OPTIMIZATION OF ACOUSTIC CONDITIONS IN MUSIC PRACTICE ROOMS

Gígja Gunnlaugsdóttir

Línuhönnun hf.
Acoustics and Noise Control
Suðurlandsbraut 4a, 104 Reykjavík, Iceland
gigja@lh.is

ABSTRACT

The acoustic characteristics do vary from one room to another and often depend on the use of the room. A music practice room is a good example of a room where the acoustic conditions are important. The purpose of the work discussed here is to try to optimize the acoustic conditions in music practice rooms. This was done by attempting to simulate several music practice rooms. Measurements of the impulse response were made at the Royal Danish Academy of Music (Det Kongelige Danske Musikkonservatorium) to obtain objective measures to use as reference in the simulation. The main objective parameters used in the simulation are the reverberation time and the strength. The simulation was carried out in an anechoic room with four loudspeakers and a microphone. Processors and attenuators were used to control the reverberation and strength and thereby simulate a music practice room. Musicians were asked to play in several different setups and to give their opinion on the acoustic conditions on a specially designed evaluation form. The subjective measures obtained from the forms were then compared to the objective measures to see if there is a relation between them. From these comparisons the optimal acoustic conditions of a music practice room were to be obtained.

1. INTRODUCTION

The optimal conditions for music practice rooms can differ from one musician to another and often depends on their instruments. The acoustics of a practice room are very important, but the surroundings do also matter. The room should be inspiring and comfortable.

Optimal acoustics for a music practice room can also vary from musician to musician playing the same instrument and often it depends on the musical piece being played. If a musician is beginning to work on a new piece, he often prefers a dry room where it is easier to distinguish different tones. After practicing that piece for some time, a room with a longer reverberation time may be preferred to make the music more lively.

Music practice rooms are often very different from concert halls. If the musician is used to play in the same practice room it can become difficult for him to adjust to playing in a concert hall or other rooms different from the usual practice room. It can therefore be preferred to have a room with variable acoustics so that the musician can practice under different conditions in the same room.

Some research has been carried out on this subject [1, 2, 3, 4, 5]. None of these approach the problem in the way adopted in this work, that is an adaptation and extension of an earlier master's thesis [2].

In the present project ten to fifteen musicians were contacted in order to participate in the experiment. The musicians played in several different simulated rooms and evaluated them using a specially designed evaluation form. The results from the evaluation form together with measured results of the simulation were used to assess the properties of the simulated rooms and to determine the optimal acoustic conditions for music practice rooms.

2. EXPERIMENTAL METHODS

2.1. Measurements

Measurements were made at the Royal Danish Academy of Music (*Det kongelige danske musikkonservatorium*, DKDM). Six different rooms were selected and measured so a broad range of different conditions were obtained to use as references in the simulated rooms. The size range of the rooms were from 50 m^3 to 246 m^3. In some of the rooms the acoustics could be varied for example by folding panels or heavy curtains to obtain a greater variety.

A room acoustics measurement software tool, DIRAC, was used to measure the impulse response. An e-sweep signal was used in the measurements.

Music practice rooms are often relatively small. Some of the most interesting parameters to study for such small rooms are for example the reverberation time and strength.

The reverberation time of a room is important for the musicians and their opinion of a relevant reverberation time varies from musician to musician depending on their instrument. Therefore the reverberation time is one of the main parameters studied in this project.

In small rooms, early reflections increase the sound strength strongly. If the strength gets too high it can be damaging for the musicians ear. Strength is considered an important acoustic parameter and one of the main parameters studied in this project.

2.2. Simulation

Is it possible to simulate a musical practicing room? Many details are important for the musicians when practicing and not only the acoustical parameters. The environment, for example, is really important for the musicians as previous researches have shown [3, 2]. The room should be inspiring and bright, perhaps with mirrors and a window is preferable although with privacy. This needs to be taken into account when the results from this experiment are evaluated.

The main idea for this project was to try to simulate several musical practicing rooms by using four loudspeakers and a microphone, set up in an anechoic room of size 60 m^3, and use the measured results from the rooms at DKDM as reference. From the results of the simulation the idea was to try to optimize the acoustical conditions. The main parameters that could be controlled in the simulation were the reverberation time of the room and the strength. The main instruments used for the simulation were two processors, four loudspeakers and a microphone. This section describes the process of the simulation, instruments used and setup of the simulation.

With the processors, the size of the simulated room, the reverberation time, level of the sound and thereby the strength, early reflections and many other factors could be controlled. In this project the main parameters that were varied by the processors were the size of the room and the reverberation time. The size of the room was defined by indicating the longest side of the room. The reverberation time is defined for two frequency ranges, low frequencies and high frequencies and the division between high and low frequencies was set at the value of 530Hz. By varying these parameters, a simulation of a number of different rooms were made.

After some considerations and tests on different simulation setups the following procedure and setup was found to be most convenient while others were found impossible to carry out due to feedback.

The idea is to calibrate the musical instruments in a free field to get the relative strength G in the simulated room. The idea was to take the response from the instrument and try to equalize it such that the difference between the power response of the reverberation room and the power response from the instrument would be constant for each frequency band and thereby neglect the frequency dependence of G. Then the transfer function for the reverberation room would be described by

$$\Delta L_{rev} = G_{rev} + x, \tag{1}$$

where ΔL_{rev} is the constant difference between the spectra, G_{rev}, the strength of the reverberation room and x a constant calculated to get the right strength in the simulated room. With this constant x and the strength G

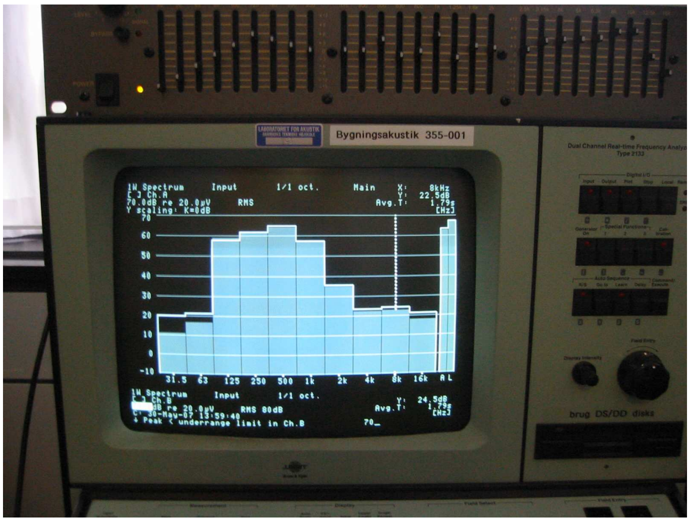

Figure 1: The figure shows frequency analyzer and the spectra of the two responses for which the constant difference x is to be determined. The equalizer used to obtain this constant difference can also be seen on top of the frequency analyzer. See text for further discussion.

measured in DKDM, one could calculate the difference, ΔL of the spectra needed to get the wanted strength in the simulated room. The relation,

$$\Delta L_m = G_m + x, \tag{2}$$

would then be the relation used for simulated room number m to obtain the relative strength of that room.

A small wireless clips microphone of the type Sennheiser was used. It sent the signal to a Sennheiser True Diversity Receiver which forwarded the signal into the control room. The microphone was mounted on the musical instrument where it radiates the sound most.

The simulation process began in a reverberant room with volume of 240 m^3. There, another microphone or more precisely a sound level meter, B&K 2230, was used to measure the power response of the reverberation room and the clips microphone on the instrument registered the direct sound. By a dual channel frequency analyzer, B&K 2133, the spectrum from the microphone mounted on the instrument which should give the direct sound, and the spectrum from the room could be compared in order to get a constant difference between the spectra for all frequencies, see figure 1. The musician was asked to play a scale in order to try to get all the frequencies in the spectrum and an equalizer used to get a constant difference for all frequencies. The setup is shown schematically in the left panel of figure 2.

When the difference between the spectra became constant everything was moved into the simulated room and the procedure repeated. The musician played the instrument in the control room and the measure microphone was placed in the simulated room at the height of a sitting musicians ear. The signals from the two microphones were then sent to the two channel frequency analyzer where the spectra could be compared. The setup of the calibration in the simulated room can be seen in the right panel of figure 2.

Then by the help of an attenuator one should try to get the same difference between the two spectra as in the reverberation room. To obtain similar strength as measured in the rooms at DKDM, the difference between the strength in the reverberation room and the measured room should be added or subtracted to the difference in the spectra as was described above by equations 1 and 2.

At this stage the strength had been determined. The reverberation was controlled by the processors. The reverberation time in each simulation was measured using DIRAC. The sweep signal was sent out into the four loudspeakers and by having a sound level meter at the musicians ear recording the signal, the RT was measured. It proved to be difficult to get exactly the same reverberation time as measured in the real rooms and keyed into the

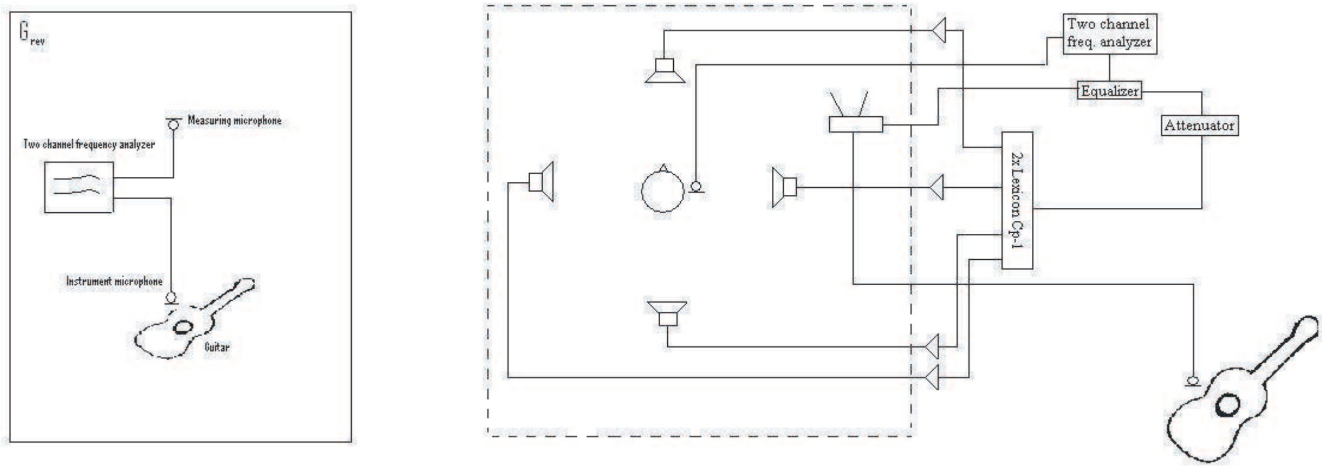

Figure 2: Left panel: The setup of the calibration in the reverberation room. Right panel: The setup of the calibration in the simulated room.

processors. Despite these difficulties, a wide range of different reverberation times were obtained. Five different reverberation times were used and the relative strengths of these chosen rooms were varied by $\pm 5dB$ to see if it was preferred to practice in a small room with high strength, large room with high strength or low and so on. Thus, a total of fifteen different setups were used in the experiment. Parameters other than reverberation time and strength did not seem to give any conclusive results.

When the setup was tried out, a considerable hum came from the loudspeakers. This was thought to be due to the amplifiers for the loudspeakers lying on the floor. The amplifiers were therefore moved into the control room. That setup is shown in figure 3 and became the final setup used in the experiment.

In spite of moving the amplifiers into the control room, the hum was still present when strongly amplified. It was finally discovered that it came from one of the processors and was impossible to get rid of. So, when having to amplify strongly, the hum was heard but the musicians, all except one, said it did not have any influence on them and that their playing often masked the humming.

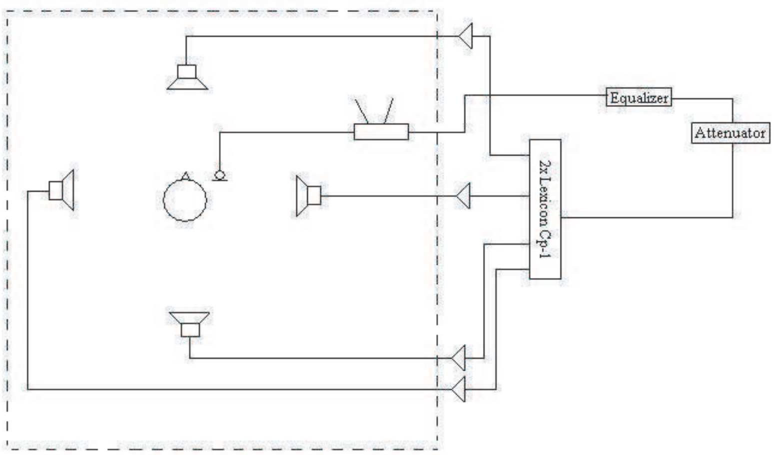

Figure 3: The final setup of the simulated room.

Description	*Opposite pair*
Overall Acoustics	Bad & Good
Clearness	Blurry & Clear
Support	Hard to play & Easy to play
Damping	Dead & Lively
Brightness	Dark & Bright
Timbre	Cold & Warm

Table 1: The pairs used to describe the conditions.

2.3. Evaluation Form

The evaluation form is an important factor in this project and the setup and wording can make a difference on the outcome. After some considerations a final version of the evaluation form was constructed with a bipolar scale and a 10 cm long line between the two opposites where the musician was asked to place a mark on the line to describe the conditions. The center of the line was marked on the scale.

Six pairs of opposites were used to try to get a description of the acoustic conditions and a space given for the musician to describe the conditions with own words. For each pair, a question was asked, such that the musician would maybe better understand what he was supposed to describe.

The pairs used and what they were supposed to describe are listed in table 1.

The musicians were also asked to give a short description of their musical experience in order to see how that might affect their interpretation of the acoustical conditions in the simulated rooms. Before beginning the experiment each musician was introduced to the form and questions related to that discussed and answered.

3. RESULTS FROM THE EVALUATION

Ten musicians took part in the experiment, one at a time, and gave their opinion on the simulated rooms: Four guitarists, three wind instrument players and three string instrument players. The musicians had very different backgrounds, some of them were professional musicians, others played their instrument as a hobby. Most of them had a rather high educational background, almost all had taken at least 11 levels in music. Each musician played in all fifteen setups, three different strengths for each reverberation time. Fifteen setups can easily be tiring so the musicians were encouraged to take breaks when needed.

When this project was defined, it was expected that the results would show correlations between the musicians responses in different instrument groups. It was also conjectured that there might be a correlation between musicians with similar background.

The results from the experiment turned out differently. Only weak correlations were seen in the results. Because of this it is difficult to reach any specific conclusions on the optimal acoustics for music practice rooms.

4. CONCLUSION

When this project was defined it was estimated that ten to fifteen musicians would be sufficient to obtain definite conclusions on the optimal acoustical conditions in music practice rooms. Fourteen musicians signed up for the experiments but four dropped out and only ten musicians ended up participating. This was not thought to be a problem at that time so the experiment began. All the musicians did their best to give an honest opinion on the conditions and tried to describe their feeling of the acoustics in the simulated rooms.

The main result of the experiment is that no significant difference was observed between the different reverberation times. This also holds for the strength. There are though a few exceptions to this. The results are however not sufficiently general to be helpful in optimizing the acoustical conditions for a music practice room. It may also be of interest to examine the correlation between different parameters. The existence of such correlations, e.g. if timbre is well correlated with overall acoustics, could potentially be very helpful. However, given the results from the ANOVA analysis performed in this work, such correlations did not appear to be significant.

A general conclusion from this experiment is that using simulated rooms to optimize the acoustical conditions for music practice rooms is not easy. Several factors contribute to this. One of them is for example the surroundings that many participants found very artificial. Some even mentioned a claustrophobic feeling in the anechoic room which can highly influence their performance and concentration. The room was probably too small and the air conditioning insufficient. Due to the large number of setups the procedure may have been too long and tiring for the musicians. The flute players also experienced that the sound from the buttons was amplified too much and they also mentioned that the sound was sometimes too loud as their instrument is relatively strong.

In a follow-up to this project, several improvements could be made: The experiment should perhaps be performed in a larger anechoic room to avoid claustrophobic feelings. Concentrating on one particular instrument group could provide stronger statistical signals. Such a group should contain around ten to fifteen musicians. The strength variations should be considered carefully as perhaps ± 5 dB may be too big steps.

It is also essential to reduce the hum in the processors as much as possible, and of course preferable if the hum can be eliminated altogether. Some musicians in the present project found it very artificial to hear the sound coming from the loudspeakers. This is very difficult to deal with because of the way the experiment is constructed.

The masters thesis that this paper summarizes, was carried out under the supervision of Anders Christian Gade.

5. REFERENCES

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