Orchestra Conductor Acoustics

Magne Skålevik[1,2]

[1]AKUTEK, www.akutek.info , Spikkestad, Norway

[2]Brekke & Strand, Oslo Norway

While the playing and listening conditions for musicians have been studied and taken into consideration in research and design practice since Gade's early work in Podium Acoustics in the 1980s, the impact of room acoustics on the conductors working conditions are only rarely addressed in scientific papers. In preparation of a concert performance, conductors typically need to hear in considerable detail what is going on in the orchestra, perhaps even more during rehearsal than during the actual concert. Importantly, the conductor needs to prepare the orchestra sound and balance to be presented to the audience. In this paper, sound from a symphony orchestra in various rehearsal rooms and a typical concert hall is simulated. Features of orchestra sound at the ears of the conductor's ears and at the ears of the audience is studied. The impact of varying acoustics and the difference between sound at conductor's ears and sound audience ears are commented. In particular, the significance of compliance with ISO-23591:2021 is studied. A questionnaire suggested by this author for a survey among conductors is presented and discussed, the purpose being to provide a basis for finding acoustic measures that can describe critical aspects from the conductors' perspective.

Keywords: orchestra acoustics, orchestra conductor, rehearsal room acoustics, room acoustics

1 Introduction

While the playing and listening conditions for musicians have been studied and taken into consideration in research and design practice since Gade's early work in Podium Acoustics in the 1980s, the impact of room acoustics on the conductors working conditions are only rarely addressed in scientific papers. A noteworthy exception is the work of Jürgen Meyer[1].

In preparation of a concert performance, conductors typically need to hear in considerable detail what is going on in the orchestra, perhaps even more during rehearsal than during the actual concert. Unfortunately, due to the shorter critical distance in most rehearsal rooms, details in the orchestra are more audible for the conductor from the podium of the concert hall than in the rehearsal room.

Importantly, the conductor needs to prepare the orchestra sound and balance to be presented to the audience.

Most conductors would ideally like the sound of the orchestra at the podium to be as similar as possible to that at the audience' ears.

However, this condition is practically impossible to achieve. Then, several questions arise: How can conductors judge and adjust the orchestra balance, articulation, intonation, dynamics, etc., as perceived in the audience?

More practical, but important in the daily work for conductors – how does varying acoustics in rehearsal spaces influence on ease of speech when giving verbal instructions to musicians.

In general: What are the critical subjective aspects of acoustics, from conductors' perspective, and what are the acoustical parameters that would best describe them?

In this paper, some of these questions will be addressed. Acoustical conditions of rehearsal rooms will be categorized with regards to whether they comply with the combinations of volume and reverberation time recommended by the recent rehearsal room acoustics standard ISO-23591:2021 [2].

2 A conductor's perspective

"A conductor's task is to prepare sound and balance for the audience in the best possible way.

Good conductor acoustics would therefore,

- ideally, provide listening conditions for the conductor like those in the audience
- make balance judgements possible

As to Reverberance, preferences vary, from one piece to another, from one conductor to another."

This quote by conductor Eivind Gullberg Jensen[1], from personal communication with the author, represents the perspective of one conductor, and was the assumption of the work presented in this paper. To establish a more general representation of conductors' perspective, this author intends to conduct an online survey among conductors. A questionnaire is proposed and presented for discussion in a paragraph below.

Lehtimäki (2019) investigated the effect of concert hall acoustics on the work of a conductor by means of a questionnaire, answered by 25 conductors among 69 invited. An important result was reported on page 25 in the thesis: "Balance is the aspect that almost all of the participants reported having been affected by the acoustics of a concert hall in their performances"[3]. Moreover, the conductors express the need to judge orchestra balance by listening from the auditorium, and there is no consensus as to an optimum way of combining this with the obvious need for the orchestra to be conducted. Different from the current study, orchestra rehearsal rooms as such was not an objective in the thesis.

3 Symbols and Definitions

The following definitions apply to some frequently appearing symbols in this paper.

- V Volume in cubic meters (m^3)
- T Reverberation Time in seconds (s)
- V-T Diagram in ISO-23591:2021 for indicating recommended combinations of V and T
- G Sound Strength in dB, as defined in ISO-3382
- G_{refl} Sound strength of reflected sound, also referred to as "Room Response"
- D-R Direct-to-reverberant sound level balance, 10*log(d/r) in dB
- STI Speech Transmission Index, dimensionless (1)

Note: In this paper STI is applied for two different purposes. One is for assessing the ease of speech, i.e. the conditions for the conductor to communicate vocal instructions during rehearsals. Less obvious, perhaps, STI from an instrument group to conductor and to audience is used to assess musical articulation. The latter is based on the understanding that musical notes, in addition to tonal characteristics, has transients and transitions that could be represented by amplitude modulation like the algorithm of STI. Values are only used for comparison between rooms and receiver positions, and of course not directly comparable to recommendations for speech. For information about the sources and directivities used to simulate STI measurements, please refer to section 6 Models.

[1] Chief Conductor of the Noord Nederlands Orkest from 2022/23 season and Artistic and General Director of Bergen National Opera. Jensen has previously conducted the Berliner Philharmoniker, Münchner Philharmoniker, Hamburger Symphoniker and WDR Sinfonieorchester in Germany, Amsterdam's Royal Concertgebouw Orchestra, Vancouver, North Carolina and Oregon symphony orchestras in North America, and further in Europe the Royal Stockholm and Netherlands Radio philharmonic orchestras, Orchestre de Paris and Tonhalle-Orchester Zürich

4 Method

To learn more about how room acoustics supports the conductor's work conditions, as described above, and to address some of the questions in the Introduction, the following procedure was chosen.

- 3D-models of altogether 5 rehearsal rooms of various volume and absorption factors and one typical concert hall, all containing one and the same 90-piece orchestra, was built for acoustical simulations in the software Odeon 17
  - Two of them with V and T inside limits given in ISO-23591:2021
  - Three of them with V and/or T outside the limits of the standard (red numbers in Table 1)
- Sound emission from the symphony orchestra in the various room models was simulated by using the multi-source feature in Odeon
- Selected features of orchestra sound at the ears of the conductor's ears and at the ears of the audience is simulated and analysed, including
  - Orchestra balance, i.e. level profile of instrument groups
  - Articulation of music, in terms of the STI profile of instrument groups
  - Reverberance, in terms of the EDT profile of instrument groups
  - Localization, in terms of the Direct-to-Reverberant ratio profile of instrument groups at conductor's ears
- Global parameters of the unoccupied room models, including T and $G_{reflected}$ were simulated
- The difference between sound features at conductor's ears and those at audience' ears, and it's dependency on V, T and $G_{reflected}$ is identified and commented
- Features in orchestra sound at conductor's ears in various rehearsal room models are compared with
  - Listening quality for the conductor in the concert hall
  - Listening quality in audience
- Ease of speech during verbal instructions to the orchestra, in terms of STI, in various rehearsal rooms are compared relatively and assessed with common criteria
- In particular, results are commented relative to whether or not the various rehearsal rooms comply with the requirements in ISO-23591:2021

5 The rehearsal room acoustics standard, ISO-23591:2021

In the recently published rehearsal room standard ISO-23591:2021, requirements are given for minimum volume per musician, in addition to a range of V-T combinations, i.e. combinations of room volume and reverberation times, applying to symphony orchestra rehearsal rooms. In the current study, rooms complying to the standard as well as rooms not complying to the standard are included, to be able to see what significance such compliance has for the conductor acoustics.

6 Models

The geometrical rehearsal room models had the same floor and orchestra while heights varied, to produce the room volumes V=2700m^3, 5400m^3 and 6500m^3. The two bigger rooms have volumes that comply with the ISO-23591:2021 for a 90-piece orchestra (at least 60m^3 per musician). The smaller one had half the volume required by the ISO-standard. A fourth room was a typical concert hall in shoe-box shape, having a volume of V=20.000m^3, in which the rehearsal room floor forms the stage floor. To the orchestra and conductor, the concert hall auditorium would be like an extension to a big rehearsal room where one of the walls were knocked down. The four geometrical string models are shown in Figure 1 below.

Various degrees of absorption was assigned to walls and ceiling of the models in order to generate rooms with various T, and in particular some inside and some outside of the range of V-T combinatins given by the standard. Altogether 7 room models are generated by this process. Their key properties are given in Table 1, and they are plotted by their V-T combinations into the ISO-23591:2021 V-T diagram in Figure 2.

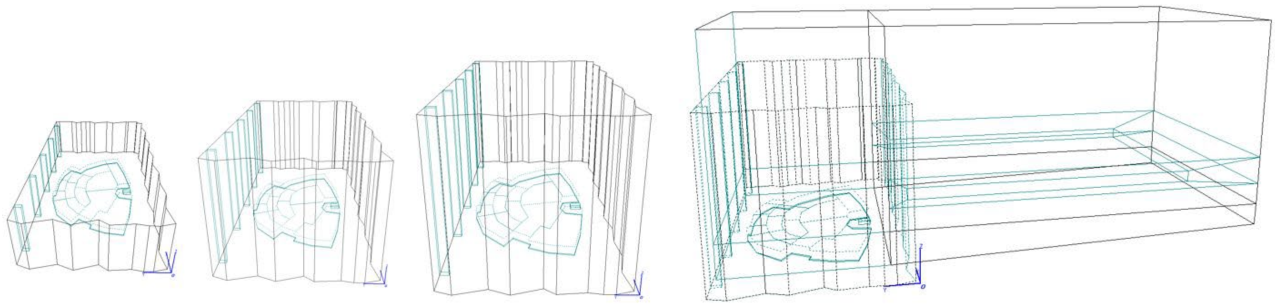

Figure 1 Geometry of the 3D-models in this study

Table 1 Key properties of the models included in the study. Table entries of models not complying with the volume or revrberation time limits in ISO-23591:2021 are in red.

Model #	Volume (m^3)	α walls+ceiling average	T_m empty (s)	G theoretical (dB)
1	2770	0.18	1.93	13
2	2770	0.25	1.43	11
3	5400	0.25	1.87	10
4	6500	0.30	1.63	8
5	5400	0.37	1.23	8
6	6500	0.40	1.20	7
CH	20515	0.24	2.10	5

Sound sources were simulated with the built-in sources in Odeon 17. String groups were simulated with multi-surface sources with spherical radiation characteristics, while other instruments were simulated as point sources. Wind instruments were pointing towards the conductor, with the instrument-specific directivities provided by Odeon, while percussion instruments were simulated by omni-directional point sources.
In this study, the individual sound powers did not have any effect on the results, since all results are either related to levels received by the conductor or in the audience statistics or expressed in terms of strength (G) related to free-field SPL at 10m distance from omni-directional source.
For the assessment of ease of speech for the conductor, the conductors voice was simulated with an omni-directional source, to mimic the always varying head orientation of a conductor, who needs to be understood by the all orchestra members regardless of the orientation of the conductor’s head.

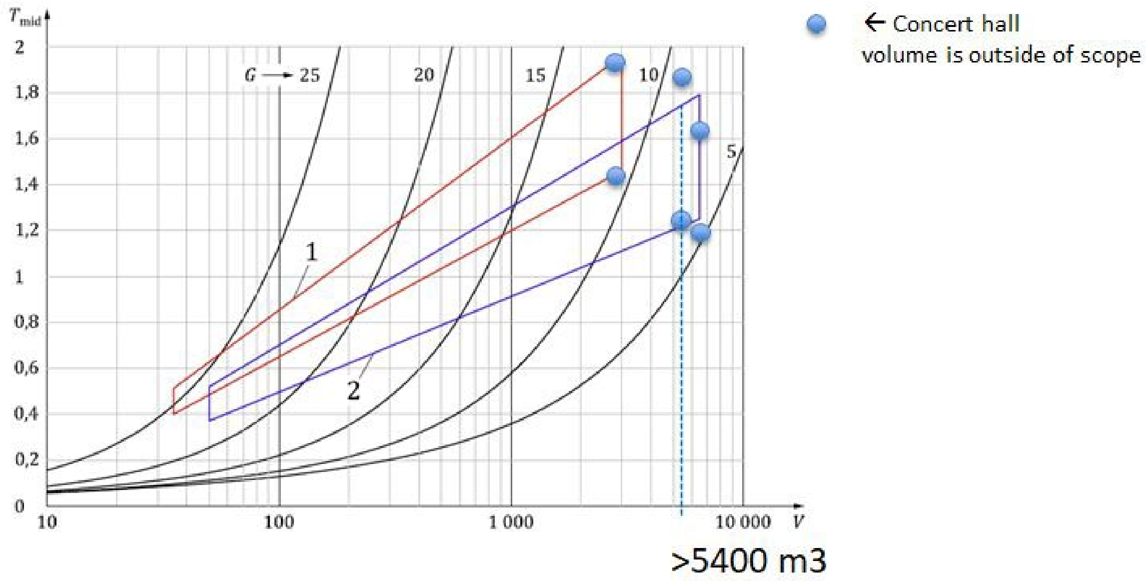

Figure 2 All models in Table 1 plotted in the V-T-diagram of ISO-23591:2021, where the blue box indexed ”2” marks the range of V-T combinations applying to rehearsal rooms for Loud Acoustic Music. The vertical dashed line marks the volume limit 5400m^3 implied by the 60m^3 per musician requirement

7 Results and comments

Results from the simulations and analysis are given in diagrams below, together with relevant comments in captions, according to the method presented above. In all the profile diagrams, rooms are ordered by their theoretical Strength, G in dB, decreasing towards the right, and where the rightmost is the concert hall podium. Theoretical values are calculated outside the reverberation radius, thus $G \approx G_{refl}$.

7.1 Orchestra Balance at conductor’s ears

From Figure 3, it is concluded that the orchestra balance in the audience cannot be judged and adjusted directly by listening to the orchestra balance at the conductor’s ears. For the balance at audience’ ears to be perfectly according to the conductor’s intention, the string groups 1st & 2nd violins, violas and celli would need to dominate by 3dB over the orchestra average, while brass and percussion would need to sound a bit weaker than the orchestra average. This difference in balance is due to the four mentioned string groups are closer to the conductor than the average instrument, and the brass and percussion are farther away than the average instrument. As a preliminary conclusion it is advised that the conductor needs to find other cues for orchestra balance in the audience than the balance at conductor’s own ears.

This observation is very important, and can explain the unison expression from conductors, reported by Lehtimäki [3], that working with orchestra balance is challenging, and that they feel they must listen from the auditorium themselves to confidently judge whether or not the orchestra balance is according to their intention.

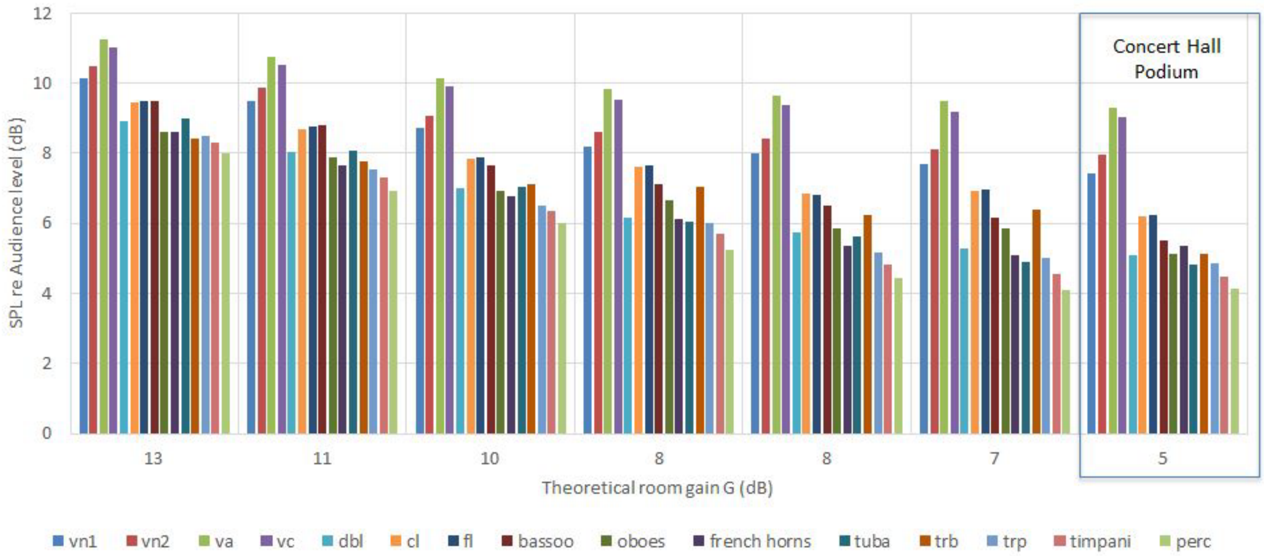

Figure 3 Instrument group level profiles at conductor's ears in the 7 rooms. Vertical axis is level in dB where 0dB is defined as the levels at median (50 percentile) audience ears. Note that on the concert hall podium (room model # 7), strings groups except double basses dominate at conductor's ears by approximately 3dB over ther rest of the orchestra, relative to the balance at audience ears.

In our search for a parameter that for the conductor can serve as a cue of orchestra balance in the audience, Figure 4 reveals that indeed, the room response, i.e. the profile of G_{refl} in dB from the instrument groups to the conductors ears can serve as such a cue. This suggests that in optimisation of rehearsal rooms and podium acoustics for the conductor, one should pay attention to acheiving a flat G_{refl} -profile, with the audience profile defining 0dB like in Figure 4.

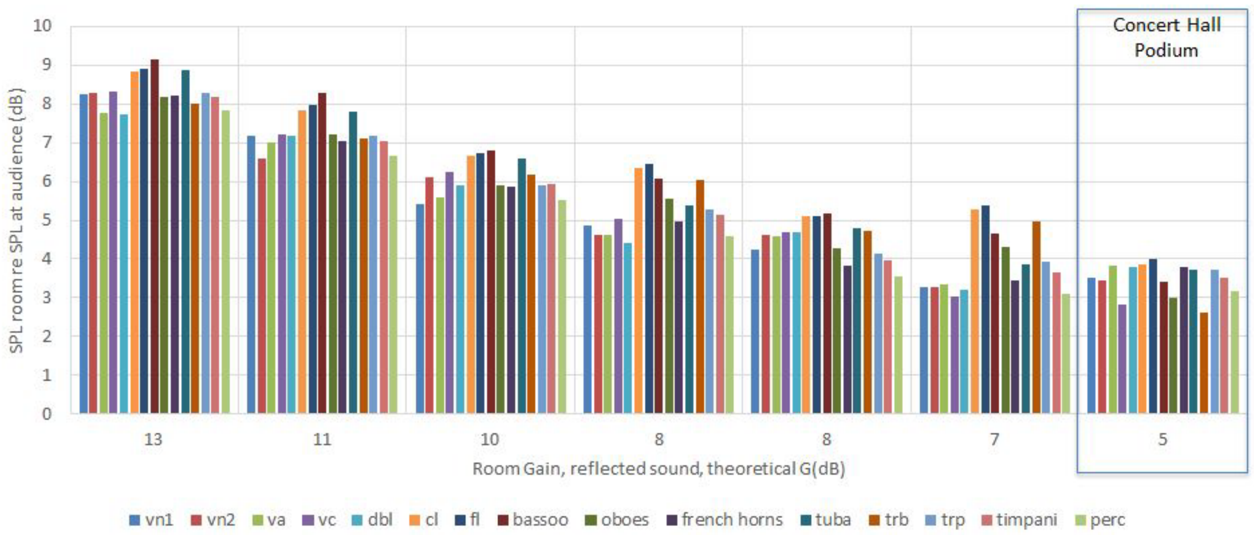

Figure 4 Room response profiles at conductor ears in the 7 rooms. Vertical axis is room response (G_{refl}) in dB where 0dB is defined by the room response heard at median audience ears (50 percentile). Note that on the concert hall podium (room model #7), the profile is effectively flat, i.e. with less than a noticeable difference from the 3dB level above the levels at audience' ears. Moreover it is noteable that the profile in room model #5 is also quite flat, though on average 1.5dB stronger than on the concert hall podium.

7.2 Articulation

Articulation of music, as heard by the conductor, is represented by the STI-profiles in Figure 6. Note that on the concert hall podium, the articulation is from considerably higher to much higher than in the audience.

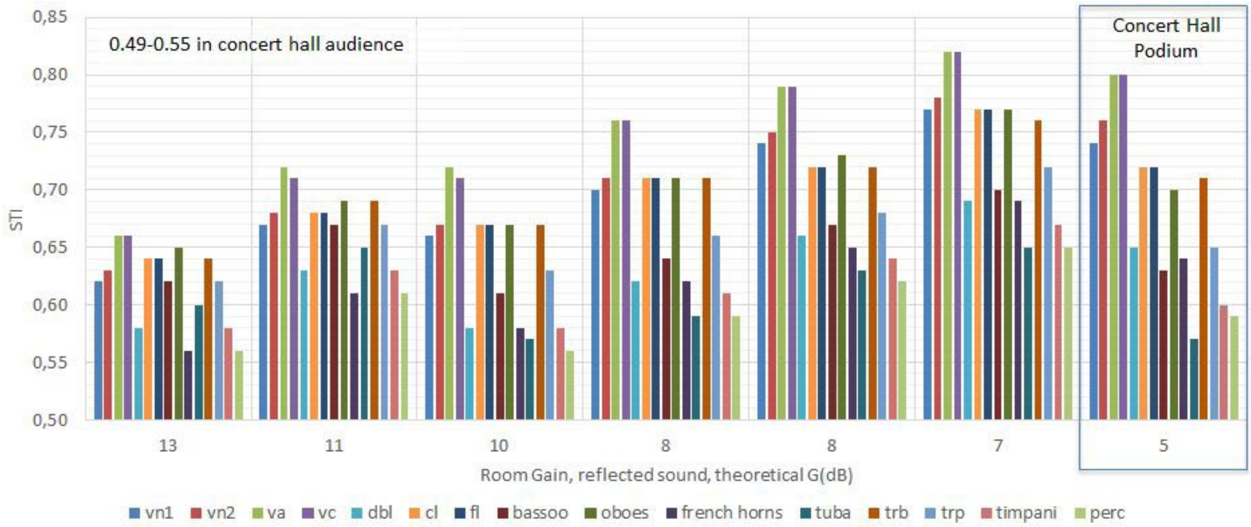

Figure 5 Instrument groups' articulation profiles in terms of STI from each instrument group to the conductors ears in the 7 room models. In the concert hall audience, the articulation is 0.49-0.55, which represent the baseline of the diagram.

The articulation profile received at the concert hall podium is quite uneven, ranging from 0.57 to 0.80, which is more uneven than in most of the rehearsal room models. However, the important fact is that in any of these room models, the articulation of any instrument group is higher at the conductor's ears than in the audience.

This means, 1) that any articulation details audible in the audience, will be detactable by the conductor, but 2) the articultaion will be softer, or more blurred, in the audience than perceived directly by the conductor, and the conductor cannot exactly judge to what degree the musical articulation is conveyed to the audience. Whether this lack of monitoring the musical articulation is an actual problem or not is not clear, but it is hypothised that while conductors sometimes work hard to over-emphasise articulation to fight excessive blending in over-reverberant rooms, they would rather not do it if they could be sure the articulation was sufficient.
So, for now we assume that it is important for a conductor to know whether or not the music is articulated just adequate, but we conclude that the exact judgement of articulation cannot be made from the conductors position in any room, regardless of its acoustics. This means that the conductor in this concern has to move into the concert hall auditorium to make the judgement.

7.3 Reverberance

The reverberance profiles in Figure 6 shows that the reverberance of the instrument groups heard by the conductor on the concert hall podium is quite representative for the reverberance in the audience, with a exceptions. Again, the proximity to the nearest strings, the violas and celli in particular, affects the orchestra EDT-balance, but 1st & 2nd violin groups are not as strongly affected by proximity as was the level balance in Figure 3. Room model #3, which does not comply to the V-T requirements of the standard, is the rehearsal room that has reverberance at conductor's ears closest to that on the concert hall podium. Among the rehearsal room models that comply with the standard, #4 is the one with conductor's reverberance closest to that on the concert hall podium.

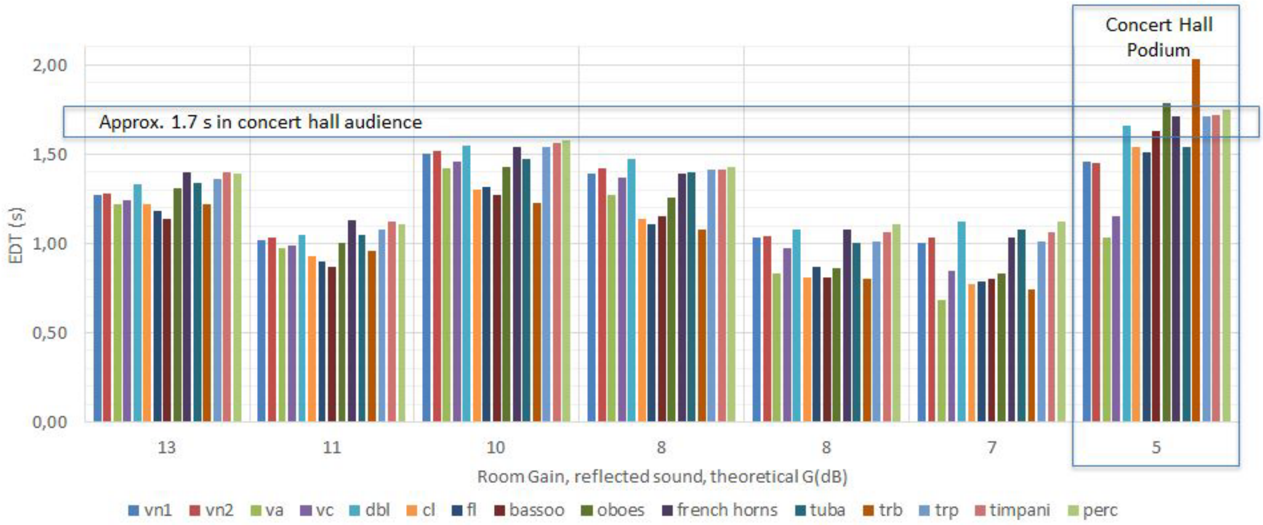

Figure 6 Instrument groups' reverberance profiles, in terms of EDT (s) from each individual instrument group to the conductor's ears, in the 7 room models. In the concert hall audience, EDT is in the 1.6 to 1.8s range. Note that on the concert hall podium, the four string groups, 1st & 2nd violins, violas and celli, are perceived with less reverberance than the audience, while the rest of the instrument groups are perceived with revereberance similar to that in the audience. One exception is the trombones (trb) which sounds more reverberant in the conductor's than in the audience' ears, which in the concert hall model is due to a rather late reflection off the back wall in the auditorium, an effect made stronger by the directivity of the trombone.

7.4 Direct-to-Reverberant level balance

From Figure 8 we see that the closer the theoretical G_{refl} is to 5dB, the closer the D-R is to 0dB, i.e. the direct sound from the orchestra equals the room response. A relatively high D-R makes localization possible, a feature which is very important during rehearsal sessions, in order for the conductor to presicely localize and detect details in individual instruments or groups. D-R should not too high, though, and D-R=0dB is considered an optimum. G_{refl} =5dB is considered to be optimum in concert halls, but since this requires a lot of absorption, such conditions would require volumes of more than 10.000m^3, to provide for other acoustical aspects.

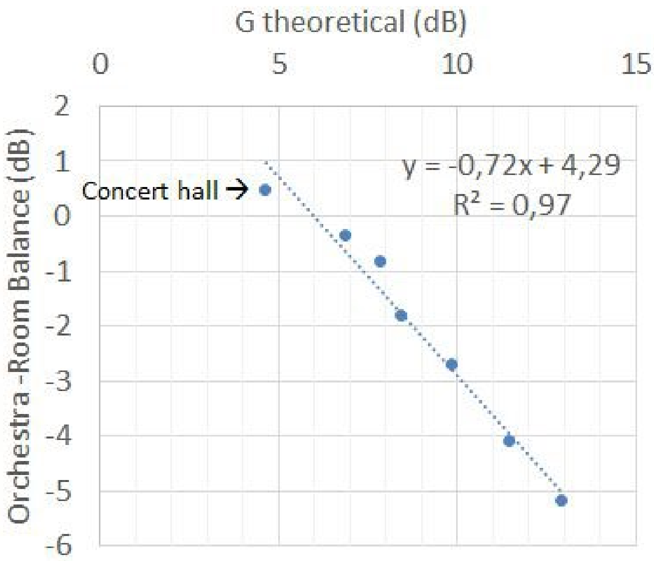

Figure 7 The seven room models plotted with orchestra's D-R level balance on the vertical axis and theoretical G_{refl} on the horizontal axis. The closer the theoretical G_{refl} is to 5dB, the closer the D-R is to 0dB

7.5 Ease of speech during vocal instruction

From Figure 9 we see that conditions for vocal instruction are very good in the rooms complying with the standard. The concert hall deviates negatively from the trend, naturally due to late reflections from the beck of the concert hall auditorium. In the rehearsal rooms, though, the trend is again - the closer to G=5dB, the better.

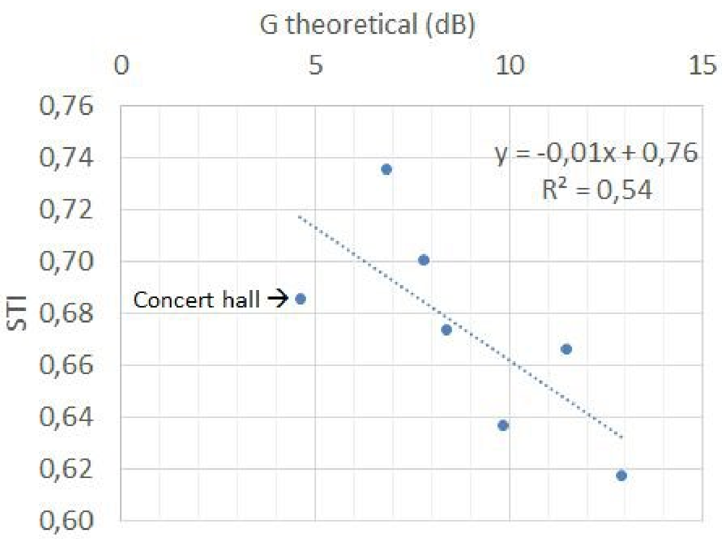

Figure 8 Average Speech Transmission Index (STI) in the communication line between conductor and musicians, in the 7 room models. During rehearsal on the concert hall podium, STI=0.68, whis is considered very good. In the two room models comlying with the standard, #4 and #5, values are 0.68 and 0.70.

8 Conclusion

Orchestra level balance as heard by the concert hall audience cannot be judged directly from the conductor's podium in any of the rooms. However, it can be judged by listening to the instrument balance in the room response, on the concert hall podium and in one of the rooms (#5) complying with ISO-23591:2021. Articulation of music is sufficient in all the rooms studied, but it cannot be optimized in any of the rooms. For this purpose, the conductor needs to visit the concert auditorium. Reverberance in the approved rehearsal halls is too dry to be representative for the concert hall audience' sound, while reverberance on the concert hall podium is quite like that at audience ears, except for the reverberance from the violins nearest to the conductor. When it comes to conductor's localization of individual instruments as well as conditions for vocal instructions, the rule seems to be the closer to G_{refl} =5dB, the better. However, such low room response must be combined with somewhat bigger volume than in the current study, bringing us closer to the point where the rehearsal room volume approaches that of a performance hall.

9 Further work – Questionnaire

To learn more about how conductors at work are influenced by acoustics, a questionnaire is suggested below, as a starting point for discussion. The intention is to simulate acoustics of the performance rooms judged by the conductors, in search for critical features that can be predicted and used to assist the design of new spaces or the problem-solving of existing spaces.

"In this questionnaire, we invite you to judge the conductor acoustics of several well-known performance spaces, specifically how well their acoustic conditions support your work as a conductor.

- In a performance space in the list where you have conducted an orchestra once or more, what is your overall judgement of its Conductor Acoustics, on a scale from 1 to 5?
- On a scale from 1 to 5, how much do the following questions count in your judgement?
    - How easy/difficult is it, at conductor's podium, to prepare the orchestra's sound and balance as you would like it to be heard in the audience?
    - How easy/difficult is it, from the podium, to judge the audience' listening conditions?
    - How easy/difficult is it to hear important details in the orchestra?
    - How easy/difficult is it to give verbal instructions during rehearsal
    - Do you hear an adequate amount reverberance from the room? "

Acknowledgement

The author wishes to acknowledge conductor Eivind Gullberg Jensen for fruitful input and discussions, and the reviewers for their helpful and encouraging comments.

Reference

[1] Meyer, J., Acoustical Demands for the Conductor's Location, Build.Ac., June 2008

[2] ISO, Acoustic quality criteria for music rehearsal rooms and spaces, ISO-23591:2021

[3] Lehtimäki E., The effect of concert hall acoustics on the work of a conductor, MSc Thesis, Aalto University, School of Electrical Engineering, Helsinki, Finland