ISRA 2019 AMSTERDAM

PROCEEDINGS of the
International Symposium on Room Acoustics

15 to 17 September 2019 in Amsterdam, Netherlands

NAG NEDERLANDS AKOESTISCH GENOOTSCHAP

Orchestral Preferences for Discrete Overhead and Side Wall On-Stage Reflections

Gregory MILLER[1]; Carl GIEGOLD[2]; Scott PFEIFFER[3]; Dawn SCHUETTE[4]; Laura BRILL[5]

[1,2,3,4,5] Threshold Acoustics, LLC, United States of America

ABSTRACT

While it is understood that orchestral musicians benefit from reflections derived both from overhead and side wall surfaces, most existing metrics focus on reflection timing and level in relatively broad time windows and without regard for direction. Studies with orchestras who perform on a wide range of stage configurations have led the authors to conclude that discrete first-order overhead and lateral reflections are at least as important as statistical energy/time-based metrics for ensemble support. For overhead reflections, a predictable relationship was found between the preferred timing of first-order reflections and the strength of those reflections, considering ceiling or canopy height (for timing) and a combination of ceiling openness, diffusivity, height, and angle (for strength). Studies of lateral reflections focused on downstage conditions for string players, whose preferences were primarily affected by proximity downstage side walls and the diffusivity of those walls. Preferences for overhead/lateral reflections were found to be similar comparing performance versus rehearsal, especially for professional orchestras who consistently rehearse on the stage of their own hall. The understanding of these preferences has been used to improve conditions for a number of long-suffering orchestras, sometimes via simple- but-counterintuitive changes to overhead canopy settings and/or introduction of modest downstage surfaces.

Keywords: Sound, Stage, Orchestra

1. INTRODUCTION

The on-stage environment for orchestral musicians can significantly influence the quality of the performance perceived by an audience. Unlike contemporary amplified performances, in which musicians hear themselves via adjustable monitor loudspeakers, orchestral musicians rely on the architecture of the room to provide sound reflections that allow them to perceive the loudness, timbre, and timing of both their own playing and the integration of their playing into the larger ensemble.

The necessity of providing early reflections from the stage enclosure for clarity of sound, and later reflections for perception of room response have understood for some time. Metrics for evaluating on-stage hearing conditions have been proposed by Gade [1], Barron [2,3], and others. These metrics – including Support (ST), Ensemble Level (EL), Ensemble Balance (EB), and the use of Late Strength (G_{late}) – have been adopted in many building design briefs and, in the case of ST, included in international measurement standards. In each case, however, the metrics involve the integration of acoustic energy over a relatively wide window of time. This integration has the potential of masking the effect of individual sound reflections which, in the authors' experience, can have a significant affect on a successful stage environment. The focus of this paper is on the role of a few of those discrete reflections on stage acoustics.

The genesis of this investigation came from work with several orchestras who played in halls with variable-height over-stage canopies, each of whom had chosen to set their canopy at unusually low positions. Each of these orchestras complained of loudness on stage and expressed concern about cross-stage hearing conditions, yet when the canopies were raised to higher elevations the downstage strings all expressed a severe lack of support, both for their own sound and for hearing other nearby

[1] gmiller@thresholdacoustics.com
[2] cgiegold@thresholdacoustics.com
[3] spfeiffer@thresholdacoustics.com
[4] dschuette@thresholdacoustics.com
[5] lbrill@thresholdacoustics.com

string musicians. The introduction of new downstage side wall surfaces, nearer to the longitudinal centerlines of the stages than the prior side walls, provided the strings with the support they needed to allow the canopies to be raised, reducing loudness and improving cross-stage listening conditions.

After working on several stages with similar themes in both deficiency and solution, a more formal review of the reflection patterns for these and other stages was undertaken to refine the understanding of the most preferred level and timing for downstage side wall and overhead reflections.

2. REFLECTIONS FROM DOWNSTAGE WALL SURFACES

Downstage instruments, typically violins and sometimes celli, have fewer nearby-surfaces to provide acoustic support compared to the rest of the orchestra: they are most remote from the upstage wall, are under the highest point of a sloped ceiling, and at the widest point of angled side walls (these last two do not apply to perfectly rectilinear rooms, of course). In a number of halls, the width of the stage is significantly less than the width of the audience chamber; rather than making a single large step from the stage width to the audience chamber width, many architects resolve this offset by stepping the walls to an intermediate width at the downstage edge. Two halls that are exemplars of this condition are Verizon Hall at the Kimmel Center for the Performing Arts in Philadelphia, USA; and the Concert Hall at the John F. Kennedy Center for the Performing Arts in Washington, DC, USA.

Figure 1 – Case Study Halls (Verizon, Kennedy Center left to right)

These halls are configured as follows:

Table 1 – Stage Widths Pre- and Post-Renovation

Concert Hall	Mid-Stage Width	Downstage Width (Pre-Renovation)	Downstage Width (Post-Renovation)
Verizon Hall	23m	29m	24m
Kennedy Center*	18m	26m	21m

* Kennedy Center renovation is not yet complete; "post-renovation" refers to mockup testing completed with the National Symphony Orchestra to confirm renovation goals

Orchestras are typically seated up with the first stand musicians about 2.5m off centerline at the downstage edge. At the Kennedy Center, the concertmaster position was approximately 11.5m away from the downstage sidewall. Each subsequent stand of strings was 1.2m further from centerline. This led to a delay time of approximately 65ms back to the concertmaster for sound they created, and approximately 55ms between the concertmaster and third stand violins. At Verizon Hall these were measured to be approximately 70ms back to the concertmaster, and approximately 60ms between concertmaster and third stand.

While reflections in these time ranges could contribute to strong ST ratings, and would contribute to other measures of good clarity, the downstage string musicians in both halls reported feeling "exposed" and unable to gauge the level of their own musical dynamics relative to the rest of the orchestra.

To combat this sense of exposure, orchestra managers had reduced the elevations of overhead canopies at both venues, assuming that bringing the overhead surface closer to the orchestra would solve all of their concerns. At the Kennedy Center the canopy was reduced to 7.5m above the stage elevation, for a delay of approximately 35ms both to self and between first/third stands. At Verizon Hall the canopy was set 10m above stage, resulting in a delay time of approximately 55ms to self and between first and third stands. The strings within both orchestras reported a sense of support from the overhead reflections with the lower canopies, but these settings led to a host of other concerns as related in the following section on overhead reflections.

With the need to raise the canopies to higher elevations, the goal of replacing overhead reflections with more supportive downstage side wall reflections was explored. At both the Kennedy Center and Verizon Hall, temporary lightweight "mockup" panels were installed for a set of rehearsals and one weekend of concerts. In each case, the mockup panels were placed in-line with the walls that were further upstage, reducing the width of the downstage zone as much as was deemed architecturally viable at the time of the test. The narrower widths, reported in Table 1, resulted in delays of approximately 45ms to self and 35ms between first and third stands at the Kennedy Center, and approximately 55ms to self and 40ms between first and third stands at Verizon Hall. In both cases, the downstage string musicians reported feeling supported and able to gauge their loudness better regardless of overhead canopy elevation. Permanent surfaces were incorporated as part of renovations to Verizon Hall, and are planned for future implementation at the Kennedy Center.

Based on interviews with musicians in the string sections who had rotated through various stand positions, subjective listening by the authors within the orchestra, the following observations were made:

- A sound reflection arriving more than 50ms after direct sound, and being preceded by no other reflections (except off the floor and stands), did not help musicians feel supported or able to judge loudness balance. Such a reflection appears to have a "distancing" effect, leading musicians to feel as though they are remote from any supportive surfaces.
- There was a preference for the reflections off narrower downstage side walls than the reflections off a very low ceiling reflector. It was suspected, but could not be confirmed, that this was due in part to the relative continuity of the new downstage side walls with the side walls further upstage.

These same principles were applied to numerous other halls, including renovations to Symphony Hall in Atlanta, USA and the National Arts Centre in Ottawa, Canada. The downstage width in Atlanta was reduced from 22.5m to 20.5m, and in Ottawa from to 27.5m to 21.5m. While these changes were made in combination with other renovation work and their effect cannot be completely isolated, it was noted that the downstage string musicians all reported strong feelings of support throughout the process during which overhead surfaces were being adjusted during hall tuning.

In summary, downstage string musicians were found to feel strongly supported by reflection patterns that included a first side wall reflection-to-self of less than 50ms, and an intra-sectional reflection (i.e. first stand to third stand) of less than 37ms. This single path of reflection – the downstage side wall – played a significant role in improving on-stage acoustic conditions.

3. REFLECTIONS FROM OVERHEAD SURFACES

As noted in the previous section, the overhead canopies in the two side wall case-study halls (Verizon Hall and the Kennedy Center) were set quite low. While some authors have recommended stage ceiling elevations below 10m [4,5,6], in the case study halls the sound within the audience took on a highly frontal character – which could be characterized as a limited Apparent Source Width – and the sound on stage became much too loud for musician comfort. The choice to move a canopy down to a lower elevation to improve on-stage hearing is an intuitive choice: if hearing is challenged, bring reflecting surfaces closer. As discussed by Blair [7] and others, however, a more appropriate choice may be to raise the elevation to reduce loudness and allow other reflective surfaces to provide beneficial sound reflections.

The authors have identified a preference for overhead reflecting surfaces ranging from 11m to 15m. As discussed below, however, this range should not be read to suggest that "anything within that range will be acceptable." Stage ceiling height guidelines are often expressed without any additional context. This may be a result of guideline originators' assumptions that the height guideline is attached to a particular ceiling design strategy: a spaced array of reflectors; a more solid canopy; a strongly diffusive fixed ceiling, etc. The findings in this paper are based on understanding the acoustic behavior of different ceiling configurations, and successful means of deploying these different configurations based on the needs for timing and level of overhead reflections.

Several different kinds of overstage ceiling configurations were reviewed.

- Spaced array of relatively lightweight reflectors, with approximately 40% openness (Strathmore Concert Hall in Bethesda, USA as case study)
- Canopy of several large elements, but still with gaps approximating 15% openness (Kiewit Concert Hall in Omaha, USA and Kennedy Center Concert Hall as case studies)
- Canopy of large horizontal elements with effectively 0% openness (Verizon Hall as case

study), or fixed ceiling with 0% openness

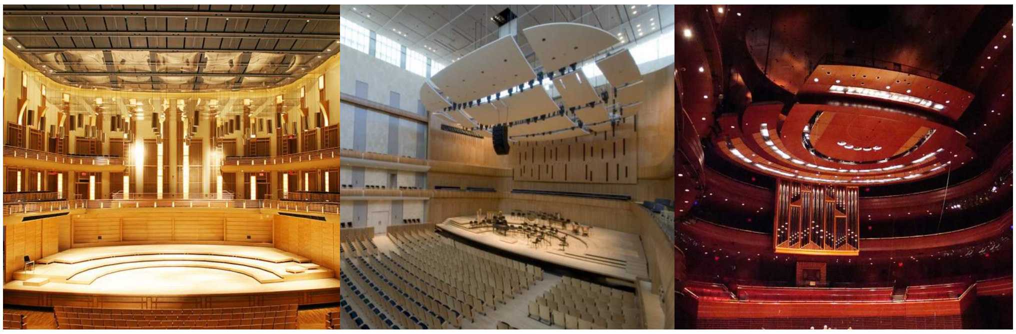

Figure 2 – Case Study Halls (Strathmore, Kiewit, Verizon left to right)

In each case, the heights of the ceiling elements were set (to the extent they were variable) through subjective listening exercises and consultation between the acoustician, orchestra artistic leadership, and musicians. The heights of the canopies were set as follows, measured as the elevation above stage directly over the conductor: 11m for Strathmore; 12.5m for Omaha; and 14m for Verizon.

While the elevations of the canopies are different, two key similarities were observed for all three conditions:

1. For a cross-stage source/receiver combination separated by approximately 10m, the arrival time for an overhead reflection was <55ms at a level of -10±1dB, both relative to the direct sound.
2. For a source-to-self-receiver combination, the arrival time for an overhead reflection was >55ms at a level of <-27dB, both relative to the direct sound.

The levels stay consistent, despite the changes in height, due to the openness of the different styles of canopy. A reflection off the Strathmore canopy, for example, allows enough energy to pass through gaps between panels that it the reflection is approximately 4.5dB lower (broadband) than if the canopy were solid. This permits the canopy to play at a lower elevation without generating excessive loudness on stage. Conversely, the canopy at Verizon Hall must play at a higher elevation to control loudness. The character of sound reflecting off the different style of canopy varies significantly, both on stage and in the house, due to the timing and frequency content of the reflections. This variation in character is more of an aesthetic choice than a functional evaluation of success.

Based on these observations, in combination with the subjective responses of musicians and acousticians listening with the orchestra, it is proposed that the overhead reflection may be useful for cross-stage communication in support of ensemble playing (timing, loudness, etc.), but that the overhead reflection to self may not stand out as a distinct contributor to the acoustic impression of one’s own playing.

These findings have been applied to the setting of numerous other canopies, with similar results. Similar timing and levels have been observed for cross-stage communication within orchestra shells mounted within stagehouses, but no attempt has yet been made to correlate angle/openness of orchestra shell ceilings with this effort. This could be a subject of future work.

4. FINAL REMARKS

This paper has explored the role of discrete reflections in the success of stage acoustics in concert hall venues. By drilling down deeper into the impulse response than a statistical metric may allow, the precise timing and level of downstage side wall and overhead reflections can be evaluated to assess the potential acoustic success of a stage.

The reflection path between downstage musicians and downstage side walls is crucial. These walls are most supportive when they provide reflections of a musician’s own sound back to them in less than 50ms, and when they provide intra-sectional reflections in less than 37ms relative to direct.

The reflection path between downstage musicians and overhead reflecting surfaces is equally crucial but in different ways. The ceiling is most supportive when providing a cross-stage reflection within the first 55ms after direct at a level of -10±1dB. The overhead reflection-to-self should adequately blend into the rest of the sound without standing out, which was found to require a level of less than -27dB relative to direct with an arrival after 55ms.

Finally, we note that further work is encouraged to broaden the number of halls studied in order to generalize the findings and refine the evaluations of timing and level. The authors had hoped to include more data, especially from well-regarded historic halls, in this paper. Very little data, however, is publicly available for stage acoustic measurements in such venues. Many recent measurement programs, including those from universities both in the USA and Europe, have focused on receivers within the audience without inclusion of on-stage receivers. This lack of data limits the ability to further analyze and refine acousticians' understanding stage acoustics. Whether or not data can be gathered according to the precise definitions of measurement standards, or under idealized conditions, the authors urge the acoustic community to both measure and share stage acoustic measurements to help further the understanding of this critical issue.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the generosity of those who shared data for analysis and comparative purpose, including Joseph Myers and Brian Bellie at Kirkegaard Associates and Dr. Angelo Farina at the University of Parma.

REFERENCES

1. Gade A. C. Investigations of Musicians' Room Acoustic Conditions in Concert Halls. Part I: Methods and Laboratory Experiments. Acustica, 1989;65:193–203.
2. Barron M, Dammerud JJ. Stage Investigations in Concert Halls - Early Investigations. Proceedings of the Institute of Acoustics, 2006;28(2).
3. Dammerud JJ, Barron M, Kahle E. Objective Assessment of Acoustic Conditions for Symphony Orchestras. Building Acoustics, 2011;18(3-4):207-219.
4. Barron M. The Gulbenkian Great Hall, Lisbon, II: an acoustic study of a concert hall with variable stage. J. Sound Vib. 1978;59:481-502.
5. Jaffe C. The orchestra platform – the last frontier to listen where few men or women have listened before. Sabine Symposium. 1994;287-290
6. Rindel JL. Design of new ceiling reflectors for improved ensemble in a concert hall. Applied Acoustics 1991;34:7-17.
7. Blair C. Orchestral Acoustics 101: Hearing Troubles? Adaptistration Blog (https://adaptistration.com/2009/08/03/orchestral-acoustics-101/) accessed 1 Sept 2019.