International Journal of Occupational Safety and Ergonomics (*JOSE*) 2010, Vol. 16, No. 1, 93–104

Facilities for Music Education and Their Acoustical Design

Heli Koskinen

Helimäki Acoustics, Helsinki, Finland

Esko Toppila
Pekka Olkinuora

Finnish Institute of Occupational Health (FIOH), Helsinki, Finland

Good rehearsal facilities for musicians are essential. Directive 2003/10/EC necessitates that musicians are protected from noise exposure. A code of conduct gives the guidelines how this should be done. This study examines room acoustics recommendations provided by the Finnish code of conduct, and discusses whether they are adequate. Small teaching facilities were measured after renovation and compared to earlier measurements. Teachers' opinions were inquired about the facilities before and after. The renovation did not decrease the noise exposure of the teachers. However, the majority preferred the facilities after the renovation. The Finnish code of conduct is not sufficient for facilities where loud instruments are played, or band practise. Good facilities can be designed but they must be specified at the designing stage for their intended use.

music   sound exposure   room acoustics   reverberation time   sound absorption

1. INTRODUCTION

The new noise directive (2003/10/EC) requires that member states of the European Union (EU) shall draw up a code of conduct for the music and entertainment sector [1]. The purpose of this code is to provide practical guidelines to help workers and employers meet the legal obligations laid down by that directive. The Finnish code of conduct [2, 3] was adopted in February 2007, one year after the noise directive was included in Finnish legislation.

The Finnish code of conduct states that the music and entertainment sector consists of musicians, actors and technical personnel [2]. In addition, those who work in discos and concert houses are in this sector, too. The final group that are included are music teachers. The code of conduct also acknowledges that there are permanent and temporary workers in all of these groups.

As with the noise directive [1], the code of conduct [2] prioritises collective measures such as the design of the rooms and the selection of quiet instruments. The remaining risks should be covered by the use of hearing protectors. Some form of noise exposure monitoring scheme is also required.

The Finnish code of conduct acknowledges that the music being played sets requirements for rooms [2]. It provides recommendations for room volumes and reverberation times. Design issues are referred to in Standard No. SFS 5907:2004 [4]. The special requirements of high intelligibility are recognised in the selection and use of hearing protectors.

This research has been supported in part by grants provided by the Academy of Finland.
Correspondence and requests for offprints should be sent to Heli Koskinen, Leenankuja 2 C 21, 02230 Espoo, Finland. E-mail: <akasha@iki.fi>.

However, the Finnish code of conduct is merely a list of good guidelines, but does not provide any practical tools for the implementation of these suggestions in practice [2]. For this, more detailed instructions are needed unless the quality of playing is to be compromised. Musicians spend most of their time in practice rooms [5]. Music teachers spend an even bigger share of their time in rehearsal rooms, indicating the major role of these places in attempts to reduce noise exposure.

The code of conduct for the entertainment sector is mandatory in EU countries. The European Agency for Safety and Health at Work published recommendations for the entertainment sector [6]. In these recommendations it is identified that noise reduction can be obtained by organisational measures, through technical and architectural measures and by using hearing protection. For practice rooms a size of 17 m^3 is recommended. Good acoustic design and proper absorption are recommended to reduce the sound levels. The European Agency also conducted a survey on the methods used to implement the code of conduct [7]. Out of 16 countries from which information was returned in this survey, 11 put in force new laws implementing the directive's requirements and two were awaiting new regulations in 2007. Seven countries introduced a 2-year transitional period (typically ending early in 2008).

In addition there are many laws and regulations in the EU member states, which can be applied to control sound levels in the music and entertainment sectors, e.g., in German Technical Direction on the Protection against Noise, Federal Immision Protection Law, Sport Facilities Noise Protection Directive for sport facilities, and certain regulations coming from accident insurers (BGV B3 Noise regulations) or other industrial sectors as the Gaststättengesetz (Restaurant law). Also, regulations to protect the audience limit the exposure of workers, e.g., regulations limiting the level to 85–90 dB(*A*), demanding control of the settings to be conducted by a competent technician, or certain environmental laws on noise control.

The recommendations come both from various governmental (federal or local) and nongovernmental social partners. Governmental agencies mentioned in the report include German Federal Institute for Occupational Safety and Health, Finnish Institute for Occupational Health, Swedish Institute of Working Life, governments of Land Bremen, or city of Hamburg. Examples of nongovernmental groups include Danish Musicians' Association, German Federal Medical Doctors Chamber (Bundesärztekammer), Institute of Music Medicine of University of Music in Freiburg, and Swedish Artists and Musicians Against Tinnitus. Various projects have arisen due to a close co-operation between governmental and nongovernmental partners.

Other initiatives of various kinds have been started by diverse social partners. In Germany, Länder committees started cross-departmental working groups dealing with the noise problem in the entertainment sector. In Austria, due to co-operation of different social partners a website containing information on risks in the music and entertainment sectors was started. Seminars on problems related to the risk of hearing damage by music were initiated in the UK and France. Promotions and campaigns, publications and lectures on the required policies on harmful effects of loud music were started in the UK, Sweden and Poland, as well as certain research leading to hearing conservation programs (Finland) or acoustic projects for discos and music clubs (Finland, Sweden).

Examples of large-scale initiatives include establishing indicators showing protection of the audience in discos by Land Sachsen in Germany, seminars organized by the French Acoustical Society (SFA), a Hein campaign launched across France by the French National Modern Music Forum AGI-SON, a hearing conservation program among workers and artists of the Finnish National Opera, a website by the Swedish Institute of Working Life (NIWL) and Artists and Musicians Against Tinnitus (Ammot), and a number of awareness raising campaigns such as Don't Lose the Music by RNID (the UK charity for deaf people), and seminars organised by the Chartered Institute of Environmental Health in co-operation with the Health and Safety Executive (HSE) in the United Kingdom.

As shown by the report typically the recommendations are given to different branches of entertainment sector separately. The Finnish approach is different. The code of conduct is intended to be used as a checklist by labour inspectors. It does not provide any practical solutions how to achieve the goal, but it provides an overall view of the requirements and possibilities. Also, the UK HSE provides a similar overall view in their web pages[1]. The instructions are given by the type of music: concert halls and theatres, amplified music, studios, schools and colleges, pubs and clubs and marching bands. The needs of different worker groups like technicians and freelancers, are identified is a similar way to that in the Finnish code of conduct [2].

Directive 2003/10/EC is intended to protect workers from the risks "arising from noise owing to its effects on the health and safety of workers, in particular damage to hearing" (p. 38) [1]. Musicians commonly suffer from hearing loss, tinnitus, diplacusis and hyperacusis [5, 8, 9]. Tinnitus and hyperacusis may actually be more disturbing for a musician than hearing loss. However, there is no dose–response relationship available for noise.

Music education facilities and professional orchestras need facilities that can be used both for playing and for quiet activities. Music students need to study the theory of music, history, sheet music, etc., while professional musicians study sheet music before they actually start to play them. Professional musicians also wish for quiet facilities during their breaks [9]. For all of these factors, sufficient sound insulation between the different facilities is the key. Unfortunately, functional solutions are often more expensive than nonfunctional ones, and the possibility to build surroundings that everyone can enjoy, both students and professionals alike, is often undermined by a tight budget.

When room acoustics are designed, little or no attention is paid to small rooms. Practice rooms for small teaching classes of one student or a small group of students are often neglected and built at the minimum cost. This usually backfires with a need for repairs when the sound insulation is insufficient and complaints arising about the rooms being too small for loud instruments. Unfortunately, the repairs often take the form of compromises and are expensive to make.

There is little research on the subject of how good practice rooms should be built, and few recommendations for educational institutes [10, 11, 12]. Lane and Mikeska studied four schools to determine the proper amount of absorption, sound isolation and the size that would be suitable for music education [13]. Their resulting sound isolation figure cannot be compared to modern values as calculation methods differ, but users expressed their satisfaction. The reverberation time was set to 0.4–0.5 s at lower frequencies, and 0.6–0.7 s at higher frequencies for smaller rooms; while the figures were 0.55–0.65 s and 0.8 s respectively for larger rooms. They did not find any minimum satisfactory size for small practice rooms, and concluded that, for a room to be suitable for musicians, the total volume of the room required could not be built within the budget.

Knudsen and Harris emphasised sound isolation in music rooms [14]. However, the solution they offered would be considered insufficient today. They gave sound isolation requirements for single parts, and reminded readers of the importance of preventing sound transferring through the ventilation system. Other recommendations included nonparallel walls that helped to avoid flutter echo. Their studies showed that, with the help of an experienced acoustician and a realistic budget, good small rooms could be built.

Teuber and Voelker studied the requirements for music rehearsal rooms [15]. Good sound isolation, a short reverberation time and reflections necessary for audibility were prerequisites for smaller rooms. They had concerns regarding sound isolation from outside noise and restricting the noise from heating, ventilating and air conditioning (HVAC). Convertible room acoustics was also desirable.

The need to pay attention to small practice rooms was acknowledged in studies on noise

[1] http://www.soundadvice.info

exposure for musicians [16, 17, 18, 19, 20]. Behar, MacDonald, Lee, et al. studied the effects of classrooms on music teachers' sound exposure [21]. A comparison was made in two rooms of different volumes with the same kind of acoustical treatment and the same teachers teaching similar music. Doubling the volume brought a 2-dB decrease in sound levels, which was within the measurement error. The facilities were not changed in any way. They concluded that, because teachers have to be close to a student, additional absorption would not greatly help to decrease the sound levels and thus the exposure.

The requirements for good rehearsal facilities are

- good sound insulation (should be ensured when built, as it is difficult to improve later without extensive repairs) and proper background noise levels;
- a sufficient amount of absorption;
- special requirements for the instruments need to be met (floor, reflecting wall, etc.);
- other environmental controls were needed (ventilation, lighting, temperature).

The Finnish code of conduct provides requirements for the space that is needed for instruments: grand piano and drum set need ≥80 m^3/person, wind instruments ≥20 m^3/person and other instruments ≥10 m^3/person [2]. Wenger's planning guide for secondary school music facilities gave values for area and by person: one student 3–4 m^2, 2 students 5–6 m^2, 4 students 7.0–7.5 m^2, and 6 students 9.0–9.3 m^2 [12]. Chasin recommended a minimum volume of 17 m^3 for a rehearsal room [22]. The code determines the acoustic properties of facilities by using Standard No. SFS 5907:2004 acoustic classification of spaces in buildings, where the reverberation time for special classrooms is <1 s, and the apparent sound reduction index R_w is >57 dB [4]. When building a new structure or renovating an old one, the code provides a class B to be used for music facilities (reverberation time 0.8–0.9 s and the apparent sound reduction index R_w is >65 dB). Class B is a very demanding facility to achieve sufficient sound insulation, especially when renovating an old facility. Class B almost always requires an acoustician to plan it.

The adjustable room acoustics can be achieved in many ways. The simplest way to vary reverberation time is by hanging absorbent panels that are hard on one side and are easily turned over when needed. To remove flutter echo, sound absorption should be placed on adjacent walls; nonparallel walls can also be used. The absorption material should be at a player's ear height, whether they are standing or sitting. The amount of absorption material necessary depends on the usage of the room. Sound isolation should not only be sufficient inside the building, but also between the room and the outdoors to prevent either traffic noise entering the room or music practice disturbing neighbouring buildings. When designing such a room, the sound insulation design should include structures (detailed drawings from solutions) and HVAC systems (silencers in the ventilation and the separation of a room-in-a-room system from the surrounding building). One popular misconception is the belief that practice rooms that are built in basements with heavy walls are sufficient in sound isolation.

Good acoustics are essential for a musician, professional or student to achieve perfect performance. If these conditions are not met, a music student will not develop into the professional they have potential to be. Studies show that, with the help of an experienced acoustician and a realistic budget, good small rooms can be built. However, the question remains whether the sound exposure of teachers is thus reduced.

The purpose of this study is to discover whether the room acoustics recommendations in the Finnish code of conduct are adequate for developing a good teaching environment with reduced sound exposure [2].

2. MATERIAL AND METHODS

A music institute in Espoo, Finland, participated in the study. The facilities there were measured earlier for reverberation time and sound insulation [23]. Those facilities that did not meet with the requirements of the code for reverberation time, or were otherwise considered difficult to teach in, were scheduled for renovation by adding more absorption. The amount of material to be added was calculated using the Sabine formula. The teachers' opinions were sought through a questionnaire before and after the renovation. In addition, the teachers who were using the facilities that met the requirements of the code were also included in the study. The questionnaire had questions about hearing protector usage and possible hearing symptoms. The questionnaires were distributed to the teachers, who then returned them to the institute.

After the renovation, the reverberation time of the facilities was measured again. Sound exposure measurements were performed for teachers before and after the renovation to establish the actual sound level decrease through the additional absorption.

3. RESULTS

3.1. Reverberation Time

Table 1 shows the reverberation times measured before [23] and after the renovation in the facilities. Classrooms I, II and III were located in a bomb shelter facility with concrete walls, floors and ceilings. Classroom IV also had concrete walls, floor and ceiling. The music playschool hall had one mirror wall, while Classrooms V and VI were regular rooms with minor absorption. One facility was not renovated, but was measured nevertheless, and this showed very good repeatability in spite of different instrumentation and personnel. The reverberation time is given at 1 kHz. The measurements at low frequencies were disturbed in Classroom II due to timpani. The absorption material added was mineral wool, with a thickness of 50 mm.

3.2. Sound Level Measurements

Table 2 shows the sound exposure measurements of teachers' 8-h sound level exposure (L_{eq}), the average taken before and after renovation. Unless otherwise stated, the equivalent sound level measurements were performed using a dosimeter (Larson & Davis 705, USA). The microphone was located in middle of the teacher's left or right shoulder. Teachers recorded the style of music that they taught. Unfortunately, the pieces used were different in each classroom.

TABLE 1. Reverberation Time Measured Before [23] and After Renovation

Room	Area (m^2)/Volume (m^3)	Reverberation Time (s)			Absorption
		Before	After	Change	
Classroom I	40/10	0.5	0.4	–0.1	bass element, 10 m
Classroom II	38/103	0.6	0.3	–0.3	increased by 7% + bass element, 10 m
Classroom II	90/246	0.7	0.5	–0.2	increased by 30%
Classroom IV	35/120	0.6	0.3	–0.3	increased by 70%
Music playschool hall	111/311	1.2	0.7	–0.4	increased by 20 m^2
Classroom V	48/116	0.6	0.4	–0.2	increased by 27%
Classroom VI	75/209	0.5	0.5	—	no absorption material added

Notes. Bass element—large triangle-shaped absorption material in the cross-section of ceiling and wall.

TABLE 2. Sound Exposure Measurements Before and After Renovation

Room	Instrument	L_{eq} (dB(*A*))		Comment
		Before	After	
Classroom I	trumpet	85	84	
Classroom II	drums	91	93	
Classroom II	drums	87	85	fixed point
Classroom III	French horn	80	84	
Classroom IV	accordion	84	75	
Classroom IV	accordion	81	71	fixed point

TABLE 3. Number of Respondents Using Hearing Protectors at Personal Rehearsals, Orchestral Rehearsals (Not Teaching), Performances (Not Teaching) and While Teaching

	Respondents Using Hearing Protectors				
Activity	***never***	***seldom***	***sometimes***	***often***	***always***
Personal rehearsals	17	8	2	3	1
Orchestral rehearsals	13	7	3	0	1
Performances	21	6	2	0	1
Teaching 1–3 persons	15	5	4	2	3
Teaching 4–6 persons	15	3	5	1	1
Teaching an orchestra	13	1	1	1	1

TABLE 4. Questions Asked Seeking Evaluation of the Facilities

Key Word	Question	5-Point Scale
Satisfied	Are you satisfied with the teaching facilities?	*very satisfied – very unsatisfied*
Support	Support received from the facility (is it easy to play in the facility)?	*very good – very bad*
Dynamics	Dynamics of the facility?	*very large – very small*
Sound level	Sound level of the facility?	*too quiet – too loud*
Hear self	Can you hear yourself?	*very well – very badly*
Mistakes	Can the mistakes of the student can be distinguished?	*very well – very badly*
All in all	The overall acoustics of the facility?	*very good – very bad*

3.3. Questionnaire

There were 31 responses to the questionnaire before and 8 after the renovations. No statistical analysis was performed due to the small sample size.

Enquiries were also made about the usage of hearing protectors. Table 3 lists them. For instruments where a mute could be used, 13 out of 30 respondents used it in their instrument.

Teachers reported hearing symptoms as follows (31 respondents): continuous tinnitus 6 respondents; hyperacusis 10 respondents; and distortion 6 respondents. Diplacusis was not reported.

The facilities that were commented on in the questionnaire, besides the renovated facilities already mentioned, were larger classrooms, volume ~100 m^3; smaller classrooms, volume ~35 m^3; classrooms in another building, which were office rooms renovated into music facilities; orchestral rehearsal room with variable acoustics, volume ~400 m^3; and a classroom used for teaching harp playing.

Teachers were asked which teaching facility they used most. The replies were grouped according to the volume and reverberation time, and approximately the same usage. The resulting groups were classrooms I, II and III (almost entirely of concrete, some absorbent material); larger classrooms; smaller classrooms; classrooms in another building; music playschool hall; classrooms V and VI; classroom IV (almost entirely of concrete, with some absorbent material); orchestral rehearsal room; and a classroom used for teaching harp playing (over 100% absorbent material).

Teachers were also asked about support, dynamics, sound levels in the room, whether they could hear themselves, whether they could detect mistakes easily and the reverberation in the room. In addition, their overall opinion about the room acoustics was sought.

The averages by group are given in Figures 1–3. Table 4 contains the questions on which the evaluation key words were based in the figures.

The questionnaire results showed a major improvement in the sound levels of the rooms. However, sound level measurements could not confirm this improvement. One explanation could be that the bass elements decreased low frequency sound, which did not contribute greatly to the *A*-weighted exposure. Thus, the musicians might have rated their annoyance at the room instead of the sound level.

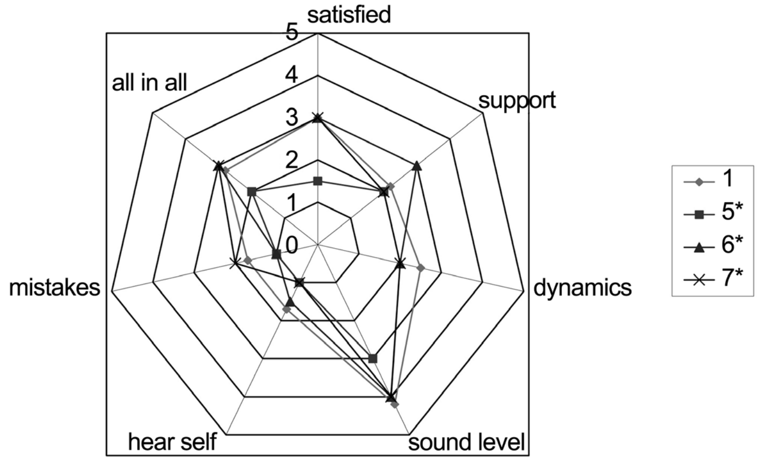

Figure 1. The averages of room acoustical evaluations of classrooms to be renovated, on a 1–5 scale (5—worst case). *Notes.* *—groups with <5 respondents.

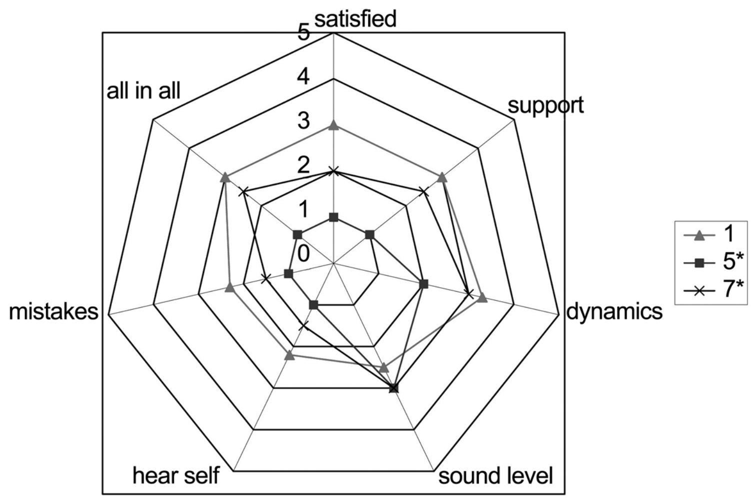

Figure 2. The averages of room acoustical evaluations of renovated classrooms, on a 1–5 scale (5—worst case). *Notes.* *—groups with <5 respondents.

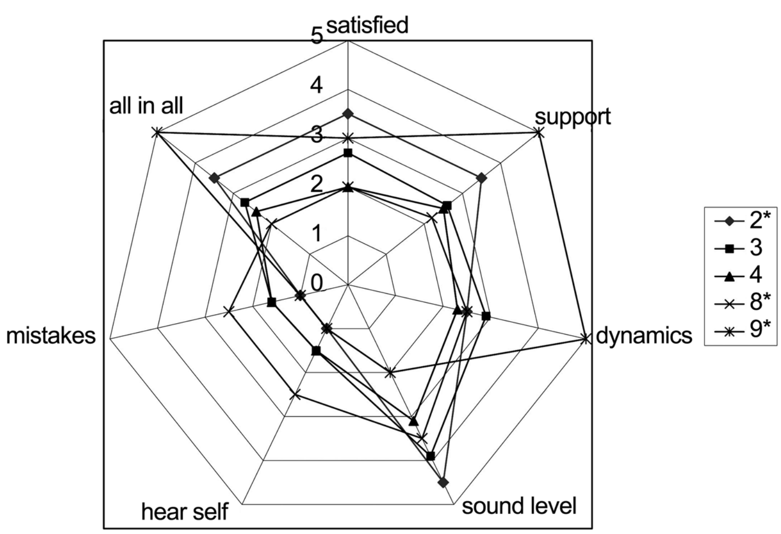

Figure 3. The averages of room acoustical evaluations of other classrooms, on a 1–5 scale (5—worst case). *Notes.* *—groups with <5 respondents.

Room No. 9, used for harp lessons, was rated as very poor. In addition to the sound level, the dynamics and support were also considered poor. This poor rating was probably due to the high damping in the room.

Questions about the sound insulation asked whether teachers were disturbed by or thought they disturbed others. Most respondents were satisfied with the sound insulation and were not aware if they disturbed others. According to earlier measurements [23], most facilities did not meet the requirements of Standard No. SFS 5907:2004 [1] for the minimum level of sound insulation.

The teachers were asked whether they were satisfied with the teaching facilities; they showed no complete dissatisfaction with the facilities. They were also asked whether the music style affected how they felt about the facilities. Around half of the respondents (12 out of 26) were convinced that music style did not affect their opinion; while the other half (10 respondents) thought that music style mattered. Three respondents considered the age and playing ability of the students more important than the music style.

Some respondents thought that a hard wall was needed. The instruments that needed a hard surface varied, and teachers of the same instrument had different opinions. Floor material seemed to affect the sound of instruments. Sixteen out of 17 respondents thought that a wooden floor was the best material for an instrument. Only 2 teachers liked concrete floors, and 3 wall-to-wall carpeting.

Teachers had the opportunity to comment freely on the facilities. Twelve teachers felt that the classrooms were too small. Other comments included suggestions that the working position could be better, the room could be higher, there could be better sound insulation, stairs could be improved (one facility had steel stairs), there could better lighting in some rooms, less reverberation, better ventilation, concrete flooring annoyed, and the absorption material should be mounted on the walls instead of the ceiling to avoid the bow breaking when hitting the absorbent.

Teachers also commented on the facilities. An ideal facility for teaching, according to them, would be one that had ample space, large volume, a high ceiling, and not too much reverberation, but was also not too dry.

In addition, there were a few comments dealing with windows, hard floors, the concert stage, wooden flooring, the need for furniture, and freedom from other noise.

Six out of eight teachers were either very positive or positive about the effects of renovation on the facilities. The two teachers who thought it negative both taught woodwind instruments. The following comments were given about the renovation: the concrete floor could be covered with wood, which would make the facility even better; the smearing of sound has reduced; they were very satisfied with the facility; the music did not bother their ears as much after the renovation; listening was easy; and reverberation and booming had been reduced, but sound insulation did not get any better.

Teachers of woodwind instruments did not like the reduced reverberation. This was problematic because the same facility was also used by drums. Teachers of wind instruments felt that it was harder to play after the renovation and that was more difficult to hear the mistakes of the student. Volume reduction was also criticised, as well as the impression that the attenuation of the facility was not even. One teacher stopped personal rehearsals in the classroom. Another one described the volume reduction as shocking, but admitted they became used to it.

4. DISCUSSION

Changing the room reverberation characteristics did not decrease the level of exposure of teachers or students. This result is not surprising because the level of playing can be controlled by the player. Reverberation is thus more related to the quality of sound, and therefore to job satisfaction. The recommendations regarding room size are hard to meet in most places. However, this study shows that decent room acoustics can be achieved even in relatively small rooms. The major problem seems to be the amount of the absorption material needed to find proper reverberation which is instrument dependent. Because teachers use the same classrooms for different instruments, they should be designed for an easy change of reverberation time. In addition, teachers have to get used to the new facility. Another advantage is that, because of tuning possibility, there is no need for measurements to adjust the acoustics of the room. A sufficient range can be obtained through acoustical modelling.

Reverberation times were shortened in all of the facilities that were renovated. A simple calculation seems to be precise enough to design facilities for both practice and teaching. The decision regarding the amount of absorption material to be used should be carried out by a professional. However, sound insulation in the bomb shelters was not sufficient, mainly due to insufficient sound insulation for such high demands (the loud instruments used). A common misconception is that thick walls prevent sound travelling from one facility to another, because sound travels both in the structure and through ventilation ducts. A room that is in a room-structure should always be used for loud instruments and band practice. In addition, concrete (or some other extremely hard surface) as the surface material does not provide good acoustics for practice rooms; it is almost always too reverberant for music. If concrete is used, there is a need for highly absorbent, space requiring materials that absorb sound, especially at lower frequencies. In spite of insufficient sound insulation, teachers generally do not seem to be bothered by weaker sound insulation. There could be two reasons for this: the first is that the sound insulation is quite good, and so it does not cause any great problems in teaching; and the second is that the teachers are used to the situation and have learnt to deal with it.

The code of conduct [2] uses Standard No. SFS 5907:2004 [1] as a guide for its recommendations for reverberation time and sound insulation. However, the standard is suitable only when designing a regular music classroom in a school [4]. In addition, the standard does not give any practical means for designing rooms. In Finland, there is a guide "Acoustical design of buildings: schools, auditoriums, spaces for sports and libraries" that can be used [24]. This guide follows Standard No. SFS 5907:2004. The limits given in that standard and the advice in the guide are not suitable for small spaces where loud instruments are played, such as band practice or individual practice of loud instruments. The requirements for sound insulation in these cases are greater, while sound reverberation time must be reduced at such facilities. Planning requires good knowledge of building acoustics. If proper sound insulation is not achieved, a simultaneous use of facilities can be impossible (e.g., band practice disturbs education in classrooms on the upper floors of the building).

The acoustical design should also be reviewed with occupational healthcare in mind. If one considers sound exposure levels, differences in sound reverberation times are usually not significant. However, even small changes and correct reverberation time can be heard and can improve job satisfaction. Thus high quality in acoustical design is important when good occupational healthcare is desired.

Sound levels were considered to be a problem in almost all facilities. These were thought to be decreased in the renovation, although shorter reverberation time began to be a problem for some instruments. Some teachers have hearing problems, but the use of hearing protectors is low.

Sound level measurements before and after the renovation must be compared with care. The reverberation time measurements confirm that the sound level is somewhat reduced at the facilities, but the sound level measurements do not confirm that. The variance in teaching situations masks the small reductions in sound level. A large difference can be seen in an accordion class, but even there the effects of different teaching material cannot be excluded. However, when all the sound level measurements are considered together, it is possible to confirm the prediction of the modelling: sound levels and therefore sound exposure will not change significantly through changing the room acoustics. Satisfaction in the work environment and teachers' opinions of the room acoustics change. For most of the teachers who responded, the situation improved, while for a minority it worsened. It would seem that wind instruments suffered the most, since the negative replies were all given by wind instrument teachers. The reason for this is probably that useful feedback from the reflective wall decreased. Because many rooms still had convertible acoustics, the teachers could adjust each room to their satisfaction. However, the convertible acoustics has been designed so that it is very difficult to use. Even if exposure does not decrease, the effect on job satisfaction is important, because the sensation of a noisy environment is related to both stress and job satisfaction [5].

Some teachers felt that the skills of students are the major cause of sound exposure. However, Mace made experiments with university music teachers and found that there was little if any effect on average sound levels [25]. In her study the freshmen had at least some skill while in our study this was not guaranteed. Lack of technique can be a cause of an increased/decreased sound level in some instruments, although music can appear noisier even when sound levels are the same.

Building and renovation are expensive. There are often complaints that extensive planning and the services of an acoustician increase the cost of an already expensive project. However, these can also save money. In this case, the cost of renovation was determined by a call for offers. The initial offers were relatively high, so the author then went through the offers with the builders. The results were significantly lower after the precise needs of the music institute were determined. If the builder has no experience in building this kind of facility, estimating the cost can be difficult. Thus an hour of consultation can save thousands of euros on an offer.

When totally new facilities are built, or extensive renovation is necessary, consulting an acoustician in the early stages of planning when the budget is estimated and decided on, and later having the acoustician supervise the construction site, can save additional correction costs.

The results suggest that practice rooms and classrooms for music require careful planning, although comprehensive measurements are not always necessary. If there are problems with sound insulation and room acoustics, by measuring the worst cases and going through the facilities on site and looking at earlier plans, the condition can be identified and renovations planned. The ideal situation is for planning to be finished well before the facilities are built.

Convertible acoustics is highly recommended. Only if the use proposed for the room is known well in advance and is not going to change can acoustics be planned for that one particular purpose. Even then, individual preferences may vary and, while the facility is good for one instrument player, it can be bad for another player of the same instrument. The solutions for convertible acoustics can be simple: a frame with a soft and hard surface that can be turned easily is cheap yet effective. The experiences at the institute showed that if convertible acoustics is thought to be tiresome or too complicated to use, it will not be used, and in the worse case is not even perceived as convertible. The solution is relatively simple: the users must be taught how to use this kind of acoustics. The principles of how, why and when should be taught to users at the beginning, and should be included in the orientation of new employees. Using convertible acoustics should be as automatic as turning the lights on when it is dark.

5. CONCLUSIONS

- To be successful, the reverberation time of facilities must be specified at the designing stage for the volume of the room and its intended use. This goal is relatively simple to achieve for an experienced acoustical designer.
- The addition of sound absorption material that provides reverberation times meeting the requirements of the Finnish code did not produce any significant reduction in sound exposure [2]. The acoustical improvement does have a profound and positive effect on job satisfaction and work surroundings.
- If the facilities are designed properly, are aimed at good quality and if users are taught to use them, satisfaction in the work

surroundings is achieved. This also adds value to occupational healthcare in the workplace.

- The code of conduct does not provide sufficient guidance or room acoustical parameter limits to plan or renovate band practice or small facilities for loud instruments [2]. The limits are sufficient for an ordinary music classroom in a school.
- As the rehearsal rooms are often to rehearse different types of music, rehearsal rooms with variable acoustics should be preferred. In addition, their musicians should learn how to change the acoustics properties of the room.

REFERENCES

1. European Union. Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). OJ. 2003;L42:38–44. Retrieved December 15, 2009, from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:042:0038:0044:EN:PDF
2. Code of conduct for music and entertainment sector; 2006. Retrieved December 15, 2009, from: http://fi.osha.europa.eu/good_practice/ohjeet/meluntorjuntaohje.pdf. In Finnish.
3. Toppila E, Starck J, Kyttälä I. Implementation of the noise directive in the entertainment sector in Finland [abstract]. Acta Acustica united with Acustica. 2006;92 Suppl 1:S43.
4. Finnish Standards Association (FSA). Acoustic classification of spaces in buildings (Standard No. SFS 5907:2004). Helsinki, Finland: FSA; 2004. In Finnish.
5. Laitinen H. Factors affecting the use of hearing protection among classical music players. Noise Health. 2005;7:21–9.
6. European Agency for Safety and Health at Work. Reducing the risks from occupational noise. Luxembourg: Office for Official Publications of the European Communities; 2005. Retrieved December 15, 2009, from: http://osha.europa.eu/en/publications/reports/6805535
7. Augustyńska D, Buffet MA, Karjalainen K, Kuhl K, Młyński R, Toppila E, Żera J. TCWE Task 3.2.2 Report, Noise in the entertainment sector version 5.0 final. European Agency for Safety and Health at Work. In press.
8. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians. Int J Audiol. 2003;42:279–88.
9. Laitinen H, Poulsen T. Questionnaire investigation of musicians' use of hearing protectors, self reported hearing disorders, and their experience of their working environment. Int J Audiol. 2008;47:160–8.
10. Kemp W. Music education suites. Washington DC, USA: National Clearinghouse for Educational Facilities; 2000.
11. Mehta M, Johnson J, Rocafort J. Architectural acoustics: principles and design. Upper Saddle River, NJ, USA: Prentice-Hall; 1999.
12. Wenger Corporation. Planning guide for music facilities. Version 3.0. Owatonna, MN, USA: Wenger; 2006. Retrieved December 15, 2009, from: http://www.wengercorp.com/images/lit/lit/Wenger%20Planning%20Guide.pdf
13. Lane RN, Mikeska EE. Study of acoustical requirements for teaching studios and practise rooms in music school buildings. J Acoust Soc Am. 1955;27(6):1087–91.
14. Knudsen VO, Harris CM. Acoustical designing in architecture. New York, NY, USA: Acoustical Society of America; 1978.
15. Teuber W, Vöelker E-J. Acoustical requirements and results for music rehearsal rooms (Paper No. 3549). In: The 94th Audio Engineering Society (AES) Convention. Berlin, Germany: AES; 1993.
16. Early KL, Horstman SW. Noise exposure to musicians during practice. Appl Occup Environ Hyg. 1996;11:1149–53.
17. Harding RA, Owens DT. Sound pressure levels (dB) experienced by conductors in collegiate music rehearsal settings. In: Proceedings, Hawaii International Conference on Arts and Humanities; 2003. Retrieved December 15, 2009, from: http://www.hichumanities.org/AHproceedings/R%20A%20Harding%20&%20D%20T.%20Owens.pdf

18. Flottorp G. Music—a noise hazard? Acta Otolaryngol. 1973;75(4):345–7.
19. Owens DT. Sound pressure levels experienced by the high school band director. Med Probl Perform Art. 2004;19(3):109–15.
20. Pang-Ching GK. Hearing levels of secondary school band directors. J Aud Res. 1982; 22:284–8.
21. Behar A, MacDonald E, Lee J, Cui J, Kunov H, Wong W. Noise exposure of music teachers. J Occup Environ Hyg. 2004;1:243–7.
22. Chasin M. Musicians and the prevention of hearing loss. San Diego, CA, USA: Singular; 1996.
23. Lokki T, Salmensaari O. Measurement report: Espoon Musiikkiopiston opetusluokat [Teaching facilities of Espoo music institute] (Report No: 71119-1). Helsinki, Finland: Akukon Oy; 2007.
24. Kylliäinen M, Hongisto V, Helimäki H. Rakennusten akustinen suunnittelu: oppilaitokset, auditoriot, liikuntatilat ja kirjastot [Acoustical design of buildings: schools, auditoriums, spaces for sports and libraries]. Helsinki, Finland: RIL Finnish Association of Civil Engineers; 2007.
25. Mace ST. A descriptive analysis of university music performance teachers' sound-level exposures during a typical day of teaching, performing, and rehearsing. In: Baroni M, Addessi AR, Caterina R, Costa M, editors. In: Proceedings of the 9th International Conference on Music Perception and Cognition. Bologna, Italy: ICMPC, ESCOM; 2006. p. 271–7.