

SUBJECTIVE AND OBJECTIVE EVALUATION OF SUGGESTED CHANGES FOR IMPROVING STAGE ACOUSTICS IN GÖTEBORG KONSERTHUS, SWEDEN

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SUMMARY

In 1993 Jordan Akustik was asked by the Gothenborg Philharmonic Orchestra to suggest changes in their home hall: The Gothenborg Concert Hall for improvement of the acoustic conditions on the orchestra platform. This resulted in a one day full scale experiment, in which possible alterations were temporarily implemented and tested by the orchestra members as well as by objective measurements as described in the following.

BACKGROUND

*rear
pod!*
The hall which was inaugurated in 1935 and seats an audience of nearly 1300 is famous for its clean architecture and good acoustics for the audience; but already from the outset the musicians experienced ensemble problems on the podium in the hall [1]. (The hall is further described in this reference.) Even before the inauguration the architect supplemented his design with a small massive reflector over the back of the podium. This was not so much in order to enhance ensemble conditions (a term seldom focused on at that time) but in order to counteract an echo experienced on the stage and believed to come from the rear wall in the hall.

No doubt the strengthening of energy build-up caused by the reflector can have suppressed this echo, but it also had the adverse effect of strengthening the heavy brass instruments rather than the softer string instruments. The answer to this became the curtain on the podium back wall. The orchestra lived with this situation for nearly half a century. But with an increase in orchestra size an enlargement of the podium became necessary and was carried out in the mid eighties. In order to help the bow instruments, who now was pushed even further out in the open auditorium (about two metres) it was decided at the same time to extend the reflector further out and to give it a more convex shape, believing this would be beneficial for the whole orchestra. The experience with this new podium has not been a happy one for all orchestra members.

SUGGESTED CHANGES

Having studied the situation during a rehearsal and a concert with the orchestra playing the Leningrad Symphony it became obvious from listening in positions both on the podium and in the hall, that the original fault still existed, that is the strings were still dominated by brass and percussion.

Besides, a measured average value of $ST_{early} = -14,3$ dB on the stage as published in [2] (equivalent to ST_1 , obtained in 1988 with the rear curtain in place) suggests, that on average the early energy reflected back to the musicians is too low for easy ensemble playing. Thus, the

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problem seemed to be, that reflections support the brass and percussion excessively; but even more severe is the lack of support of the instruments closer to the front edge of the platform (strings and wood winds).

With an angle of about 70° between the existing smooth side walls (which should be respected as an essential part of the hall design), modifications in the reflecting energy would have to come from surfaces above the orchestra.

In principle, reduction of the reflected energy from the rear part of the stage (beyond the capability of the existing curtain on the rear wall) must involve modifying the existing overhead reflector, either by raising, perforating, adding sound absorption or simply by removing it. On the other hand, new reflecting surfaces would have to be added over the front part of the stage in order to provide further reflections from sound sources in this area.

Our experience from the renovation of the podium in DR's "Studio 1" in Copenhagen [3] had clearly demonstrated the advantages of letting the suggested acoustical changes be experienced live by the orchestra in order that they themselves are able to judge the differences and participate in the decision process. It was hence decided to carry out full scale experiments with the orchestra playing in an number of different situations.

For this experiment, the aim of which was primarily to study ways for improving the ease of ensemble, the following variables were selected:

- a. adding a light reflector array over the string instruments (in order to increase the amount of reflected energy in the front part of the stage).
- b. suspending absorption material under the existing reflector (which - in connection with this test - was the most convenient way of reducing its impact).
- c. use of the curtain engagement on the rear wall (as a further means of reducing the amount of reflected energy in the rear part of the stage, i.e. a supplement to b).

Besides, studying different combinations of the three measures was of interest.

PRACTICAL EXPERIMENTAL DESIGN

Concerning the degree of variation possible, the experiment was somewhat limited by the practical considerations of time and economy. Element a) was implemented by a lightweight reflector array with total dimensions $14\text{m} \times 5\text{m}$ made from twenty slightly curved $1\text{m} \times 2\text{m} \times 6\text{mm}$ masonite boards suspended from the ceiling in front of the existing reflector, while b) consisted of five $1.2\text{m} \times 0.9\text{m}$ wooden frames containing 50mm mineral wool slabs hung centrally under the existing reflector. Only six of the possible eight combinations were presented, whereby the whole exercise could be carried out in one day.

An overview of the variable settings in the six different situations is summarized in Table 1. The order of presentation was to a large extent determined by attempts to minimize the time for changing setup. Among these, setting 4 equals the podium as it is used by the orchestra today (except for frequent use of the existing curtain).

The orchestra played the same 20-30 minute programme (mainly excerpts from the classical and romantic repertoire and selected to involve simple as well as more complex orchestration and dynamic differences) in all six sessions, and each member was asked to comment after each session by markings on rating scales in a prepared questionnaire sheet. The questionnaire contained questions regarding four room acoustic aspects: ease of ensemble, sound level, support to the sound of one's own instrument and timbre. A total of 77 questionnaires were returned by

the musicians for analysis. Also changes to the listening conditions in the auditorium were observed through all six sessions both by vacant musicians and by experienced people knowing the hall. (However, these responses were too few to be treated statistically.)

Session No.	1	2	3	4	5	6
Reflector array	+	+	-	-	+	+
Mineral wool	+	+	+	-	-	-
Curtain(exist.)	+	-	+	-	+	-

Table 1: *Combinations of variables tested in the full scale experiment on the stage in Göteborg Konserthus.*

It appears from Table 1, that the experiment does not represent a full factorial design. However, efficient analysis of the effects of the different variables was still possible due to the many number of responses.

Among the objective room acoustic parameters measured in the six situations, EDT (Early Decay Time [4]) and ST_{early} [5] are the most relevant to discuss.

RESULTS

A correlation test indicated, that the responses on the different scales were mutually independent. An overview of the results from a multi-factor analysis of variance analysis of the subjective data is shown in Table 2. All effects listed were significant at a 1 % level (except for a single 5 % written in parenthesis).

Resp. \ fact.	Reflect.	Min. wool	Curtains	Instrument	-interact.
ENSEMBLE	better	worse		yes	Reflect.
LEVEL			(softer)	yes	Curtains
SUPPORT			less	yes	Reflect.
TIMBRE			darker	yes	Reflect.

Table 2: *Significant effects of variables on each of the subjective responses in the Göteborg Konserthus experiment. For further explanation, see text.*

It is seen, that - averaged over instruments - the reflector array had a positive and the mineral wool on the existing reflector a negative influence on ensemble, while the curtains caused (a slightly) reduced perceived level, less support to one's own instrument and a darker timbre. However, the four "Yes"-es in the second column from the right indicate, that on all four scales the different groups of instruments (violins, violas, cello + bass, wood winds, brass, percussion) responded significantly different, i.e. they did not agree in their evaluation in the changes introduced by the variables. Obviously, this is the reason why some factors turned out to be insignificant, since often individual groups reacted strongly on a certain variable - but with their responses going in opposite directions. For example, this was the case for the influence of the added reflector array on Support, as also reflected in the rightmost column - showing significant two factor interactions - i.e. the pattern of differences between instrument groups changed significantly between situations with and without reflectors.

With ease of ensemble being the main concern in the experiment, the averaged subjective responses for this aspect have been shown in Figure 1 as a function of the corresponding objective measures of ST_{early} for each of the six different settings presented. It is seen that the musicians are grateful to whatever change is introduced; but situations with the reflector array in place and without mineral wool are given the highest preference. A certain correlation with ST_{early} is seen ($r = 0.51$), although the tendency is weaker than what we found in The Danish Radio experiment [3] (where r -values varied between 0.7 and 0.9). The present value of ST_{early} in the Danish Radio Hall is indicated at the bottom of the figure along with the value in the Grosser Musikverein Sall in Wien [2].

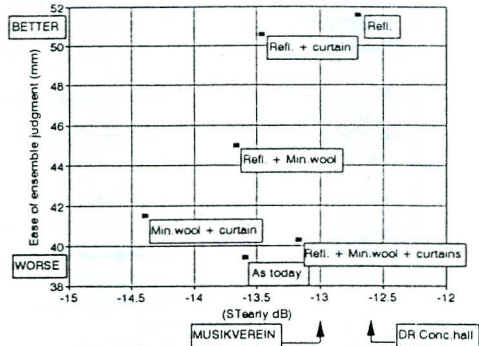


Figure 1: Subjective versus objective evaluation of ease of ensemble for the six different situations tested.

Impulse response records revealed a large amount of reflected energy about 300 ms after the direct sound - most likely coming from the rear of the hall behind the audience. This not only causes EDT on the stage to be higher than EDT in the audience area, but may also mask the ensemble cues contained in the early reflections.

DISCUSSION

Of course the fact that the modifications tested were visible to the musicians introduces a question of whether the evaluation was only based on their acoustical impact. Thus, it is hoped that this has influenced the negative response to absorption being mounted under the existing reflector, since this response was against what the authors had hoped for!

The objective variations of ST_{early} are seen to be fairly small in this experiment: less than ± 1 dB according to Figure 1 (compared with the ± 2 dB in our previous experiment in the DR concert hall [3]). This is also small compared to the variations measured between different positions on the platform (which in itself was part of the problem as stated earlier). This fact has most likely contributed to the ambiguity and differences observed between the different groups of players. This also makes one wish, that more radical changes - especially towards better conditions - could have been presented. Still, the experiment has given fruitful indications of feasible paths for improvements in the acoustical conditions for the orchestra.

At present, no decisions have been made about proceeding any renovation plans.

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