ACOUSTICAL RENOVATION OF THE JYVÄSKYLÄ SINFONIA REHEARSAL HALL

H Niemi AINS Group
M Kylliäinen AINS Group
J Lietzén AINS Group

1 INTRODUCTION

Jyväskylä Sinfonia is a small symphony orchestra with 38 musicians, conducted by Mr Ville Matvejeff. The orchestra performs 1–2 times per week, its repertoire consisting mostly of baroque, symphonic and contemporary music. The rehearsal hall used by Jyväskylä Sinfonia is located on the top floor of a shopping center (Fig. 1), originally built in 1938. Prior to being used as a rehearsal hall, the attic space was originally designed as a tennis hall.

The inclined walls of the room were lined with mineral wool, and the ceiling was otherwise covered with convex surfaces, probably designed to act as diffusors. Vertical plates backed with mineral wool had been also suspended from the ceiling (Fig. 2). Musicians from the orchestra reported that the rehearsal hall was too dry for symphonic music. The hall had also been reported to be very loud, leading to occupational health issues in the orchestra. There had apparently been an attempt to control the loudness of the space, by adding a substantial amount of mineral wool, which had the effect of reducing the reverberation time to an unacceptable level.

Acoustic criteria for rehearsal rooms are presented in the Norwegian standard NS 8178:2014[1]. According to the standard, a rehearsal hall for a symphony orchestra should have a net volume of at least 1800 m³. However, the space in question consisted of a 264 m² rectangular rehearsal room, with an arched ceiling and a volume of 1100 m³. For this smaller volume, the standard gives a recommended reverberation time of 0,9–1,4 seconds for acoustically loud music.

Figure 1: The Kolmikulma shopping center, showing the rehearsal hall roof windows in the attic.

Figure 2: The attic rehearsal space features a high arched ceiling with diffusing convex surfaces and suspended vertical plates on the side walls.

Considering the dimensions of the room and the opinions of the musicians, an acoustic renovation was designed for the room by AINS Group, focused on increasing the reverberation time of the space, without increasing the loudness.

2 METHODS

2.1 Measurements

To determine the acoustical properties of the space, room acoustic measurements according to the standard ISO 3382-1[2] were conducted in the rehearsal room using the integrated impulse response method. The measurements were performed with sine sweeps, using the Odeon measuring system. From the measured impulse responses, the reverberation time T_{30}, early decay time *EDT*, sound strength *G*, and clarity C_{80} were determined. 4 source positions and 8 receiver positions were used in the measurements. These were selected, so that each section of the orchestra had their own source position. Additionally, the stage parameters ST_{early} and ST_{late} according to ISO 3382-1 were measured using the same 4 loudspeaker positions as with the previous parameters. These measurements were also performed after the renovation to confirm the modelling results.

2.2 Room acoustic modelling

A three-dimensional geometric model of the rehearsal room was created in Sketchup, and then converted into a room acoustic model using the Odeon Auditorium software (Fig. 3). The absorption and scattering coefficients were then calibrated using the measured room acoustic parameters from the actual space. In the calibrated model, the modelled room acoustic parameters *EDT*, *G*, T_{30} and C_{80} corresponded with the measured parameters within the limits of the measurement accuracy.

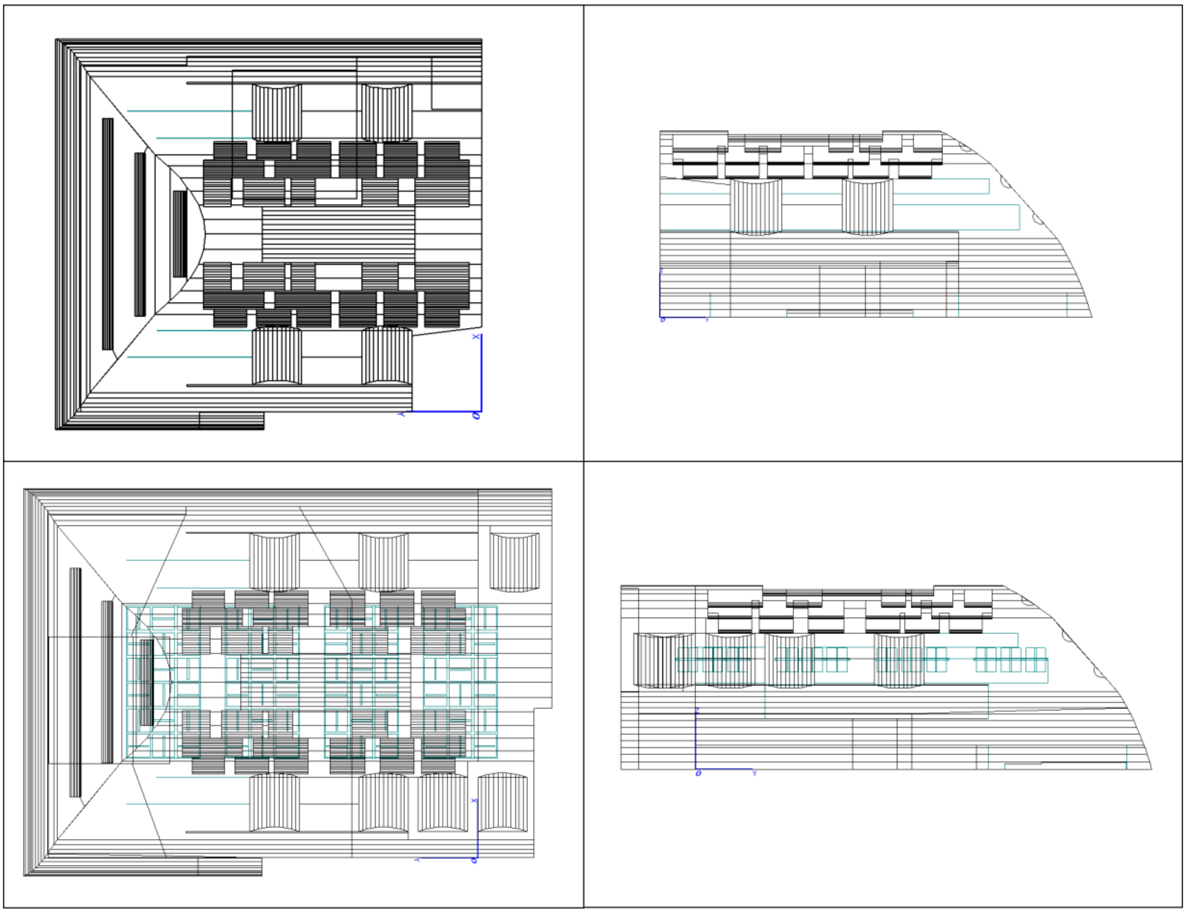

Figure 3: The room acoustic model of the rehearsal hall before renovations (top) and after (bottom)

2.3 Questionnaire

To study the subjectively experienced changes the renovation had on the acoustics, a questionnaire was distributed to the musicians after they had rehearsed in the renovated hall for about a month. The musicians were first asked their instrument and seating place in the orchestra. They were then asked to rate how different aspects of the acoustics had changed due to the renovations on a scale from 1 to 5. These included questions about how well they could hear themselves and their colleagues during rehearsal, their ability to create subtler nuances, general ease of playing, listening to the tuning and their general assessment of the acoustics of the room.

3 RENOVATION

To improve the acoustics of the room, several changes were undertaken to increase the reverberation time without increasing loudness. Volume diffusors consisting of vertical panels arranged perpendicularly in a grid, as described by Arau-Puchades[3,4], were added. (Fig. 4)

The vertical end wall of the rehearsal room was demolished, increasing the total volume of the space from 1100 m^3 to about 1500 m^3. The floor surface increased from 264 m^2 to 312 m^2. Due to this addition of volume, 30 m^2 of 20 mm thick mineral wool was added to the newly exposed wall.

The existing suspended vertical plates backed by mineral wool were removed and 3 additional gypsum boards were added to the inclined side walls, to decrease absorption in the lower frequencies. In the finished room, diffusing pyramid surfaces were added to all the vertical walls below 2,2 m.

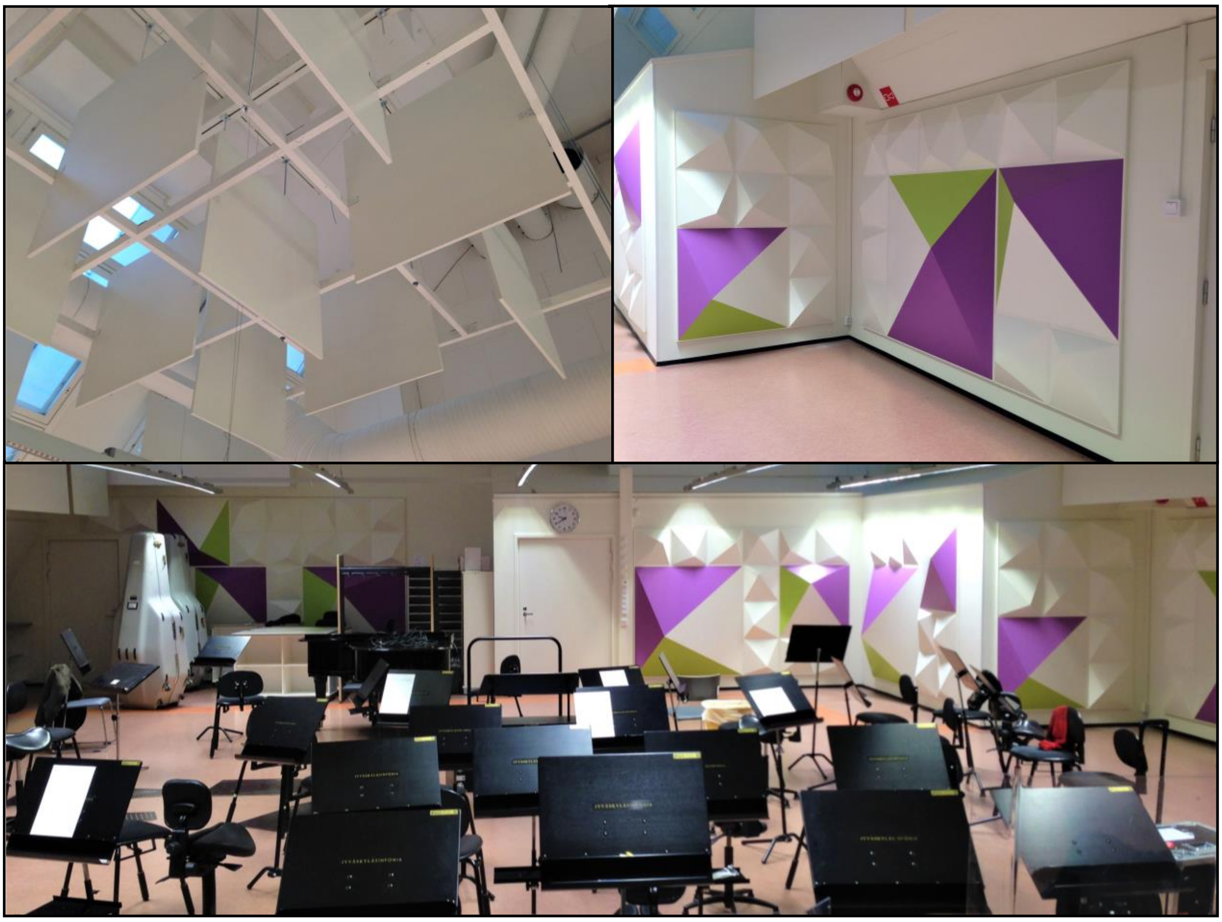

Figure 4: The rehearsal hall after the renovations. The newly mounted ceiling (top left) and wall diffusors (top right) can be seen in the image.

4 RESULTS AND DISCUSSION

4.1 Measurements

The results of the room acoustic measurements averaged over all receiver and source positions before and after the renovation are given in table 1. The reverberation time, early decay time, clarity and loudness are presented in figure 5 before and after renovation. The dashed line represents the parameter before renovation and the solid red line after renovation.

From the results, we can see that before renovation, the reverberation time of the room is below the recommended 0,9 s given by the NS 8178:2014 standard for a 1100 m³ space. The EDT is also noticeable shorter in the lower frequencies, giving the orchestral sound less warmth. Due to the shorter reverberation time, the value for clarity is quite large. Additionally, the values given for strength are quite large, explaining the comments from the musicians about excessive loudness.

The measurements after the renovation show, that both the reverberation time *T* and early decay time *EDT* were increased. Correspondingly the clarity of the room decreased. Interestingly in the lower frequencies, there was a contradictory change in *T* and *EDT*. While the reverberation time curve is quite flat, the early decay time is clearly shorter in the 125 Hz octave band. The loudness did not increase with the renovation. A decrease in loudness was also measured in the 4000 Hz octave band.

Table 1: Room acoustic parameters in the rehearsal hall before renovation.

Measured parameter		**Octave band frequency [Hz]**					
		125	**250**	**500**	**1000**	**2000**	**4000**
T_{30} [s]	(before)	0,9	0,8	0,8	0,8	0,9	0,9
	(after)	0,9	1,0	1,0	1,0	1,0	0,9
EDT [s]	(before)	0,6	0,7	0,8	0,8	0,9	0,8
	(after)	0,7	1,0	1,0	1,0	1,0	0,9
C_{80} [dB]	(before)	7,5	6,1	5,8	4,9	4,1	4,8
	(after)	5,7	3,0	3,4	3,5	3,3	4,1
G [dB]	(before)	11,5	12,1	12,9	12,8	14,0	14,6
	(after)	10,7	11,5	12,6	13,1	14,1	11,8
ST_{early} [dB]	(before)	-10,6	-10,1	-8,4	-8,0	-6,0	-6,9
	(after)	-10,3	-8,6	-8,1	-8,2	-6,9	-6,5
ST_{late} [dB]	(before)	-16,7	-15,8	-14,7	-13,3	-10,6	-12,3
	(after)	-15,1	-12,7	-12,3	-12,0	-10,9	-11,2

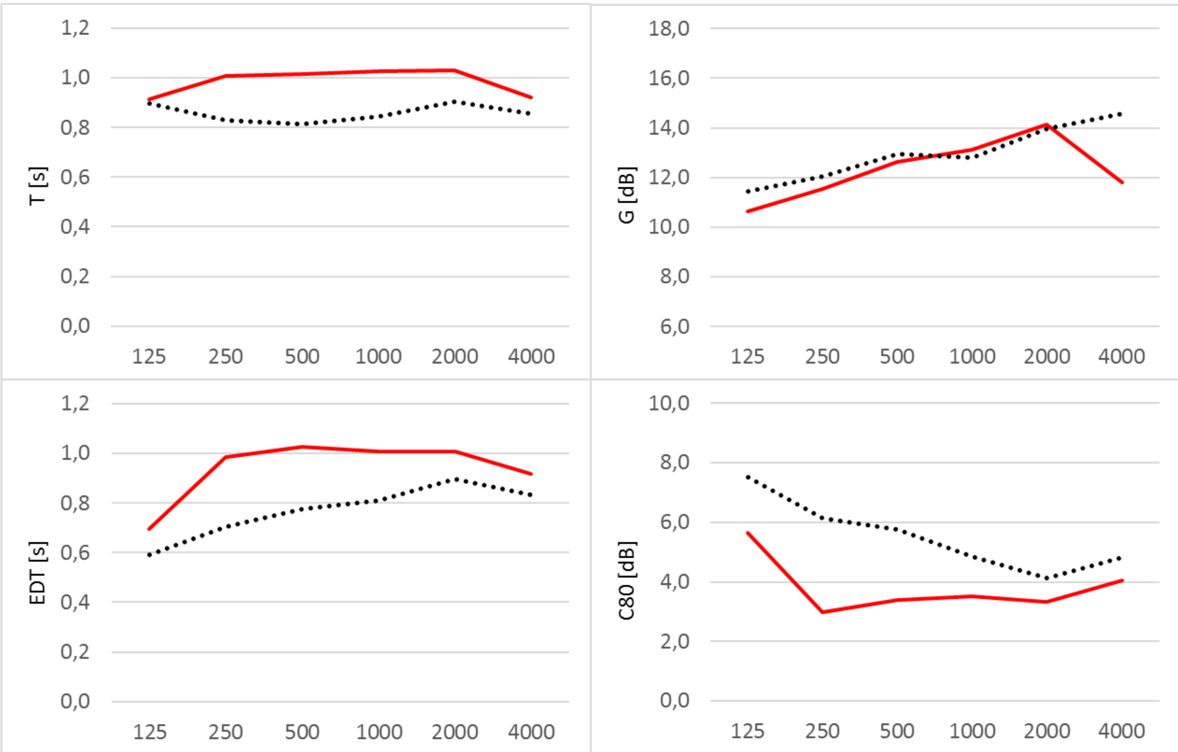

Figure 5: Measured room acoustic parameters before (dashed line) and after (solid red line) renovation.

The stage parameters are presented in figure 6 before and after renovation. In the dashed line represents the parameter before renovation and the solid red line after renovation. It can be seen from figure 6, that there is no significant change in the early support. In the late support, there is an increase in frequencies below 2000 Hz. The late support correlates with perceived reverberance, which is also reflected in the increased reverberation time.

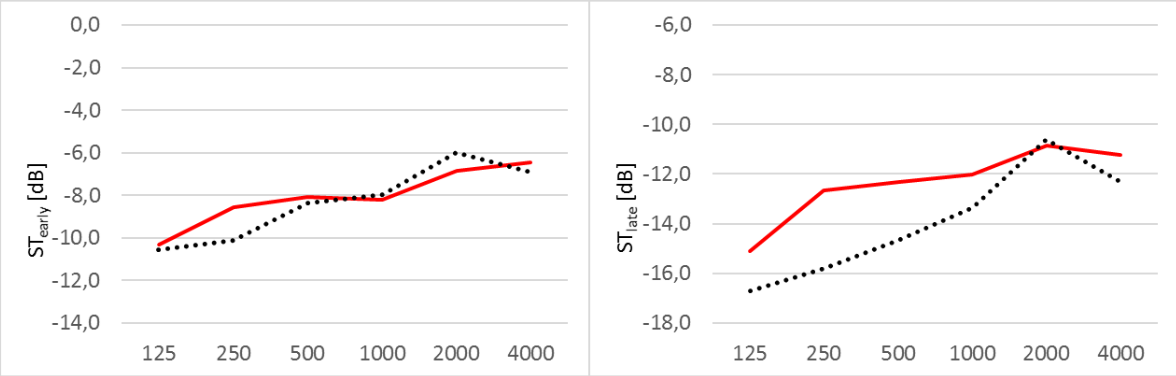

Figure 6: Measured stage parameters before (dashed line) and after (solid red line) renovation.

4.2 Room acoustic modelling

The results of the room acoustic modelling are presented in figures 7 and 8 before and after the renovation. The dashed line represents the calculated parameters from the room acoustic model calibrated to fit the measurements before renovation. The blue line represents the calculated parameters with modelled renovation measures. The calculated reverberation time, early decay time, clarity and strength are presented in figure 7.

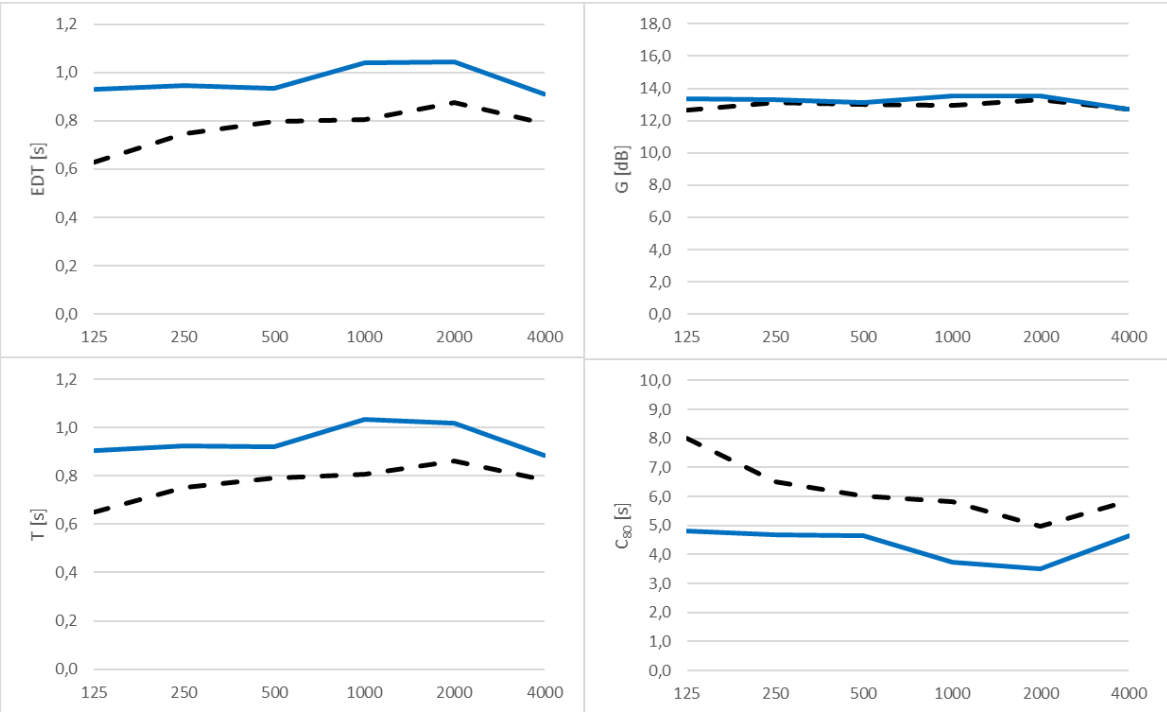

Figure 7: Calculated room acoustic parameters before (dashed line) and after (solid blue line) renovation.

In general, the calculated reverberation times agree well with the measurements. However, the measured *EDT* shows a drop in the 125 Hz octave band, which was not predicted by the room acoustic model. Additional gypsum boards were added to the walls to improve low-frequency reflections from the walls. However, due to load-bearing concerns with the weight of the gypsum boards, the ceiling was left untouched. It is possible, that the ceiling area contributed more to the low-frequency absorption, than was predicted by the model. This discrepancy with the *EDT* also explains why the high value of C_{80} present in the measurements cannot be seen in the calculated data. The loudness parameter *G* predicts high values, but there is no significant change due to the renovation. The measured drop in loudness in the 4000 Hz octave band is also not present in the model.

The calculated stage parameters are presented in figure 8 before and after renovation. The dashed line represents the calculated parameters from the room acoustic model calibrated to fit the measurements before renovation. The blue line represents the calculated parameters with modelled renovation measures.

The calculated stage parameters show similar trends as the measured values. The early stage support is lower than the measurement at frequencies above 500 Hz, suggesting that the model is missing some early energy present in the real hall. Since the reverberation time was a good fit in the model, this extra early energy could be a result of focusing effects from the arched ceiling and convex diffusor surfaces, which could not be recreated properly in the room acoustic model. However, the model predicted accurately the increase in late support and no change in early support, due to the renovation.

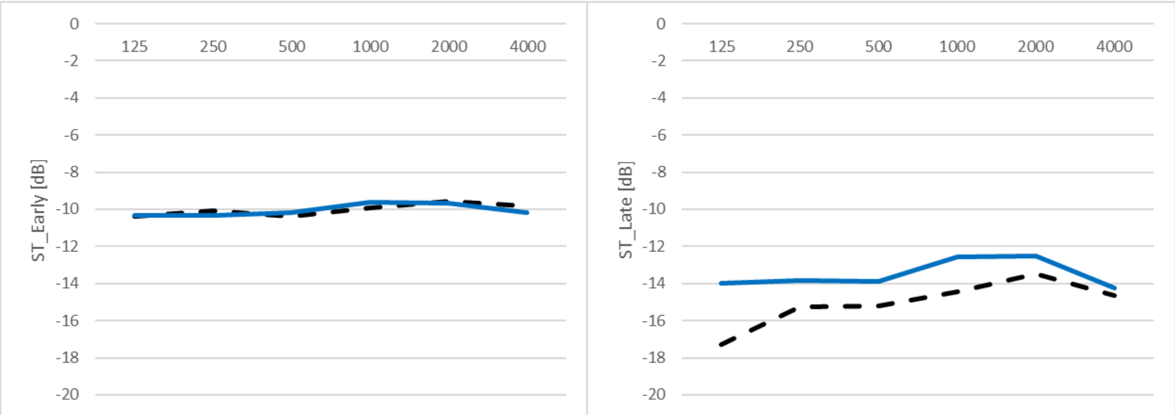

Figure 8: Calculated stage parameters before (dashed line) and after (solid red line) renovation.

4.3 Questionnaire

The questionnaire for the orchestra was distributed to 38 musicians, of which only 16 returned answers. Hence only 42 % of the musicians responded to the questionnaire, possibly leading to biased results. The musicians were specifically asked to rate the change compared to the hall before renovation. The answers to the questionnaire are presented in table 2.

In addition to these answers, several musicians commented that the wind instruments, especially brass and timpani were too loud. It was often unclear though, whether they felt the situation had worsened, or the loudness problem was one which simply persisted despite the renovation. The results show a consensus, that the reverberance of the hall and the acoustics of the room in general had at least somewhat improved.

In addition to the questionnaire, a committee of the musicians was interviewed after the renovations. The interview yielded more positive results than the questionnaire. The committee felt that the room was now more reverberant, the strings no longer had to play as forcefully as before and the audibility between sections and between musicians within each section had improved. In general, the committee was of the opinion, that working conditions for the musicians had improved due to the renovation.

Table 2: Questionnaire answers after the renovation

Question	Scale (1–5)	Average
How well can you hear your own playing?	weaker - louder	3,6
How well can you hear your own section?	weaker - louder	3,1
How well can you hear the 1st violins?	weaker - louder	3,6
How well can you hear the 2nd violins?	weaker - louder	3,1
How well can you hear the violas?	weaker - louder	3,3
How well can you hear the cellos & contrabass?	weaker - louder	3,6
How well can you hear the woodwinds?	weaker - louder	3,7
How well can you hear the brass?	weaker - louder	3,9
How well can you hear the percussion?	weaker - louder	3,7
How has ensemble playing changed?	worse - better	3,5
How easy is it to listen to the intonation in general?	more difficult - easier	3,5
How easy is it to create finer tones and nuances?	more difficult - easier	3,4
How loudly do you feel you need to play	louder – more quietly	3,1
The timbre of the room is	drier – more lively	3,7
The acoustics in general is now	poorer - better	3,6

5 CONCLUSION

Due to complaints of insufficient acoustical conditions, an acoustic renovation was designed for the rehearsal room of the Jyväskylä Sinfonia by AINS Group. The design focused on increasing the reverberation time of the space, without increasing its loudness. Room acoustic measurements confirmed that the space was too dry and too loud, even for a smaller symphony orchestra of 38 musicians.

The measurements were used to create a room acoustic model of the room, which was then used to test the renovation possibilities. The volume of the room was increased and volume diffusors, as described by Arau-Puchades[3,4] were suspended from the ceiling, to increase reverberation without increasing the loudness. Additional gypsum boards were also added to the walls of the room in order to improve the reverberation time in the lower frequencies. These measures were shown by the room acoustic model to improve reverberance without increasing loudness. Measurements performed in the room after the renovation verified the calculation results.

A questionnaire was given to the orchestra and a committee of the musicians was interviewed after the renovation. The feedback revealed that although especially the wind instruments were still considered to be loud, the subjective reverberance of the room had improved. The measured results also showed that the physical loudness of the room had not increased, despite an increase in the reverberation time.

6 REFERENCES

1. SFS-EN ISO 3382-1. 2009. Acoustics - Measurement of room acoustic parameters - Part 1: Performance spaces. Helsinki, Suomen Standardisoimisliitto SFS ry
2. NS 8178. 2014. Acoustic criteria for rooms and spaces for music rehearsal and performance. Lysaker, Standard Norge.
3. H. Arau-Puchades. 2012. The refurbishment of Tonhalle St. Gallen. Building Acoustics. Vo.l 19(3), p. 185-204.
4. U. Berardi, H. Arau-Puchades. 2013. Increasing reverberation time with diffusers: a new acoustic design for more sustainable halls. International Symposium on Room Acoustics. Toronto, June 9–11.