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Questionnaire investigation of musicians' use of hearing protectors, self reported hearing disorders, and their experience of their working environment

Key Words

Hearing protector
Hearing impairment
Hearing loss
Orchestra
Classical music
Musicians
Tinnitus
Hyperacusis
Diplacusis

Abstract

Musicians in symphony orchestras are exposed to harmful sound levels. Although research shows that industrial workers have a higher propensity to noise-induced hearing loss, musicians can also develop a hearing loss from noise exposure. Furthermore, musicians can suffer from tinnitus, hyperacusis, and distortion, among other hearing disorders, which can affect their work more severely than a hearing loss. This study investigated the use of hearing protectors, the prevalence of self-reported hearing disorders among musicians, and the importance of these hearing disorders to the musicians. The musicians at three Danish symphony orchestras were asked to complete a questionnaire on the topic. Results showed that Danish musicians are aware of the dangers of loud music, yet they rarely use hearing protectors and not always correctly; however, musicians with hearing disorders use hearing protectors more frequently. In addition, the musicians questioned suffered from different hearing disorders. Education is needed to change musicians' opinion of hearing conservation and hearing protectors. The education must be directed to both the musicians and the administration of the symphony orchestras.

Sumario

Los músicos de las orquestas sinfónicas están expuestos a niveles dañinos de sonido. Aunque las investigaciones muestran que los obreros industriales tienen una mayor propensión para la sordera inducida por el ruido, los músicos también pueden desarrollar una hipoacusia producto de la exposición al ruido. Más aún, los músicos pueden sufrir de acúfenos, hiperacusia y distorsión, entre otros trastornos auditivos, los cuáles pueden afectar su trabajo más severamente que una pérdida auditiva. Este estudio investiga el uso de protectores auditivos, la prevalencia de la hipoacusia auto-reportada entre los músicos, y la importancia de estos trastornos auditivos para ellos. Se les pidió a los músicos de tres orquestas sinfónicas danesas que completaran un cuestionario sobre el tema. Los resultados mostraron que los músicos daneses están concientes de los peligros de la música fuerte, aunque ellos raramente utilizaban protección auditiva, y no siempre en forma correcta; sin embargo, los músicos con trastornos auditivos utilizan más frecuentemente los protectores auditivos. Además, los músicos interrogados sufrían diferentes trastornos. Se requiere educación para cambiar la opinión de los músicos sobre la conservación de la audición y los protectores auditivos. La educación debe estar dirigida tanto a los músicos como a los administradores de las orquestas sinfónicas.

Researchers have studied the sound exposure of classical musicians for more than 40 years, and they still do not agree if the measured peak sound levels in symphony orchestras are as harmful as industrial noise of the same energy (Kähäri, 2002; Kähäri et al, 2003; Behar et al, 2006). The European Union (EU) directive on noise at the workplace was adopted in 2003 and was implemented in the member states in the following years (EU, 2003). Because of the special problems in the music and entertainment sector, the EU directive allowed a transition period for the implementation, and the directive must be in effect by February 2008. Unlike the sound from industrial work, the sound in the music and entertainment sector is produced by the employee, and it is therefore not relevant to ask for noise reduction of the sound source. Hearing protectors are seldom the optimal solution for musicians; however, it may be one of the means to fulfil the EU directive. The aims of the present investigation were to examine the use of hearing protectors in various Danish symphony orchestras, to investigate musicians' self-reported hearing disorders and to obtain information about musicians' experience of the sound levels in their working

environment. Note that the term 'hearing disorder' is used for the various *self-reported* hearing problems musicians indicate in the questionnaire. No objective measurements (e.g. of hearing loss) are made in the present investigation.

With regard to hearing loss, musicians' audiograms do not always show hearing loss consistent with their noise exposure (Obeling & Poulsen, 1999). In addition, researchers consistently search for a method for early detection of a possible hearing loss (Reuter & Hammershøi, 2007). Obeling and Poulsen (1999) studied 57 Danish musicians. This included an audiological evaluation, an interview about their work, and sound level measurements in the orchestra. When audiograms were age-corrected in accordance with ISO 7029 (ISO-7029 1984), they were consistent with the typical hearing loss for the age. The audiograms were also compared to the ISO 1999 prediction for occupational noise (ISO-1999 1990), which showed no hearing loss. The authors concluded that musicians cannot be expected to acquire pronounced hearing loss from playing in a symphony orchestra; however, the authors note that limited data was used in the study. Other studies have assessed hearing thresholds of

musicians as well (Axelsson & Lindgren, 1981; Karlsson et al, 1983; Johnson et al, 1985; Ostri et al, 1989; Royster et al, 1991; Schmidt et al, 1994; Kähäri et al, 2001; Kähäri et al, 2003). For a review, see Sataloff et al (2006).

Noise at the workplace is usually measured as the A-weighted equivalent continuous sound level, L_{Aeq} , for definitions see ISO-1999, 1990. The L_{Aeq} is the level (in dB(A) re. 20 μ Pa) of a steady sound which, over the same interval of time as the fluctuating sound of interest, has the same mean square sound pressure. The daily noise exposure level ($L_{EX,8h}$) is the time-weighted average of the noise exposure levels for a nominal eight-hour working day as defined by international standard ISO-1999, 1990, point 3.6. It covers all noises present at work, including impulsive noise (EU 2003). The action- and limit levels in the EU directive relate to an eight-hour working day. As musicians seldom play continuously for eight hours, this should be taken into account when orchestra sound levels are evaluated. A L_{Aeq} of 83 dB for four hours corresponds to a $L_{EX,8h}$ of 80 dB.

Several studies have investigated musicians' exposure to sound (Jansson & Karlsson, 1983; Royster et al, 1991; Laitinen et al, 2003b; Frölich, 2005). In some parts of the orchestra, the levels are below the EU action level, $L_{EX,8h} = 80$ dB, but in other parts of the orchestra, the levels are too high. For the conductor, the L_{Aeq} level is 88 dB with a 65-person symphony orchestra, 91 dB for a mixed choir (114 persons), and 96 dB for a jazz orchestra (Harding & Owens, 2003). Levels in the orchestra pit were below the risk criterion, $L_{EX,8h} = 80$ dB (Lee et al, 2005). One literature review illustrated that the average sound level was 80 to 100 dB(A) for symphony orchestra musicians and 90 to 105 dB(A) for jazz musicians (Peters et al, 2005).

With regard to other health effects the working environment of a musician is quite different from the industrial workplace; therefore, a hearing conservation program must be adapted to this special situation. Aspects other than sound exposure and hearing loss must be considered including auditory disorders (e.g. tinnitus, distortion, and hyperacusis), attitudes, and use of hearing protectors. Furthermore, occupational effects like ergonomics, stress, and stress related problems must be taken into account. Sometimes these problems are related. One of the aims of this study was to investigate not only the prevalence of self-reported hearing disorders among musicians, but also the importance of these hearing disorders to the musicians.

The use of hearing protectors may seem awkward in an orchestra situation. Under usual working conditions, hearing protectors should be the last resort in hearing conservation; however, to a musician, they are often the only functional option. Hoffman et al (2006) investigated the use of hearing protectors among percussionists. Better hearing thresholds were found among those that used hearing protection (foam plugs); however, Rudel et al (2006) found that only 1.5% of the musicians in their study accepted and used hearing protection. Laitinen (2005) found that 6% of the musicians reviewed in their investigation always used hearing protection. In a Spanish investigation (González & Armendáriz, 2001) 20% of musicians found hearing protectors acceptable. Cederstam (2006) found no difference between musicians and non-musicians in their views on using hearing protection when listening to loud music. One study assessed hearing protection amongst a Swedish and an American pop-concert audience. Results showed that women use more hearing protection than men and that

Swedish men use more hearing protection than American men (Widén, 2006; Widén et al, 2006). Based on interviews among 500 English musicians, Reid (2001) found that 65% of the woodwinds and 55% of the strings used earplugs. To summarize preferred recommendations, Chasin (1996) developed a table of recommended hearing protectors for different instruments.

The present investigation examined the use of hearing protectors in symphony orchestras, how they are used, the difficulties that musicians experience, the usage rate, and how the usage rate might be improved. These are all important issues as the EU directive on noise at the workplace (EU, 2003) included musicians. In the present investigation, the musicians are asked about the occlusion effect in particular. The occlusion effect is well known in connection with hearing aids (Schweitzer & Smith, 1992; Ballachanda, 1995); however, there is only one article found that assessed the occlusion effect among musicians (Oberdanner et al, 2002).

With regards to other means of protection, the sound level in an orchestra can be reduced to some extent by increasing the acoustic absorption in the room; however, the sound source (the instrument) is close to the musician, and thus, the protection from absorption is limited. The musicians need to hear each other as well as the other instrument groups; therefore, much absorption around the podium is not desirable. In a concert hall, the acoustics of the hall is a major part of the audience's experience, and a change of the absorption in the hall will almost be 'forbidden'.

Materials and Methods

Three major Danish orchestras participated in the investigation. The musicians at the orchestras received a short lecture to inform them about hearing loss, hearing disorders, and hearing protection. After the lecture, questionnaires were given to the orchestra members. The members completed the questionnaire and returned it on location. The lecture and the questionnaire were administered over approximately two hours during the orchestra's normal working hours.

The orchestras and the (total) number of members in each orchestra included South Jutland Symphony Orchestra, 66 musicians; Aalborg Symphony Orchestra, 65 musicians; and Aarhus Symphony Orchestra, 72 musicians. In total, 145 of 203 musicians (71%) attended the lectures and filled in the questionnaire. All answers were submitted anonymously.

The questionnaire used in this study was designed based on questionnaires from a previous study in Finland (Laitinen, 2005), a study in Sweden with rock musicians (Kähäri, 2002), and a questionnaire about the occlusion effect (Østergaard Hansen, 1997). Sections from the EQ-5D questionnaire, a standardized instrument for the measurement of health (Brooks, 1996) and the EQ-15D (Sintonen, 2001) were also included.

There were 91 questions; 27 were open answered, and the rest were multiple-choice. The questionnaire was divided into sections that included (1) General, (2) Hearing protection and sound level reduction, (3) Occlusion effect, (4) Health related questions (questions about hearing disorders), (5) Work surroundings, and (6) Rehearsal and performance facilities. Note that the questionnaire can be downloaded from <http://server.elektro.dtu.dk/ftp/tp>

The questionnaire incorporated questions pertaining to age, gender, instrument group, and playing experience. One section included questions about how often and in which work situations hearing protectors were utilized as well as which kind of hearing protector the musician used and the reason for choosing that particular hearing protector. Another question asked for other means to reduce the sound levels in the orchestra. The musicians answered questions about different hearing disorders (tinnitus, hyperacusis, diplacusis, and distortion), job satisfaction, and a possible feeling of stress (note that this is self-reported stress; no physiological or behavioural measures of stress symptoms are made in the present investigation). The musicians were asked about their physical playing facilities and the possible need for quiet facilities at work. The musicians were asked to complete the entire questionnaire; however, not all participants answered every question. The duration of the questionnaire ranged from 30 minutes to an hour.

Of the 145 respondents, 61% were men and 39% were women. The response data were analysed using SPSS 9.0. The results from the three orchestras were analysed separately, and no significant differences were found between the orchestras ($p \geq 0.10$); therefore, the data from the three orchestras were pooled and analysed as one group. When the data were subdivided into instrument groups, pooling of data ensured anonymous responses.

Results

Symphony orchestras consist mainly of string players, and in the current study, 62% of the respondents were string players. The remaining respondents were woodwind instrument players (18%), brass players (16%), percussion players (4%), and other (1%). The group 'other' was small and was therefore not included in further analyses.

Use of hearing protectors

The use of hearing protectors is summarized in Table 1. The usage rates are lowest at personal rehearsals and teaching and slightly higher at orchestra rehearsals and performances. Figure 1 shows the ease of adjustment to using hearing protectors. Only 13% of the respondents adjusted to hearing protectors right away, 15% required time to adjust, 43% were not used to hearing protectors (but used them anyway), and 29% stopped using hearing protectors because it was too difficult. Few musicians answered the question pertaining to the length of time they required to adjust to hearing protectors. The few answers obtained varied among the choices 'weeks', 'months' and 'years' with slightly more answers at 'weeks'. The results indicated that musicians find it hard to control their playing when using hearing protectors, some have problems fitting the

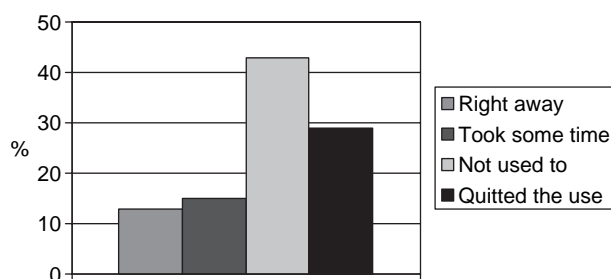


Figure 1. Adjustment to using hearing protectors (Right away – participants reported adjusting to the hearing protection right away; Took some time – participants reported taking weeks, months, or years to adjust to hearing protectors; Not used to – participants reported wearing hearing protectors regardless of the fact they are not used to them; Quitted the use – participants reported not being able to adapt to the hearing protectors and no longer using them.)

earplug in the ear canal, and some are not concerned about their hearing. The experience of hearing protector use varied from half a year to 20 years with an average of 8 years.

Hearing protectors were used in both ears by 49% of the participants, as many as 35% used them in only one ear, and 16% said that it depended on the situation. Whether the left or right ear was protected depended mostly on the location of the loudest sound source. Only violinists reported using hearing protection on their left ear more often. Few musicians (15%) reported always using hearing protectors, and the majority (83%) used them only occasionally. Of these, the majority responded that they use them only during loud passages or when sitting near loud instruments. The participants responded that they are more likely to use hearing protectors when they are tired or when playing contemporary music. Some removed their hearing protectors when the conductor or colleagues were speaking, during breaks, or when playing difficult passages.

Types of hearing protectors used (or tried) included disposable foam earplugs (39%), custom-moulded musicians' earplugs (35%), and hi-fi earplugs (16%). Ten percent of the musicians used other protection means: shield behind the chair (one player), electronic hearing aid (two players), rubber plugs (one player), cotton wool (four players), ear muffs (one player), and paper towels (one player).

The results showed that the use of hearing protectors at the three playing situations addressed—personal rehearsals, orchestral rehearsals, and performances—was to some extent related to temporary ringing in the ears (tinnitus). The correlation coefficients were in the range of 0.2 to 0.4. Some correlation was found between hearing protector use at orchestra rehearsals and being worried about hearing ($r=0.28$). In addition, a

Table 1. Percent of respondents using hearing protectors at personal rehearsals, orchestral rehearsals, performances, and while teaching.

	<i>Never</i>	<i>Seldom</i>	<i>Sometimes</i>	<i>Often</i>	<i>Always</i>
At personal rehearsals	84	7	6	2	2
At orchestral rehearsals	39	31	18	8	5
At performances	48	31	11	7	4
While teaching	94	1	5	0	0

correlation was observed between using hearing protection and considering rehearsals being noisy ($r=0.35$) as well as between hearing protection use and performances being noisy ($r=0.43$). The same correlations were found for hearing protector use at performances. There was no correlation between self-reported stress and hearing protector use in the three playing situations ($r = -0.04, 0.05, 0.04$).

Forty percent of the musicians answered that they have changed from one hearing protector type to another. Compared to the type they used earlier, they preferred custom moulded earplugs (Etymotic Research earplugs, 10 respondents), hi-fi plugs (7 respondents), cotton wool (7 respondents), and hearing aids, ear muffs, and foam earplugs (one respondent each). The musicians who preferred the custom moulded protectors to the other types liked them because of their frequency independent attenuation, better fit, and better protection. Disposable earplugs were criticized for being too visible. Musicians who changed from the custom moulded devices to the disposable plugs found the fitting of the custom moulded earplugs more time consuming. In addition, they reported that the custom moulded earplugs changed the perceived sound quality, were warm and sweaty, and the disposable earplugs attenuated less than the custom-moulded earplugs.

The musicians reported itching, infection in the ear canal, pain, and hearing their own breathing as problems that caused them to stop using hearing protectors. The hearing protectors were seldom cleaned. Some musicians reported cleaning their hearing protector after every use or every day; however, many do not feel that they clean their hearing protectors often enough. Some reported cleaning their hearing protectors only once a year.

The participants were provided with six possible problems in connection with using hearing protectors. Eighty-four of the participants responded; the possible problems were as follows: difficult to hear others playing (82% of the responses); hindering own performance (76%); uncomfortable (52%); difficult to put into the ears (30%); feeling of pressure from the earplugs (23%); other (10%, comprising occlusion, ear disease, other musicians' comments, and bone conduction from the mouth to the ear (same as the occlusion effect)).

Participants were also asked to list any problems in connection with hearing protector use; the responses included 'hindering own performance', 'lack of control', 'lack of sound quality', 'problems in intonation', and 'occlusion effect'. One musician had no problems at all in connection with hearing protectors. Infections bothered 5% of the hearing protector users and 23% had a tendency to create a large amount of ear wax. Seventy-nine percent reported an 'enclosed feeling' while wearing hearing protectors.

Sixty-six respondents mentioned other annoyances such as itching in the ear canal (15 respondents), feeling of having moist ear canals (14 respondents), pain in the ear canal (7 respondents), smarting pain in the ear canal (4 respondents), and eczema in the ear canal (1 respondent).

Other sound level reductions

Sound level reductions can be achieved by means of Plexiglas screens, risers/platforms, acoustic improvements, seating arrangements, and Hearwig®/Goodear ear protection systems

Table 2. Number of hearing disorders in the orchestras (N = number of musicians who answered affirmative to the specific question. The percentages are calculated from the number of respondents who gave a response (yes or no) to the specific question).

	<i>Tinnitus</i> N (%)	<i>Hyperacusis</i> N (%)	<i>Distortion</i> N (%)	<i>Diplacusis</i> N (%)
ALL	34 (24)	33 (25)	15 (12)	6 (5)
Women	10 (18)	16 (31)	7 (14)	3 (6)
Men	24 (27)	17 (21)	8 (11)	3 (4)

among other strategies. Almost half of the musicians were satisfied with the sound level reduction in the orchestra. Those musicians who were not satisfied suggested acoustic improvements (including other rooms/facilities; 9 respondents); lower playing style (6 respondents); greater distance between players (5 respondents); more cooperation from conductors (5 respondents); change of seating arrangement (5 respondents); less talk, more action (4 respondents); reduction of sound from some instrument groups (4 respondents); moderate sound levels at rehearsals (3 respondents); and use of Hearwig®, use of risers, removal of screens, instruments with less sound, cooperation of all (each suggested by 2 respondents).

Occlusion effect

In total, 89 participants (of 145) responded to the questions about the occlusion effect. The distribution of the results included 88 respondents reporting their own instrument sounds different, 63 respondents reporting their own voice sounds different, 35 respondents reporting they can hear their own breathing more clearly, and 34 participants reporting a blocked feeling of their ears.

The occlusion effect caused 43% of the users to stop wearing hearing protectors.

Hollow sound quality was experienced and found to be annoying by 20% of the respondents, and very annoying by 50% of the respondents.

Hearing disorders

The hearing disorders tinnitus, hyperacusis, distortion, and diplacusis were included in the questionnaire, and the distribution of the responses is shown in Table 2. The musicians were asked if they had a hearing loss at their latest audiological

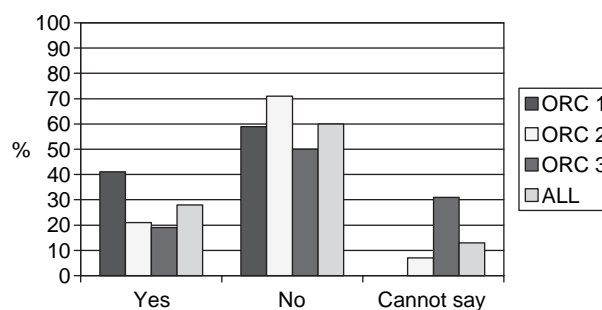


Figure 2. Self reported hearing loss for the female musicians for each orchestra included in the study (ORC 1–3), and the total of all of the respondents (ALL).

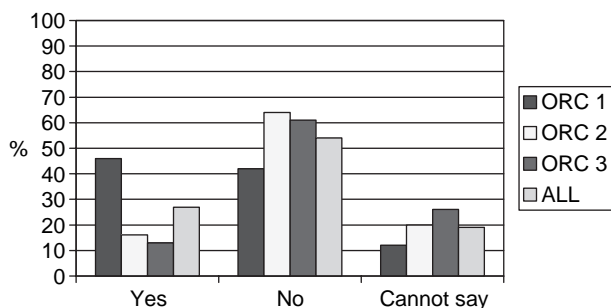


Figure 3. Self reported hearing loss for the male musicians for each orchestra included in the study (ORC 1–3), and the total of all of the respondents (ALL).

examination. Self reported hearing loss is shown in Figure 2 and Figure 3 for women and men, respectively. Self reported hearing loss was included as a hearing disorder in the subsequent analysis.

A Kendall's tau_b analysis was used to find possible correlations between hearing disorders and other variables (about 100 respondents in every analysis). The hearing disorders were combined into one variable where one disorder adds one unit to the variable. For example, if a person has tinnitus and hyperacusis, the variable would have the value of two. No disorders would have a value of zero, and all of the disorders would create a value of five; however, none of the musicians reported all of the disorders. The analysis showed that the more hearing disorders a musician has, the more worried the musician is about hearing, there is more self-reported stress, the musician perceives the working conditions as noisier, and the musician uses hearing protectors more often at rehearsals and performances. This is shown in Figure 4 for hearing protector use at different playing conditions.

TINNITUS

Tinnitus was defined as 'a sound of duration of minimum 5 minutes, an intermittent sensation of a ringing, roaring, or buzzing sound in the ears or head even though no such sound is present'. Thirty four respondents (of 145, i.e. 24%) reported that they experience tinnitus according to this definition, see Table 2. Of these, 42% reported it was always present, and 24% reported it affects their sleep. Tinnitus is exacerbated mainly by

loud sounds and stress. Nine percent of the participants have tried a form of treatment for their tinnitus, including physiotherapy, meditation, vacation, and acupuncture. Individual methods to cope with tinnitus were to live with it and ignore it (9 responses), protection from loud sounds (4 responses), less stress (2 responses), not playing music (2 responses), positive attitude (1 response), and practice away from a reflecting wall (1 response).

HYPERACUSIS

Hyperacusis was defined as 'abnormal sensitivity to everyday sound levels or noises. Often there is also sensitivity to high pitched sounds.' Seven percent of the respondents tried hyperacusis treatment, consisting of less stress and a cranio-sacral massage. Other solutions the musicians reported included silence (five people), accepting the situation (two people), and using hearing protectors, telling people about it, not playing, avoiding noise as much as possible, reducing stress, resting more, being prepared, and less playing (one person each). Hyperacusis respondents often experienced high sensitivity to light, problems with balance, and/or vertigo.

DISTORTION

Distortion was defined as 'when sound reaches a certain level, it is perceived as being impure, cracked, distorted.' Eight percent of the respondents had tried a treatment for distortion. The musicians' own methods to reduce distortion included positive attitude, less sound, hearing protectors, less stress, enough sleep, and relaxing.

DIPLACUSIS

Diplacusis was defined as 'pitch of a sound presented to both ears is heard differently in the two ears.' Diplacusis was experienced by six respondents. Due to the small sample size of this disorder, no further analysis could be made.

HEARING

Figure 5 shows the time since the last audiological examination. Figure 6 shows the distribution of the answers to the question, 'Are you worried about your hearing?'

Working environment, working conditions

The musicians in this study reported they were happy with their work, 55% completely agreed that their work is inspiring and

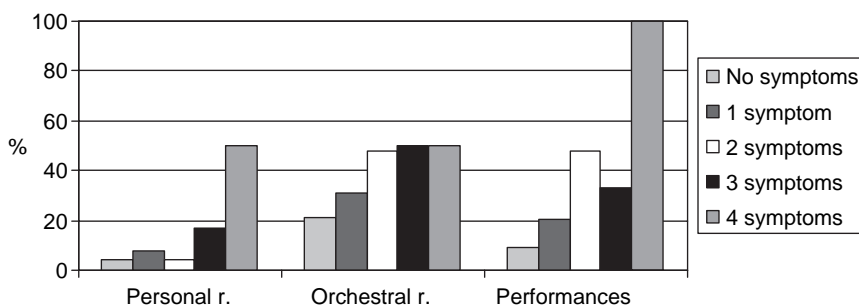


Figure 4. Hearing protector use at personal rehearsal (Personal r.), orchestral rehearsal (Orchestral r.), and performances, divided into the number of hearing disorders. The percentages are a sum of the responses to the usage question, comprising those musicians who used hearing protectors 'sometimes', 'often', and 'always'.

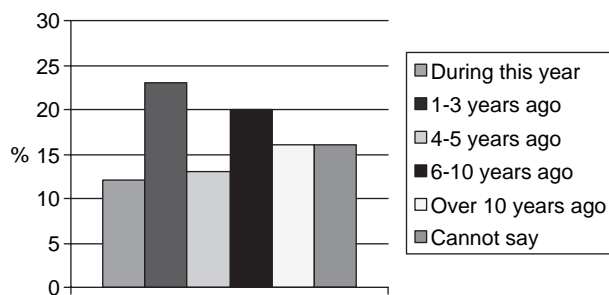


Figure 5. Percentage of responses to the question 'When was your hearing last checked?'

meaningful, and 29% almost agreed with this statement. Figure 7 shows the percentage of self-reported stress responses. For musicians who also worked at nights, on the average, 21% of their working hours were during evening hours.

Musicians felt that they could influence the working conditions by having improved communication with colleagues and management, by having a positive attitude themselves, and by playing well. There were also individual comments about seating arrangement, playing softer, and spending (more) time on personal rehearsals. Table 3 shows the distribution of responses per orchestra on the possibility to influence work conditions.

Most musicians did not consider personal rehearsals noisy, 3% found them quite noisy, and no one found them extremely noisy. Orchestral rehearsals were considered quite noisy by 27% and extremely noisy by 7% of the participants. Performances were considered quite noisy by 25% and extremely noisy by 5% of the participants.

The musicians rated the noisiness of instrument groups. The distributions of the ratings are shown in Table 4. It can be seen from the table that the quieter their own instrument is, the noisier they consider other instruments. Also, for loud instruments, only the instruments that are louder are considered noisy to those musicians. In Table 4, the instrument groups are roughly listed in intensity order. Woodwinds (which are louder than string instruments) are considered noisy by the string musicians, brass instruments were felt to be noisy by the string and the woodwind players, and percussion was felt to be noisy by everyone except the percussion players. The reduced use of hearing protectors at personal rehearsals and classes supports the conclusion that musicians find their own instrument less noisy than other instruments regardless of the instrument group.

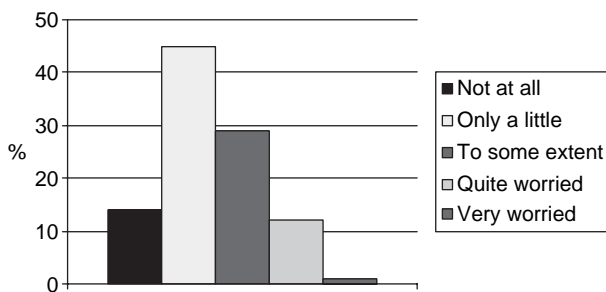


Figure 6. Percentage of responses of the musicians who were worried about their hearing.

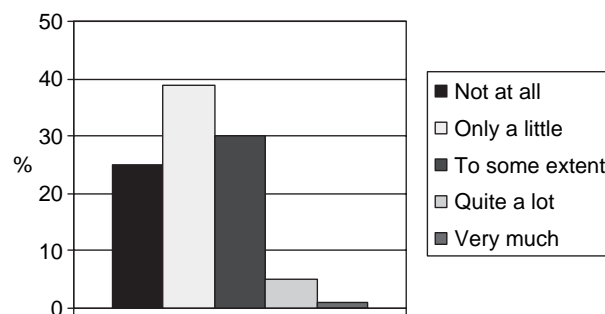


Figure 7. Self-reported stress as indicated by musicians.

Eighty percent of the musicians reported that the orchestra has played uncomfortably loud. Most of those situations were related to playing modern or amplified music, to bad acoustics, a certain production or composer, certain instrument groups, or having a certain conductor.

REHEARSAL AND PERFORMANCE FACILITIES

Musicians were asked where they find it difficult to play. Most often, musicians mentioned their rehearsal hall. Other places frequently mentioned were churches (or reverberant places in general), small and dry halls, the orchestra pit, sport halls, multipurpose halls, and facilities that are not specifically designed for music.

OTHER COMMENTS FROM MUSICIANS

Other comments from the musicians included the following: (1) a wish for quiet rest facilities, (2) the negative effects of stress, fatigue, or general dissatisfaction with work, (3) good concert halls are pleasant working surroundings, (4) halls with bad acoustics increase the sensation of having hearing problems, (5) personal attitude is important, (6) some instrument groups could reduce their sound levels, (7) playing with lower sound levels is possible only if all agree to do so, (8) instruments today were built to play louder than before, and (9) the general tendency is to play louder.

Discussion

Most musicians do not use hearing protectors on a regular basis. Usage rates observed in this study strongly agree with a recent study conducted in Finland (Laitinen, 2005). Surprisingly, many musicians in the present study use a hearing protector in only one ear, namely the ear with more perceived exposure. The other ear is then used to listen to the music.

Only 15% reported that they constantly use hearing protectors. Most of the musicians wear hearing protectors only occasionally, especially during loud passages. Calculating the musicians' sound exposure level is somewhat complicated due to

Table 3. The ability to influence one's working conditions.

	Yes (%)	No (%)	Cannot say (%)
Orchestra 1	63	15	23
Orchestra 2	28	28	44
Orchestra 3	34	32	34

Table 4. Noisiness of the instrument groups as reported by the musicians and totalled per instrument type. The left column shows the grouping of musicians by instrument. The percentages shown reflect the percentage of individuals in each class of instruments that felt the instrument group (strings, woodwind, brass, percussion) was noisy. For example, in the first row, 3% of the string musicians think that their own instrument is quite noisy, whereas 20% of the string musicians think that woodwind instruments are quite noisy, and 40% of the string musicians think that brass instruments are quite noisy.

	<i>Strings</i>	<i>Woodwind</i>	<i>Brass</i>	<i>Percussion</i>
Strings				
Quite noisy (%)	3	20	40	43
Extremely noisy (%)	1	3	32	40
Woodwind				
Quite noisy (%)	0	11	50	48
Extremely noisy (%)	0	0	38	36
Brass				
Quite noisy (%)	4	9	30	38
Extremely noisy (%)	0	4	13	33
Percussion				
Quite noisy (%)	0	0	20	20
Extremely noisy (%)	0	0	0	0

the dynamic nature of music. In addition, the duration of hearing protector use must be considered (Laitinen et al, 2003b). These issues become more important with the new European directive, which states sound exposure must not exceed 87 dB(A). The directive assumes that employees use hearing protectors in both ears.

Musicians need some time to get acquainted to hearing protectors. Ten percent of the musicians adjusted to hearing protectors right away, but for the majority of the musicians, it took some time, months or even years. Many stopped using hearing protectors or never tried them. Development of hearing protectors that are immediately accepted is necessary. It may seem awkward to recommend hearing protectors for musicians; however, it seems to be the only way musicians can be protected and fulfil the EU directive about noise at the workplace. The sound levels in the orchestras are usually not extremely high; thus, a protector with limited attenuation (achieved passively or electronically) is sufficient for many musicians.

For musicians, disposable foam or cotton earplugs are free of charge. Custom moulded musicians' earplugs are more expensive; however, they are often paid for by the orchestra for the musicians. Two musicians used hearing aids as hearing protection. The hearing aids were modified in such a way that they prevented high peaks to be transmitted into the ear, but otherwise, in principle, they were transparent to the user. These two users expressed great satisfaction with this method, which calls for further study and development of a transparent hearing protector for the music and entertainment sector. In Europe, hearing protectors must have a certain minimum attenuation to be marketed as hearing protectors. A transparent hearing protector does not fulfil these minimum requirements; however, in order to overcome this issue, the designation 'hearing protector' could be avoided.

Custom moulded hearing protectors are often considered to be the best choice for professional musicians, but some

musicians change to other types of protectors. According to musicians, one of the reasons why they consider custom moulded earplugs inferior is the time it takes to insert the earplugs. This issue emphasizes the necessity to train musicians on the fitting of the earplug. It takes only seconds to insert the earplug; however, this must be learned under relaxed conditions, not in the middle of a concert.

Musicians feel that cotton wool preserves a better sound image; however, cotton wool attenuates very little at high frequencies; thus, the protection is mainly psychological. The tendency to change from custom moulded plugs into another form of hearing protection was also observed in a previous study (Laitinen, 2005). The present study was the first time that the reason for changing hearing protector type was investigated.

The occlusion effect changes the sound of the musicians' own voice and the sound of their instrument. Hollow sound quality and changes in the sound image are considered very annoying. The general problems of a blocked feeling in the ears, moist ear canals, and an itch in the ear canal are not the worst problems for musicians. Although musicians acknowledge that there are differences between hearing protectors, the occlusion effect has caused almost half of them to stop using hearing protectors. These occlusion effect problems indicate that the individual fitting of musicians earplugs is not optimal in all cases. Another possible explanation is that the musicians have misunderstood the word 'occlusion' or mixed it up with the typical high frequency attenuation from conventional hearing protectors. Thus, the responses might be about hearing protectors in general and not specifically about musicians' earplugs.

Musicians with hearing problems use hearing protectors more often and perceive their working surroundings as noisier. Correlations were found between hearing disorders and hearing protector use, being worried about hearing, and stress. Similarly, musicians feel that hearing disorders could be reduced by avoiding stress and noise, sufficient rest, and by having a positive attitude.

Eighty-four percent of Finnish musicians have had a hearing check within a three year period (Laitinen et al, 2003a); whereas, this was the case for only 35% of Danish musicians in the current study. Danish musicians are not as worried about their hearing, have less stress, and are slightly more satisfied with their work than their Finnish colleagues as shown in the Laitinen et al study (2003a).

Musicians are concerned about the acoustics of their working environment. Typically they find the acoustics of the concert hall satisfying, but the rehearsal hall and other playing rooms are not always found appropriate. Further, musicians want a quiet room for rest. The present study did not investigate the acoustics of the halls; thus, the criticism of the rehearsal halls may be a psychological factor. Musicians' evaluation of other playing environments (not their usual concert and rehearsal hall) is always related to poor acoustics in one way or another (e.g. reverberant places, dry halls, orchestra pit, sport halls, small halls, etc.).

Musicians seem to be concerned about their proximity to instruments that are louder than their own or even to instruments that are at the same sound level as their own instrument. Even a small increase of the distance to other instruments can affect the musician's satisfaction.

The musicians reported that having good communication with their colleagues and the management, having a positive attitude, and playing their instrument in a correct manner were ways to influence their working conditions. The selection of program, seating arrangements, acoustic changes, and more moderate sound levels are issues that the individual musician cannot influence.

The musicians accuse contemporary music and the composer for increased sound levels; however, sound level measurements show that this is not necessarily the case (Laitinen et al, 2003b). Due to the characteristics of contemporary music, it is only perceived as noisier than classical music. However, job satisfaction and reduced stress are two of the important keys to the occupational health of musicians; therefore, the repertoire should be carefully considered.

The data collection method can influence the results of a questionnaire investigation. When the questionnaires are distributed to the orchestra and they voluntarily answer in their own time, the answer rate might be lower than when answering is obligatory and completed on location. Even though the response rate might be high, the motivation of some respondents may be low; thus, the answers may be short, insufficient, biased, or even erroneous. Data collection on location also has positive effects; possible problems with the questionnaire or unclear questions can be solved immediately. Those who do not have any problems with hearing might be more eager to reply than with volunteer-based questionnaires. Thus, the percentage of hearing disorders found in the present study is assumed to be more representative.

The musicians' language skills were assumed to be sufficient as they are accustomed to working with foreign conductors, are professional, and travel abroad; however, one flaw of the questionnaire was that the questions were written in English. To compensate for a possible language concern, answers were allowed in both English and Danish. Further, the musicians received a lecture on the topic, which served as an introduction to the vocabulary used on the questionnaire. The multiple choice questions yielded no language problems. For the open response questions, it was easy to understand the responses even when the grammar was not entirely correct.

Conclusions

- Musicians do not wear hearing protection continuously, and many use hearing protection in one ear only.
- Getting used to hearing protection is time consuming for most of the musicians. One third of the musicians 'gave up' and stopped using hearing protectors.
- Disposable earplugs and custom moulded earplugs are the two most common types of hearing protectors used.
- Better fitting of musicians' earplugs is necessary to avoid the occlusion effect. The musicians need time to learn how to insert the earplug within seconds.
- More education is needed for the acceptance of hearing protectors and to change the attitudes towards hearing conservation among musicians and administration.
- Quiet facilities for rest during working hours are an advantage.
- The musician's personal instrument is not considered as noisy as the others' instruments.

- Hearing disorders exist and affect musicians' work. The most frequent hearing disorders were tinnitus and hyperacusis. Hearing protector usage increases with an increasing number of hearing disorders.

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