures unrelated to individuals, he must provide the individuals concerned with suitable hearing protectors without the workers incurring any expense. He is also obliged to ensure that the hearing protectors are used in a proper fashion and are maintained.

The workers are obliged to use the hearing protectors as intended (Occupational Safety and Health Act).

Note: Many practising artists (for example musicians) work for more than one employer and are freelance. Workers who have been given suitable hearing protectors by an employer for a particular activity should consider whether they will give adequate protection for all their activities. A DJ normally needs different, more highly absorbent hearing protectors than a cellist; e.g. an individually adapted otoplastic can be combined with levels of different filter ratings and hence adjusted to the relevant sound levels.

The present guide describes hearing protection strategies which will help you protect your hearing from sound-related hazards.

5.3.1 Selection of hearing protectors

5.3.1.1 Hearing protectors for musicians

Music contains many portions with higher frequencies. This makes hearing protection strategies necessary in particular for those who work with music or close to music. Artists, sound engineers and other workers must lower the sound levels without thereby substantially modifying the high frequency portions, which are important for the quality of the music.

Where does the problem lie?

The introduction of an object into the auditory canal changes the ear's natural acoustic characteristics of course (occlusion effect).

The occlusion effect

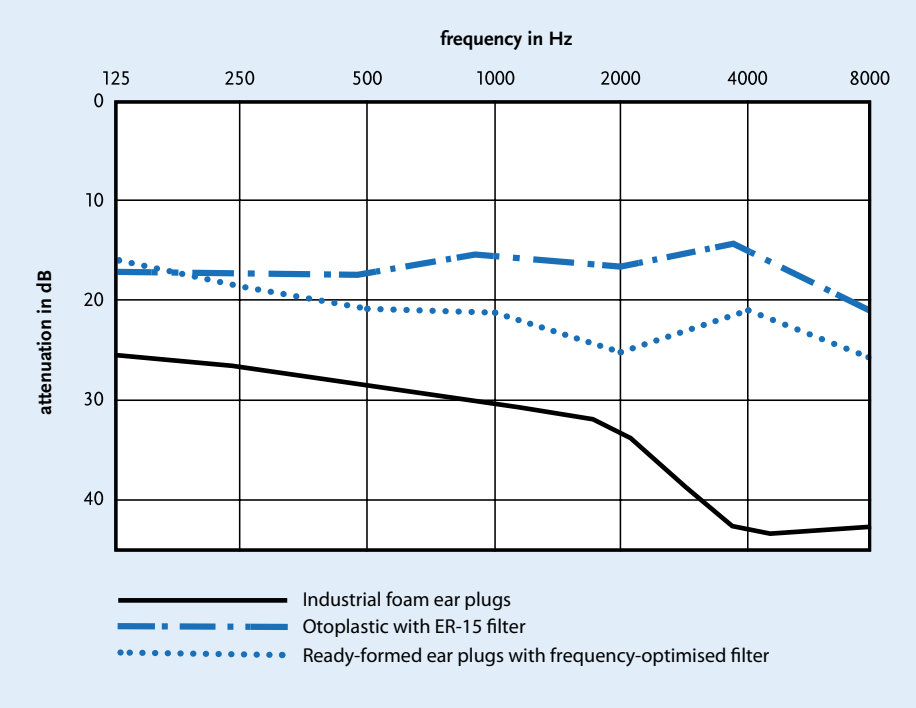
An occlusion effect arises when an object is inserted in the ear. Blockage of the auditory canal enhances the perception of the sound of the musician's own instrument conducted by the jaw bones, especially for the lower frequencies. This causes one's own voice to sound loud or hollow.

Making music with hearing protectors changes in particular the balance between the musician's own instrument and the orchestra.

In order to counter the occlusion effect the following is recommended: Use an adjusted ear plug which sits deep in the ear and reaches as far as the inner boney part of the auditory canal.

In addition, conventional ear plugs attenuate higher frequencies more than low ones. For example, an ear plug which lowers the sound by 25 dB in the range of 125 Hz can lower sound by almost 40 dB in the range of 4,000 Hz.

There are today special types of hearing protectors, however, with a so-called flat attenuation characteristic which substantially reduce the sound for all frequencies with approximately the same intensity.



Attenuation curves of hearing protectors

Hearing protectors for musicians, singers, conductors and music teachers

Who	Typical problems	Possible hearing protection
Flautists	– high peak levels – very high sound levels can arise at the ear on the side of the instrument	
Woodwind players	– more intense perception of the bone-conducted sound by the occlusion effect makes it more difficult to check the instrument when using ear plugs	
Brass players	– with the use of ear plugs the occlusion effect makes it more difficult to check the instrument	– otoplastics with flat attenuation characteristic
Stringed instrument players, harpists, pianists, harpsichordists, conductors and music teachers	– for stringed instrument players and harpists very high sound levels can arise at the ear on the side of the instrument	– ready-formed ear plugs with filter
Percussionists	– high sound levels	
Singers	– the voices of singers may be alarmingly loud (e.g. on the stage, in the chorus), especially sopranos' voices – the sound of other instruments makes it more difficult to check one's own voice	
Electrically amplified instruments	– amplifiers may cause extremely high sound levels	– otoplastics with flat attenuation characteristic possibly fitted with filters with higher sound attenuation – ready-formed ear plugs with filter – in-ear monitor systems

– In the case of trumpets and trombones there arise directional, sometimes extremely loud sound emissions which may affect other musicians in the orchestra. This means that musicians playing quieter instruments may also be subject to a hearing risk.
– Musicians playing close to kettle drums and percussion instruments can be affected by extremely loud sound emissions.

5.3.1.2 Hearing protectors for other artists and workers

For artists and other workers who have to hear the sound quality very precisely, but do not need to worry about the visibility of their hearing protectors, the possible strategies tend to be simpler.

If the sound quality heard is not of any great significance, artists and other workers can normally resort to hearing protectors which are both simple and inexpensive.

Hearing protectors for other artists and workers

Who?	Typical problems	Possible hearing protection
DJs, live-sound engineers, studio artists, studio technicians, other artists	– high sound levels due to loudspeakers – increase in sound level to mask the background noise	– otoplastics with flat attenuation characteristic, possibly equipped with filters with higher sound attenuation – ready-formed ear plugs with filter – in-ear monitors – monitoring headphones
Performers and personnel at theatrical and other live performances	– continuous sound (e.g. generators) – impulse noise (pyrotechnics, shots) – stage noises – technical noises	– ready-formed ear plugs – foam ear plugs – ear muffs
Workers in bars, clubs and at concerts	– protection against high sound levels which does not impair communications essentially	– communication necessary: – otoplastics with flat attenuation characteristic – ready-formed ear plugs with filter communication not necessary: – foam ear plugs

Impact of other sounds

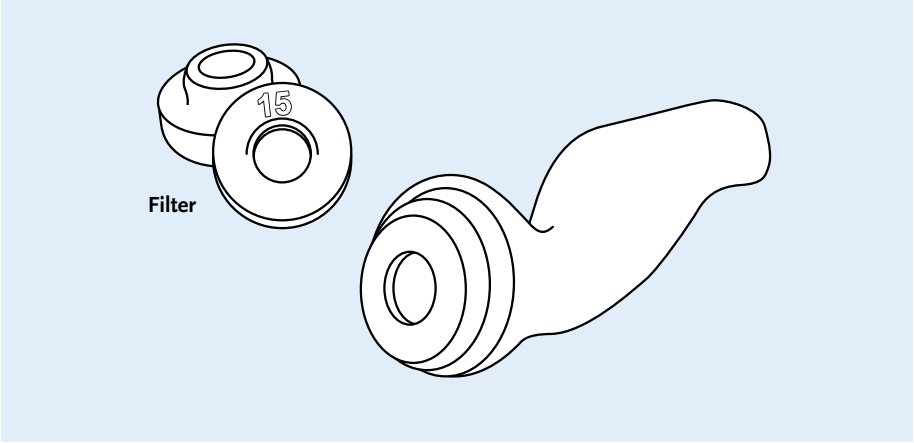
Where non-musical noise (background noise) impacts with high sound levels, it is possible to use hearing protectors which meet the simplest requirements. The frequency dependence of the sound attenuation is then less important. The sound attenuation must be so great that the possibility of hearing damage can be discounted. Excessive attenuation is not appropriate, however, because feelings of isolation may arise, communication can be made more difficult and warning signals are not heard (over-protection). The attenuation value of the hearing protectors should therefore be selected in accordance with the sound level.

5.3.2 Types of hearing protectors

5.3.2.1 Otoplastics with flat attenuation characteristic

Otoplastics with flat attenuation characteristic are individually adapted ear plugs which reduce the sound level over the whole frequency range by almost the same amount. They reduce the sound without substantially impairing sound quality.

Otoplastic with replaceable filter



How do otoplastics with flat attenuation characteristic work?

Otoplastics with flat damping characteristic consist of a silicon ear plug adapted individually to the user's auditory canal, then given a hole and subsequently covered with a button-sized filter. Otoplastics are normally made in a laboratory which supplies hearing aid acoustics specialists or hearing protection manufacturers.

The hearing protection filter types used – ER-9, ER-15 and ER-25 – lower the total sound level by 9, 15 or 25 dB. A smaller version with the name ER-15SP attenuates less at high frequencies (similarly to ER-9 and ER-25). The smallest changes in the sound impression are generated by the ER-15. As soon as you have the actual, adapted ear plug, you can use any of the filters ER-9, ER-15 and ER-25 because the filter size is the same.

The conch otoplastics which are worn in the outer ear have a higher occlusion effect than otoplastics which extend deep into the auditory canal.

Advantages

Advantages of otoplastics with flat attenuation characteristic:
- small changes in the sound impression
- optimum seat and protection by means of individual adjustment
- otoplastic (colourless, beige or brown) is optically not conspicuous
- can be used for years

Disadvantages

Disadvantages of otoplastics with flat attenuation characteristic:
- expensive
- adjustment by specialist necessary

User group

- musicians
- anyone who works with or close to electronically amplified sound (for example musicians, singers, DJs, sound engineers, conductors and music teachers)
- anyone who needs sound attenuation which modifies the sound as little as possible (flat frequency curve of attenuation).

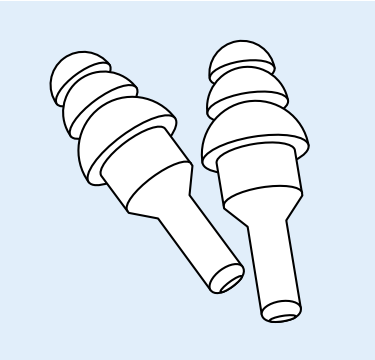
Sources

The filters of the ER series are supplied by a manufacturer and are inserted in the otoplastics which are made in laboratories and marketed by hearing aid acoustics specialists or hearing protection manufacturers.

5.3.2.2 Ready-formed ear plugs

User group

Ready-formed ear plugs have a universal form which fits the auditory canal of the average person. Most ready-formed ear plugs have a re-usable plug part with three ring stages, which has a certain similarity to a beehive.
Ready-formed ear plugs save one the need to compress before insertion. They adjust to the auditory canal as they are inserted in it. It is not possible to draw any conclusions from the design with regard to the level of sound attenuation or the frequency behaviour. These characteristics are mainly determined by the nature of the filters used. Some models contain a built-in filter with a quite flat attenuation characteristic:



Ready-formed ear plugs

Advantages

Advantages of ready-formed ear plugs
- less expensive as otoplastics
- longer service life than ear plugs that have to be formed
- no adjustment required
- easy to insert
- can be washed
- can be used frequently

Disadvantages

Disadvantages of ready-formed ear plugs
- more expensive than foam ear plugs
- attenuation characteristic basically not so flat as with otoplastics with ER filter
- wearing comfort less than with otoplastics
- optically more conspicuous than otoplastics

User group

- musicians and singers wishing to have less expensive ear plugs with quite flat frequency curve
- other artists and workers wishing to have inexpensive ear plugs and good speech intelligibility

Sources

- hearing aid acoustics specialists or specialist occupational safety and health trade

Sound attenuation values (HML values)

In Europe it is specified that the H values (high; sound attenuation values for high-frequency noises), M values (medium; sound attenuation values for middle-frequency noises) und L values (low; sound attenuation value for low-frequency noises) be given. If the three values are equal, the hearing protectors have a flat attenuation characteristic.)

5.3.2.3 Foam ear plugs

Foam ear plugs consist of a soft material (PVC or polyurethane foam) which is pressed together using one's fingers and then inserted in the ear. In the ear the plug expands again and adjusts to fit the form of the auditory canal. Such plugs are intended both for single and for multiple use – depending on the manufacturer's instructions.

Advantages

Advantages of foam ear plugs
- effective protection against high sound levels
- inexpensive
- can be carried at all times
- more comfortable than ear muffs in a warm environment

Disadvantages

Disadvantages of foam ear plugs
- no flat attenuation characteristic: high frequencies are attenuated more intensively than low ones
- occlusion effect falsifies the sound sensation in the case of woodwind and brass players
- hinders speech communication
- lack of ventilation can give rise to a sensation of perspiring
- care must be taken to ensure correct insertion in order to achieve full sound attenuation

User group

- performers and personnel, organiser's staff and other workers in situations where the sound quality and speech communication are not important, especially in music-free environments

Sources

Drugstores (chemists) and similar retail outlets sell several brands of foam ear plugs.

5.3.2.4 Ear muffs

Ear muffs are the classic hearing protectors for industrial workplaces; they are an excellent choice when appearance and frequency curve are not significant. Many ear muffs offer a high level of sound attenuation.

Advantages

Advantages of ear muffs
- easier to use and inexpensive
- effective protection against high sound levels
- easier to put on and take off than ear plugs
- more comfortable in a cold environment than ear plugs
- weaker occlusion effect than with foam ear plugs

Disadvantages

Disadvantages of ear muffs
- heavier and more conspicuous than ear plugs
- most models do not exhibit a flat attenuation characteristic
- perspiration around the ears when physical activity is being performed
- wearing over long periods unpleasant

User group

- workers close to loud sound sources (sound systems, pyrotechnic effects), the visibility of the hearing protectors not being a significant factor.

Products

A distinction is drawn between products where the headband passes over the head and those where it rests on the back of the neck.

5.3.3 Monitoring systems

5.3.3.1 In-ear monitoring systems

In-ear monitors are in principle ear plugs with built-in miniature monitors (loudspeakers).

How do in-ear monitors work?

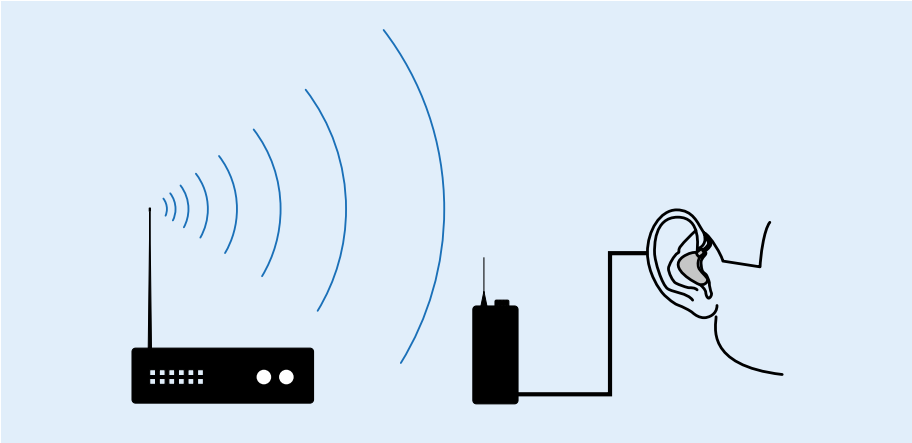
Functioning of in-ear monitors

An in-ear monitor normally consists of an ear plug adapted to fit your auditory canal and a cordless transmitter/receiver system you can carry on your belt. Inexpensive in-ear monitors sometimes only have earphones in universal form such as are used with MP3 players instead of adaptable ear plugs. It is not recommended that such earphones be used because they do not fit exactly and may allow sound from outside to penetrate, which will lead to higher monitor levels.

Pay close attention to tight fit and reasonable level

In the case of adapted models, the formed ear plugs must sit tightly and must reach as far as the bend in the auditory canal; otherwise background noise may penetrate past the plug. A poor fit may cause the user to turn the monitor level up in order to drown out the undesirable background noise.

Even if the ear plug fits well, the user must keep the loudness at a reasonable, not excessively high level. There are also systems with adjustable limiter.



In-ear monitoring system

Advantages

Advantages of in-ear monitors
- adapted ear plugs protect against undesirable background noise
- stage monitors are superfluous and lower the sound level there
- cordless transmitters/receivers give freedom of movement
- smaller and lighter than monitoring headphones

Disadvantages

Disadvantages of in-ear monitors
- expensive
- incorrect use possible: sound levels of as much as 120 dB(A) can be generated at the eardrum
- if the ear plugs do not fit tightly, background noise will penetrate, which leads to the temptation to raise the monitor level

Use

- at live music performances: reduction of the sound levels and individual levelling out

Warning:
Even when these systems are in use the maximum allowable exposure values must be complied with. A type examination (CE mark) does not automatically means that the sound levels have been effectively limited by the manufacturer. In cases of doubt one should contact the manufacturer. In-ear monitors should only be regarded as effective hearing protectors if they have passed a type examination according to DIN EN 352 and bear a mark accordingly. In practice this hardly ever arises. Therefore in-ear monitors are not generally considered to be hearing protectors within the meaning of the Noise and Vibration Occupational Safety and Health Ordinance LärmVibrationsArbSchV.

5.3.3.2 Monitoring headphones

Monitoring headphones are used for the kind of work with music where their visibility does not disturb the listener, for example in a sound studio. Sound engineers and other workers also use headphones in theatres and at other live performances for reciprocal communication.

Many headphones have ear muffs which provide a certain degree of protection against background noise. The more protection that is needed against background noise, the higher the passive sound attenuation indicated by the manufacturer should be (SNR or H, M, L values). Headphones equipped with noise suppression technology are also available as hearing protectors. This noise suppression technology (active noise reduction – ANR) helps in suppressing background noise in the frequency range up to 500 Hz. The effect to be achieved can generally be achieved just as well with good conventional hearing protectors with flat attenuation characteristic (e.g. with the marking NST®) – and much more cheaply.

Advantages

Advantages of monitoring headphones
- easier to put on and take off than in-ear monitors
- adapted shaped part not required

Disadvantages

Disadvantages of monitoring headphones
- heavier and more conspicuous than in-ear monitors
- high price

Use

- studio use (musicians, singers and sound engineers)
- live events (DJs and sound engineers)
- communication at live events

5.3.4 Choosing and using the right hearing protectors

There are five important features of hearing protectors to which attention must be paid when choosing and using them: quality, comfort, design, handling and of course sound attenuation.

Buying the right ones

Quality

Foam ear plugs with type approval do not normally display any major differences in quality. In the case of the more expensive adapted ear plugs or in-ear monitors, you should take care to ensure that you buy a high-grade product and that the person taking an impression of your auditory canal is well trained and experienced (e.g. hearing aid acoustics specialist)
.

If you are looking for ear muffs or headphones, you should consider the depth of the muffs and the padding of the muffs and headband.

Finding well fitting hearing protectors

Comfort

When buying ear plugs choose a comfortable, well fitting product. Comfort is especially important if you intend to wear plugs over extended periods.

If you are looking for ear muffs or headphones, pay special attention to the weight. Lighter products are more likely still to be comfortable after being worn for lengthy periods. The headband of ear muffs or headphones should be comfortable, but still sit tightly enough to prevent it from falling down. The padding of ear muffs or headphones mostly contain plastic foam. Try various hearing protectors out to find the ones that are most comfortable for you.

Whatever kind of hearing protectors you choose: wear them before you really need them for the first time. You can thus get used to them, see how they feel and how they modify the sound.

Use in compliance with regulations

Design

Use the product in accordance with specifications.

- Do not make any modifications to hearing protectors.
- Do not re-use ear plugs when they are soiled.
- Do not use ear muffs whose muffs display fractures or whose padding is damaged.

Ear plugs should not fit so tightly that they are uncomfortable and not so loosely that sound can penetrate past them. If a certain ear plug does not fit your auditory canal (especially a ready-formed ear plug), try another product or a quite different type of hearing protectors.

Choosing the correct sound attenuation

Necessary sound attenuation

Under the Noise and Vibration Occupational Safety and Health Ordinance LärmVibrationsArbSchV the sound attenuation of hearing protectors must be selected to ensure that a daily noise exposure level of 85 dB(A) is not exceeded.

A compromise must always be found between the necessary protective effect and the practicability without modifying the sound texture or hindering communication. Typically the residual sound level will then be below hearing protection at 70 to 80 dB(A). More precise details of the selection of hearing protectors can be found in the information and rules issued by the Statutory Accident Insurance (BGI 5024, BGR 194).

Pay attention to correct fit

Handling

Insert ear plugs and in-ear monitors correctly into the auditory canal to ensure that they can effectively fulfil their function:

1. If you use foam ear plugs, roll them between your fingers to compress them.
2. With your other hand, reach over your head and pull the upper part of the ear conch upward and backward to ensure that your auditory canal is straight.
3. With the auditory canal straight push the plug or in-ear monitor in until it sits firmly in your ear (but not to deep).

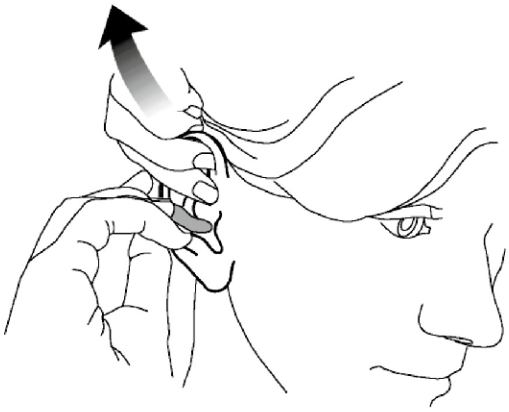
Note: To achieve a greater degree of sound attenuation, insert the ear plug with your mouth open. This will facilitate placing it more deeply.

4. If you use a foam ear plug, hold it firmly in your ear until it has expanded completely and has adapted to the form of your auditory canal. This may take 30 to 60 seconds.

Note: Please note that you will not get the full protection for your hearing if the ear plug or the in-ear monitor does not fit exactly in your auditory canal.

5. When using ear muffs or monitoring headphones ensure that the padding rests evenly and firmly around your ear so that no sound can penetrate from outside.

When inserting an ear plug, ensure your auditory canal is straight by pulling your ear upward and backward.



Information and support

Please note that the following links refer to German-language pages.

Support for the use of suitable hearing protectors can be obtained by selecting with reference to the publications of the institutions for statutory accident insurance and prevention (Berufsgenossenschaften – BG), BGR 194 "Use of Hearing Protectors"

www.dguv.de/psa/de/regelwerk/bgr_194.pdf

and BGI 5024 "Information on Hearing Protectors"

http://publikationen.dguv.de/dguv/pdf/10002/bgi5024.pdf

or by consulting the IFA database; here determination of the level of exposure, as is necessary for the selection procedure, is possible using the IFA musician exposure calculator

www.dguv.de/ifa/de/pra/softwa/musiker/index.jsp

The hearing protector selection program of the IFA can be found on the Internet at:

www.dguv.de/ifa/de/pra/softwa/psasw/index.jsp

The contractually mandated company physicians and specialists for occupational safety and health of the relevant institution are available as contact persons. Via these it is possible to contact experts of the Deutsche Gesetzliche Unfallversicherung (German Statutory Accident Insurance):

www.dguv.de/psa/de/index.jsp

and

www.dguv.de/ifa/de/index.jsp

Furthermore there is a series of cross-company occupational health services which can be consulted or which offer regular occupational medical examinations (audiometric testing).

From a physical and medical point of view, music can put one's hearing at risk. Education, advice and early detection are therefore important modules of responsible and forward-looking occupational health care.

6
Occupational Health Care

Healthy hearing thanks to prevention!

Music is pleasure – for the one who is listening and for the one playing or presenting it. But whoever finds loud music subjectively pleasant or is exposed to loud music for professional reasons can objectively, i.e. physiologically, suffer impairment of his hearing. Often this expresses itself initially as certain restrictions to the quality and precision of one's hearing, and subsequently hearing losses in certain frequency ranges will occur increasingly. The whole thing is quite insidious because the signs of impairment normally appear gradually – for a long time the sufferer does not notice a thing because his own hearing ability can only be assessed subjectively to a limited extent. Since this is so, experts have to be consulted. They can use a hearing test to establish any changes as early as the "harmless" initial stage – and to counter them accordingly! The message is: if detected early enough, any further deterioration in hearing quality or irreparable damage can often be avoided. That is why all those who have to deal with loud music in their job should pay appropriate attention to their hearing in their interest – after all the "hearing instruments" are irreplaceable.

Professional musicians are one of the occupational groups at risk and for them in particular there are possibilities of prevention which can assure them of healthy hearing – for the whole of their professional career. For example, health surveillance of the hearing function offers a well thought-out system of examination and advice which can give workers effective support in terms of individual care – provided they take advantage of it! This graded prevention programme begins with the initial examination. This takes place before the possibly hazardous activity is commenced. Then the individual concerned is granted a little respite – at least in this respect. Other follow-up examinations are conducted – depending on the extent and intensity of the specific noise exposure at the workplace, at intervals of a few years.

As far as the organisation and arrangement of preventive audiometric examinations are concerned, the employer is the one responsible. But this does not entitle him to be informed about the results of such an examination – the diagnosis is of course subject to the doctor's obligation to maintain confidentiality. But the employer is formally notified as to whether there are any health reasons standing in the way of employment. These could, for example, be temporary and/or involve other activities subject to conditions, such as technical or organisational sound reduction measures. The notification is necessary since the employer has to ensure, if there are any reservations, that the auditory health of the workers is maintained by taking suitable measures. And he can only do this if is made aware of such reservations.

The aim of the preventive audiometric examinations is then not to identify workers with hearing impairment so as to disadvantage them in their job. Rather the occupational health care programme is merely aimed at maintaining the workers' hearing at a high level and hence assuring their ability to work in an enduring fashion. But this assumes the willingness of all to take advantage in good time and on a regular basis of the health care provided. Only in this way can the worst conceivable scenario for everyone working in the music industry be avoided: the diagnosis of hearing damage which may entail a permanent exclusion from the profession. The principle therefore is to undergo a regular hearing test before the warning falls on deaf ears!

Seen in purely physical terms music is also "noise" and is not fundamentally different from industrial, traffic or recreational noise with respect to its impact on hearing. Where it acts over a long period, there is the risk of incurable damage to the inner ear. That is why professional musicians, like other workers exposed to noise, must take suitable preventive measures.

The sense of preventive audiometric examinations

Health surveillance of the hearing function encompasses measures for the early detection of hearing damage and education and advice on meaningful prevention. It assumes that the consulting physician is familiar with the special aspects of sound exposure in musical occupations and the specific workplace conditions, and it is therefore normally provided by the competent company doctor.

The aims of regular audiometric examinations on workers are:
- the earliest possible detection of occupational hearing damage (unnoticed subjectively for a long time) and the initiation or intensification of countermeasures, such as technical and/or organisational limitation of exposure or the use of hearing protectors
- detailed advice and motivation to implement individual hearing conservation

The further aspects of the preventive audiometric examination are:
- uncovering any specific disposition with regards to the development of hearing damage, e.g. due to special auditory sensitivity, prior illnesses, leisure activities which can put hearing at risk or additional hearing-endangering factors such as nicotine or medication
- establishment of the conditions for the initiation of occupational illness procedures and granting of compensatory benefits
- collection of statistical data and information for epidemiological questions and the optimisation of preventive concepts
- advice in musical training and education on hearing-aware behaviour.

The primary protective goal and hence the most important substantial reason for the measures proposed below is the prevention of noise-induced hearing impairment as an occupational illness (BK 2301 in the German list of occupational illnesses or No. 503 in the European list), and hence the maintenance of the health and work ability of workers. It must be noted here that the hearing requirements in the musical domain are substantially more rigorous than for speech intelligibility. This is due to the extended frequency range and the necessary precision, as well as the spatial, temporal, dynamic and intonational perception. Maintenance of hearing ability up to an advanced age is also of special importance for these workers on account of their occupational dependence on impeccable hearing.

Possibilities for audiometric examinations

The aim of the preventive audiometric examination is to establish the hearing ability or its reduction (hearing loss) and its allocation in terms of stage, localisation and what gave rise to it. In particular there is a need for a detailed anamnesis with respect to hearing ability,

disorders, prior illnesses and things that have a damaging effect on the hearing (occupational anamnesis), an examination of the outer ear and an endoscopy of the auditory canal and ear drum (otoscopy), and determination of the hearing ability for certain frequencies in air and with bone conduction (tone threshold audiometry) in combination with a simple tuning fork test of the sound conduction. If these examinations yield an abnormal result normally an ENT specialist can perform additional examinations to provide a differential diagnosis of the hearing loss. With these examinations any damage to the inner ear can be detected with great accuracy and it may be possible to establish that it is noise-induced. If there is a suspicion of inner ear hearing impairment it will be necessary for an ENT specialist to carry out an extended examination, including also a speech audiometry, an impedance measurement of the ear drum to check the sound conduction function in the middle ear and possible further special examinations.

More extensive examinations involve a relatively great effort and are therefore reserved for special questions, such as the procedure to establish an occupational illness. They can only be performed at specialised examination facilities. They include, for example, an examination of the oto-acoustic emissions (OAE), which yield information on the functioning of the outer hair cells and can give an indication of noise-induced damage at a very early stage, brain stem audiometry (BERA) as an objective procedure to exclude damage to the auditory nerves and high-tone audiometry, which extends the frequency range examined upwards and provides a particularly sensitive testing method.

System of health surveillance of the hearing function

The examinations to be conducted are governed in Germany at present by the Noise and Vibration Occupational Safety and Health Ordinance LärmVibrationsArbSchV, the Occupational Safety and Health Act and the regulations of the Berufsgenossenschaften BGV A4 "Occupational health care" (GUV-V A4 in the area of the public accident insurance institutions). Under these, workers may only be assigned to locations with noise which is harmful to hearing if they undergo regular audiometric examinations. In the case of activities which involve a corresponding risk there is therefore a legal entitlement to specific occupational health care.

Preventive audiometric examinations must be provided or arranged for by the employer if the workplace risk assessment reveals a noise exposure level of $L_{EX,8h} > 80$ dB(A) or $L_{EX,8h} \geq 85$ dB(A), or if at least one peak value of $L_{pC,\,peak} > 135$ dB(C) or $L_{pC,\,peak} \geq 137$ dB(C) is obtained.

Who has to be examined?

Indications of the type, scope and frequency of the examinations can be found in "Berufsgenossenschaftlicher Grundsatz für Arbeitsmedizinische Vorsorgeuntersuchungen G20 (Lärm)"/Principle of the Berufsgenossenschaft for Preventive Audiometric Examinations (Noise). Here the examination phases, which build up successively and whose application depends on the results obtained, are called "Noise I" ("Screening"), "Noise II" and "Noise III". With the graded procedure specified in G20 it is possible to react flexibly and in a differentiated fashion to the stages of an incipient, existing or increasing hearing damage and to the different factors which may be involved in its development. It is a simple and generally recognised screening procedure for the standardised collection of results which has proven its value in long-standing practice.

The selection criteria according to which workers are deemed to be exposed to noise and a list of the activities most frequently affected can be found in the information sheet of the Berufsgenossenschaften BGI 504-20 of the German Statutory Accident Insurance. According to scientific studies and current risk assessments, professional musicians are, for

example, also among the persons which have to be examined, even though they are not expressly mentioned in the list.

The need for the provision of examinations arises from the risk assessment conducted by the employer. This must be done in relation to the specific workplace and/or person and must be documented where relevant by measurement results. According to current knowledge it must be assumed that the lower action values are normally exceeded at music workplaces and numerous other workplaces in the music and entertainment sector. Even so there is a need for an individual risk assessment, where relevant with location-related and individual sound level measurements which also take account of all the burdens on hearing due to occupational reasons (practise times, teaching, hearing habits) – especially with a view to their preventive consequences for music workers in particular. In cases of doubt it is advisable, even without any reliable evidence that the action values are exceeded, to offer the examination in order to give musicians the opportunities presented by a motivational and medical appropriate measure which is supported by the employer.

The regulations mentioned do not, however, regulate the health surveillance of the hearing function for freelance musicians, schoolchildren and students. In view of the comparatively high sound exposure and the important aspects of preventive care and awareness building which are important precisely in the areas just mentioned, they should, however, also be taken as recommendations here. For these groups of persons it is only possible to point out the need for a voluntary, regular audiometric examination and consultation and to appeal for responsibility in handling the "hearing instruments".

It would appear appropriate and meaningful to take closer account of the notion of prevention as early as the stage of musical training and to create corresponding examination facilities in music colleges and training institutes – it is also possible to interpret this as part of the preventive mission of the statutory accident insurances. Parents, teachers and professors should also urge music students or schoolchildren to undergo such examinations on a regular basis.

When must the examinations be conducted?

Initial examination

The initial examination according to G20 must be conducted prior to commencement of the activity that is a hazard to hearing. This does not take account of the fact that the musician has normally been exposed to noise over several years during his training before he took up his professional career. Given this, commencement of the professional activity is not the same as the actual start of exposure. It is not possible to give a general answer to the question of whether the exposure due to compulsory participation in the college orchestra, temporary work in orchestras parallel to the musician's studies or even lengthy practice times on the instrument has actually reached or exceeded action values which would entail a compulsory examination. An obligation to undergo examinations at the training stage, which would in principle be desirable, does not apply at the present time and is thus the responsibility of the persons concerned or the training institutions.

Follow-up examinations

The first follow-up examination must be conducted before a period of 12 months expires. If requested or at the doctor's discretion the interval before the follow-up examination can be shortened, for example under certain conditions if the health reservations are of a temporary nature, or if hearing disorders arise in the intervening period. All other follow-up examinations are, according to BGV A4, still dependent on the weighting level and are,

at < 90 dB(A), every five years, and at > 90 dB(A) at three-yearly intervals, provided an occupational medical assessment does not establish that a shorter interval is appropriate.

Health records

The employer must arrange for the examinations to be performed at the specified intervals by an appropriately qualified physician. For the organisation of the preventive audiometric examinations the employer must log all workers in the noise zone and maintain health records. This will include information on the nature of the activity, the examination intervals and whether there are health-related reservations regarding this activity (The options are: yes, no, no conditonally, temporarily until). In view of the physician's obligation to maintain confidentiality, the health records will not include any detailed examination results.

Assessment of the examination results

Certificate

Further to the result of the examination, the employer and the worker will receive a certificate stating whether, with regard to continued employment in the noise zone, there are "no health-related reservations", "no health-related reservations under certain conditions", "temporary health-related reservations" or "permanent health-related reservations". Diagnoses or findings may not be passed on to the employer because they are subject to patient confidentiality. An examination result which deviates from a normal finding must be explained in detail and comprehensibly to the worker and the personal implications discussed with him or her.

Health-related reservations

Health-related reservations must be expressed in particular when there is a suspicion of an individually elevated risk of hearing damage. This is the case, for example, with certain disorders of the inner ear, after operations and injuries or even when use of hearing protectors is not possible for health reasons (e.g. eczema of the auditory canal, secretions from the middle ear, inflammatory skin reaction at the outer ear).

If the examining physician expresses health-related reservations, the employer must take appropriate action to eliminate the reservations. If, for example, he expresses "no health-related reservations under certain conditions", such conditions may take the form of special recommendations concerning the use of suitable hearing protectors, a consultation on hearing behaviour during work and leisure time, a check of findings or the workplace at shorter intervals with differentiated recommendations concerning the technical and/or organisational arrangement of work.

Permanent health-related reservations, which are established in rare exceptional cases, normally mean ending the activities that are a hazard to hearing and examining any occupational (co-)causation as a condition for registration as an occupational illness.

Health surveillance of the hearing function in the music and entertainment sector

In terms of the assessment criteria for expressing health-related reservations, there is no difference between the preventive audiometric examination of workers in the music and entertainment industry and that for the preventive audiometric testing of other workers. But to take full account of the more rigorous hearing requirements, it is advisable to make additions to the standardised procedure according to G20 at three points:

- The possibility of a follow-up examination at the request of the worker before expiry of the regular interval should be available at all times and should be supported by the employer.
- Special care must be exercised in the context of the screening (Noise I) to the provision of detailed advice on hearing protection, where relevant with repeated re-presentation appointments to check the acceptance, compatibility and effectiveness of the hearing protectors and with a renewed consultation.

– If the supplementary examination after Noise II yields an abnormal result within the sense of hearing impairment, the accident insurance institution must also prevent the development and deterioration of an occupational illness by all suitable means. In this connection it is advisable to consult a physician experienced in this field, who can, among other things, give detailed, specific advice on suitable hearing protectors and, where relevant, further preventive measures.

A detailed anamnesis with a logging of all current and earlier workplace-related and extra-occupational exposure sources, the skilled conduct of the clinical and technical examinations and a competent consultation on the possibilities of personal prevention with check of the effectiveness of measures proposed form the basis for meaningful health surveillance of the hearing function. This provides an excellent opportunity to reduce any reservations and prejudices with respect to occupational health care and, by information and motivation, to make a valuable and highly important contribution to the preservation of workers' hearing ability.

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