Early subjective and objective studies of concert hall stage conditions for orchestral performance

Updated version compared to what was presented in Madrid

Jens Jørgen Dammerud
Michael Barron

University of Bath, UK

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My name is Jens Jørgen Dammerud and I will here present some of the latest results from a 3 year on-going project on stage acoustics in concert halls. The project is lead by Mike Barron at University of Bath in England and is sponsored by EPSRC.

Our project (2005 – 2008)

Dialogue and questionaire with orchestras (Bournemouth Symphony Orchestra so far)

Objective measurements of stages the orchestras regularly play at

Scale and computer modelling

What are the acoustical conditions preferred by the musicians, and how can this be achieved through the architectural design of the hall?

Our project is at the beginning of its last year and the approach for the project is to have dialogue and questionnaire with orchestras, do objective measures of the stages the orchestras regularly play at and studies with scale and computer modelling. The main question to gain knowledge about is: What are the preferred acoustical conditions by the musicians and how can this be achieved through the architectural design of the hall?

Results from orchestra questionnaire

Results from BSO (Bournemouth SO) questionnaire:

- Stage acoustics in general
- Best and worst hall regularly played at
- Best hall ever played at

- Musicians need to hear the whole orchestra clearly
- High sound level often problem for brass and woodwind
- Risers important for woodwind and very important for brass
- Reverberant sound is not essential but makes it more enjoyable/reassuring

55 players responded (81 %), 38 string, 9 woodwind and 8 brass players (no percussion)

FOCUS FOR THIS PRESENTATION:

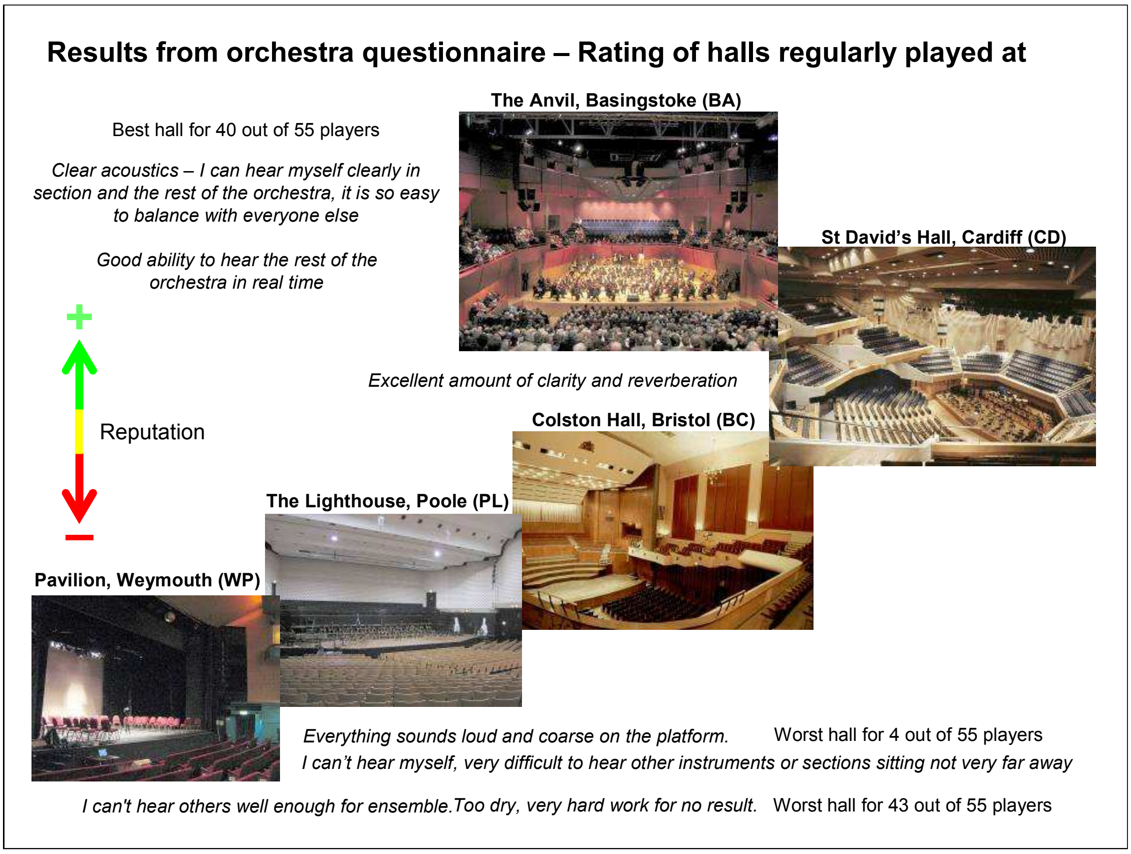
Which physical properties relate to being able to hear oneself and whole orchestra?

Submitted paper discusses stage clarity as well

Bournemouth Symphony Orchestra has responded to our questionnaire about stage acoustics in general, the least and most preferred hall they regularly play at and best hall ever played at. 81 % of the players responded. The results show: (…)

Focus for this presentation is: Which physical properties relate to being able to hear oneself and the whole orchestra?

Our submitted paper discusses stage clarity as well



When asking BSO about the best and worst halls where they frequently perform, the results are as follows:

The least preferred venue has a proscenium stage of a small theatre with drapes on stage. Some of their comments are:

"Can't hear others well enough for ensemble. Too dry, very hard work for no result"

The least preferred purpose-built concert hall is their home stage, The Lighthouse in Poole.

"Everything sounds loud and coarse on the platform"

"I can't hear myself, very difficult to hear other instruments or sections sitting not very far away"

Colston Hall in Bristol and St David's Hall in Cardiff are mentioned by a few players as the best halls with reasons like:

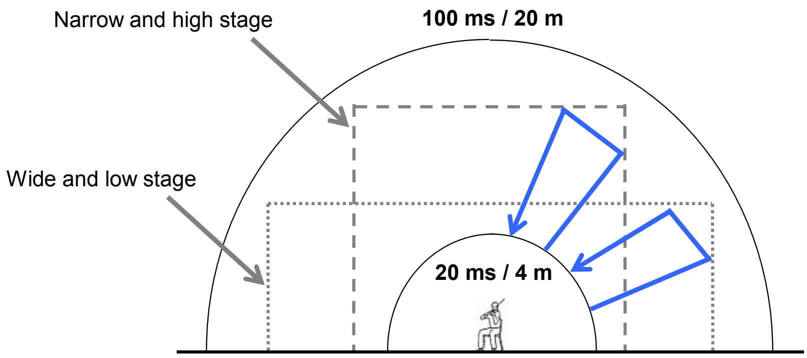
"Excellent amount of clarity and reverberation"

The most preferred hall for 40 out of 55 players is The Anvil in Basingstoke, mentioned by all instrument sections. Some of the reasons given are:

"Clear acoustics – I can hear myself clearly in the section and the rest of the orchestra, so easy to balance with everyone else"

"Good ability to hear the rest of the orchestra in real time"

Acoustic support, ST, as proposed by Gade



$$ST_{early} = 10\log\frac{E(20-100\ ms)}{E(0-10\ ms)} \qquad ST_{late} = 10\log\frac{E(100-1000\ ms)}{E(0-10\ ms)}$$

No discrimination of direction of arriving reflections

ST_{early} found by Gade to correlate with impressions of acoustic support and ensemble
ST_{early} found by Gade to correlate with stage volume

After pioneering studies on the orchestra's impression of stage acoustics, Anders Christian Gade, proposed the ST parameter to evaluate stage acoustics. ST measures the energy of reflections coming back to a musician.

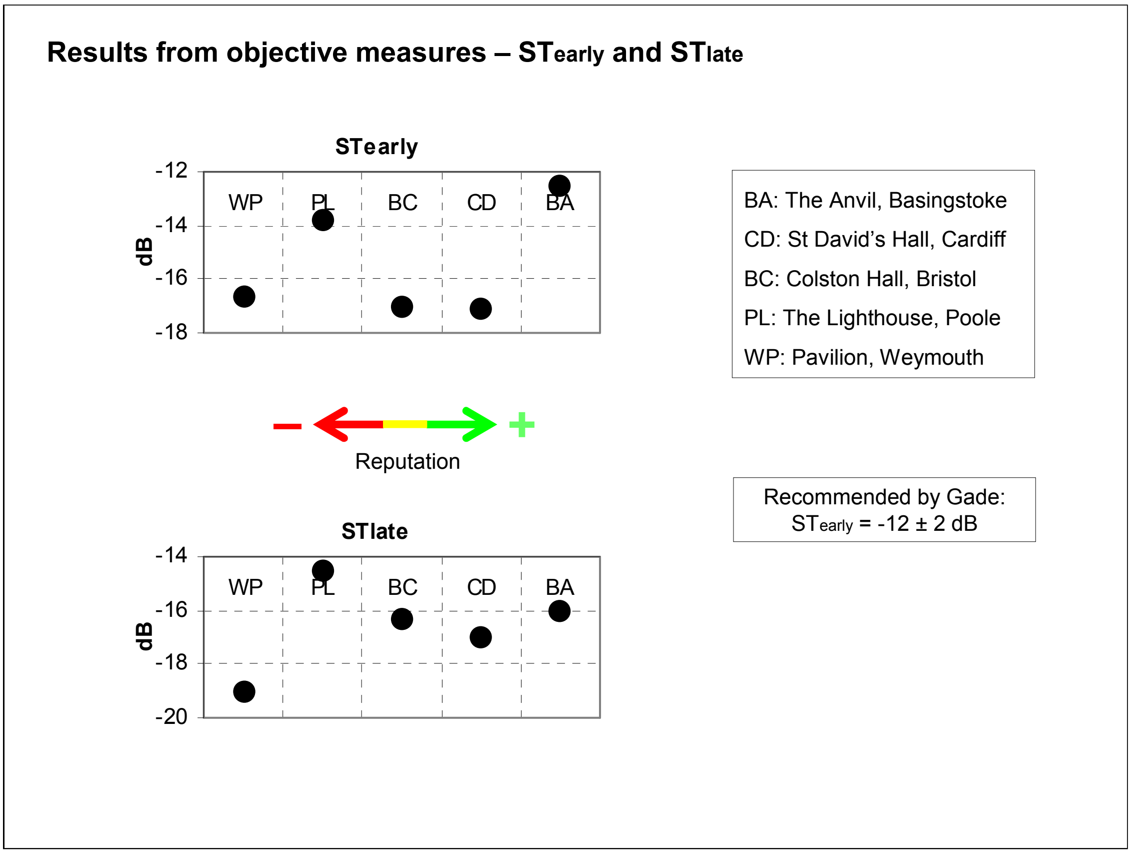
STearly measures the total early energy, defined within the time interval 20-100 ms relative to the direct sound. The direct sound 0 – 10 ms is used as a reference for measured level. STlate measures total late energy, in the time interval 100-1000 ms.

Since this is recommended measured on stage with omni-directional transducers, there is no descrimination of direction of arriving reflections

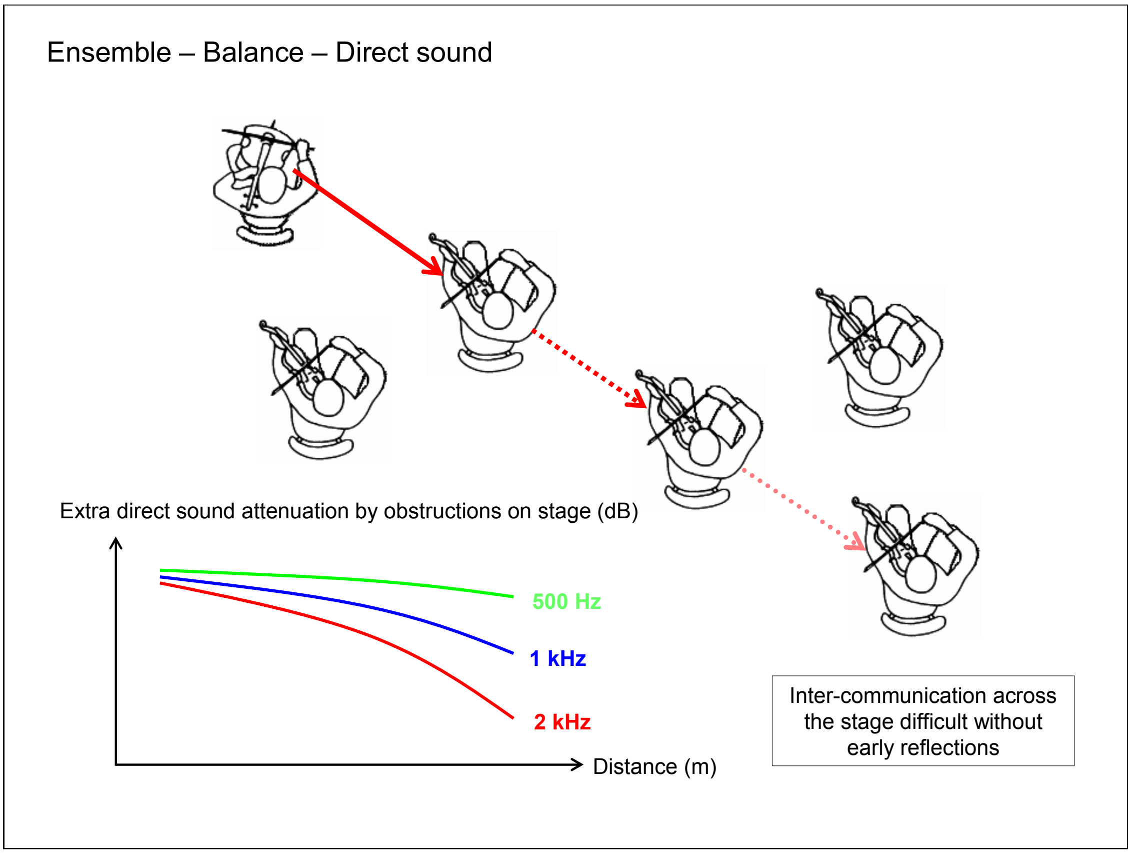
During the '80s STearly was found by Gade to correlate with the musicians' impression of acoustic support and ensemble and to correlate with stage volume.

Based on this we can see that STearly of a wide & low stage will be much the same as STearly for a narrow & high stage if the stages have similar stage volume

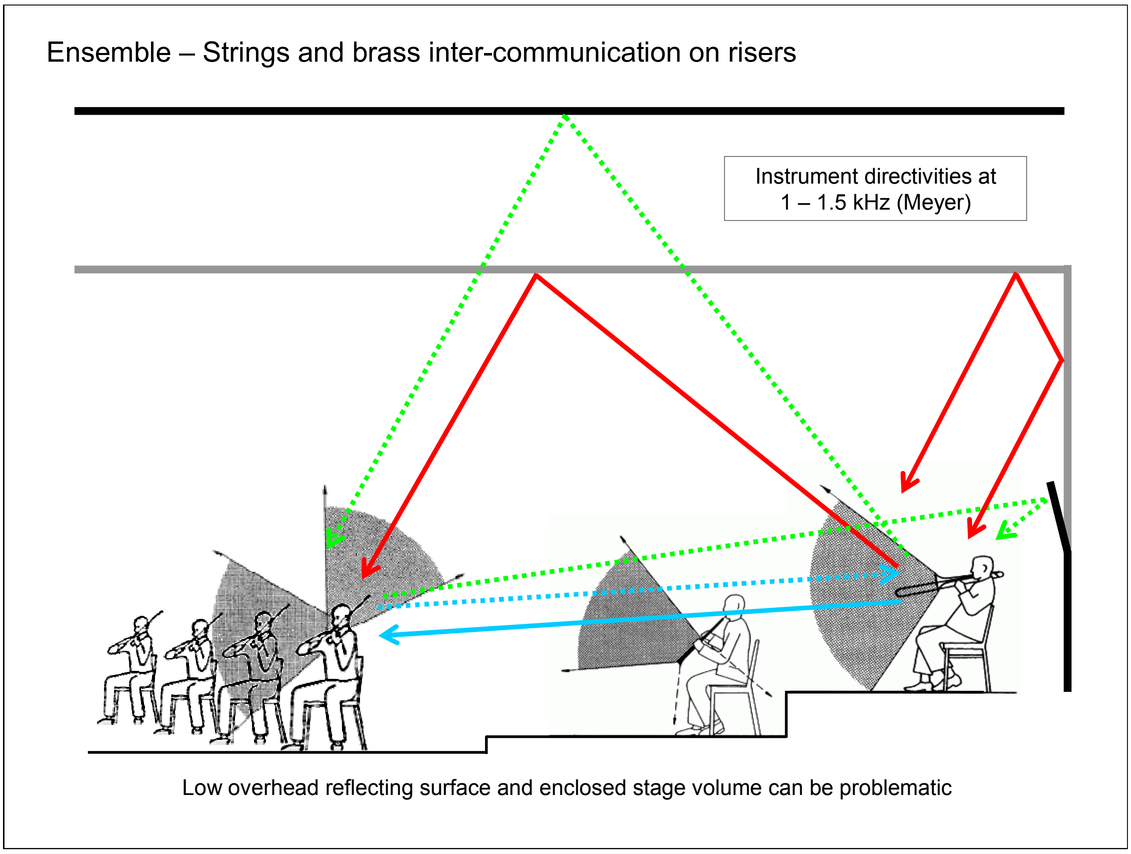
Is this ratio between width and height of importance for the orchestra?



Before we look into that in detail I'll present our results for STearly on the 5 stages studied so far. The graph shows measured STearly sorted according to reputation. When comparing the result for STearly on these stages, the values do not match good ensemble experienced in Basingstoke and Cardiff and poor ensemble experienced in Poole. The most preferred stage, The Anvil in Basingstoke, has a value comparable to the not preferred stage in Poole, and Cardiff appears to have have too low level of early reflections to achieve good ensemble according to Gade's recommendation.
STlate can be seen to agree with perceived dead acoustics in Weymouth and as an indication of perceived high sound level in Poole

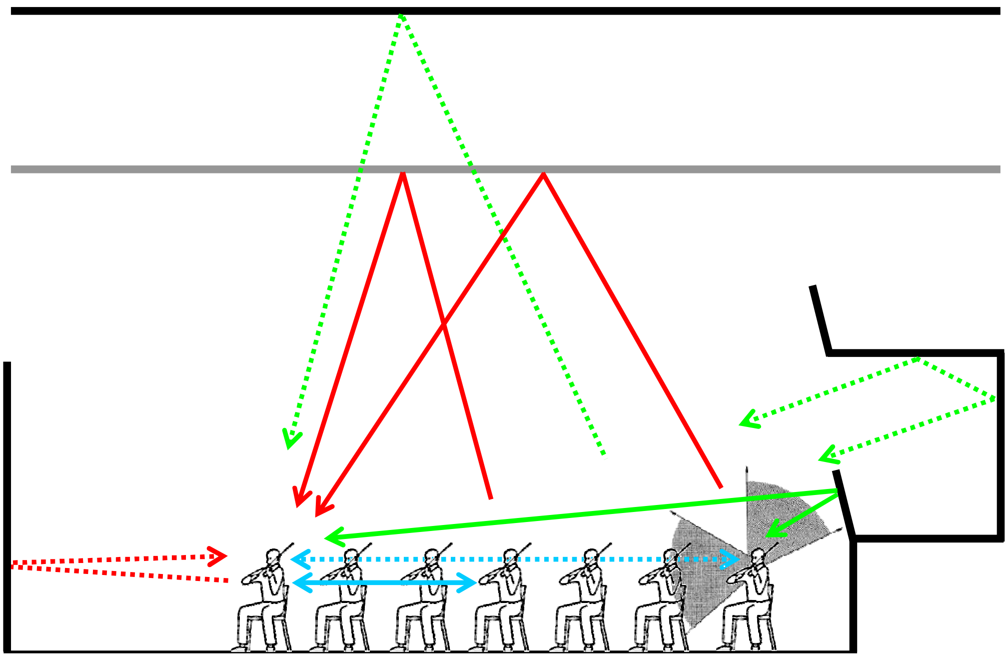


STearly starts integrating the acoustic response from 20 ms and the direct sound level is only used as a reference for measured level. The direct sound appears to play an important role for the musicians. Obstructions (musicians, music stands, instruments) start getting acoustically significant above 500 Hz and musicians sitting far apart will struggle to hear each other, both because of the large distance and excess attenuation on stage. The instruments also start getting directional above 500 Hz. String players sitting far apart will suffer the most since they are sitting on a flat floor on stage. One of the important features of the early reflections is to compensate for low direct sound level. But how?



When looking at the inter-communication between the brass and the string section, the use of risers and the directivity of the brass instruments will enable the strings to hear the brass sufficiently. The brass section's ability to hear the strings is limited due to masking effects of the brass sound and the directivity of the strings. This is supported by string players not very demanding on having risers, but brass players are. The string-brass communication can be improved by having a reflecting surface behind the brass, which will 'catch' the sound from the strings without reflecting much of brass sound at higher frequencies. But this reflection path can be problematic since percussion instruments are more omni-directional at higher frequencies, making percussion too loud for the strings.
A low ceiling will reflect brass at higher frequencies, and raise the level of brass at the string section, making it difficult to hear oneself and other string players. As mentioned is the brass section normally loud enough for the strings based on the direct sound only, making it difficult to hear oneself and within the strings. An enclosed stage will also reflect much low frequency sound which contributes to mask the strings at higher frequencies. It can also produce multiple reflections in the stage area, which to contribute to mask sound from others, oneself and the late sound from the hall. Clarity for the orchestra and for the audience can also be reduced because of higher order reflection in the stage area.
A high ceiling will move the reflection path for the brass outside the main radiation sector for the brass, and the increased distance contributes to reduce the level.
A conclusion from these observations is that overhead reflections and a low enclosed space can be problematic, while a small reflector behind the brass and percussion can be helpful for brass but often not for the strings. These observations should be considered if designing a reflector.

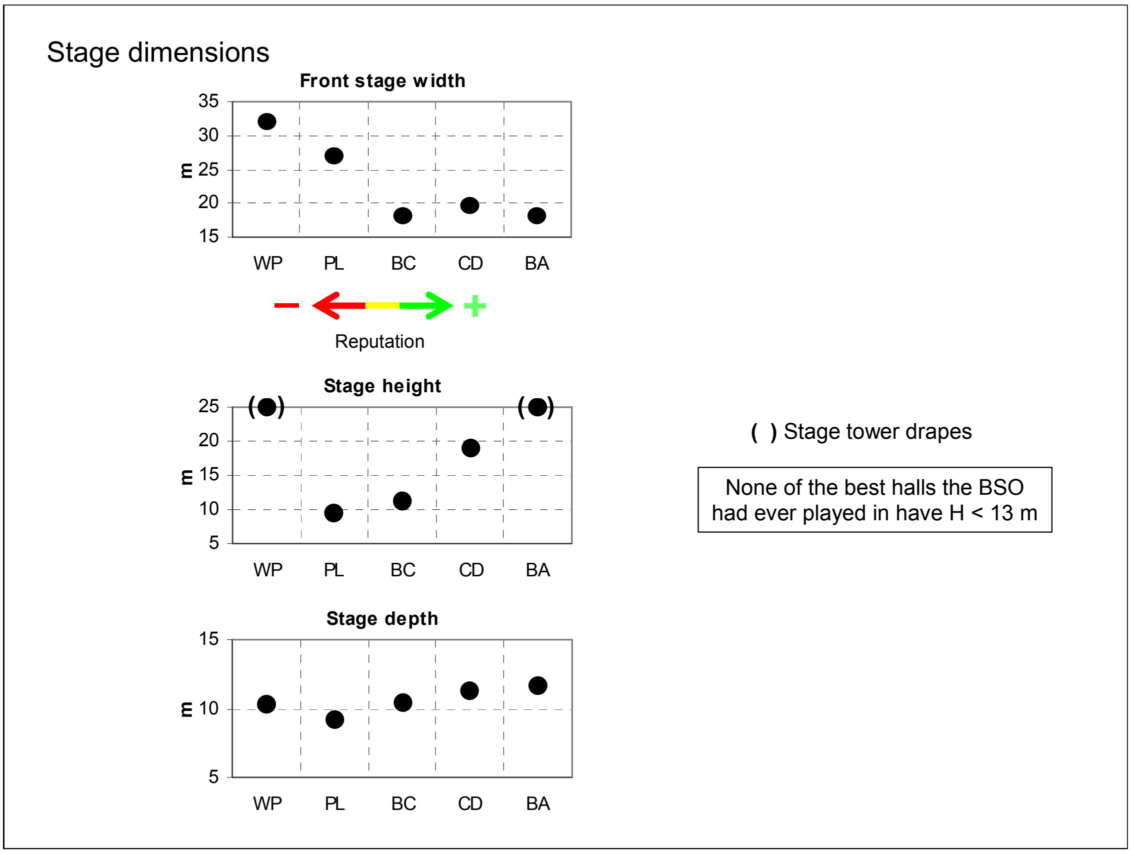
Ensemble – Strings inter-communication on flat floor



Overhead reflections can be problematic, side reflections are good

Across the stage, the attenuated direct sound level makes it difficult to hear the players on the opposite side of the stage. Players not far away will be adequately heard if not other instruments mask their sound. The most effective treatmeant will be to put a reflecting surface close the players who are difficult to hear. Both short distance to the reflecting surface and a short time delay of the reflection contribute to raise the level of the players at the opposite side. It also will arrive almost at the same direction as the direct sound. A wall 1.5 m from closest musician will result in a time delay across the stage of 7 ms, probably soon enough to avoid coloration negative coloration effects on stage observed by Halmrast. A near side wall will also raise the low frequency level of the double basses. Cornice reflections from overhanging balconies might contribute positivily as an additional reflection as this reflection path will not be much attenuated by the orchestra. A wide stage will not give a reflecting surface close to the players and the time delay of such a reflection might also be disturbing for the players sitting next to it. A wall 4 metres away will result in a time delay of one-self of about 23 ms – in the time range for disturbing coloration effects. An overhead reflection will reflect the different players almost equally and will not help for the problematic balance based on the direct sound. A ceiling of 9 metres height will give time delays of about 20 ms for the players at the opposite side, again in the range for coloration effects, and since it arrives from a different direction than the direct sound it might not fuse as easily with the direct sound as a side reflection (precedence effect considerations). The raised level of others can have a negative effect on hearing one-self and the sound from the hall. A raised ceiling will lower the level of the problematic reflections and better allow the string player to hear themselves. A conclusion from this will be that overhead reflections again can be problematic while side reflections are good.

If we take a look at the stage in Basingstoke we can recognise many of these positive elements for a good level balance: High ceiling, narrow stage, tilted reflecting panels along the edge of the stage and cornice reflection from the side. The effect of the rather small reflector in this hall, tilted to reflect down towards the audience at the stalls, has not been properly investigated yet.



Based on the observation of the positive effects of narrow side walls and high ceiling, it is interesting to study the significance of stage width, height and depth. The width is measured on stage front where the strings are sitting. When looking at the front stage width related to reputation, narrow stages are preferred, while greater height is preferred. The heights in Weymouth and Basingstoke are not so relevant because they have an absorbing stage tower.
The ratio of height and width is 0.3 in Poole while 1.4 in Basingstoke (and 1.1 in Cardiff). If studying the best halls the BSO players had ever played at a minimum height at stage of 13 metres has been found, taking any large reflectors into account.
The variation in stage depth is less significant than height and depth, and it is difficult to draw any conclusion on preference of stage depth based on the information available at this point.

Conclusions

Results so far in this project, related to orchestra balance indicate:

• For level balance within the orchestra, a narrow and high stage area appears to be better than a wide and low stage area. The differences in reflections between these design factors are not measured by ST_{early}

• An enclosed stage house can result in many reflections back to the musicians, which can contribute to mask the sound of other players, one-self and late sound from the hall

• By providing only necessary early reflections, sound level on stage is kept moderate

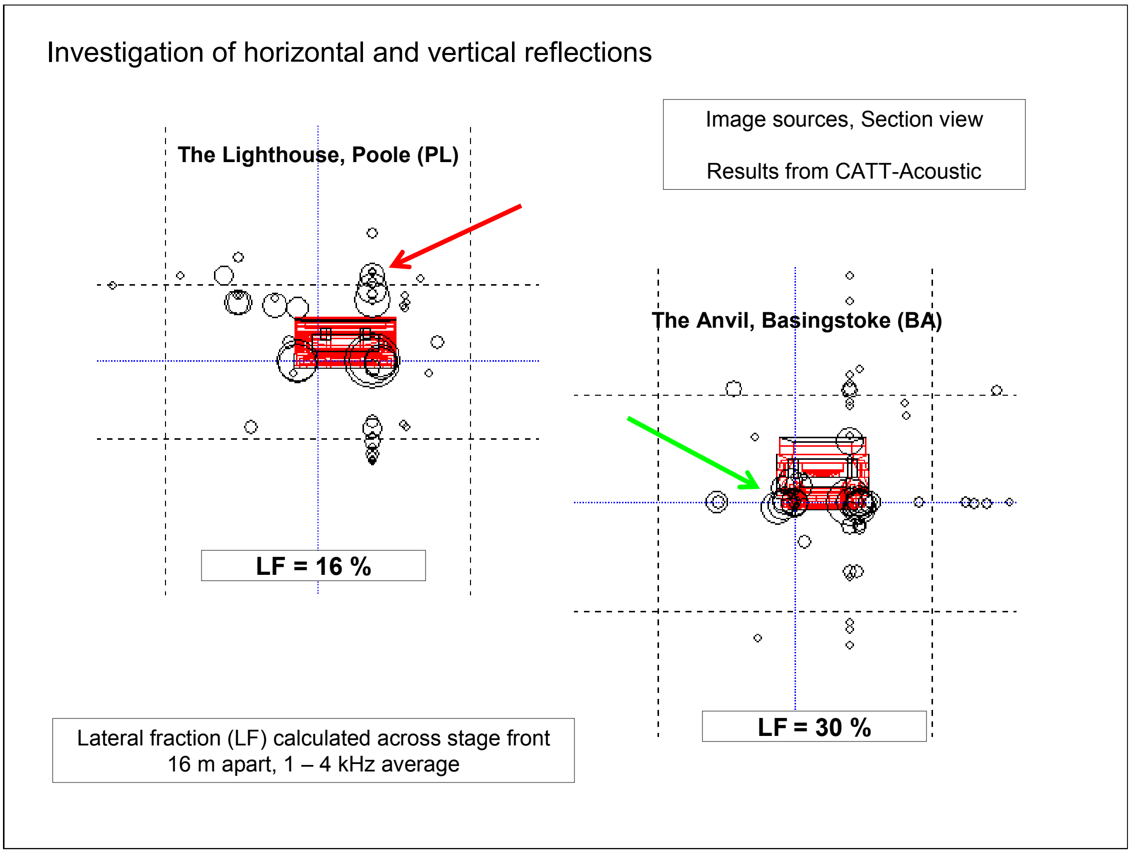
• See written paper for a possible new measure of clarity on stage

Similar results showing negative effects of too many reflections in a moderate sized concert hall will be reported by Alf Berntson and Johan Andersson in Seville ISRA

For more information, visit

http://people.bath.ac.uk/jjd22

Thanks for your attention!

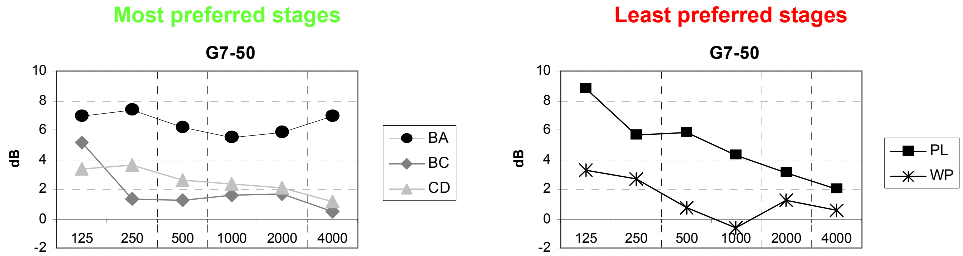


NOT PRESENTED:

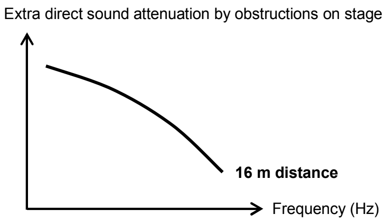
Alternative ways to investigate presence of horizontal and vertical reflections on the stage is by use of computer modelling and studying image sources in the section view. The red drawings represent the hall seen vertically facing the audience. The results show a clear dominance of vertical reflections in the less preferred stage in Poole while a dominance of horizontal reflections in the preferred stage in Basingstoke.

Lateral fraction, the ratio of side reflections (figure-8) compared to omni response, has been calculated based on these simulations and the results show a clear difference between the two stages, about a doubled value in Basingstoke.

Early reflections – Frequency and time



Based on 16 measurements on stage with source receiver distances above 4 m. Chairs on stage



Small surfaces reflect more at higher frequencies

Early reflections versus time not discussed here, see our paper for proposed method for evaluating clarity on stage

NOT PRESENTED:
The discussion above focused on the direction of early reflections, but also the frequency response of the early reflections is rather different between the stages. The graphs show G in the time interval 7 to 50 ms for the most and least preferred stages. The level decreases from 250 to 2000 Hz in Poole and Weymouth, which is not helpful for compensating for the attenuated direct sound level. In Basingstoke and Cardiff the level of early reflection is close to equal at all frequencies 250 to 2000 Hz. Small surfaces on stage contribute to the early reflections having a complementray frequency response. As mentioned, early reflections versus time is discussed in our paper and a method for evaluating clarity on stage is proposed.