FINE TUNING OF THE SIBELIUS HALL STAGE ACOUSTICS

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1 INTRODUCTION

The Sibelius Hall, completed in February 2000, has a versatile adjustable acoustics. On both sides of the actual hall there are full height coupled volume chambers [1] through which the audience enters the hall. Between the hall and the chambers, on the sides of the hall and in the rear corners of the stage, there are a total of 188 continuously adjustable acoustic doors, which are one floor in height. In addition, the coupled volumes have a total of 2.7 km of continuously releasing two-layer wool curtains covering the area of the acoustic doors. With the curtain, the amount of reverberation can be varied when the acoustic doors are open. In addition, the canopy above the stage is adjustable in three parts.

The Lahti Symphony Orchestra moved to Sibelius Hall in early 2000 and has been playing on the stage ever since, basically with the acoustic configuration tested and instructed at the first Sibelius Festival in autumn 2000 by Artec Consultants Inc. team lead by Russell Johnson.

Over the past twenty years, the orchestra has expressed hopes at times for exploring and optimizing acoustics for different ensembles. Deficiencies in stage acoustics, i.e., problems with mutual hearing and hearing within the orchestra, have been particularly highlighted. Previous attempts at testing and possible improvements of stage acoustics had usually been hampered by budgetary constraints and, above all, a lack of final activity. Part of the reason for the latter is the fact that the acoustics in the hall have already been quite favourable as such.

Scattered experiments with adjustments have been made over the past couple of decades, but due to a lack of expertise and systematization, the attempts have mainly been inconclusive.

In spring 2020, the Lahti Symphony Orchestra decided to take advantage of the expertise of Akukon Ltd and have the tests executed. The auditorium measurements were carried out in early 2021, and when in autumn 2021 the pandemic was easing and the orchestra was back on stage in full numbers, the actual tests could be scheduled in the normal setting.

Compared to the earlier published procedures of adjusting and improving stage acoustics for a resident orchestra [2], this study had the advantage of utilizing original and versatile means for acoustic regulation, enabling precise systematization. This paper describes the investigations by objective measurements and subjective assessments by orchestra members for exploring and evaluating the improved acoustic settings for symphony orchestra.

2 MEASUREMENTS IN THE SIBELIUS HALL

To better understand the overall conditions and the variability of hall acoustics, we conducted an objective investigation by spatial impulse response measurements and spatiotemporal analyses. In addition, supplementary data was collected with a binaural head (B&K KEMAR). Measurements were repeated with a wide set of hall setups across parameters of the variable acoustics. The explored settings included several combinations of door panel openings to the coupled volume chambers, chamber curtains, and canopy heights.

2.1 Measurement positions and analysis

Measurement positions for sources and receivers used in the hall measurements are shown in Fig. 1. Room impulse responses were primarily measured spatially with a tetrahedral open microphone array (CoreSound Tetra) with logarithmic swept sinusoidal excitation signals from each source channel individually.

Measured spatial impulse responses were analyzed using the Spatial Decomposition Method [3] and with the spatiotemporal visualization approach [4].

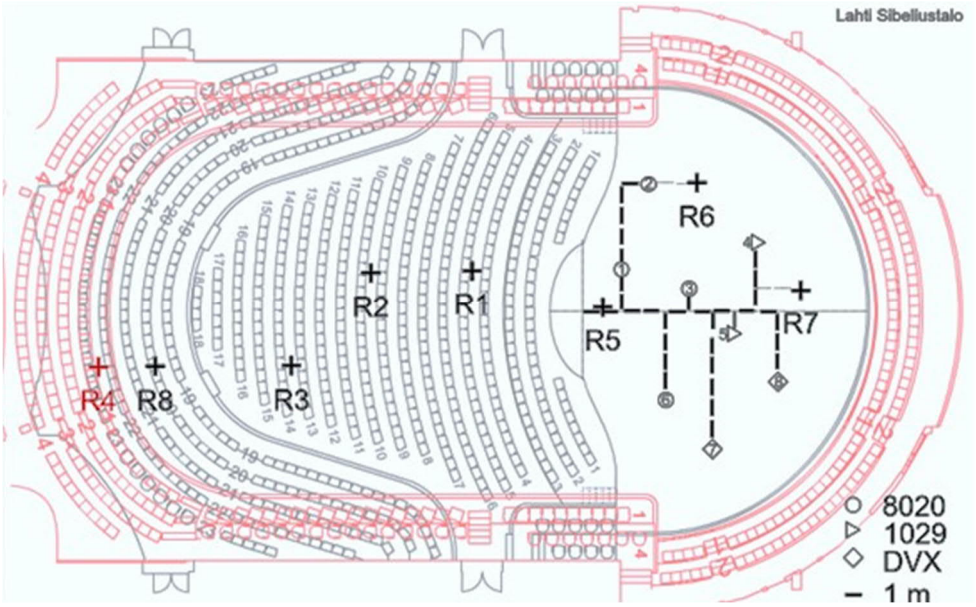

Figure 1. Measurement source (1…8) and receiver positions (R1…R8) in the hall. First balcony geometry with balcony receiver position R4 are shaded in red. Sources on stage are indicated with respective symbols for Genelec 8020 and 1029, and dB Technologies DVX speaker types.

2.2 Spatial measurement analysis and result application

The measurements were analyzed in two manners. First, the spatiotemporal analyses were evaluated separately for assessing the overall reflection patterns in different receiver positions. Then, analyses from various acoustic configurations were compared to the results from the initial acoustic setting for assessing the effect to reflected energy and directions. An example of the comparative principle is shown in Fig. 2, where the receiver position at the conductor podium is compared between settings with chamber doors open around the stage and in the hall and chamber curtains deployed, and initial setting with all doors closed. The red curve shows the cumulative energy up to 1 s with doors opened, and the green curve shows the respective result with all doors closed. The reverberant energy is higher in most directions with the doors closed, which is expected with more solid reflective surfaces towards the hall.
The corresponding approach was employed for several various comparisons between the measured range of acoustic settings. The observations from the results were subsequently applied to planning of suggested improvements to the new base setting for orchestral use.

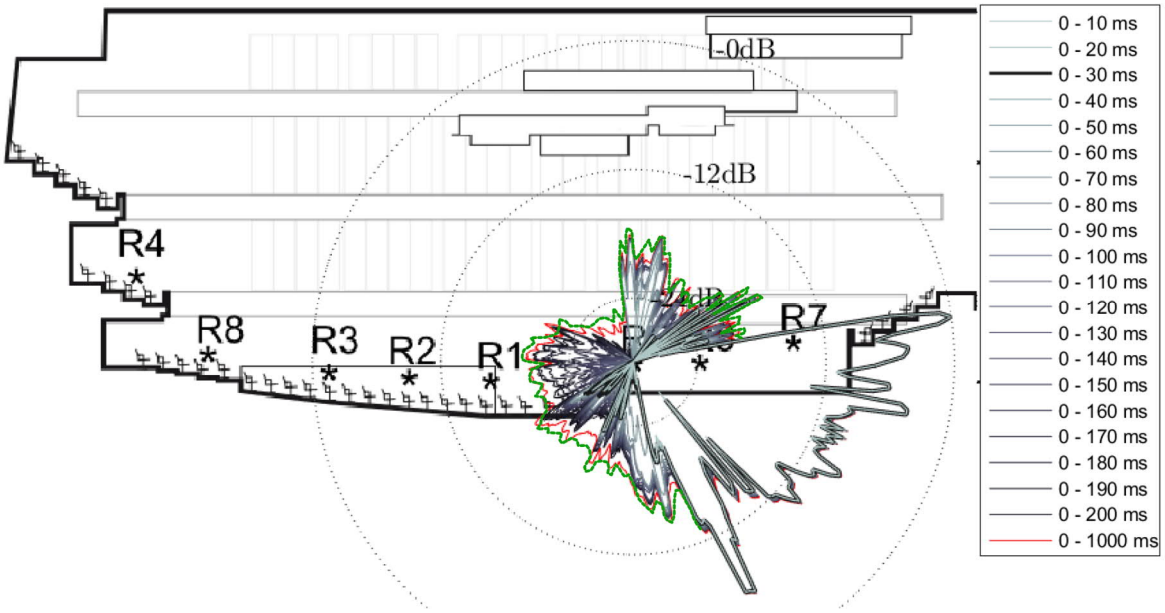

Figure 2. Example of overlaid spatiotemporal visual analysis between two hall settings. Grey and red: stage and coupled volume chamber doors open and curtains deployed; Green: 0-1000 ms window from all doors closed setting (directly comparable to red curve).

3 ORCHESTRA TESTS

3.1 Test routine

Subjective tests were conducted with the full orchestra for gathering perceptual evidence to reflect objectively measured and compared data. The procedure of the orchestra tests was based on music excerpts of 5–7-minute in total that were chosen from the concert programme of the week. This music was first played at the orchestra's then standard acoustic setting (A). After that, the orchestra left the stage to avoid direct visual cues on the changes being made. The acoustic adjustment proposal (B) was then set up. The orchestra then returned to the stage and played the musical excerpt with the new setting. The orchestra left the stage once again while the original setting (A) was restored, after which the orchestra played the musical example one more time. After the procedure, the orchestra members filled out a questionnaire form and gave oral feedback.

Four separate tests were organized, and the music excerpts were from the following works: *Cello concerto* by Antonin Dvořak; *Stabat mater* by A. Dvořak; *Sinfonia Brevis* by Helvi Leiviskä; and Suite from opera *"Les Indes Galantes"* by Jean-Philippe Rameau (in the chamber orchestra test).

3.2 Auditorium control

During each orchestral test, Akukon team, Chief conductor Dalia Stasevska and General manager Teemu Kirjonen formed a control group distributed to the auditorium to monitor the changes of the sound to the audience area. The test excerpts were conducted by an assisting conductor. Author PL acted as a "double agent" working both in Akukon team and playing in the orchestra double bass section.

3.3 Questionnaire and subjective evaluation

The acoustic impressions experienced by the orchestra on stage were investigated with subjective evaluation from musicians. After orchestra tests with modified acoustics, responses from the musicians were collected with a questionnaire which included the following five main questions:

1. Where is your seat on the stage?
2. In your experience, how did the timbre to your seat change with the new setting? ("Change in timbre")
3. How did you consider the acoustic feedback in the hall (spatial impression from the hall to the stage) with the new setting? ("Change in acoustic feedback")
4. Was it easier to hear certain instruments or groups of instruments with the new setting than with the original setting? ("Change in orchestra balance")
5. Your overall impression of the acoustic conditions in the hall with the new setting ("Overall change")

Each question was answered using a 7-point Likert-scale. The structure of the questionnaire was based on the studies by Barron and Dammerud [5].

4 PROPOSED ACOUSTIC MODIFICATIONS AND EVALUATION

The propositions for the orchestra tests' acoustic modifications were drafted according to the findings from the measurements as well as the conductors' and the orchestra members' remarks.

Prior to the testing sessions the Akukon team had several discussions with the chief conductors Dima Slobodeniouk (former), Dalia Stasevska (present) and the orchestra members to collect the comments about the stage acoustics.

The conductors appeared moderately confused about the difference of the orchestra sound to the conductor's podium and to the auditorium. This contrast can be attributed to the difference between relatively absorbing curved rear wall of the stage and typically reflecting surfaces in the auditorium. Furthermore, the conductor's position receives slightly focusing reflections locally, creating a characteristic acoustic impression.

For the musicians, the acoustic feedback on stage appeared not accurate enough and the sound rather boomy in fortissimo. The measurement results showed rather continuous increase in the reflected energy on stage from the upper hemisphere in the approximate time-interval of 30…50 ms from the canopy region as well as from surrounding upper surfaces. Based the perceived boominess and lack of accuracy in the acoustic response, the possibility of excessive reflections was considered. Therefore, Akukon team aimed for particularising the diffusion of acoustic response on stage and letting the excess sound mass out, which can be described as a concept of "ventilating the stage". However, the already good general acoustic quality and the overall gain to the audience was seen important to retain.

4.1 Symphony Orchestra Test I

The acoustic doors in the rear corners of the platform were 100% open on the 2^{nd} – 4^{th} floor (4^{th} floor above the canopy and service loft) and the curtains were completely deployed. In the auditorium, all doors were closed. The canopy was at Artec original height; front 13.7 m, middle 14.2 m, and rear 14.7 m.

4.1.1 Evaluation

This acoustic setting was received remarkably positively by woodwinds and string players sitting in

the middle of the orchestra. It was easier to hear and control one's own playing. In the large violin groups, satisfaction decreased towards the end of the sections. The brass players and timpani sitting on the third riser at the rear of the stage did not notice much difference. The original slight sense of acoustic separation from the rest of the orchestra remained. The overall distribution of responses to each question is shown in Fig. 3.

The impressions of the auditorium control group were slightly differing by the seat. To some places, the new setting slightly zoomed out the overall sound, for others it zoomed in. However, the negative effects were minimal.

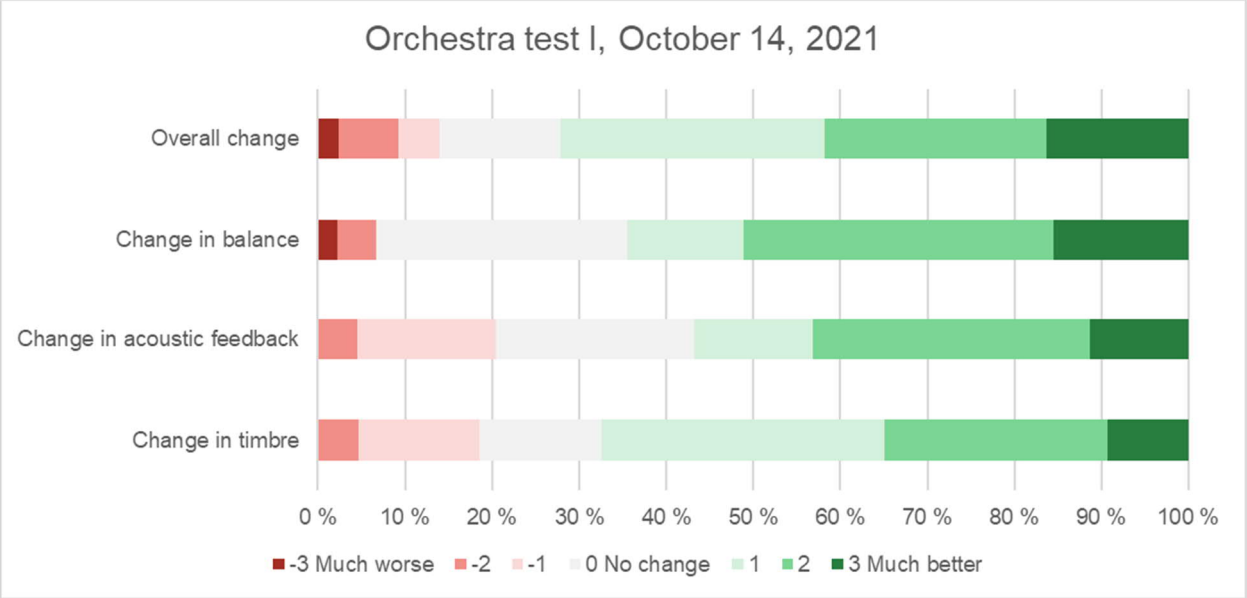

Figure 3. Results from subjective evaluation by musicians who observed difference between compared original and modified acoustic configurations (total N=66, 12 responses with no perceived difference omitted).

4.2 Symphony Orchestra Test II

Given the largely positive feedback in the previous test setup, especially in terms of ensemble control, Akukon team decided to use it as the new initial start setting (A) for subsequent tests. It was necessary to follow the direction for acoustic tuning the first test clearly indicated.

In the further adjusted setting (B), the doors at the rear corners of the platform were open 100% on the 2nd – 4th floors and on the sides of the auditorium on the 4th floor. The curtains were fully deployed. The plan to lower the canopy was thwarted by technical failure, so the test was partly incomplete. The orchestra was naturally not informed about this shortcoming.

4.2.1 Evaluation

The starting point for the test was poor as new canopy adjustments were impossible. The feedback from the orchestra was also clearly scarcer in numbers and, in practice, also worse than received from the first test. The overall results are shown in Fig. 4.

The auditorium panel also considered this stub option to be worse than the first.

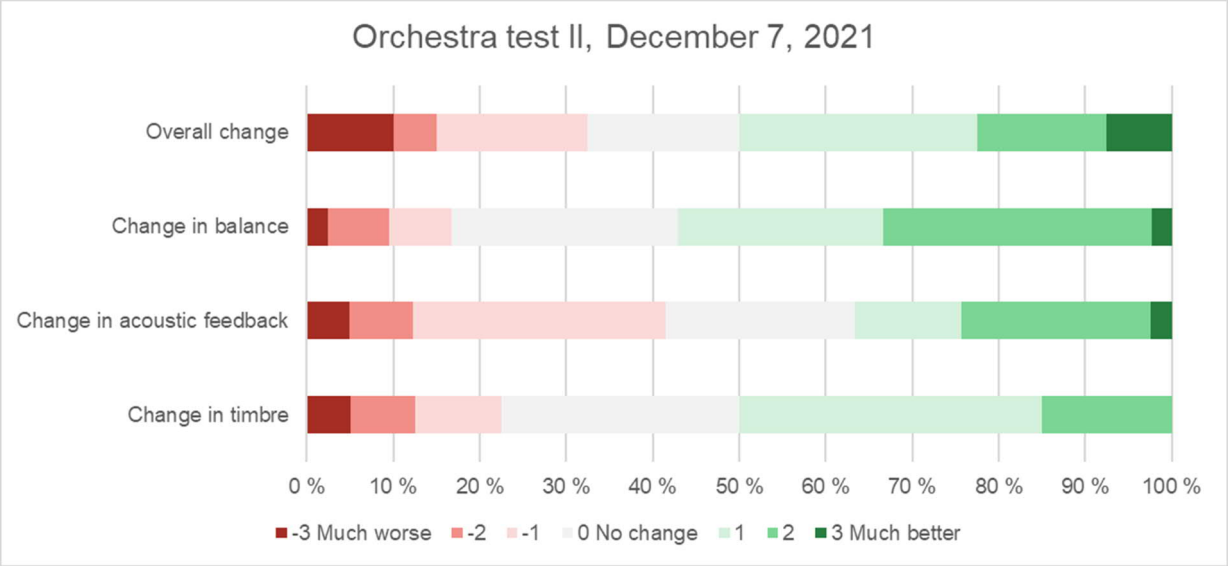

Figure 4. Results from subjective evaluation by musicians who observed difference between compared original and modified acoustic configurations (total N=64, 21 responses with no perceived difference omitted).

4.3 Symphony Orchestra Test III

The acoustic doors in the rear corners of the stage on the 2nd and 3rd floors were partially open allowing the sound transmission to the coupled volume chamber as well as reflecting sound towards the audience and the stage with increased diffusion. The aperture of the doors was adjusted following a geometrical projection from the centre of the stage to induce a uniform distribution of the sound reflections across the audience. The curtains were fully deployed and the canopy in Artec original setting.

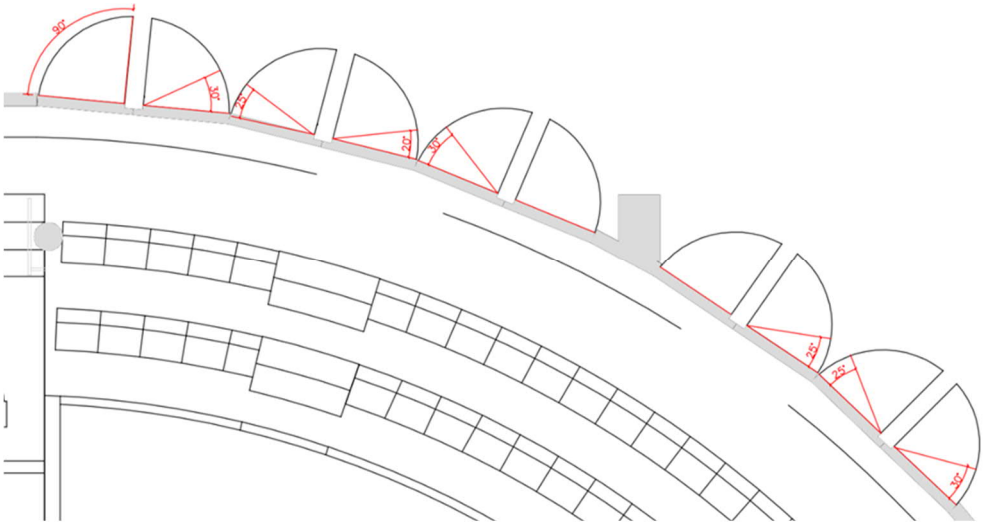

Figure 5. Door positions during test 3.

4.3.1 Evaluation

The test results now highlighted remarkable evenness of acoustic feedback in the orchestra's seating area. The players liked the ease of controlling the playing and the pleasantness of the general sound. For the first time timpani and brass on the third riser also experienced a clear improvement in their playing touch and mutual hearing. Their feeling of acoustic unity with the rest of the orchestra also improved markedly. Overall results are shown in Fig 6. It should be reminded that this comparison shows the evaluation between the originally suggested improved condition and the further optimized setting.

The panel seated in the auditorium considered this option to be the absolute best, and especially the most balanced and unanimously assessed configuration at the audience area.

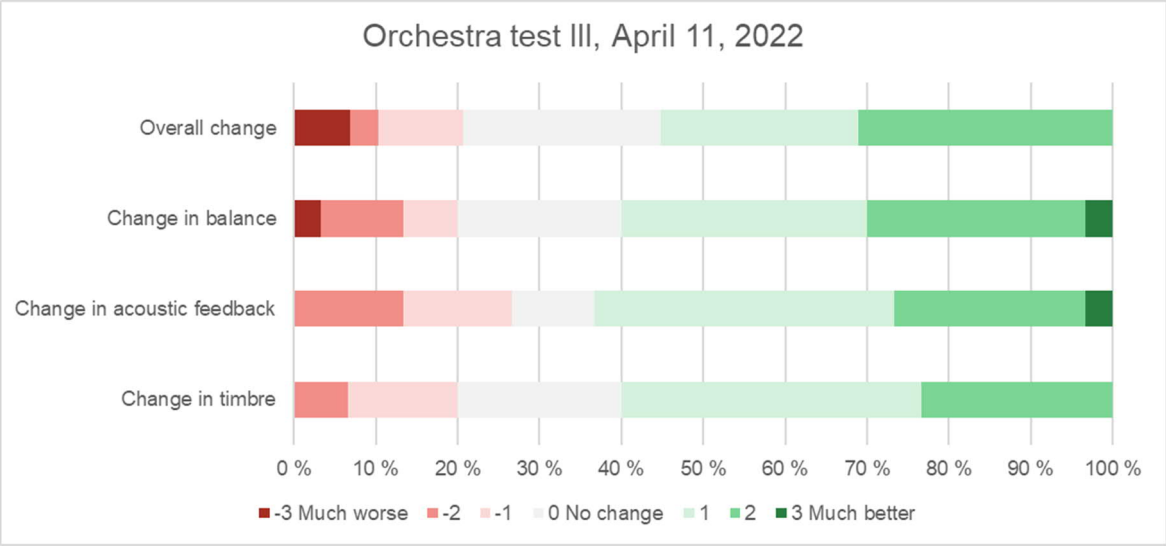

Figure 6. Results from subjective evaluation by musicians who observed difference between the originally improved and the further modified acoustic configurations (total N=53, 23 responses with no perceived difference omitted).

4.4 Chamber Orchestra Test

One test with the same procedure was conducted with a chamber orchestra ensemble of 28 musicians. The doors in the back corners of the stage were open 100% on the floors 2nd – 4th and on the 4th floor also in the auditorium. The curtains were fully deployed. The canopy assembly was set 0.5 m lower from Artec original height.

4.4.1 Evaluation

The results of the test were positive, but not very conclusive. Opinions were divided. Lowering the canopy was not a good solution for this relatively large chamber ensemble. It caused a vertical compressing effect, a “widescreen” sound picture. The overall results are shown in Fig. 7.

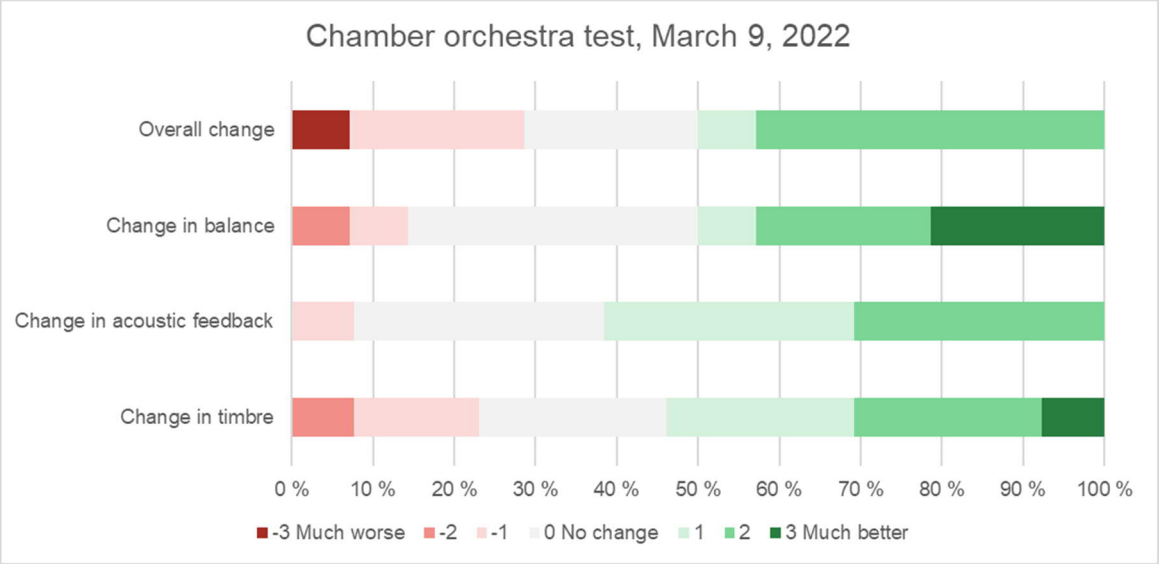

Figure 7. Results from subjective evaluation by musicians in the chamber orchestra ensemble who observed difference between the originally improved and the further modified acoustic configurations (total N=26, 12 responses with no perceived difference omitted).

5 CONCLUSIONS

Already after the first orchestra test, the acoustic adjustment possibilities enabled by the hall appeared adequate for reaching the desirable enhancement of stage acoustics.

The musicians' preferences of the proposed settings seemed to be, naturally not unanimous, but rather clear from the beginning. However, only the third setup proposition, being already more detailed fine tune, was able to make an obvious improvement to most of the players. In the first test, approximately 65% of the respondents who observed some overall change in the acoustic quality from the initial hall condition found the first proposed setting at least slightly favourable. Subsequently, the third orchestra test with further developed setting resulted in an additional approximately 60% at least slightly favourable opinions. In both these development stages the proportion of at least slightly displeased responses was substantially lower than those for the opinion of improved stage acoustics.

Based on the author’s personal experiences, the acoustic conditions at the rear percussion and brass instrument risers are typically felt challenging. However, the responses received from this area also indicated a positive development during the process. Other select comments from the musicians reported improvement in the touch and responsiveness of their own instrument, as well as in the mutual hearing for most sections. In summary, the subjective evaluation on acoustics both on the stage and in the auditorium suggests that the adjustments accomplished by the existing tools for variable acoustics provided a clear improvement for the overall acoustic quality.

An interesting concluding work would be to repeat the spatial impulse response measurements, now comparing the initial setting and the specific final preferred configuration. For more comprehensive results, a larger number of sources and receiver positions could be beneficial for more detailed analysis. However, this phase is left for future work.

6 REFERENCES

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APPENDIX: FINAL SUGGESTIONS FOR ACOUSTIC SETUPS

Proposed setup for symphony orchestra

Akukon team proposed the setting of the 3rd test as such for the Lahti Symphony Orchestra:
Acoustic doors in the rear corners of the stage on the 2nd and 3rd floors open according to the presented irregular, but symmetrical scheme. Curtains fully deployed and canopy in the original Artec setting.

Proposed setup for chamber orchestra:

Acoustic doors in the back corners of the stage on floors 2nd – 4th, and on the 4th floor of the hall open 100%. Curtains fully deployed. However, the canopy in Artec original setting.

Proposed setup for small chamber ensemble

Due to the Covid-dictated repertoire changes during the concert season, Akukon team was not able to test the stage acoustics with a small chamber ensemble. However, based on the tests executed and previous experiences in the hall, for an ensemble max. 7 players the team proposed:

Acoustic doors in the back corners of the stage on the 2nd – 4th floors, as well as on the 4th floor of the hall open 100%. Acoustic curtains fully deployed. The original canopy assembly 1.5 m below basic Artec setting. Therefore, the audience would use only the parterre.