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Titel
Akustiskt åtgärdsprojekt av en rockmusikklubb där live-musik spelas. Vad kan en audionom bidra med?

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Sammanfattning

Bakgrund:Andelen hörselskadade i Sverige ökar. Den största ökningen finns hos 25-44 åringar. Det finns anledning att tro att dessa hörselnedsättningar är orsakade av buller. Fritidsbuller kontrolleras inte på samma sätt som industribuller. En pågående konflikt mellan myndighetspersoner och musikutövare om ljudnivåer som överskrider nationella riktlinjer skapade behovet av ett åtgärdsprojekt där ljudnivåerna på små rockklubbar kunde sänkas utan att inkräkta på musikernas artistiska frihet.

Syfte: Syftet med uppsatsen är att presentera de tekniska och akustiska metoder med vilka åtgärdsprojektet genomfördes, samt att presentera resultaten av den kompletta akustiska renoveringen av en mindre rockklubb som spelar live-musik. Författarens roll i projektet kommer också att beskrivas.

Forsknings och datainsamlingsmetoder: En tillämpat åtgärdsprojekt utfört på ett explorativt sätt.
Relevanta resultat: En akustisk renovering av en mindre rockklubb gjordes. Nytt vägg- och takmaterial installerades. Ljudanläggningen byttes ut och placerades på ett nytt sätt. Scenen byggdes om och förstorades. Ljudnivåmätningar under konserter före och efter ombyggnad visades ljudnivåreduceringar med 9 dB.
Diskussion: Detta project visade att det är möjligt att sänka ljudnivåer under konserter, direktljud från scenen och ljudnivåvariationer I en typisk mindre rockklubb. Tyvärr finns det förmodligen flera mindre klubbar där detta inte fungerar. Många små klubbar har så dåliga akustiska förutsättningar att ingen förstärkt musik borde få framföras överhuvudtaget. Det finns ett stort behov av förebyggande åtgärder och forskning inom området hörsel och ljud, vilket är en passande uppgift för audionomer i framtiden.
Nyckelord: sound levels, music club, acoustic intervention, sound screens, absorption

The Sahlgrenska academy
AT GÖTEBORG UNIVERSITY
Institute of Neuroscience and Physiology
Audiologist program

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MASTER RESEARCH THESIS IN AUDIOLOGY, 20 credits
Advanced level 2 (D)
Within master level, audiologist programme, 120+40 credits

Title
Acoustic intervention in a live music club. What can an audiologist contribute to?

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Abstract
Introduction: The number of hearing impairments in Sweden is increasing. The largest increase is seen in ages 25-44. There are reasons to believe that these impairments are noise induced. Leisure time noise is not controlled in the same manner that industrial noise is. An ongoing conflict between city council officials and rock club owners, musicians and music event organizers about sound levels at smaller live music clubs exceeding the national sound level restrictions created the need for an acoustic intervention project. The purpose of that project was to lower the sound levels without compromising the artistic freedom of the musicians.

Aim: The aim of this paper is to present the technical and acoustical procedures as well as the results of a complete acoustic intervention in one small club, where live music was played. The author's participation in the acoustic project will also be described.
Research and data collection methods: This was an applied, intervention study implemented in an explorative way.
Results: An acoustic renovation of a small live music venue was accomplished, with new wall and ceiling material installed. The sound system was replaced and the stage was enlarged. Sound pressure level measurements during concerts before and after the intervention showed a sound level reduction of 9 dB.
Discussion: This intervention project showed that it is possible to decrease sound levels during concerts, the direct sound from stage and the sound level variation in a typical small live music venue. However, there are probably several music clubs where this is not possible. Many live music clubs have such poor basic conditions that no amplified music should be allowed to be presented at all. There is a great need for prophylaxis and prevention, and research in the areas of hearing and sound, and that is a job well suitable for audiologists in the future.
Keywords: sound levels, music club, acoustic intervention, sound screens, absorption

FÖRORD

Tack Kim för att du sparkade igång mig
när det var motigt.
Tack Alf, Per och Guran för ovärderlig hjälp.

Tack Daniel, för att du såg till att markservicen fungerade, och för att du alltid lyssnar.
Utan dig hade jag brutit ihop.

CONTENTS

GLOSSARY

A-weighted sound pressure level, dB(A): Weighted average of the sound pressure level within the frequency spectra of human hearing, measured with an A-filter according to the standard SS-EN 61672-1.

C-weighted sound pressure level, dB(C): Weighted average of the sound pressure level within the frequency spectra of human hearing, measured with a C-filter according to the standard SS-EN 61672-1.

dB(A)L_{Ex}8h: Daily noise exposure level. Equivalent A- weighted sound pressure level, normalised to an 8 hour work day. Includes all the noise in the work place, even impulse noise.

dB(A)L_{Fmax}: Maximum A-weighted sound pressure level set to the time measure “F” (fast) according to the standard SS-EN 61672-1.

dB(C)L_{peak}: Impulse peak level. Maximum C-weighted instantaneous sound pressure level measured with an instrument with a rise-time of less than 50µs.

Dry sound image: When the walls are so absorbing that there are very few reflections. The sound does not soften from echoes.

Haas- effect: The ability of the ear to add sounds into a time-series in order to experience sound as coming from one and the same direction. In a room, all reflected energy that comes to the ear within 50ms will be integrated and experienced as a direct sound and enhance the sound level. Longer time intervals than that between the sound sources and the sound will be experienced as an echo.

dB(A)L_{eq}: Equivalent sound pressure level. Average over time that takes high sound pressure levels into higher consideration than regular arithmetic averages.

PA- system: Public Announcement system. The sound system from which all amplified sound is distributed.

SPL= Sound pressure level: Logarithmic unit for sound pressure related to human hearing.

$$L_P = 10 \cdot \log_{10}\left(\frac{\tilde{p}}{p_{ref}}\right)^2$$

$p_{ref} = 2 \cdot 10^{-5}$ Pa = Reference zero for sound pressure level measurement.

1. INTRODUCTION

Over a million of the 9.1 million people in Sweden suffer from hearing impairment, of which over 60% are of working age. The largest increase in hearing impairment is seen in the ages between 25-44, which means that a larger number of people will live for a very long time with an impairment directly affecting their most common way of interacting and communicating with other people. It is not certain what has caused this increase in hearing impairments, but since the increase is mostly seen in people of working age it is probable that the impairments are noise induced rather than genetic (1). In order to grade different hearing impairments, a standard classification is needed. Many different forms of classification of hearing impairment grading exist, but ordinarily they only take pure tone average based on three frequencies (0.5, 1 and 2kHz) into consideration. This was recognized in 1980 by the World Health Organization, who then standardized grades of hearing impairment based on a better ear pure tone average across the frequencies 0.5, 1, 2 and 4 kHz , and by five descriptors. The hearing impairments were divided into groups of none, slight, moderate, severe and profound (including deafness) (2). In 1996, the HEAR group revised the levels within the descriptors (3) (Fig 1).

WHO		HEAR	
Grade of impairment	Hearing Level dB HL	Grade of impairment	Hearing Level dB HL
None	≤25	Normal	<20
Slight	26-40	Mild	20-39
Moderate	41-60	Moderate	40-69
Severe	61-80	Severe	70-94
Profound	<81	Profound	<95

Fig 1. Grading of hearing impairments as divided by WHO and HEAR.

The problems of noise induced hearing loss (NIHL) and tinnitus are no longer confined to middle aged industrial workers. It is becoming more and more common among younger persons, even persons who have not yet begun a working career, to visit clinics because of tinnitus and NIHL, due to exposure to loud leisure time noise such as music from pop/rock concerts (4). Noise induced hearing loss begins as a dip at one frequency (somewhere between 3000-6000Hz), and if the noise exposure is continued over time, spreads to affect all the high frequencies. In time the loss will also include middle and lower frequencies (5).

Tinnitus is characterized as a sound that is subjectively heard from one or both ears but lacking of external sound source. It is often, but not always connected with hearing loss.

Tinnitus is entirely subjective and varies from person to person. Some people are severely impaired by very loud internal noise and some people learn to live with it fairly well (6). Extreme sensitivity to sound, hyperacusis, is another hearing disorder that has been connected with NIHL. Jastreboff & Hazell 1993 has theorized that hyperacusis may be a pre-stage to tinnitus, and Anari, Axelsson, Eliasson and Magnusson describe hyperacusis as often having debuted after for example exposure to loud noise, such as screaming or loud music (7, 8).

The view on leisure noise differs from that of industrial noise in the way that the work place takes responsibility for the noise hazard in the industry, but leisure time noise is each person's responsibility. That is why it is necessary for people to be informed about risks, sound pressure levels (SPLs), hearing and early symptoms of hearing impairment (9). There are many leisure time activities that are loud, for example races (cars, motorcycles), commercial sporting events, recreational use of motorcycles, snowmobiles, fire arms and power tools as well as the use of fireworks, loud toys and all kinds of electronically amplified music with high sound pressure levels (4, 10). A study on sound pressure levels during the NHL play offs 2006 showed that the average sound pressure level of all three games (more than three hours per game) was over 100 dB(A), not because of loud music or highly amplified sound, but from the hockey spectators themselves (11). Long term exposure to loud noise is harmful enough, but the exposure to loud impulse noise is also severe, since the short duration of the noise makes people exposed to it, estimate the sound as much quieter than it really is (4). There are many studies on how firearms affect peoples hearing, mainly carried out by army researchers (12, 13).

Most noise researchers seem to be in agreement of that loud leisure time noise is particularly harmful to adolescents and young adults, since this is the group of people mostly exposed to amplified music through portable music players, rock concerts and discotheques as well as fire works and firecrackers. A longitudinal study on adolescents (14-17 years old) shows that hearing thresholds decrease slightly over time at the same time as visits to concerts and discos became more frequent (14). Eggeman, Koester and Zorowka mean that adolescents (ages 14-20) on average listen to amplified music for at least 3 hours a day through head phones, in discos and at concerts, where sound pressure levels of 100 dB are easily exceeded (15).

Peters discusses the effects of hearing protectors during noisy leisure activities, and is certain that the use of hearing protectors would be more common if there was more easily accessible information, guidance and advice on risks of hearing impairment as well as information about different kinds of hearing protectors and where to purchase them (16). There are numerous studies on loud music and NIHL, but a more common hearing disorder in connection with music exposure is tinnitus. Tinnitus may even be more disturbing and impairing to the person who has it than a mild high frequency NIHL (9, 17).

It has been common knowledge for many years that the sound pressure levels in live performances of pop/rock music very often are much too high. A number of studies have reported measurements of high sound pressure levels at nightclubs and concerts (18-20). Reports from the early 1970's of sound pressure levels at pop concerts which exceeded an Leq of 100 dB(A), with equipment easily managing sound pressure levels of 120-130 dB(A), show that this is not only a recently occurring phenomenon (21).

For people working in nightclubs, high sound pressure levels cause difficulties in the communication with customers and constitute a clear risk of acquiring severe hearing damages (22-24). The people most likely to be at risk are those working in environments with amplified music, and those daily subjected to loud noise (25). Kähäri et al. has discovered a prevalence of hearing disorders in 74% of 139 studied rock- and jazz-musicians. The occurrence of tinnitus and hyperacusis were more common than hearing loss (26).

As far as we know, there has been no focus on acoustic intervention in small live music clubs (with room for 150-300 guests) in the literature, and yet, when visiting such an establishment, one realises that something needs to be done to lower the sound pressure levels. Due to the high sound pressure levels, the risk of hearing loss is often present but depends on several factors.

Sound pressure level, exposure time and individual sensitivity to sound are all contributing to the development of hearing loss. In a study by Axelsson & Prasher, it was suggested that if the exposure time is limited, it might be relatively safe to listen to sound pressure levels of 97-100 dB(A) (9). On the other hand, records of temporary threshold shifts (TTS's) and noise induced tinnitus show that although safe from hearing loss, exposure to high sound pressure levels may well cause other hearing disorders (9, 27).

Other factors that could be of importance for the high sound pressure levels in these types of small clubs are that the ceiling is often very low, the stage is small and that it is possible for the audience to be close to the stage and loudspeakers. Metternich & Brusis have concluded that the superior way to lower the risk of hearing problems is simply to remove the loudspeakers from the audience or vice versa (19). Other problems often occurring in small venues are the negative effects caused by a reflecting stage, resonant stage floor or sound radiation from instrument loudspeakers and feedback monitors (28, 29). Musicians playing acoustic instruments want to “feel” their instrument, and reverberation can, under certain circumstances assists to that feeling. Classical musicians tend to feel their own and other musicians instruments the best when the stage is hollow and slightly vibratious (30). Rock musicians accomplish the feeling by electric amplifiers and feedback monitors, which usually require much less reverberation.

The lack of knowledge (in acoustics, hearing and technical sound level control), music genre and the number of musicians on stage, the audience noise and sometimes also more or less inadequate technical equipment are other factors that may contribute to a poor and hazardous sound environment (28, 31).

In Sweden, noise exposure is regulated by two different authorities: The Swedish Work Environment Authority regulates noise exposure in the work place, which is limited at 85 $dBL_{Ex}8h$, 115 $dB(A)L_{Fmax}$ and 135$dB(C)_{peak}$ (32). The environmental and safety departments in Swedish cities rely on the “public advice” issued by the National Board of Health and Welfare, which regulates leisure time noise, and rely on the environmental law for instructions on sound pressure level limits and measuring techniques. (33, 34) The “public advice” sets the limits for music with high SPLs at 100 $dB(A)L_{eq}$ during the performance and 115 $dB(A)L_{Fmax}$ at “the loudest possible location where the audience is allowed to be” or so called “worst position” in venues where children under the age of thirteen are not allowed (33).

In order to counteract and prevent putting peoples’ health at risk, club owners are prescribed by law to regularly inspect and control that their venues are up to code and meeting the regulations. To regularly control the sound pressure levels should therefore be self-evident (35).

In the spring of 2005, a newly designed method for the measurement of high sound pressure levels of music was introduced in Sweden. The method has been adjusted to fully reflect the sound exposure of visitors at nightclubs and concerts, by including corrections for measured time, type of venue and kind of concert (34).

In the fall of 2003 and January of 2004, a group of people came together to discuss the problem with high sound pressure levels in rock music clubs. The group consisted of government officials, a researcher in the field of audiology, musicians, event organizers, the board of culture, acousticians, sound technology delivering firms etcetera. One purpose of these meetings was to discuss the sound pressure level restrictions, especially the difficulties for smaller music clubs to meet these restrictions. Another important issue to discuss was the conflict between event organizers and environmental department officials regarding the sound pressure level restrictions versus the artistic freedom of the musicians to perform their music at any sound pressure level intended. The result of those meetings was a decision to start a project called “The Acoustic Project” with the explicit aim to explore the possibilities of keeping sound pressure levels within prescribed limits, without compromising the artistic freedom of the musicians or the audience’s appreciation for live music. A rock club in Göteborg was selected as target for acoustic treatment and reconstruction (36).

The project group consisted of a majority of professionals in their trade with great knowledge of the live music scene and the cultural values that it holds. Nine out of 15 persons in the project group were professional musicians, and six were hobby musicians with a profound and genuine interest in music. The author’s role in this project was to be the coordinating link between all different professions and opinions of the project group. As an audiologist with an interdisciplinary education of social sciences, technology and medicine it was possible to fully take part of every aspect of the project.

Persons representing the environmental office of the city of Göteborg, the institute for working life, AMMOT (Artists and Musicians Against Tinnitus), the Event Organizers Association, Göteborg University, acoustic firms, sound delivery firms and the chosen venue, were all part of the project group. The common passion for music was of great importance in a group with otherwise different interests in this project.

At the time of the project, the experiment of acoustically remodelling a rock club to meet government standards without compromising the artistic freedom and listening experience was, as far as we knew, the only one of its kind.

Aim

The aim of this paper is to present the technical and acoustical procedures as well as the results of a complete acoustic intervention in one small club, where live music was played. The author’s participation in the acoustic project will also be described.

2. MATERIAL

As the subject of the experiment, the venue had to fulfil the following criteria:

-There had to be enough room to accommodate 150-300 guests and have different styles of live music played several times a week.

-The venue needed to accommodate guests of varying age, but have a focus on “young” people in the age group 18-25.

-The club owners had to be cooperative and accept certain modifications in the club’s interior design and have a long-term contract with the landlord of the building so that there would be no sudden change of business in the premises, at least during the project.

With this description of a typical live music venue, six different clubs in Göteborg were considered as possible.

One club fulfilled the decided criteria completely. The room was long and narrow, the ceiling height was low and the stage was triangular and small (fig.2). The absorption in the room was low due to the acoustically hard surfaces on the walls, ceiling and floor (on stage as well as in the audience area). The sound system in the room consisted of four modified loudspeakers containing two Celestion 15” units each, with a domestically inserted tweeter horn placed at ear height (175cm above the floor surface), one Alto Macro 2400 amplifier, two LAB 1300 amplifiers and one Spirit Live 4, 16 channel mixer board. The loudspeakers were stacked together in two columns, one on each side of the stage. All of the amplified sound from the PA -system was delivered through these stacks and straight into the audience closest to the stage.

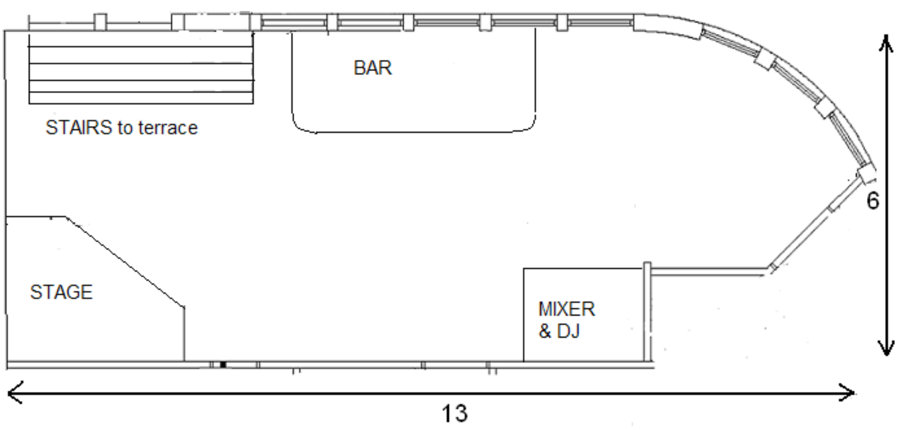

Fig. 2. The live music club before acoustic intervention. Measurements are shown in meters.

The bar was placed in the same room as, and situated close to, the stage (fig 2), which lead to a high sound pressure level exposure for the bar personnel.
The ceiling was covered with sound absorbing but painted tiles.

3. METHOD

This was an applied, intervention study implemented in an explorative way.
All sound pressure level measurements, calculations and technical assessments were carried out, or supervised, by well-known acousticians/ sound designers and sound technicians with many years of experience in the field. The measuring equipment used in this study was thoroughly calibrated before each measurement, and all measurements were made following standardized methods commonly used in Sweden (33).
"Worst position" was determined by control measurements throughout the venue. The loudest spot became "worst position".
The author worked in this project as the project coordinator, partook in all measurements in the anechoic chamber and venue, as well as was responsible for sound pressure level measurements with dose meters during concerts.
All decisions on remodelling, absorbers and sound equipment was democratically made during project group meetings.
For all measurements done on acoustic drums, in laboratory as well as at the venue, an experienced drummer was chosen. The drum-set consisted of one bass drum, two tom-toms, a snare drum, cymbals, crash and hi-hat.

Methods in detail

3.1. Measurements of sound pressure levels at live music concerts

According to measurement guidelines, the microphone should be placed at "worst position" when measuring sound pressure levels at a live music concert, (33, 35).
A Larson & Davies Spark^{TM} 703 dose meter was put behind the absorbing tiles in the ceiling 1 meter from the loudspeaker, with a microphone hanging down 25 centimetres from the ceiling in worst position. The dose meters were calibrated before being installed, and were programmed to collect data during the entire concert. Sound pressure levels were measured during two concerts before the renovation and six concerts after the acoustic intervention.

Body-worn Larson & Davies Spark™ 703 dose meters were also used during the course of one additional evening with three concerts before the renovation, where two persons wore them and were instructed to stand in “worst position”, immediately in front of the speaker stack.

During one concert before the intervention, random samples of sound pressure levels were taken. The positions chosen were at the edge of the stage, at the bar and at worst position (immediately in front of the speaker stack). The instrument used for random sampling was a calibrated Brüel & Kjær 2225 sound pressure level meter. Short time Leq measurements were carried out using a Brüel & Kjær 2260 sound pressure level meter.

3.2. Acoustic radiation of a drum-set, and measurements of screen attenuation in a laboratory setting

In order to establish the acoustic radiation of an acoustic set of drums, the acousticians performed measurements in an anechoic chamber (sized 8x8x10 meters, 640 cubic meters) at the Chalmers University of Technology, the Department of Applied Acoustics in Göteborg. The technical equipment was a Brüel & Kjaer 4189 sound pressure level meter, 4190 microphones and a Portable Pulse (7700) analyzer with front end 3109.

At first the drummer’s accuracy was ensured. One microphone positioned near the right ear of the drummer and two other microphones at a distance in front of the drummer recorded the sound pressure levels, (fig. 3, 4). The drummer played a drum sequence of 50 seconds, six times. The drum sequence included the use of all different drums in the set. The drum-set was placed on a square platform in the middle of the chamber (fig. 3, 4).

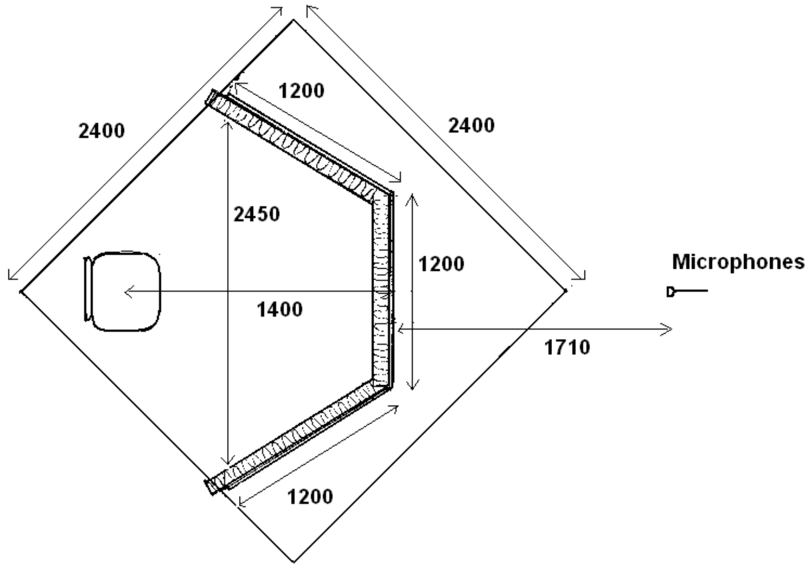

Fig. 3. The drum podium placed in the anechoic chamber (as seen from above and with all length measures in millimetres). The screen consists of 18mm thick plywood with 100 mm Ecophon industry modus 6143 absorbent. The podium is 400 mm high and consists of 22mm thick particleboard.

Next, measurements using screens of different heights in front of the drums commenced. The drum sequence was played two times for every screen height (80, 100, 120, 150 centimetres high), with and without an absorber on the inside of the screen. The reason for testing with absorbers on the inside of the screen, was to see whether that would reduce the sound pressure levels further, especially at the ear of the drummer. The drummer differed 0.5 dB in sound pressure level between the fourteen sequences (6 sequences without screens, and 8 sequences using screens).

The microphone behind the drummer's ear recorded the drummer's sound exposure, but was also used to monitor whether the levels changed with different screen heights or not. The screens consisted of 18 millimetres (mm) thick plywood and covered three sides of the drum-set (fig. 4).

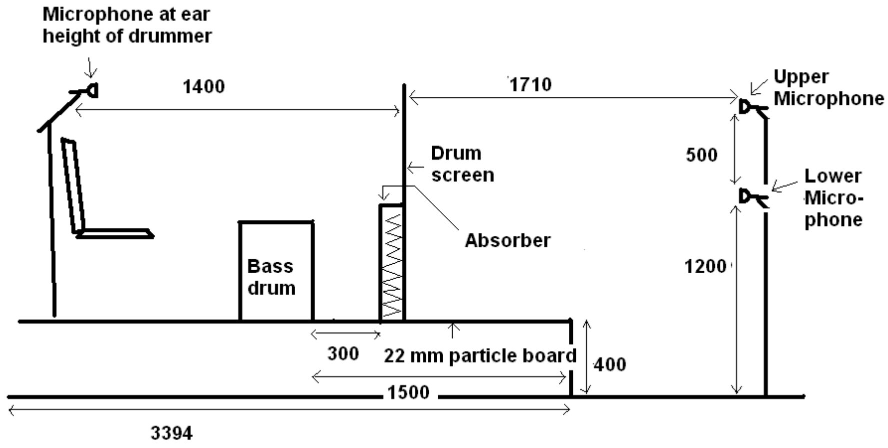

Fig. 4. The drum arrangement during measurements with and without screen in anechoic chamber. The drum screen consists of 18 mm thick plywood of different heights (800, 1000, 1200, 1500mm). Absorber on the inside of the drum screen consists of 800 mm high, 100 mm thick Ecophon Industry modus 6143. All length measures are shown in millimetres.

3.3. Acoustic emission from a drum-set and stage monitors at the live music club

The sound pressure levels caused by the acoustic radiation from the drums, were measured at six selected positions at the venue, and analyzed in third-octave bands.

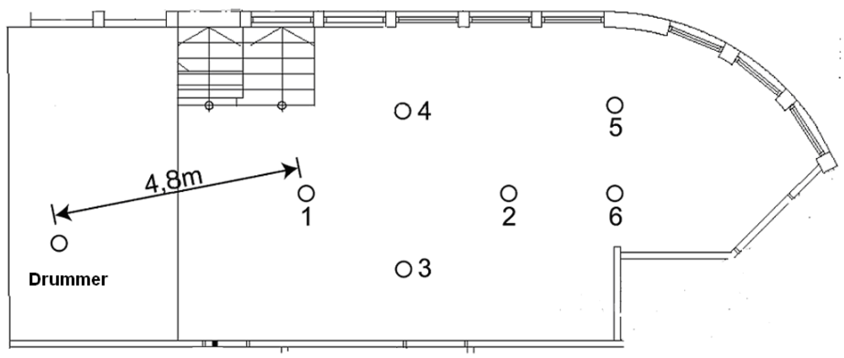

Fig. 5. The microphone positions when measuring sound pressure levels from acoustic drums and stage monitors at the live music club.

The drummer played the same drum loop as in the anechoic chamber, and the acousticians measured the sound pressure levels at the six different measuring points (Fig.5).

In order to investigate the acoustic leakage from the monitors into the audience, which affects the general sound pressure levels, pink noise was sent through the monitoring system while measuring the sound pressure levels at the six measurement points. Instead of a real musician on stage, a tripod with a microphone at “ear height” of a “musician” was used to ascertain that the sound pressure levels from the monitors were constantly of 100 dB(A). The monitor was turned toward the “musician” (fig.6).

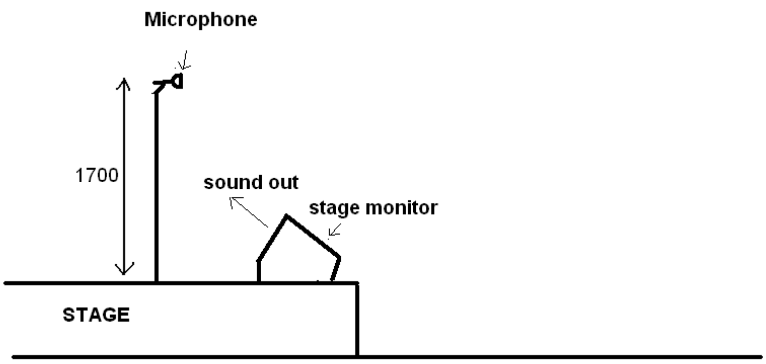

Fig. 6. The placement of stage monitors when measuring sound pressure levels at the musicians’ ear. The sound pressure level was kept at a constant 100 dB(A) at ear height. Measurements are shown in millimetres.

3.4. Measurements of sound pressure level variations in the room

In order to receive results of sound pressure level variations at the venue, two different measurement methods had to be applied. During a concert before the intervention, the sound pressure levels were measured at worst position (approximately 0.5 meters from the front of the speaker stack) and at quietest position (in the back of the room where the inner ceiling absorbents stopped).

When the venue was empty, measurements using pink noise through the PA-system were made at the six microphone positions according to fig 5.

3.5. Computer aided acoustics, renovation in virtual reality

The computer software used by the acousticians for exploring alternatives for remodelling the club was the “Computer Aided Theatre Technique (CATT)” (37). CATT is a room acoustic prediction program, and was in this project used as a tool for optimizing loudspeaker positioning. Specific types, numbers, positions and directivity for the speakers were chosen to achieve an A- weighted sound pressure level as evenly distributed as possible over the entire audience surface. It was also possible to simulate different materials on the walls and the ceiling in order to see the absorption and directivity of the room.

3.6. Statistics and ethics

Only descriptive results are reported for this study. No significance levels have been calculated due to the small number of measurements completed, and lack of comparative material. All dose meter data was transferred to a computer and analyzed with the Larson & Davies computer software Blaze™. Other sound pressure level measurement calculations were done using Microsoft Office Excel 2003.

No specific ethic questions were raised in this study, except for one. The test persons were exposed to hazardous sound pressure levels during our measurements. The risk was minimized by the aid of hearing protectors used at all noise exposures.

4. RESULTS

4.1. Measurements of sound pressure levels at live music concerts

Before the intervention, sound pressure levels from two concerts were registered. The mean sound pressure level value in "worst position" was 107,7 dB(A)L_{eq} (114,2 dB(A)L_{Fmax}). At the six concerts following the intervention the mean sound pressure level value was 99,0 dB(A)L_{eq} (109,7 dB(A)L_{Fmax}) at "worst position", when measuring with dose meters (fig 7).

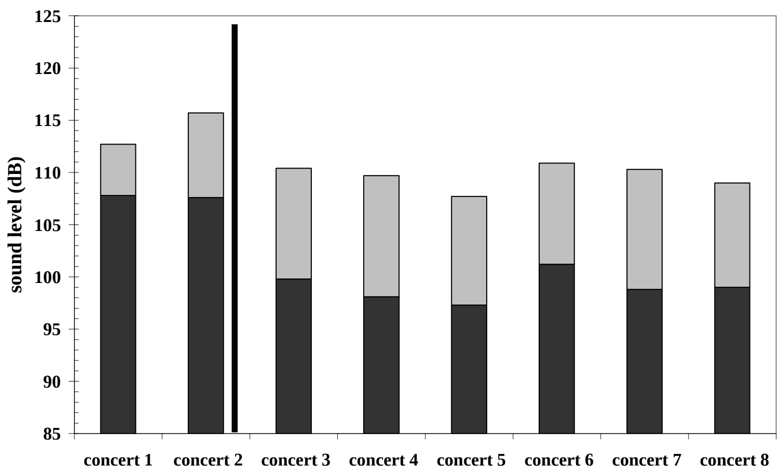

Fig. 7. Results from sound pressure level measurements from two concerts before (concerts 1 and 2) and six concerts after intervention (concerts 3- 8). Measurements are performed with a fixed microphone placed in "worst position".

dB(A)L_{eq}: ■ *dB(A)L_{Fmax}*: ■

Portable dose meters were only used before the intervention. The mean sound pressure level value from six concerts was 110, dB(A)L_{eq} (119,9 dB(A)L_{Fmax}), ranging from 108-114,3 dB(A)L_{eq} (117,3-123,6 dB(A)L_{Fmax}).

Results from random samples at one concert before intervention, showed short time sound pressure levels of 107 dB(A)L_{eq} immediately in front of the stage, 112 dB(A)L_{eq} in "worst position" and 102 dB(A)L_{eq} in the bar. Sound pressure level measurements done by the environmental and safety department of two concerts after the intervention showed sound pressure levels of 98 dB(A)L_{eq} (114 dB(A)L_{Fmax}) and 95 dB(A)L_{eq} (107 dB(A)L_{Fmax}) in worst position.

4.2. Acoustic radiation of a drum-set, and measurements of screen attenuation in a laboratory setting

The average sound pressure level from the drum-set was 97,7 dB(A) at the measurement point two metres away. The microphone was at the height of 170 centimetres (see fig. 4 for details). When measuring the impact of screens on the acoustc radiation from drums, the average sound pressure levels recorded in the anechoic chamber were 92,7 dB(A) using an 80 centimetre high screen, 90,6 dB(A) with a screen the height of 100 centimetres, 87,8 dB(A) when the screen was 120 centimetres high, and finally 85,3 dB(A) using the highest screen that measured 150 centimetres (fig.8). The measuring point was again two metres away, and 170 centimetres from the ground. This is a distance from the drums that in a small club could mean approximately the edge of the stage and "worst position" for the audience.

The sound pressure level at the ear of the drummer was on average 108,3 dB(A), but increased slightly with the height of the screen. When a screen with the height of 150 centimetres was used, with no absorber covering the inside, the sound pressure level at the ear of the drummer was 110 dB(A). A screen with the height of 80 centimetres and an inside absorber showed no difference in sound pressure level at the drummer's ear compared to playing without screens (107 dB(A)).

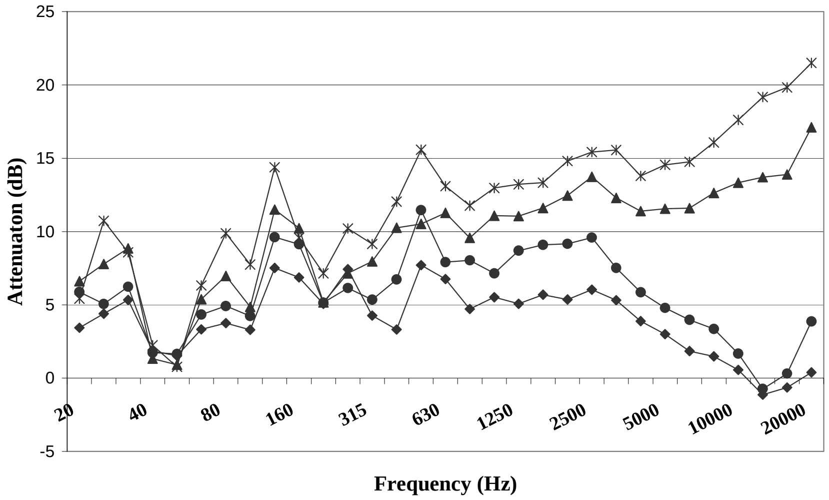

Fig. 8. Results from of screen attenuation for four different screen heights as measured in an anechoic chamber. The measurements were made without an absorber on the inside of the screen. The recording microphone was placed at the height of 170 centimetres above stage floor.

80 cm: ◆ *100 cm:* ● *120 cm:* ▲ *150cm:* ✳

4.3. Acoustic radiation of a drum-set and stage monitors at the live music club

Before the intervention, the average sound pressure level recorded from drums at the venue was 96,3 dB(A). When recording the average sound pressure level after the intervention, it was 92,6 dB(A). The measurements were calculated as the mean value of the six measurement points as seen in fig. 5. Before the remodelling of the club, the sound pressure level at the ear of the drummer was 104,8 dB(A) on average. After the renovation, the sound pressure levels at the drummer’s ear were 105,5 dB(A).

With screens, the sound pressure levels emitted from the drums were further reduced. When using the lowest screen (80 cm’s), the average sound pressure level from the drums was lowered by 4 dB (table I).

	Before	After	After, w screen 80 cm's	After, w screen 100 cm's	After, w screen 100 cm's +abs.	After, w screen 120 cm's
position1*	96,9	94,1	90,4	88,9	87,8	87,2
position2*	96,6	92,3	88,6	87,3	86,5	85,2

*Table I. The screen attenuation, presented in dB(A), from measurements done at the music club. * For positions see fig.5*

When measuring the sound pressure levels emitted from the stage monitors (kept at a constant level of 100 dB(A) on stage), the mean value of the six positions at the venue before the intervention was 82,9 dB(A), and after, the mean value was 76,3 dB(A) (Table II).

	Drums		Monitors*	
	Before	After	Before	After
position 1**	96,9	94,1	84,1	76,7
position 2**	96,6	92,3	83,4	77,1
position 3**	96,9	93,4	83	79,1
position 4**	97,5	92,1	83,2	74,9
position 5**	93,4	89,2	80,5	73,1
position 6**	95,5	90,2	82,4	74,2

*Table II. Results from sound pressure level measurements from drum sound and monitor emissions taken at the six measuring points before and after the intervention at the music club. The results are shown in dB(A). * Monitor sound pressure levels are adjusted to emit 100 dB(A) at singer's position on stage. ** For positions see fig.5*

4.4. Measurements of sound pressure level variations in the room

During a concert before the intervention sound pressure levels at worst and quietest position, were 112 dB(A)L_{eq} and 96 dB(A)L_{eq} respectively. After the intervention, sound pressure levels at worst position were below 100 dB(A)L_{eq}.

In the empty venue, where sound pressure level measurements of the PA sound were made, the largest difference between the six microphone positions before intervention were 3,6 dB (mic. 3 and 5. see fig 5 for positions) with neither of the microphones placed in worst position. After the intervention, the sound pressure level measurements in the empty venue were repeated. Four new loudspeakers had then been installed, which led to the fact that one of the microphones (mic. 4) automatically ended up in worst position below and slightly in front of one of the rear loudspeakers. The difference between the six microphone positions was after the intervention at the most 2,9 dB (microphones 1 and 4).

4.5. Intervention in reality

In the renovation of the rock club, the bar was moved from the room out into a glassed-in terrace, and the stairs leading up to the rebuilt terrace were widened.

The stage was enlarged and became rectangular (2.6 metres deep x 5.8 metres wide), following the short wall of the room where the old stage was located. The new stage was built on top of the old stage and manufactured in such a way as to not sound hollow or resonant by using attenuating building material. A wool carpet was placed on the stage floor to further help reduce acoustic reflexes. Feedback monitors and stage amplifiers were lifted from the stage floor (onto boxes or the new subwoofers) and directed towards the musicians' ears (Fig 9).

Apart from that, the room itself was not changed in shape or size. There were suggestions to raise the ceiling, but concrete ventilation ducts immediately above the old absorbing tiles in parts of the ceiling made that impossible.

New technique was installed consisting of two JBL AM6212/95, 2-way speakers with a 12"-woofer and a 1.5" horn and a radiation aperture of 90° horizontal and 50° vertical, placed in the ceiling, close to the stage. Further away from the stage an additional pair were placed, consisting of two JBL AM6212/00, similar to the first pair, but with a radiation aperture of 100° by 100° (Fig. 10). Other added gear was one BSS FDS366T digital signal processor (3in/6 out), one Soundcraft GB4-24 24 channel mixer board and three Crown CTs3000 power amplifiers, each delivering 2x1500W@ 4 ohm. There was also four new JBL SRX718S, sub-woofers 1x18" installed. The new sub-woofers were incorporated into the new stage (Fig. 9).

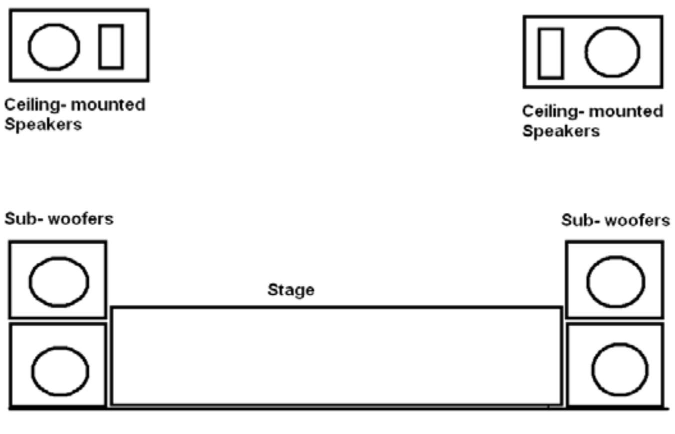

Fig. 9. Placement of the new technical sound equipment as seen from the audience area.

The four loudspeakers were mounted in the ceiling, two in the front of the room on either side of the stage immediately above the basses, and two in the middle of the room (figs. 9, 10).

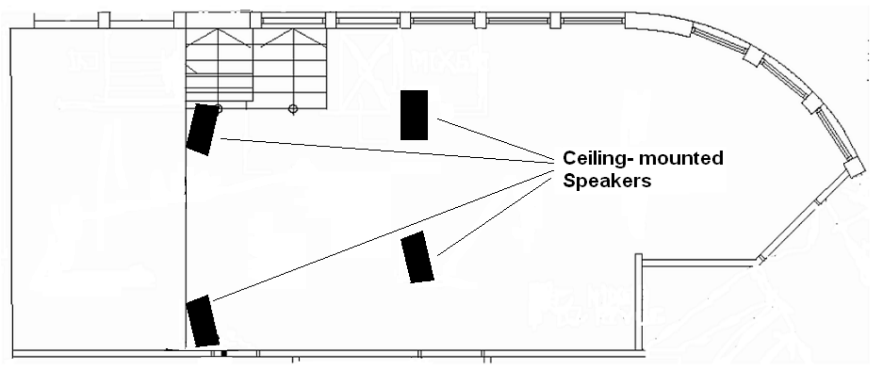

Fig. 10. Placement of the four ceiling mounted loudspeakers.

These loudspeaker positions/directivities were predicted (using CATT) to be the most efficient for spreading the sound evenly above the heads of the people in the audience, using the "Haas-effect" to create the illusion that all sound comes from the stage itself by delaying the speakers with 10-20 milliseconds relative to the main PA-system.

A new framework for ceiling absorption was installed, along with new absorbers. In the ceiling, two different kinds of black absorbers were used, Ecophon Extra Bass, which are 100 mm thick and extremely absorbing and Ecophon Sombra A-gamma, which are 20 mm thick and slightly less absorbing. Above these tiles with lower absorbency, 100 mm Ecophon Extra Bass was added. Closer to the stage, higher absorbency was needed, but since the room was so long, the last third of the room the high absorbency tiles were mixed with the combination of lower absorbency tiles underneath higher absorbency tiles, creating a as good a combination as possible between absorption and diffusion. The framework was lowered 100 mm from the ceiling creating a hollow space between ceiling and absorber, to further increase the absorption predicted by CATT (Fig. 11).

On the walls surrounding the stage two layers of absorbers were installed. The inner layer consisted of 100 mm thick industrial absorbers, and further out there was an extra 40 mm of Ecophon Sombra Wall absorber mounted. The outer layer was covered with a fire and shock resistant mesh. The thinner wall absorbers were also installed on the wall next to one of the speakers to reduce wall reflexes, and it was also necessary that the absorbers covered the back wall of the sound technician's booth.

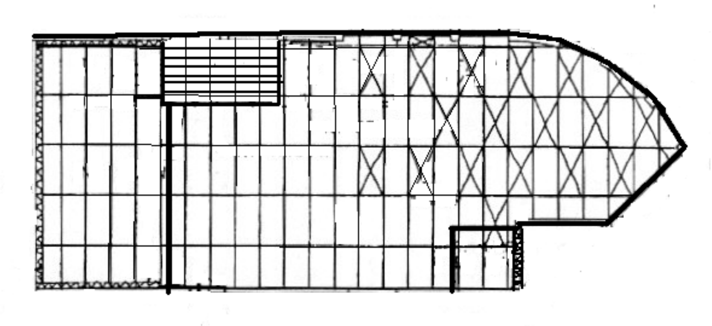

Fig. 11. The distribution of three different absorbents placed in the music club ceiling. The un-marked areas consist of Echophon Extra bass (100 mm) and de areas marked with an "X" are mounted with Echophon Sombra A gamma (20mm) + Echophon Sombra X bass (90mm). All positions of the absorbers where calculated using CATT.

5. DISCUSSION

The society, in which we live today, is one of constant sound and information. There are sounds and visual stimuli everywhere, some are sought after and some are annoying. There are demands that we register and act upon all information, preferably immediately. The pressure from being constantly reachable mixes with the stress of all auditive and visual information and creates an unfavourable environment for communication. When adding loud leisure time noise to the already sound filled everyday life, further pressure is put on our hearing and the risk for hearing impairment further increases.

Even mild hearing impairments can affect our daily communication, especially with the constant background noise that our modern society produces.

Without rest from noise, all noise exposure accumulates and fatigues the auditory system. Therefore, young people exposed to loud noise may not experience any immediate problems, and not become known to the hearing clinics until years later.

The noise exposure regulations of 85 dB(A)L_{Ex}8h (work place exposure) and 100 dB(A)L_{eq} (loud music) are based on the remaining hours of the day being relatively quiet to work as repose for the auditory system (10). However, not many people live in relative silence apart from work and the occasional concert. And the problem increases by the problem many small clubs have of actually reducing the sound pressure levels down to 100 dB(A)L_{eq}.

The sound pressure level measurements methods are standardized for Sweden and all measurements except for peak levels are done with an A-weighted filter. There are potential problems with this filter, since it cuts virtually all of the low frequency sound out of the equation, which means that there could be far higher sound pressure levels at the measured venue, than what is registered. But then again, the meaning of this filter is to register sound pressure levels at frequencies where the human ear's sensitivity to hearing loss is the largest.

In choosing a venue, a club with difficult listening conditions was sought after in Göteborg, and six clubs were found. Among other things, short term contracts with landlords and venues with not quite the sought after music genres ruled some of the clubs out. There were also some difficulties in finding a club where the owners were prepared to let the project group rebuild the entire venue into a more favourable acoustic environment. Fortunately, the club owners of the chosen venue were already planning major interior renovations. The acoustic conditions of the chosen room were also the absolutely poorest of all six clubs considered, and the one most in need for speedy alterations. The sound pressure levels in this club were dangerously high, both for visitors as well as staff members.

The group working with the acoustic intervention project was diverse in regards of background. Some people were in the project to protect the artistic freedom from being violated without consideration of hazardous sound pressure levels, others to uphold governmental regulations. Some group members were musicians who used to play loud music, but after suffering from damaged hearing wanted to make the listening environment for musicians less hazardous. As a coordinator of this project, it was part of the author's job to make sure that everyone got together at the meetings and that each person was heard and that all opinions were recorded. Other tasks that were included in the job description were:

- to handle material to the press and helping media to get the proper information from the proper person,
- responsibilities of all the written material collected or distributed,
- to work as a sort of mediator and knowledge-distributor between group members,
- planning of press conferences as well as the finishing conference and concerts,
- to be responsible of measuring all the concerts as well as calibrating the equipment,
- to lend a helping hand during measurements by acousticians,

- close cooperation with the project leaders in order to make the project run as smoothly as possible,
- to receive complaints, both within the group and from the outside.
- to translate information to and from English
- to be the general contact person for the entire project.

The fact that the group was so diverse created many discussions and clashes of opinion, but had the group been entirely one-sided, it is probable that this project would not have managed to consider the options and alternatives for improvement from both the artistic and governmental viewpoints. The simplest solution to the problem of too loud music is to turn the sound pressure level down, use earplugs and not care about the quality of sound. This group agreed to do it the difficult way, by upholding or even improving a good sound quality while lowering the sound pressure levels.

In order to minimize sources of error, certain steps were taken. The drums were first measured in an anechoic chamber to measure the true properties of the drums before entering the venue. Measuring his drum sequences repeatedly controlled the drummer's accuracy.
Originally the idea was to use portable dose meters when measuring concerts during the entire renovation process. This became problematic both in an ethical and a measurement accuracy point of view. It would have been hard to control that the test persons were standing in the same position at all concerts and that their clothing was similar at all times as well. It would also not have been ethical to force these persons to stand in "worst position" for however many concerts we decided to measure, no matter how well their hearing was protected.
It was therefore decided that the dose meter should be placed in a fixed position in the room. The preferable way to place the microphone would have been in worst position, on a tripod at ear height of a person. There were however some problems to consider, since there was absolutely no way of positioning a tripod so that people could not touch it, and there was no point in risking the microphone being stolen or broken. Therefore, the only possibility was to place the microphone hanging down from the ceiling. Control measurements in worst position and in dose meter microphone position were made to calculate differences according to the new government approved measurement method

(24). All concerts were measured according to the new standardized measuring method to ensure accuracy of sound pressure levels for an entire concert.
When measuring concerts, no bands played at the venue twice. The measuring opportunities were instead chosen by the type of music being played. All concerts measured were therefore high-energy rock or punk music.

Sound pressure levels measured at concerts before intervention were very high. Only two concerts before rebuilding were measured with a fixed microphone. The reason for this was that the results of these measurements were very high, and comparable to the six concerts measured with portable microphones. The environmental and safety office had earlier done random sound pressure level control samples at several clubs in the city, and this club was known to have problems keeping the allowed limits. There was also a time frame to keep before the renovation actually started and there were not that many concerts booked where there was an opportunity to measure.
The reduction of the sound pressure levels was substantial after the intervention. Was it possible that the bands that played after the intervention knew that the renovation was mainly acoustic, and therefore they played at lower levels? The measurements of the drums in the empty venue show quite the opposite. Our drummer knew that the venue had been acoustically modified, and records of him playing show that he actually played louder after the intervention since he felt that the back wall was extremely attenuating. There was no information given to the booked bands on what had been done in the room and they played just like they would have done any other concert. The most substantial change was that the loudspeakers had been lifted out of the audience into the ceiling.
In the beginning of the project, the majority of the project group was confident that a reduction of the sound pressure levels was going to be the result, but no one knew by how many dB. It was highly unlikely that, by just remodelling, the sound pressure levels would drop below the recommended guidelines of 100 dB(A)L_{eq}. At most we had hoped for lowering the sound pressure levels by 3 dB (which gives a sound intensity reduction by 50 %), but the results showed a reduction of almost 10 dB and the mean sound pressure levels during concerts stayed just below the 100 dB(A) limit without the use of drum screens. This meant that it was not necessary to ask the musicians to play quieter or for the drummer to sit behind screens (although this is a very good alternative where even louder music is being played), and they did not need to feel that their artistic freedom was violated.

The high sound pressure levels at this venue are not unique in any way. Reports from all over the world show problems with high sound pressure levels where live music for youths is being played (18-20).

The necessity of using an anechoic chamber to measure drums can be discussed. Why didn’t we just measure everything at the venue where we were going to apply the test results? The reason for doing these measurements was to find out the true acoustic properties of the acoustic drum set without any reflexes from the walls, ceiling and floor, and to see how high sound pressure levels each drum emitted. This was important to know before measuring the attenuation of screens, since the drums were located at different heights, different heights of screens would attenuate the drum sound differently. To measure screen attenuation was also important, and to find the lowest screen height where attenuation was satisfactory. There was no point in completely covering the drummer in screens if an 80 cm high screen was sufficient from an attenuation stand point, since the sound exposure of the drummer increased with increased screen height. There is also the risk of the drummer feeling completely isolated from the rest of the band if high screens are being used

When testing the use of screens in the anechoic chamber, the screens were made of plywood. A drum screen on stage is usually made of polycarbonate, which is transparent. The density of polycarbonate is twice the density of plywood. This means that it is possible to use a polycarbonate screen that is half as thick as the screens that we used for our measurements, and still get similar attenuation results.

The measuring points used when measuring drums and monitor sounds in the room were chosen so that they would cover as much of the audience area as possible in as few measuring points as possible.

The fact that although the drummer increased the sound pressure levels of 0,5-1 dB (measured at his ear) after the intervention and that the mean sound pressure level in the audience area was reduced by almost 4 dB showed that the attenuating steps taken in the room had worked. During and before the project a frequent discussion was whether sound pressure levels could be lowered at all because of the high sound pressure levels emitted from the acoustic drums.

Another problem with small venues like this was the sound “leakage” from the monitors on stage. When measuring before and after the intervention, using a constant sound pressure level of 100 dB(A)L_{eq} on stage, the "leakage" of sound into the audience area was lowered by almost 7 dB. The lowered "leakage" from the monitors help to further improve the quality of sound by no longer competing with the sound emitted from the loudspeakers.

In order to measure the sound pressure level variation in the room six microphones were mounted in six positions. To measure the difference between the six microphone positions is a more controlled way to measure the sound pressure level variation in an empty room, while the measurements taken at the live music concert in a crowded room shows the sound pressure level variations during "real" conditions.
No measurements of sound pressure levels in the quietest position were made after the intervention. A reason for this was that after completing the measurements in the empty room with only the PA system running, very little sound pressure level variation (2,9 dB) between worst position (mic. 4) and the other five measuring points was detected. Of course, there would be a slight difference between an empty and a crowded venue, but since the loudspeakers were mounted to the ceiling, the difference has been minimized. One problem with only measuring the sound pressure levels of the PA system is that any direct sound from the stage (sound leakage from drums and stage monitors) that is measurable at a concert was not included in these calculations.

All implemented changes to the room were first done in virtual reality using the computer software program CATT. This enabled us to change things that were not quite right for the room before actually building it. It was important to know for example how much absorbency was needed where and where to place the loudspeakers ahead of starting to rebuild since both budget and time available was limited. CATT is however a computer program and can not experience a venue the way a human being can, and therefore we only used the simulations as a guide to remodelling, certain changes from the computerized images were done, for example the directivity of the front speakers were 90x90 degrees in virtual reality, but after listening, it was changed to 90x50 degrees. An extra absorber on the wall in front of the stage was added to avoid the sound from the front ceiling speaker being reflected off that wall and interfere in sound quality. The stage became even larger than calculated.
There were some concerns that mounting the new loudspeakers to the ceiling would block the view of the stage, and quite frankly it was considered strange by many of the project group members to have the sound coming from the ceiling instead of from the stage. But

with the possibility of programming a slight delay in the speakers, the sound is perceived as coming from the stage.

The enlargement of the stage meant that the musicians could stand further apart and not risk masking from other instruments, which in reality means lower monitor sound pressure levels. The fact that the monitors were lifted slightly from the stage floor and closer to the ears of the musicians further helped reduce monitor sound pressure levels. Studies on Broadway show musicians also show that when the musicians are further apart from each other, it is easier to hear ones own instrument and not suffer from the high sound pressure levels emitted from the musician next to you (28).

The stage walls were covered with extremely absorbent material in order to reduce reflexes and to make the sound more clear and distinct, This could also help musicians to hear their separate instruments better, and most important, the sound pressure levels from the direct sound coming from the stage was lowered. A downside to all absorbers surrounding the stage was that the sound image became a little dry, comparable to a recording studio. While playing electronically amplified music that would not be a problem, but if acoustic music were to be played at that stage, there would be very little reverberation and the music would risk sounding dead (31).

At this particular venue, attempts to make the listening environment better had been made by putting up ceiling absorbers. At the time of the project, they were painted over. By covering the porous surfaces with paint, the absorbency of the tiles was drastically reduced. This is not an unusual course of action among smaller clubs, since until only recently absorbers have solely been manufactured in light colours.

What has been done to this venue has been considered controversial and many people have been opposed to the idea. The general idea of this project however is not new or strange in any way. Loud industry noise as well as traffic noise has been built away for many years. The difference here is that the “noise” we worked with was music, where the sound pressure levels according to audience and musicians should be high, but not damaging. The difficult part of this project has been to combine the knowledge of sound reduction and the desire to maintain a satisfactory musical experience.

Live music venues suffer similar problems as do factories. Employees can be subjected to extremely high sound pressure levels. Therefore, it was important to make sure that the bar personnel of the venue were protected from the loud “noise” in their workplace. Sadhra reports how noise exposures of bar personnel frequently lead to temporary threshold shifts after work (38). After moving the bar out to the terrace area, the direct exposure to hazardous sound pressure levels was minimized.

Where sound pressure levels at a live music venue are concerned, the most important person is the sound technician. A technician with little or no idea of what he is doing could easily ruin a performance, while a well educated person would be in control of a concert both regarding sound quality and sound pressure level. Yet, it is very common, at least in Sweden, that just about anyone is allowed to run the sound at smaller clubs. This was also the case at the venue we chose. In the beginning of the project, it was suggested that the venue should employ an in house technician whose foremost task would be to be present at concerts and run the sound or supervise the person who did. One person was hired by the venue, included in the project group and became very involved in the entire intervention process. During the course of the project he received proper education on sound pressure level measurements and certain aspects of the hearing system. He was present during all measurements at the venue and also helped installing the new sound system.

An educated in house technician may in the near future be seen as an important part of business competition between clubs and venues. By having one properly trained person taking care of the sound, the venue can hopefully guarantee a good quality sound and a safer listening environment for the audience.

Many people who listen to and/or play live music have a “happy go lucky” -attitude toward high sound pressure levels. “It won’t affect me, it never has before” seems to be a common thought among these people who rarely or never decide to protect their hearing. (39) It is difficult to know whether people actually understand how high sound pressure levels affect the hearing, and simply ignore that, or whether they are completely unaware of the dangers of high sound pressure levels. Mercier and Hohmann discovered that as many as 40-50% of an audience consider sound pressure levels at discotheques and concerts to be too high. And Widén and Erlandsson reports that even though people know that loud noise is hazardous to ones hearing, they rarely consider listening to very loud music as risk- taking behaviour (17, 39).

The latest report on hearing impairment and tinnitus in Sweden, show that 15% of the Swedish population suffers from tinnitus of varying degree. Noise induced hearing loss and tinnitus is not decreasing despite the efforts to control and regulate work related noise exposure. In stead, numbers are increasing and mostly among younger people (25-44 year olds) (1). Still, adolescents perceive that they are not at risk for negative consequences when exposed to loud music. Widén and Erlandsson conclude that this is may be a defence mechanism in order to uphold the self-image of being invulnerable that many young people have. And if an individual feels invulnerable, there is no amount of information that can help change the behaviour without altering a large portion of the self-image. This may be a reason as to why people don't start wearing hearing protectors until they experience symptoms of varying hearing disorders (39, 40).

The Swedish event organizers association has also been greatly opposed to the idea of lowering sound pressure levels. The attitude has been that some music has to be played at certain extreme sound pressure levels because they are part of the artwork that the artist is performing, and if the sound pressure levels are too high, people will just have to use hearing protectors.

What is difficult to understand with this theory is that the hearing protectors that most people are ready to pay for attenuate the music differently in different parts of the frequency spectra, which means that the music will be experienced as distorted. How will the audience truly appreciate the art of music if they plug their ears with material that distorts the whole experience? Would it not be better to lower the sound to less hazardous levels?

People, especially adolescents, will not stop listening to music. Music creates a sense of identity and belonging (39). Many people don't want to wear hearing protectors because of the distorted sound image they get. Instead they choose to risk hearing impairment to hear the music unmuffled. What really has to be done is to inform the public of the aspects of hearing damages caused by loud music, and to make people understand the vulnerability and sensitivity of the hearing organ.

This project holds a certain importance to audiologists everywhere. It shows another aspect of our profession. Presently, the main task of the audiologist is to help ease and rehabilitate persons who suffer from hearing disorders. As audiologists, we are usually based in a hospital or other health care facility, diagnosing hearing disorders, ordinating different technical aids and teach communication skills. Not many audiologists work with the prevention of hearing loss out in the society. There is a great need for loud leisure noise prophylaxis in this country as well as research in that area, and who better to do that than people of broad-spectrum education with a profound knowledge of hearing and sound.

Very few schools in Sweden today provide education on hearing and the risks of loud noise and how to protect oneself. This could be a future assignment for the audiologist profession.

6. SUMMARY

The mean sound pressure levels during concerts were lowered by 9 dB, to below the government recommended 100 dB(A)L_{eq}. Measurements of acoustic drums in the club showed a difference in sound pressure level of approximately four dB. When using a low screen around the drums, the sound pressure levels were lowered by another 4 dB, without the sound pressure levels at the ear of the drummer changing noticeably. The sound pressure levels from the feedback monitors into the audience area were lowered with 7 dB after the intervention, and the sound pressure level variation was also lowered, much because the loudspeakers were moved out of ear height and that the direct sound from the stage was diminished. The venue was modified to achieve better acoustic properties, and the sound equipment was replaced. The new loudspeakers were mounted to the ceiling, which further assists in distributing the sound more evenly across the room. The bar was moved to an adjacent room and that much improved the working conditions of the bar personnel.

7. CONCLUSION

This intervention project showed that it is possible to decrease sound pressure levels during concerts, the direct sound from stage and the sound pressure level variation in a typical small live music venue. Along with acousticians the event organisers, club owners and sound technicians all play an important part in managing this work. Based on the project group’s experience however, there are probably several music clubs where this is not possible. Many live music clubs have such poor basic conditions that no amplified music should be allowed to be presented at all. Hopefully, this project may serve as a source of knowledge and inspiration for future studies as well as in the development of new acoustical and technical sound monitoring solutions.

This project gives a new angle on the work an audiologist is qualified to do. Prophylaxis and prevention will become more and more common in the future. Other ideas for the audiologist profession working for prophylaxis are:

- Research. There are so many things that only audiologists are experts in, why are there so few of us who are active scientists and researchers?

- Lecturing about hearing awareness both at business corporations as well as in the schools. Only by information and good example can we change the attitudes toward high sound pressure levels.
- The government and National board of health and welfare need professional guidance when constructing rules and limitations on high sound pressure levels. It takes knowledge of audiological aspects to ascertain which levels are dangerous and why. This is also true when constructing new measurement methods.
- Audiologists can also work side by side with acousticians and help with the audiological aspects of sound and healthy sound experiences.
- Hearing protector services. Some people are always more aware of potential hearing damage than others and while the entire community still is struggling against the ideas of lower sound pressure levels, there is a need to educate and provide the public with safe hearing protection gear.

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