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Stage acoustics: experiments on 7 stages of concert halls in the Netherlands

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ABSTRACT

As presented at Acoustics'08 Paris, the need for an objective parameter proved to be necessary being able to optimize stage conditions (canopy position) for musicians as well as for the conductor. To be able to further develop and validate such an objective parameter measurements have been carried out on 7 stages of concert halls in the Netherlands within the framework of the Dutch Students Orchestra tour visiting these halls. In addition to the measurements the orchestra as well as the conductor filled in a questionnaire after each concert. So with these results we were able to check the correlation between the objective measured parameters and the musicians and the conductors subjective experience. In this paper the new parameters merit in relation to the subjective response of musicians to stage acoustics is elucidated.

1. INTRODUCTION

Every year the Netherlands Students Orchestra (NSO) goes on tour visiting a number of concert halls in the Netherlands. In a period of approximately 2 weeks they perform in 8 to 10 concert halls. Such a tour with one orchestra playing the same program in a short period of time on different stages offers a unique possibility to study stage acoustics.

The NSO proved to be very interested in the research we proposed: carrying out acoustic measurements on the stages and interviewing the musicians and conductor to try to find a

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correlation between the objective parameters describing the acoustic quality and the subjective experienced acoustics on the stage. This paper focuses on the musicians' experiences.

We determined the commonly used objective parameters as well as the new developed parameter [LQ7₋₄₀¹] for optimizing stage conditions and compared the results with subjective response of the musicians for the different halls. The concert halls included in the study are those of Amsterdam, Den Haag, Eindhoven, Enschede, Maastricht, Nijmegen and Rotterdam. In figure 1 an overview of the different stages with relevant data is given. As can be seen the concert halls and stages differ in shape, size, material and reflecting surfaces.



Concertgebouw Amsterdam

Stage 150 m ²	No canopy
1974 seats	Volume 19,000 m ³



Muziekcentrum Eindhoven

Stage 200 m ²	Two side reflectors
1250 seats	Volume 14,400 m ³



Muziekcentrum Enschede

Stage 220 m ²	No canopy
1054 seats	Volume 16,500 m ³



De Doelen Rotterdam

Stage 210 m ²	No canopy
2230 seats	Volume 27,700 m ³



Dr. Anton Philipszaal Den Haag

Stage 260	6 reflectors
1890 seats	Volume 15,500 m ³



De Vereeniging Nijmegen

Stage 240 m ²	Shell + reflectors
1450 seats	Volume 11,500 m ³



Theater aan het Vrijthof Maastricht

Stage 390 m ²	Orchestra chamber
920 seats	Volume 12,000 m ³

Figure 1: Overview of measured stages.

2. MEASUREMENTS

To be able to compare the measurement results from the different halls a grid fitting over all stages, has been developed. The starting point for the grid was the recommended measurement positions by Gade⁴ in his study for the support. The grid has been developed taking into account the musicians positions and the dimensions of the stages included in the study.

The measurements have been carried out in the non-occupied hall, with an empty stage as well as with the musician's seats on the stage. With the full orchestra on the stage also impulse responses have been measured for one source position and two receiver positions. For this measurement source position S1 (back of stage) and receiver position R4 and R10 are used.

The measurements have been carried out with an Omni-directional sound source and omni-directional microphones. Impulse responses were measured by Dirac 4.1. The height of the source was 1.3 m. During the measurements the source was rotated four times in order to be sure the source signal was fully omni-directional. The decay range (INR⁸) for all impulse responses measured had an average of 60 dB for all frequency bands, with a minimum higher than 45 dB.

Impulse responses have been measured and analyzed for orchestra combinations using four source positions (representing the percussion, woodwinds, brass and string section) and eleven receiver positions. A symmetrical stage environment is taken into account so all positions and thus combinations can be mirrored. For each source position two receivers were consequently chosen at one meter distance from the source, R10 was at the conductor's position. The other 9 receiver positions were distributed over the stage, based on a grid (1.5 m by 1.8 m). For all these source and receiver positions T_{30} , EDT , C_{80} , G , ST_{early} ST_{late} as well as LQ_{7-40} have been determined.

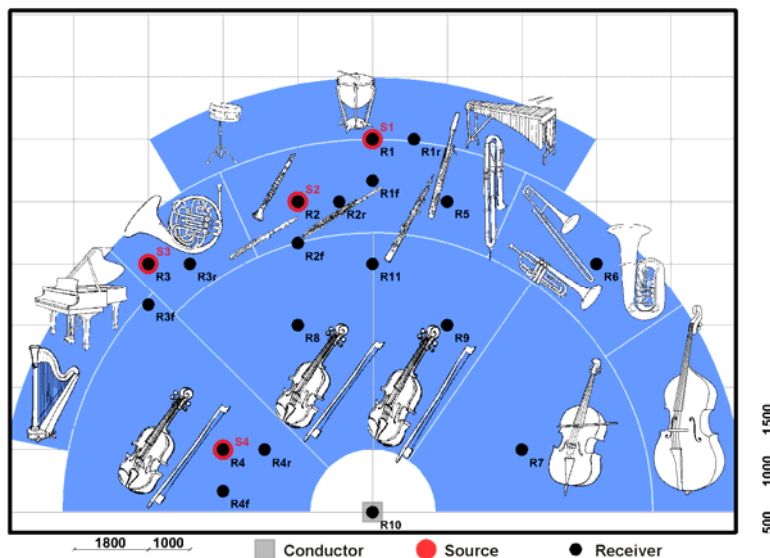


Figure 2: Grid with source and receiver positions.

In accordance with ISO-3382-1 the mean value in the 500 Hz and 1000 Hz octave bands is determined for the parameters T_{30} , EDT , C_{80} , G as well as LQ_{7-40} . The single numbers representing ST_{early} and ST_{late} , are the mean values of 250 Hz to 2000 Hz. The results are presented anonymous by describing the halls with a character.

The overall mean value for the measured reverberation times T_{30} (500/1000Hz) measured on stage vary from 1.7 s to 2.4 s for the empty stage in the non-occupied hall. The maximum and minimum measured T_{30} are indicated in fig 3a. The measured EDT on stage in the non-occupied hall ranges from 1.5 s to 2.2 s.

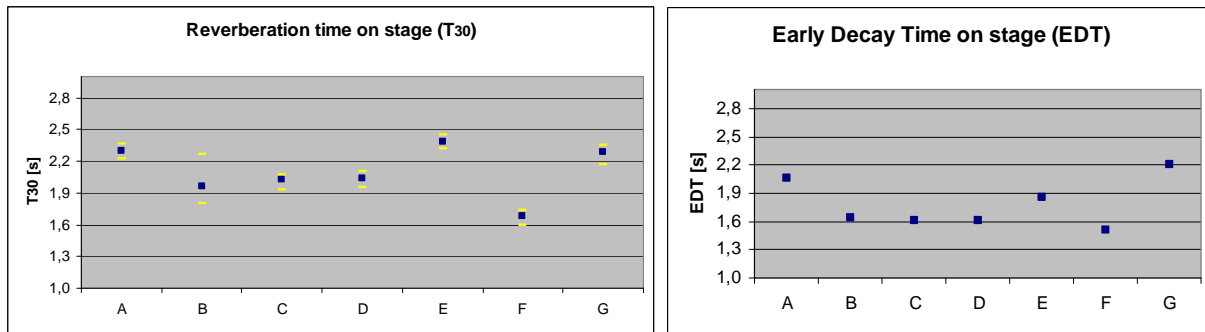


Figure 3a and 3b: Measured reverberation time T_{30} and EDT in the concert halls.

The impulse responses measured on the receiver positions using the four source positions are used to determine the Clarity (C_{80}) on the stage as well as the Strength (G). The averaged values for the Clarity (C_{80}) vary from 3.2 dB to 6.5 dB on stage. The minimum for the averaged value is -2.1 dB (hall C) and the maximum is +11.2 dB (Hall E). The Strength (G) varies between 10.4 dB to 12.1 dB.

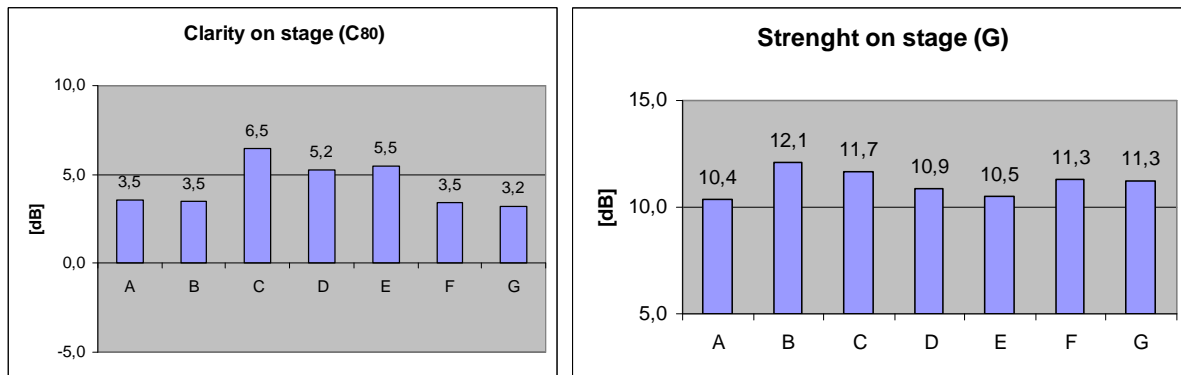


Figure 4a and 4b: Measured Clarity (C_{80}) and Strength (G) in the concert halls..

The support is also determined for the seven halls. The averaged values for the early support (ST_{early}) and the late support (ST_{late}) are presented in figure 5a and 5b. As the graphs show, the early support and the late support more or less indicate the same acoustics conditions for the stages. Most stages meet the recommended values for the support as given by Gade: -13 dB to -11 dB for the early support and for the late support.

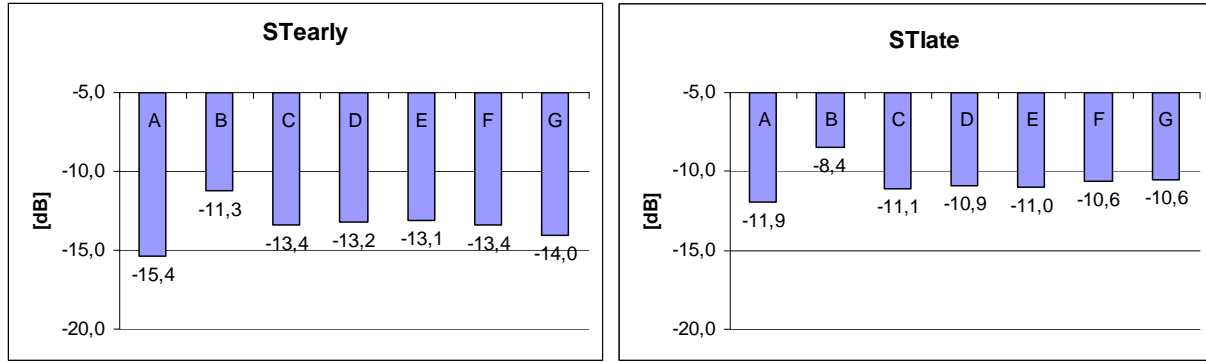


Figure 5a and 5b: Measured Early and Late Support in the concert halls.

Especially for fine-tuning the stage acoustics in Casa da Musica² a new parameter LQ_{7-40} is introduced¹. The LQ_{7-40} (eq. 1) focuses on the amount of very early sound compared to late early and late reverberant sound.

$$LQ_{7-40} = 10 \lg \left[\frac{\int_7^{\infty} p^2(t) dt}{\int_{40}^{40} p^2(t) dt} \right] \quad [\text{dB}] \quad (1)$$

In this research the values, averaged for all source and receiver positions (500-1000 Hz), for LQ_{7-40} are in a range of 0 dB to -7.60 dB. More specific results for the LQ_{7-40} are elucidated in another paper⁹. The results the averaged values for seven concert halls, differs from the results of the more common parameters describing the acoustic quality of concert halls.

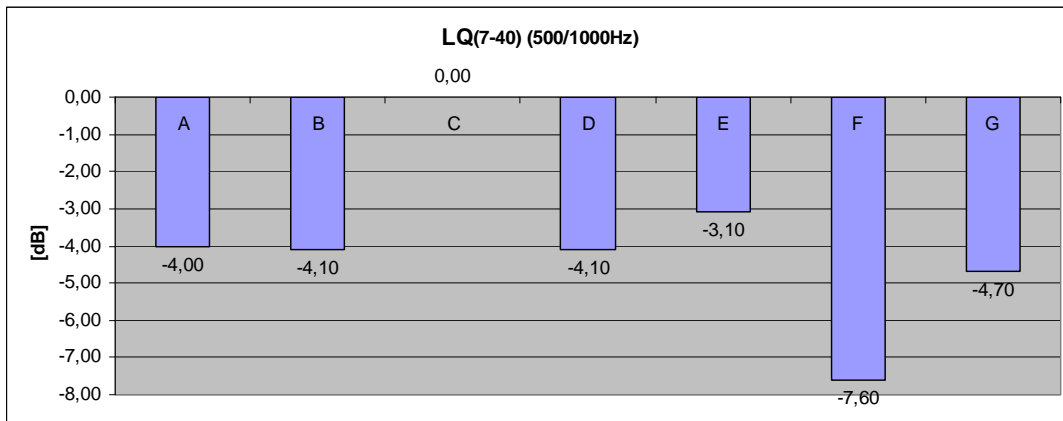


Figure 6: Mean values for LQ_{7-40} .

3. INTERVIEWS

For room acoustic research it is interesting to know to what extent the objective parameters match with the subjective response of musicians (and conductor^{1,9}). A questionnaire for investigating the musician's subjective experiences has been developed. The musicians were asked to indicate to what extent they could hear their instruments (loudness, intelligibility, timbre) and the instruments of the other instrument groups. It was also asked to indicate if the other instrument groups could be heard in accordance with their position on stage. General questions concerned the music's balance on stage and the general impression of the stage acoustics in the hall. For these two questions they could score on a five point scale from bad to good. For stage acoustics and balance a zero value indicates a neutral judgement and positive values indicate a positive experience. After each concert the questionnaires were handed over to the musicians that participated in the study.

It proved that the acoustic quality of the stage and the balance on the stage as experienced by the orchestra was in general positive.

The musicians judged the concert halls A, B and C as best with regard to the stage acoustics and balance. The conductor also preferred these halls for these reasons.

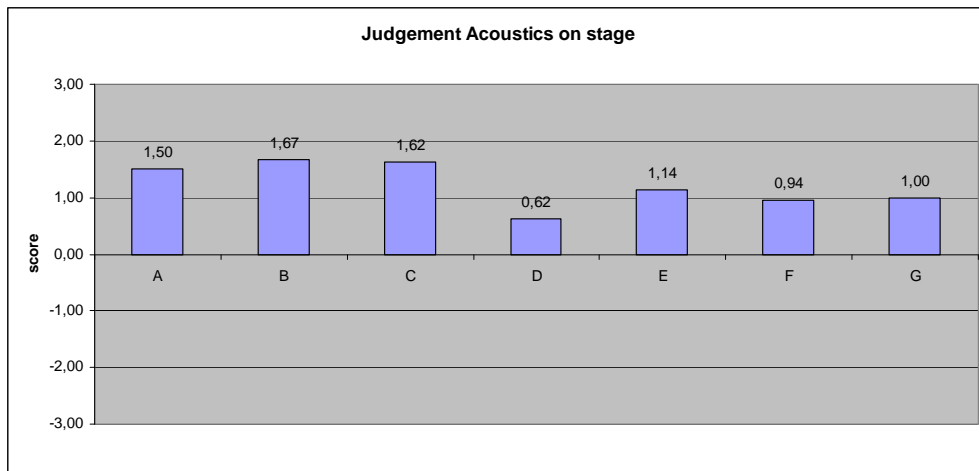


Figure 7: Stage acoustics and balance as judged by the orchestra.

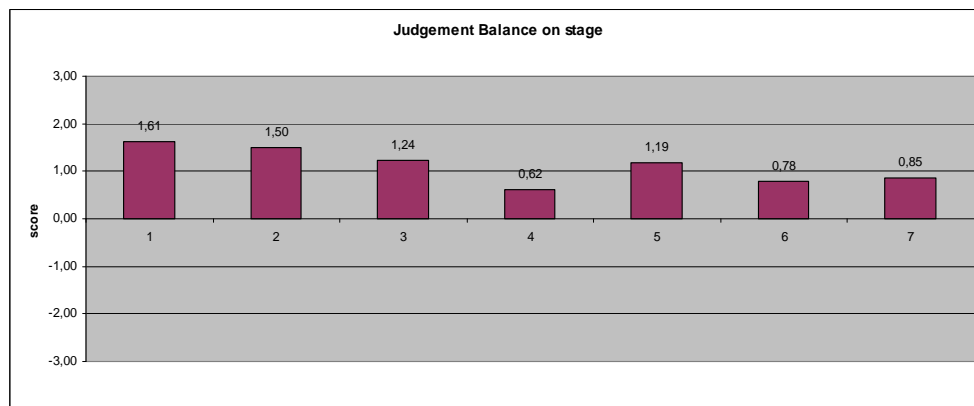


Figure 8: Balance on stage as judged by the orchestra.

In general the loudness of the own instruments was judged to be a little loud, where the loudness of the instruments of the orchestra members was a little too low for hall A, D and E. Concert hall A was judged as best with respect to the loudness of the own instrument where G was judged as best for the loudness of the other instrument groups. Stage G is also the largest one of all.

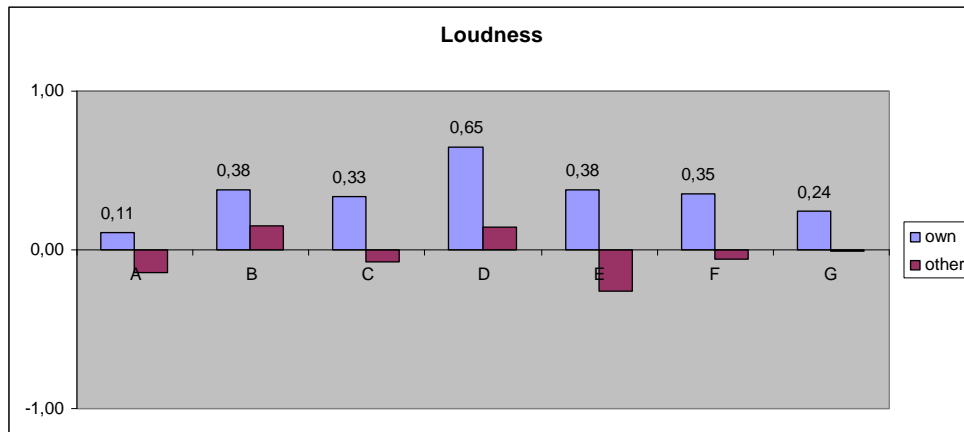


Figure 9: Loudness on stage, own instrument and instrument of other orchestra members.

All halls the orchestra played in were more or less judged positively.

4. ANALYSIS

The reverberation times had such a range, that a certain preference of the musicians could be expected. However the interviews did not show this. The question is to what extent musicians are able to make a relevant distinction between different conditions. Comparing the measured data with the outcome of the interviews did not result in relevant correlations. The orchestra indicated concert hall A, B and C as being experienced as best. The measured data for the Clarity, Strength and Support are not in line with this subjective experience. Also the data sets for the measured source receiver combinations did not show a strong correlation. The averaged values for LQ_{7-40} (500/1000Hz) also do not fully correlate with the musicians' subjective judgment of the hall but clearly show a different result. Measurements carried out on stage with and without the orchestra indicate effects of strong early reflections so this parameter seems to be interesting to develop further.

5. CONCLUSIONS

Measuring seven concert halls physically and subjectively did not yet result in a clear relation between objective parameters and subjective experiences. The new proposed parameter to study the stage acoustics LQ_{7-40} seems more promising than the well known parameters.

ACKNOWLEDGMENTS

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