Orchestral performance practice and the perception of acoustic quality in concert halls

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ABSTRACT

One major challenge in perceiving - and hence making judgments about - acoustic excellence in concert hall design relates to factors outside the framework of acoustic science. In the most iconic concert halls it is possible to hear sublime performances (thus justifying the halls’ reputations) just as it is possible to hear performances that are not well matched to the rooms' acoustic conditions, and exhibiting defects such as frequency distortion, poor balance or overloading. In architecturally displeasing halls it can be difficult to perceive musical beauty or acoustic quality, while on occasion it can be possible to experience thrilling musical performances in less than ideal acoustic environments. This paper will suggest that listening “musically” and “acoustically” are dual and intersecting skills needed by acousticians in order judge acoustic quality more effectively. Listening musically involves knowledge of repertoire and orchestral performance practice, including how the conductor’s approach, ensemble size, the setting of the musicians onstage, characteristics of the instruments, and the musicians’ experience and skill align with and respond to the hall’s acoustic character. It will be argued that acousticians can hone their musical listening skills to inform their acoustic evaluation of different halls, improve their ability to listen for the effects of architectural form, and refine aspects of their perception of acoustic parameters. The presentation is based on the author’s research and listening to concerts in great contemporary and historic halls as well as listening to particular orchestras performing the same programs or similar repertoire in different acoustic environments.

1 LISTENING MUSICALLY AND ACOUSTICALLY

1.1 Introduction

As acousticians specializing in the design of concert halls and performing arts spaces, we are on a quest to understand and to be able to quantify all aspects of the acoustic properties of concert halls and related performing arts spaces, and from this secure basis to be able to design acoustically excellent halls with certainty. We are in search of the holy grail of how to design the highest possible excellence into concert hall acoustics.
In this quest, however, we need to depend on subjective and empirical processes such as responding to the architect's artistic vision for the design, and designing acoustic environments that respond appropriately to the highly skilled and highly interpretive art of music-making. Many of our judgments in these matters relate to factors outside the framework of acoustic science as we now understand it. Dealing with such uncertainties can be uncomfortable for scientists and engineers, but is an essential component of the practice of acoustics design for concert halls and performing arts facilities.

This paper follows on from the session at ISRA 2010 entitled How Acousticians Listen, at which Leo Beranek, Tateo Nakajima, Eckhard Kahle, R. Lawrence Kirkegaard, Christopher Jaffe (in absentia) and myself as convenor presented personal insights into our approaches to listening as acousticians, and how we use the essential skill of listening in our work. I proposed this topic because of the great variability I had observed in the way acousticians go about listening, and how their perceptions and diagnosis of acoustics based on those perceptions could lead to utterly different evaluations of the same space.1

Typically, acousticians listen in concerts to the way the sound interacts with the architecture – figuring out reflection patterns and sources of anomalies like echoes and frequency distortion. We also listen to try to identify the hall’s acoustic parameters – RT, Early Decay Time, and so on. Various approaches to this were discussed at ISRA 2010.

Yet, despite this commonality of approach, we often come out with very different evaluations of acoustic quality. This paper attempts to add some order to the listening process, and suggests approaches to help make listening musically and acoustically a more layered and systematic procedure, useful for making more accurate evaluations of concert hall acoustics.

1.2 Approaching Acoustics through the Music

The process of assessing the acoustic quality of a concert hall begins with the music. Music is the foundation, the source material upon which acoustic judgments are made, the raison d’être for our work. There is a tremendous amount of information in the performance of music. To gain access to this information we need to begin with solid, informed approaches to listening musically and acoustically.

For any performance, listening as an acoustician involves assessing the sound quality of this repertoire, played by this orchestra, directed by this conductor, in this hall, using this performance practice. One needs to be able to hear, for example, that an ensemble of say sixteen musicians playing Baroque repertoire on period instruments will not have the same tone color, balance, or strength, and cannot induce the same room response, as a large modern orchestra of say 110 musicians playing a Mahler symphony.

The acoustic response of the room is always specific to the musical performance of the ensemble. Without understanding this, the acoustician will make errors of judgment about acoustic quality. With this understanding, the acoustician can make diverse, subtle, informed judgments that can be used effectively in the process of acoustic design. As Tateo Nakajima said at ISRA 2010: “A strong background knowledge of how the music should sound is a vital part of the knowledge base we need in order to do our work.”2

Listening as a concert hall acoustician therefore begins with how the music sounds versus how it should sound, and focusing on identifying all the information contained in the music. Tateo
again: “A good hall is one in which all the musical characteristics and differences can be heard well”. If we know how the music should sound we will hear well if all the musical characteristics and subtleties are present, and if they are not, we will be able to identify what is missing. Then we will be in a position to explore acoustic cause and effect.

At ISRA 2010 Larry Kirkegaard pointed out that because our measuring and modeling instruments do not yet extend to the very high and very low frequencies of human hearing, listening in these frequency ranges is critical acoustically. Listening musically to the sound itself is the only way we have to access this frequency information. The high-frequency distortion of large areas of over-diffused or similarly-diffused surfaces, for example, cannot be measured yet; nor can the timbral differences in the low frequency instruments - cellos, double basses, bass drums and timpani, or the lustrous high tones and overtones of the upper strings. Listening in these frequencies must be additive to the measured data. Auralization of computer models using measurements with limited frequency ranges, that miss the very high and low frequencies, does us little good when the client listening to the model knows how the real music and the real hall sounds. We must know this too.

Acousticians need to be able to hear interruption and distortion of the overtone series in response to room architecture. We need to be able to hear the unique aspects of the exquisite tone color of the Vienna Philharmonic Orchestra playing in the Grosser Musikvereinssaal, for example, and be able to compare this with their sound in other venues. The more well-informed musically we are, the more we know how the music should sound, the better we will be at acoustically discriminating listening.

Leo Beranek distinguishes between “the language of musical acoustics” and the characteristics of the “physical measures of acoustic quality” - the metrics. Some “language” and “physical measures” correlate readily; others do not. Moreover, the language of music itself (and the sound of music itself) sometimes correlates easily with Beranek’s “language of musical acoustics”, and sometimes does not. In these correlations and lack thereof lies much acoustic understanding still to be found. Our access to this is through listening and systematic observation.

The challenge this poses for acoustic scientists and engineers is addressed well in Barry Blesser’s book, *Spaces Speak, Are you listening?* He discusses at length the indirect relationship between perceptual phenomena and physical acoustics measures, including at the extreme high and low frequencies, and the discomfort scientists experience in grappling with this. He comments: “Understanding and measuring are neither equivalent nor interchangeable concepts. Both are required.” For acousticians working in the field of architectural design for the perception of music, this challenge is ours.

Acousticians therefore need to be able to listen at three levels: Musically – to how the music sounds in relation to how it should sound. Acoustically at the qualitative level - to the relationship between the music, the architecture, and the acoustic characteristics of the room. Acoustically at the metrics level – to identifying the acoustic parameters and what can and cannot be correlated with the parameters. Our process is to listen for each separately, and also to understand how they interrelate and inform each other. Our goal is to assess the quality of the space’s acoustics, its characteristics, strengths and defects, and then to apply that understanding to the process of acoustic design, and ultimately to advancing the science of acoustics.
Listening musically and acoustically thus are intersecting skills, based on the nexus of interrelationships between music, architecture and acoustics. Listening in this way is a high-level skill, developed over many years. It is a major foundational skill for our profession, one that needs to be continually nurtured, challenged, and grown.

### 1.3 Developing a systematic listening approach

The following is a suggested approach to listening to performances in a more systematic way. It has been developed from, and seeks to build on, the various approaches to acoustic listening presented at ISRA 2010. See also the Appendix to this paper which provides a suggested musical knowledge base for acousticians.

1. Begin with the music, listening first to the repertoire and the orchestral performance practice in relation to the room. Listen for appropriate excellences such as true and beautiful instrumental tone color, precision and unity in ensemble playing, sectional balance, dynamic range and control, immediacy and presence in the sound, an experience of connectedness with the performance. Listen also for musical defects such as orchestral imbalance, strange tonal characteristics, poor dynamic range, lack of precision in the ensemble playing. Be aware of the conductor’s direction of the performance, the size and nature of the ensemble in relation to the repertoire, this orchestra’s particular sound, the quality of soloists and how their sound integrates with the orchestra’s. This is the “listening musically” part of the process.

2. Move then to listening acoustically, first perceptually, in relation to the architecture. Identify the effects of the room’s form and materials on the qualities of the sound, excellences such as evenness of frequency response through the full spectrum, evenly spaced early side wall reflections, and useful/detrimental reflections from overhead. Identify also defects such as echoes, weakness of sound and lack of envelopment, uneven side wall reflections, imbalance in spectral frequency response caused by seat absorption, banners and drapes, and so on.

3. Then listen specifically to identify acoustic characteristics and estimating acoustic parameters. Listen for strengths such as appropriate reverberation-clarity relationships, enveloping spaciousness, strength in the low frequencies, brilliance in the high frequencies. How do these correspond with the categories in Beranek’s “Language of Musical Acoustics” and with the ideal physical acoustic parameters? Listen for both, seeking an explanation in the form of the room and what is being heard in the sound of this performance. Listen for “acoustical qualities” that do not correlate with parameters, and for gaps in what can be explained by physical measures or architectural materials and form. Clues to yet-to-be-identified parameters may lie in these gaps.

4. Now begin to move systematically between listening to each of the pairs: to the interactions of musical performance-architecture; architecture-parameters/acoustical qualities; parameters-musical performance. Move back and forth among these, testing observations between one pair against observations in another. This will deepen understanding of the acoustic qualities of the hall, and integrate observations on musical, architectural and parametric/acoustical qualities.

5. If possible listen to the orchestra in rehearsal and then in the hall. Be aware that what is heard onstage is quite different from what is heard in the hall. It is an impossibility that the two conditions could sound the same, no matter what the form of the hall. Onstage, check balance, tone color, instrumental timbre, sectional blend, the conductor’s approach to the performance.
When seated in the audience for a performance listen for how these aspects are realized in the hall acoustically. Listening onstage informs acoustic judgments made in the hall.

6. Build insights and refine judgments through listening from different seats for the same or successive performances with the same repertoire and orchestra.

7. Listen comparatively to various combinations of repertoire/orchestra/conductor and hall:
   • the same orchestra in the same hall (preferably excellent halls and excellent resident orchestras) playing a succession of different works
   • ditto with different conductors
   • the resident orchestra performing in other venues, with the same or different repertoire
   • compare the same orchestra playing in halls of different forms
   • compare between halls of the same type, e.g. shoebox, between the great historic halls (to understand their subtle differences and commonalities) and between excellent contemporary and historic halls
   • compare similar repertoire and performances in different acoustic environments – different hall types, found spaces, compromised acoustic environments
   • listen for the effects of renovations
   • listen onstage in rehearsal and then in the hall

By comparing in pairs, where one aspect is constant (same hall, conductor, orchestra) the other elements (musical and acoustical) become clearer, and correlations between cause and effect, characteristic and result, can begin to be made. Focus on identifying and categorizing the ways in which each of the performances sounds different, what is causing this difference, and what that indicates about the room’s acoustic characteristics and parameters. Identify gaps in perception and understanding, and seek to fill those gaps through listening to another set of pairs. Ultimately we arrive at an evaluation that takes account of both the music performance, the architecture, and the acoustic character and response of the room.

Listening musically and acoustically thus are intersecting skills, based on the nexus of interrelationships between music, architecture and acoustics. Listening in this way is a high-level skill, developed over many years. It is a major foundational skill for our profession, one that needs to be continually nurtured, challenged, and grown.

2 LISTENING TO THE HISTORICAL MODEL

2.1 Nineteenth Century Shoebox Concert Halls

Acousticians are fortunate that a number of acoustically outstanding late-nineteenth-century concert halls survive today, including the Grosser Musikvereinssaal in Vienna, the Concertgebouw in Amsterdam, the Grosser Tonhallesaal in Zurich, and Symphony Hall in Boston. These great halls are the living legacy of the evolution of the large public symphony concert, with their resident orchestras performing symphonies and concertos in what has since become the "standard repertoire" for orchestral concerts. Listening in these halls enables us to glimpse into the musical past even as we hear and experience the transformation of that heritage into the present. These halls are an extraordinary musical and acoustical resource for our profession.

The surviving shoebox concert halls are regarded as models of acoustic excellence; hence the acoustic quality of contemporary concert halls is typically judged in relation to these models.
Many of the acoustic parameters developed in the 20th century are based on preferred perceptual values that correspond with this shoebox form.

**Table 1:** Selected Shoebox concert halls, 1780 to 1900

<table>
<thead>
<tr>
<th>Hall</th>
<th>Opened</th>
<th>Seats</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altes Gewandaus, Leipzig*</td>
<td>1781</td>
<td>400</td>
<td>replaced by the Neues Gewandhaus a century later</td>
</tr>
<tr>
<td>Grosser Musikvereinssaal, Vienna</td>
<td>1870</td>
<td>1680**</td>
<td>renovated 1911</td>
</tr>
<tr>
<td>Neues Gewandhaus, Leipzig</td>
<td>1870</td>
<td>1560</td>
<td>destroyed during WWII, replaced by the contemporary Gewandhaus in 1981</td>
</tr>
<tr>
<td>Concertgebouw, Amsterdam</td>
<td>1888</td>
<td>2037</td>
<td>renovated stage 1898</td>
</tr>
<tr>
<td>Grosser Tonhallesaal, Zurich</td>
<td>1895</td>
<td>1546</td>
<td>renovated 1930</td>
</tr>
<tr>
<td>Symphony Hall, Boston</td>
<td>1900</td>
<td>2625</td>
<td>renovated 2008-12</td>
</tr>
</tbody>
</table>

* The Altes Gewandhaus is regarded as the first independently built hall for public concerts, established by members of a music society, rather than under the aegis of the aristocracy or the church.
** This is the seat count at the 1911 renovation; it was probably somewhat fewer in 1870.

### 2.2 The Grosser Musikvereinssaal in Vienna as Musical and Acoustic Model

The Grosser Musikvereinssaal, which opened in 1870, is widely regarded as the iconic example of the tall, narrow shoebox concert hall, and of 19th century acoustical excellence. It is unique among the great historic halls because of its musical history – the close association musically and acoustically between the hall and its resident orchestra, the Vienna Philharmonic Orchestra (whose origins as the Gesellschaft Orchestra extend back to 1842), and of major composers and conductors whose work and influence was foundational in the development of the symphony concert repertoire. The hall is also extraordinarily beautiful, which psychoacoustically influences one’s perception of sound quality there.

Compositions by Beethoven, Haydn, Schubert and Mozart formed the core of the opening programs at the Grosser Musikvereinssaal in 1870, and the programs soon included works by Brahms, Bruckner, Mahler and Richard Strauss.

Brahms was conductor of the Gesellschaft Orchestra at the Grosser Saal between 1872 and 1874, and Brahms and Bruckner both conducted their own works there. Wagner also conducted the Gesellschaft Orchestra several times, often controversially, between 1872 and 1875. Mahler was conductor of the Vienna Philharmonic Orchestra from 1898 to 1901 and conducted performances of his early symphonies in the Grosser Saal; he took his later symphonies
elsewhere because the size of orchestra he was writing for did not fit comfortably with the size of the original hall (the hall was renovated and the stage enlarged in 1911).  

The synthesis between the acoustics of the Grosser Musikvereinssaal and the sound that the Vienna Philharmonic Orchestra has developed in the hall has great relevance for acousticians. Orchestral performance practice and room acoustics are inextricably intertwined in the pinnacle of excellence that the Grosser Musikvereinssaal represents. Therefore it is both – music performance and acoustic quality – that make up this historic model. Arguably, therefore, it is the best hall in the world in which to study these interrelationships. Listening there, often, is essential training for concert hall acousticians.

I have listened to the Vienna Philharmonic Orchestra perform many times in the Grosser Saal, and agree that the match of their sound to the hall is extraordinary, their sound sublime. The hall acoustics and the orchestral performance practice of the VPO are ideally matched.

However, I have heard several other orchestras play there also (European and American), and none sounded as fine as the VPO. There was a tendency to overplay the room, resulting in excessive loudness, lack of balance, harshness and stridency. These orchestras could not of course have the “Vienna Sound” of the VPO, and they had little opportunity to match their sound well to the room because they were on tour. For a smallish (1680 seats) and highly responsive hall, with an occupied reverberation time of approx. 2 seconds, it is understandable that contemporary orchestras could easily overplay the room. In the words of Dr Clemens Hellsberg, President of, and violinist in, the Vienna Philharmonic Orchestra: “The room can be dangerous because its acoustic response is such that it is easy to become imprecise”.

Dr Hellsberg described to me some of the traditional orchestral performance practices that the VPO has developed over 150 years of playing in the Grosser Saal. Instruments that are unique to Vienna are used in all sections of the orchestra, and traditional instrumental techniques, specific to each instrument, have been handed down through generations of instrumentalists stretching back to those who worked directly with Mozart, Haydn, Beethoven and Schubert. Until very recently all the members of the VPO were drawn from the orchestra of the Vienna Opera, and hence the influence of opera performance styles, also stretching back to the 19th century is embedded in the VPO’s sound.

Orchestra members play in the manner of chamber musicians, listening to and working with each other to constantly shape their sound to each other and to the room. The strings allow their sound to resonate, their articulation is soft, attacks are not too direct, phrasing has a strong sense of the overarching line, playing is legato, with an imperceptible change of bow. Woodwinds play without vibrato, the Vienna horn sound begins so gently that the attack is inaudible, horns and trumpets blend with the string sound yet their overtones are rich and distinct, the timpani has a distinct, ‘colored’ sound. Fortissimos are vast, deep and richly colored rather than assaulting.

These characteristics, unique to the VPO, can be heard, and in many respects correlated with, the specific, demanding acoustics characteristics of this, perhaps the world’s greatest, historic concert hall. The VPO also does not have a resident conductor, but rather invites a number of leading conductors to lead them during each season; as a result their unique orchestral sound is less influenced by the conductor than happens when orchestras have resident conductors (as is usually the case).
Perhaps it was not surprising acoustically, then, that I found the VPO’s sound to be somewhat luxuriant when I heard them play at Carnegie Hall. Dr Hellsberg’s description explains why their sound does not match perfectly with the acoustics of Carnegie Hall, which a lower reverberation time, higher clarity, and a very different response to timbre and tone color. This is not to say that it was not a fine performance; it was, and the audience loved it. Acoustically, it highlighted the differences between Carnegie Hall and the Grosser Musikvereinssaal in Vienna, and distinctive characteristics of the VPO’s performance practice.

2.3 Learning from the great historic shoebox halls

From Vienna we learn that when orchestra, repertoire, orchestral performance practice and room acoustics are very well matched the musical result is sublime.

We also learn that even highly skilled world-caliber orchestras can sound less than ideal in the Grosser Saal. This often comes as a surprise to acousticians, but it is a useful lesson. These great orchestras were not able to match their sound perfectly with the Grosser Saal’s acoustics because of lack of familiarity with the hall, because of the unique instruments and orchestral performance practice of the VPO, and because their performance practices were best attuned to the acoustic environments of their home concert halls.

Thus we learn that there is no such thing as an “acoustically perfect” concert hall, and that the match or mismatch of orchestral performance practice to a concert hall’s acoustics has a tremendous influence on our perception of acoustic quality.

Dr Hellsberg estimated that it would take a fine orchestra about three months to fully adjust to the “dangerous aspect” - the very demanding acoustics - of the Grosser Saal. We might also ask whether this “dangerous” - highly responsive - aspect of a concert hall's acoustics, is a necessary component of acoustic excellence for symphonic performance.

From comparing Vienna with other very highly regarded historic shoebox halls we realize that they all vary somewhat from the Vienna model. The Concertgebouw in Amsterdam is wider than the Grosser Musikvereinssaal, has a higher stage, with steeper stage risers for the musicians, and audience/choral seating on either side of the orchestra. Symphony Hall in Boston has a partially-enclosed stage environment that places the musicians outside the main room volume. The Tonhalle in Zurich has side and rear balconies that are set back, extending beyond the footprint of the main floor. There are also marked differences between the halls in materials, degree of articulation of surfaces, and location and distribution of articulated and plainer surfaces, and in stage-audience relationships. These differences result in differences in acoustical and musical response.

All four halls are acoustically excellent, yet all four have distinctly different sound and acoustic signatures. The halls halls range in RT from 1.9 sec (Boston) to 2.0 (Vienna and Amsterdam), to ca. 2.05 (Zurich),\textsuperscript{13} and there is a similar disparity among the other parameters.

The “RT 2.0 sec” gold standard that acousticians frequently use in concert hall design comes from Vienna and Amsterdam, and from the opinions of the world-leading conductors and musicians interviewed by Dr Beranek. I agree with this “gold standard” as an ideal, based on the ideal sound it represents. I also suggest that we should be able derive some useful insights from deeper study of “the historic model” as represented by these four great halls, and from comparing those insights with a similar study of great contemporary shoebox halls. Such an
analytic process would, I believe, yield a cluster of characteristics that define, or at least encompass, the range of excellent acoustic characteristics and metrics for historic shoebox halls, and a somewhat different cluster for contemporary shoebox halls. In exploring and understanding the range and subtlety of these differences, as well as the similarities, we will begin to understand the range of acoustic and architectural qualities that make “the excellent shoebox model”. The shoebox is the one genre of concert hall that gives us such a historical/contemporary perspective.

Through listening to resident and visiting orchestras playing a range of repertoire in Vienna and the other great historic halls, we are hear a number of subtle iterations of how the music “should” sound, and well as sound that is not as it “should” be. Adding this information to the analytic acoustic approach, we will develop an understanding of what constitutes a sublime match of hall and orchestra, and what constitutes a mismatch.

Much of this information will lie in the high frequency overtones, the sounds of individual instruments, the overall orchestral balance and blend, timing and precision, dynamic range and control, musical nuance, and the color in the bass foundation. Virtually all of the content at this level of perception of musical and acoustic excellence lies outside the domain of current acoustic measurement and modeling capability. Thus, through listening musically as well as acoustically we can discover aspects of historic shoebox hall acoustics that would be inaccessible otherwise.

Looking at the historical model also brings up the importance of being aware of hall renovations and changes on acoustic quality. My research suggests that the Grosser Musikvereinssaal was almost certainly different acoustically when it opened in 1870 compared with the hall following the renovation of 1911. It is likely that the renovation resulted in increased reverberation time, that the frequency response of the room changed, particularly in increased bass response and better balance throughout the spectrum. The area of the stage increased, and the orchestra size increased. Dr Hellsberg’s descriptions of the VPO’s sound, quoted above, refer to the orchestra’s performance practice in the mid-1990s. The orchestra was smaller when it was conducted by Brahms and Bruckner in the original 1870 iteration of the hall. Though the tradition of orchestral performance practice has been handed down through the generations of VPO musicians, it is almost certain therefore that the sound of the VPO has changed over time, in response to the hall renovation in 1911, and to changes in the demands of 20th and 21st century repertoire, and to more universal changes in 20th century orchestral performance practice and conducting styles. Changes of a similar kinds have happened in all long-standing orchestras, and will happen to orchestras moving into new or renovated halls. We need to factor this awareness into our acoustics design practice.

Recently, modern new Conservatory facilities were added at the Vienna Musikverein, including a glass-paneled concert/rehearsal hall, with a very contemporary appearance and acoustic quality. Comparative listening there and the Musikverein’s Grosser and Kleiner halls provides a great opportunity for listening to differences in acoustic characteristics and orchestral performance practice. One can also listen readily (on consecutive evenings) to the Tonhalle in Zurich and the KKK Concert Hall in Lucerne to compare orchestral sound and clusters of acoustic characteristics between great contemporary and historic shoebox halls.
3. THE CONTEMPORARY CONTEXT

3.1 First half of the 20th Century

The 20th century began with high artistic energy and great hopes for the advancement of democracy and civilization. This initial burst of artistic innovation was interrupted by the 1914-18 war (World War I), was resurgent in the 1920s and early 1930s, and was then interrupted by World War II.

The contemporary era in concert hall design effectively began in the 1890s, with the opening of Carnegie Hall in New York in 1891 (2804 seats), a successful renovation of the stage end of the Concertgebouw in Amsterdam in 1898 (2037 seats), and Wallace Clement Sabine's experiments and discovery of a formula for reverberation time that he used in the design of Symphony Hall Boston, which opened in 1900 (2625 seats). Thus the scene was set for the 20th and into the 21st century – large public concert venues with over 2000, and often over 2500, seats, renovations of major halls (which usually brought improvement in their acoustics), and the development and application of acoustic science in concert hall design.

From the beginning of the 20th century, major symphony orchestras in national capitals grew, and by the 1930s large orchestras had been established in major national and regional cities across the western world. The public audience for classical music grew rapidly, and new concert halls soon followed the establishment of orchestras.

Two 19th century concert hall forms continued into the 20th century – the shoebox and the opera/theatre form. In the opera/theatre form the orchestra is accommodated in an orchestra enclosure/screen, set up within the stagehouse and designed to separate the orchestra from the fly tower with its theatrical/lighting equipment, and project the orchestra's sound into the audience. Early examples include the Semperoper in Dresden (original built in 1841), and the Philadelphia Academy of Music (1857, built as an opera house, intended primarily for symphony concerts). These can be considered as the first multi-purpose halls (although most shoebox concert halls accommodated meetings, chamber music, recitals, choral and other community performances, their design and function was for symphony concert performances).

Carnegie Hall (1891), with its opera-style audience chamber and built architectural stage enclosure, was soon followed by Orchestra Hall in Chicago (1905) and Severance Hall in Cleveland (1931). Bass Hall in Fort Worth, Texas (1998) is a contemporary example. Boston Symphony Hall (1900), which is regarded as a shoebox hall, has a built orchestra enclosure, and is thus to some extent a “hybrid”. There were also some very interesting hybrid forms, incorporating aspects of opera/theatre and shoebox forms, including Queen’s Hall in London (1895).

The fan-shaped hall was the first of the egalitarian forms, with a large splayed main floor seating area accommodating the audience in “equal” seats. Fan-shaped halls typically have a low “pancake” volume overhead, resulting in lower volume per person than in the shoebox halls, and therefore lower reverberation times than are now considered ideal for symphony orchestra. Sometimes the fan-shaped halls were purpose-built as concert halls, with an architectural stage enclosure, such as Kleinhans Music Hall in Buffalo (1940), or, more commonly, as multi-purpose halls with stagehouses and an orchestra shell for concerts.
Table 2: Selected 20th – 21st century concert halls

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<th>Hall</th>
<th>Opened</th>
<th>Seats</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Queen’s Hall, London</td>
<td>1895</td>
<td>2500</td>
<td>destroyed 1941</td>
</tr>
<tr>
<td>Symphony Hall, Boston</td>
<td>1900</td>
<td>2625</td>
<td>reno. 2008-12</td>
</tr>
<tr>
<td>Severance Hall, Cleveland</td>
<td>1931</td>
<td>2101</td>
<td>renovated 1999</td>
</tr>
<tr>
<td>Kleinhans Music Hall, Buffalo, NY</td>
<td>1940</td>
<td>2839</td>
<td></td>
</tr>
<tr>
<td>Heichal Hatarbut, Mann Auditorium. Tel Aviv</td>
<td>1957</td>
<td>2715</td>
<td>*</td>
</tr>
<tr>
<td>Serge Koussevitzky Music Shed, Tanglewood</td>
<td>1959</td>
<td>5121</td>
<td></td>
</tr>
<tr>
<td>Berlin Philharmonie</td>
<td>1963</td>
<td>2218</td>
<td>renovated 1986</td>
</tr>
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<td>Sydney Opera House Concert Hall</td>
<td>1973</td>
<td>2679</td>
<td>*</td>
</tr>
<tr>
<td>Sala Nezahualcoyotl, Mexico City</td>
<td>1976</td>
<td>2376</td>
<td></td>
</tr>
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<td>Gewandhaus, Leipzig</td>
<td>1981</td>
<td>1900</td>
<td></td>
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<tr>
<td>Suntory Hall, Tokyo V</td>
<td>1986</td>
<td>2006</td>
<td></td>
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<tr>
<td>Myerson Concert Hall, Dallas TX</td>
<td>1989</td>
<td>2065</td>
<td></td>
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<tr>
<td>Birmingham Symphony Hall, Birmingham</td>
<td>1991</td>
<td>2211</td>
<td></td>
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<td>Seiji Ozawa Hall, Tanglewood, Lenox</td>
<td>1994</td>
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<tr>
<td>Kyoto Concert Hall</td>
<td>1995</td>
<td>1839</td>
<td></td>
</tr>
<tr>
<td>Bridgewater Hall, Manchester</td>
<td>1996</td>
<td>2357</td>
<td></td>
</tr>
<tr>
<td>Sibelius Hall, Lahti, Finland</td>
<td>1996</td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>Tokyo Opera City Concert Hall</td>
<td>1997</td>
<td>1636</td>
<td></td>
</tr>
<tr>
<td>Sapporo Concert Hall, Japan</td>
<td>1997</td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>Bass Performance Hall, Fort Worth TX</td>
<td>1998</td>
<td>2072</td>
<td></td>
</tr>
<tr>
<td>Dewan Filharmonik Petronas, Kuala Lumpur</td>
<td>1998</td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>Lucerne Cultural Centre Concert Hall</td>
<td>1999</td>
<td>1892</td>
<td></td>
</tr>
<tr>
<td>Sala Sao Paulo, Brazil</td>
<td>1999</td>
<td>1610</td>
<td></td>
</tr>
<tr>
<td>L'Auditori, Barcelona, Sala Pau Casals</td>
<td>1999</td>
<td>2200</td>
<td></td>
</tr>
<tr>
<td>Verizon Hall, Kimmel Center, Philadelphia</td>
<td>2001</td>
<td>2298</td>
<td></td>
</tr>
<tr>
<td>Esplanade Concert Hall, Singapore</td>
<td>2002</td>
<td>1837</td>
<td></td>
</tr>
<tr>
<td>Walt Disney Concert Hall, Los Angeles</td>
<td>2003</td>
<td>2265</td>
<td></td>
</tr>
<tr>
<td>Melbourne Recital Centre</td>
<td>2009</td>
<td>1001</td>
<td></td>
</tr>
<tr>
<td>Koncerthuset, Copenhagen</td>
<td>2009</td>
<td>1800</td>
<td></td>
</tr>
</tbody>
</table>

* Renovations are planned for some of the earlier halls not yet renovated.

The classical repertoire of the 19th century gradually expanded throughout the 20th century, to include works of 20th century composers. Impressionism, nationalism, folk and jazz were influencing classical music composition early in the century. Concert audiences were, and continue to be, generally more conservative than the composers and performers. Stravinsky’s *Rite of Spring*, for example, was greeted with a near-riot at its premiere in Paris in 1913, although the reaction was as much to Diaghilev’s ballet as it was to the music. A year later,
Stravinsky’s score was recognized among contemporary musicians for its musical genius; now it is accepted in the concert hall as one of the great seminal works of the 20th century. More radical composers, Schoenberg and others, especially those experimenting with atonality and serialism were less accepted into the concert hall. Generally speaking, new and more radical works were performed outside the concert hall, in smaller spaces. This continues to be the case for composers today.

International star conductors began to emerge towards the end of the 19th century. Artur Nikisch (1855–1922) was perhaps the first truly international star conductor. Nickisch was conductor of the Boston Symphony Orchestra, the Royal Opera in Budapest, the Leipzig Gewandhaus Orchestra, the Berlin Philharmonic, and regular guest conductor with the Vienna Philharmonic and the Concertgebouw Orchestras. He took the London Symphony Orchestra to the US on a tour in 1912 – the first international tour for a European orchestra. In 1913 he also made one of the earliest recordings of a complete symphony – Beethoven’s Symphony No. 5, with the Berlin Philharmonic. Charismatic, innovative, Nikisch was considered an outstanding interpreter of the music of Brahms, Beethoven, Bruckner, Tchaikovsky, Beethoven and Liszt – all of whom continue to be core composers in the standard repertoire.

As the public audience grew and orchestras grew in size, so did orchestral sound and balance. Large, sweeping grand performance styles became widespread, and expected by large, enthusiastic audiences. With the development of amplification, recording techniques, and music for film, this trend intensified.

3.2 The Contemporary Era

The second half of the 20th century - our era - was for the most part an extended period of economic and population growth, with remarkable and increasingly rapid innovations in science, engineering, architecture, audio and communications technology.

An enormous expansion in concert hall building has taken place since the 1950s (see Table 2), as the public audience expanded with rising affluence in many countries around the world, including in Asia, the Middle East and South America. The economic downturn that began in 2007 has slowed concert-hall building in the West, but it continues to expand in Asia and the Middle East. Audiences for classical music have been dropping in the West in recent years, whereas they continue to grow rapidly in Asia.

Musically, the standard repertoire continues to be the core of symphony concerts, with gradual incorporation of the works of some 20th century composers. It is now usual to find at least one modern work in a symphony concert that otherwise comprises works from the standard repertoire, and more contemporary works and experimental performances are being included in concert programming.

Composers in the second half of the 20th century continued to experiment widely, drawing on the greater ethnic and multicultural influences and interrelationships in contemporary society. More radical experiments in art music are also being heard more widely by an increasingly educated concert-going public. These new musics include experiments in form, texture, harmonic structure, tonalities and atonalities, instrumentation, playing technique, incorporation of voice, speech, song, vocal sounds, dance, movement, actors, combining electronic music and recorded sounds with classical instruments, randomly generated electronic sounds, and so on.
There has been a reaction against the block-buster style of symphony performance with star conductor as the “given” performance practice, although major orchestras led by international conductors continue to be the norm. International-standard chamber orchestras are becoming more common in the concert hall, combined with a return to more authentic styles of performance, based on original instruments and reinterpretation of original scores in as close to the style of the period in which they were written as can be established through musical scholarship.

Multi-disciplinary and semi-staged performances of all kinds are also increasingly being performed in concert halls. For example, on my way here to present this paper, I will be seeing/hearing Mozart’s opera *The Marriage of Figaro* performed by the Los Angeles Philharmonic Orchestra with leading opera soloists at the surround/vineyard-form Walt Disney Concert Hall. Experimental concerts are held in all kinds of “found” spaces that provide opportunity for experimentation, or attract audiences for other reasons – spectacular views, amenity, stylish architecture, regardless of the acoustical quality of the space.

In response to falling audiences, and to changes in technology and performance type, orchestra and facilities managements are attempting to draw new audiences into the concert hall (and opera house) through innovative performance types as described above as well as staging grand performances and festivals for mass audiences (such as the Handa Australian Opera performance of *Carmen* on the shores of Sydney Harbour this past summer).

This “Gen 2 Multipurpose” is different from the multipurpose uses of the 1960s-1980s, and poses new challenges for acousticians designing concert halls. It calls for much more varied programming, much more flexibility, and much higher levels of theatre lighting, video and audio technology. The rate of IT change is now so rapid that it is impossible to conceive programming and technological requirements for concert halls even 10 years hence. Concert halls and all kinds of halls, large and small, and all kinds of and genres, are part of this new multi-purpose exploration. This is a challenging and very exciting time for the evolution of performance types, and for concert hall design.

### 3.3 Acoustic Excellence for Contemporary Concert Halls

Concert halls can now be loosely grouped into four broad categories, each of which has a distinct acoustic character: shoebox, opera/theater form, fan, and surround/vineyard.

The surround/vineyard-style hall developed early in the second half of the 20th century. This democratic form wraps the audience partially or completely around the orchestra platform. The audience area is typically subdivided into blocks at gently stepping elevations, with the partitions surrounding the blocks providing lateral and rear reflections. There have been many iterations of the vineyard/surround hall, for example, the Berlin Philharmonie (1963), the Gewandhaus, Leipzig (1981) and Walt Disney Concert Hall, Los Angeles (2003).

The shoebox hall has developed a number of types. Some shoebox halls have been based very closely on the 19th century models, such as the Sala Sao Paulo (1999), which was inserted into an existing building structure of ideal shoebox proportions, and the Konzerthaus, Berlin (1986), which was a rebuilt as closely as possible to being a replica of the original 1821 hall. Artec’s generation of modified shoebox forms take the shoebox model in a new direction, using contemporary architectural design and finishes, interior reshaping of the “box”, and insertion of a large technical and acoustic canopy over the orchestra platform. A variable
acoustic environment is provided via architectural reverberation chambers combined with adjustable acoustic absorption, to adjust the acoustic conditions for various types of classical music and other musical forms (as in Lucerne Cultural Centre Concert Hall, 1999).

As we saw in Part 2 above, the “historical shoebox” hall category is not a single model, but, rather, is better viewed as a cluster of parameters and qualities that characterize and define the range of excellence for this hall form. Similarly for contemporary shoebox halls, which vary from their historical forebears in materials and detailing, no matter how carefully we have sought to imitate the original halls.

Similarly, also, for each of the other forms - fan, opera/theater, and surround/vineyard - the acoustic characteristics of excellent halls in each of these types form a cluster, a range of parameters and acoustic qualities, that define the range of excellence for each hall type. We need to explore and define these “clusters” – musically and acoustically – to better inform our acoustics design practices.

There may also be clusters of identifiable acoustic characteristics for some of the hybrid forms that have developed out of these types; there certainly will be clusters that define the characteristics of acoustic excellence for the wide range of smaller halls that are now coming into prominence in response to “Gen. 2” multipurpose demands. This work has barely begun.

Acoustically, our response to these new trends needs to be more nuanced and more flexible than was necessary for earlier approaches to multipurpose halls. All forms and types of concert hall now need to be capable for the new multipurpose capability. As technology changes, so will the demands for hall and acoustics flexibility, and we will need to anticipate this. The new generation of multi-purpose use may indeed change the appearance and feel of the concert hall. This is a great challenge for acousticians, and requires us to think differently about how we develop our design practice and our scientific understanding. Listening musically and acoustically will become an increasingly critical acoustic tool as we respond to this challenge.

### 3.4 The challenges of Contemporary Architecture

The era of modernism that developed early in the 20th century emphasized pure geometric form, a limited palette of materials, uniformity of surfaces, and detailing for simplicity and elegance. Though the modernist influence is still foundational, it has given way to a post-modern diversity of styles, more fluid forms, imaginative use of materials, innovative geometries, sweeps of grand design, and exuberance of overall form in realizing the building as a work of art. Brilliant international architects such as Frank Gehry and Zaha Hadid are designing spectacular architecture for great concert halls and performing arts complexes around the world.

Acousticians for concert halls and performing arts facilities work in this context of contemporary architectural forms, materials and practices. Sad to say, many (though fortunately not all) contemporary architects are not particularly interested in our goals to achieve high levels of acoustic quality for the performance and related spaces, especially if our recommendations are seen as interfering with the design concept. In publications on concert hall and theater design, and websites for concert halls and performing arts spaces, it is not uncommon to find the acoustician named only in passing, or not acknowledged at all. Yet these are spaces for music, voice, and performance, and excellent acoustical quality is critical to their success.

In 1998 Robert Apfel wrote an appropriately titled book, *Deaf Architects & Blind Acousticians*, which talked about the frequent inability of both architects and acousticians to understand and
engage with each other’s point of view. If anything, the gulf between acousticians and architects is becoming worse. Concert halls are seen in the context of designing public space and grand forms. Acousticians are pressured into, for example, covering vast surfaces with the same texture and form of diffusion, even though basic good practice and some time spent analyzing great concert halls would indicate use of multiple textures and acoustically selected locations. Client/architect preference for thickly upholstered seats can wreak havoc with acoustic absorption and frequency balance, as well as row access.

We also have to contend with the “wow factor” in contemporary architecture, which attracts audiences to particular performance spaces despite their poor acoustical quality. If we cannot combine the “wow” architecture with excellent acoustics design, we leave a heritage of poor acoustics in that venue for at least another generation.

What can we do about this? Architects are generally not coming to us, so we need to go to them. We cannot ask architects to design 19th-century look-alike halls, but we can be respectful of and responsive to contemporary architectural aesthetics. We need to understand the fine detail and distribution of shaping, texture and form that characterizes the great historic and great modern halls, and the potential for translating those examples into great 21st-century concert halls using contemporary architectural forms and materials. Indeed, the post-modern architectural palette has more potential for successful acoustic shaping and detailing than the strictures of early modernism, so we have more to work with.

Heuristically, it seems that the best recent halls, acoustically and in design terms, are the work of acousticians who are very well informed musically as well as architecturally. Acousticians and architects have music and appreciation of the arts in common. Musically and artistically informed acousticians can communicate better with architects about what is needed in terms of musical, as well as visual, aesthetics. We can teach the architects to listen and design in response to what they hear. Acousticians need therefore to find common interest with architects in architectural design as art, and music as art, and the synthesis of the two in the field of acoustics.

4. **LISTENING FOR THE ACOUSTIC CHALLENGES OF OUR AGE**

We face enormous challenges as concert hall acousticians in the 21st century. We are dedicated to building concert halls of the highest excellence, and we are in a period of rapidly changing technology and demands for new kinds of multi-purpose design. Acoustic science has identified parameters and developed computer modelling techniques that give some measure of certainty to our design processes. Yet much about concert hall acoustics remains to be discovered, understood and defined. The dedicated concert halls in major cities are changing their programming, the demand for small and innovative multipurpose forms is growing, and building types are changing. With this, our acoustic thinking needs to change.

First steps towards solutions may be found through answering some critical questions, such as:

How do we move beyond our assumption of one highest “excellence,” based on 19th century concert hall design and the standard concert repertoire, to defining acoustic excellences and appropriate acoustic design processes for our 21st century context?

How do we develop our understanding of multiple acoustic excellences to reflect the variety of current concert hall forms without compromising our current view of RT 2.0 seconds and the
associated parameters and perceptual qualities that we now use to define acoustic excellence for concert halls? Do we need to compromise? Are there better, different, excellences?

How do we apply the lessons learned in 20th century concert hall design to the new and rapidly changing challenges in designing the acoustics for highly flexible 21st century concert hall and performing arts spaces?

What is an appropriate acoustic excellence for smaller, flexible, experimental halls? These are not concert halls shrunk to a smaller size; they require a different acoustic response.

The questions can also be more specific, such as:

Should the “2nd Gen Multipurpose” concert hall be based around RT 1.7-1.8 sec rather than 2.0 sec? We have plenty of evidence of excellent concert hall acoustics in halls with an RT in the 1.7 to 1.8 second range - Severance Hall in Cleveland, for example. We know that there are serious frequency imbalances resulting from introducing too much variable acoustic absorption into a space, so would this reduction in the most reverberant condition not give us greater flexibility with less compromise? Would “excellence” truly be lost?

It is my contention that listening musically and acoustically is one of our most essential acoustic tools for answering questions such as these, and guiding us in the new design challenges that we face.

Through deep musical and acoustical listening we can explore the acoustic effect of current architectural materials and forms – faceted surfaces, large areas of glass, asymmetrical shaping, use of one material over large surface areas and so on. We can use the understanding so gained to help us communicate better with and demonstrate to architects and clients how form and materials interact with each other in achieving acoustic excellence. It will help us meet architects in the arena of art. It will help us to develop acoustic forms and materials that respond to contemporary architectural aesthetics, so that acoustic outcomes can be achieved in aesthetically pleasing ways that the architect is more likely to embrace.

Through deep musical and acoustical listening we can explore the clusters of parameters and perceptual acoustic qualities that define the four hall types, small halls, and relevant hybrid forms. This will aid us enormously in understanding directions for future flexibility. It will also help us to be clearer in evaluating our current halls. A new level of acoustic understanding is asked of us.

Through deep musical and acoustical listening we will find gaps in our current acoustical knowledge that point to where new metrics and understandings may be found. As Larry Kirkegaard said at ISRA 2010: “What is yet to be learned could be more important than what we already know”.16

I believe that there will always be public demand for live musical performance no matter how life-like developments in audio, video, IT, streaming, and yet-to-be discovered technologies become. I am convinced that the art of music in all its forms, and in new forms, will endure, that orchestras and concert halls will continue to exist, and flourish. Refining our listening skills is an essential acoustics tool that will enable us to facilitate this process.
REFERENCES


2 ibid.

3 ibid.


7 Beranek Leo. Concert Halls and Opera Houses, op cit.

8 Data from Beranek, Leo, ibid.


10 And also because of conservative and anti-Semitic attacks on him and his works.

11 Clements, op. cit.

12 For more of this description of orchestral performance practice see Clements, op. cit., p. 15.

13 Beranek, Leo. Concert Halls and Opera Houses, op. cit., p. 916, Table A3.1.

14 Most data from Beranek, op. cit., some from the concert hall websites.


APPENDIX

Musical Knowledge Base for Acousticians

“The music” as used in this paper includes three essential components of musical knowledge needed for acousticians designing concert halls and related performance spaces. These are: the repertoire (composer and the works themselves), the role of the conductor, and orchestral performance practice.

Orchestral performance practice is a broad term that includes all aspects of how an orchestra performs, including: the orchestra’s overall size, sizes of the sections, disposition on the platform, type of instruments being played, the orchestra’s approach to style and manner of performance, and the role of the conductor.

Knowledge of the repertoire is fundamental.

A basic musical knowledge for acousticians thus includes:

- **The repertoire** (composers and their orchestral works, especially the symphony, the concerto, and works for orchestra and voice/s). Major periods in the development of western orchestral music, major composers and repertoire for each of these periods, from the Baroque through the 20th-21st century.

- **The instruments.** For period and contemporary instruments: instrumental timbre and tone color, characteristic resonances and frequency ranges; articulation, clarity, definition and blend; loudness/strength and fullness of sound; balance within and among sections of the orchestra, of the whole orchestra, and of soloist/s with the orchestra.

- **The role and importance of the conductor.** Approaches to conducting and how the conductor directs the performance. The choice of repertoire, orchestra setting (size and layout) and style of performance are largely determined by the conductor.

- **Orchestral performance practice** as the interrelationship between the work, instruments, conductor and performance practices of the orchestra, combined together to create the performance – the listening source for acousticians.

- **Vocal and choral repertoire and performance practices** for the periods, especially oratorios and other orchestral works with voice.

- Similar knowledge of opera, including the opera orchestra and vocal performance styles.

- Similar information for chamber orchestras and small ensembles for each of the periods.

- Similar information for other genres and musical influences, such as experimental Western art music, electronic music with orchestra, Chinese Orchestra, spoken voice with orchestra, and ethnic musics.

- Works and performance practices for orchestra with amplified and/or electronic instruments/sounds.

For a Select Bibliography on music and acoustics please contact the author directly.