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How Acousticians Listen

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ABSTRACT

Acousticians approach the critical task of listening to the acoustics of a performance space, such as a concert hall or theatre, in a wide variety of ways. Critical decisions about room acoustics design are based on our listening perceptions and judgments. It appears straightforward: we listen to inform the process of correlating aural perceptions with the room form, shaping and materials, and with various acoustic parameters. Our listening is thus an active process that is a vital part of the work of acoustic design. There's more going on than this, however. Acousticians bring a wide range of backgrounds and interests to their work, which can powerfully influence their approach to the task of listening, and thus the framework in which their perceptions are interpreted and applied. Some of us tend to focus more on listening for reflection patterns and frequency response in the room, others focus on listening specifically for different acoustic parameters, while others give primacy to the performance itself and how it would sound in an acoustically excellent (and appropriate) space, vs what is actually heard. With such different approaches to listening, it seems worth asking how design outcomes are being influenced. Does listening within one framework lead to misconceptions in another? How do our preconceptions about music, acoustics, or architecture influence what we hear? Is formal training warranted specifically for listening in performance spaces of different sizes and uses? This ISRA session is a forum, with short presentations by five eminent acousticians, followed by questions and discussion among the presenters and the audience.

PAMELA CLEMENTS: INTRODUCTION HOW ACOUSTICIANS LISTEN

This session brings together five of the world's most eminent acousticians to discuss a topic of extraordinary importance and challenge: how acousticians listen. Listening is the key to our perceptions of, and the basis of our judgments about, acoustic quality and acoustic design. Yet listening, and how we understand and communicate what we hear, is an extraordinarily inexact process. What does this mean for the art and science of acoustic design?

I became interested in the different ways that acousticians listen very early in my acoustics career, when I went to a concert at Carnegie Hall with a fellow acoustician, and discovered that we had had utterly different listening experiences, and as a result we had made quite different judgments about the acoustic quality of the room. I hear a wonderful performance of early classical repertoire played by a small ensemble in the style of performance practice of the period, beautifully clear, resonant, luminous and moving. I was transported by the acoustic quality of a room that could give me such a musical experience. My colleague heard a distant and unengaging performance in a room with not much reverberation and little presence or fullness of sound. It was as if we had been on different planets.

Not long after this I was able to listen to several rehearsals and performances in quick succession over a period of ten days in the Grosser Musikvereinssaal in Vienna. I had heard the Vienna Philharmonic Orchestra before, in concert and recordings, and had found their sound opulent and rapturous. But in their own hall, in which they had carefully nurtured and developed their sound over 125 years, I experienced the most glorious match of performance and acoustics that I have ever experienced. No wonder this hall is regarded as the world's greatest acoustic icon. But – and this is an enormous but - I also heard several other orchestras (from Europe and the USA) play in the Grosser Musikvereinssaal during that time, and they sounded frightful: each different, but in common they were overwhelmingly too loud, harsh, unbalanced, and poorly blended. I was astonished: this was the same room, same glorious acoustic potential, but I was hearing performances utterly "out of tune" with the room's acoustics. This was an unforgettable lesson for a budding acoustician – that room acoustics and performance are inextricably linked.

Dr Clemens Hellsberg, President of the Vienna Philharmonic, told me that he is convinced that the Musikvereinssaal's acoustics are an integral part of the orchestra's special sound. He also believed that if the visiting orchestras were resident in the hall *for several months*, their sound would change in response to the acoustics.

These experiences led me to a quest for listening to as many performances of all types of music in all types of halls, to explore and better understand how performance and room acoustics interrelate, and from this understanding to better understand how to design rooms for excellent acoustics.

One thing I have discovered in this listening journey is that, as in my early experience in Carnegie Hall, when acousticians listen to the same performance we do not necessarily focus on the same things acoustically or musically. I would venture to say that more often than not there is a core in common but much that is different in what we hear. Even in a controlled situation such as Arup's SoundLab, when comparing a simple before/after simulation, we would not necessarily agree, although when we discussed what we were hearing and why, we would each begin to hear the others' preferences more clearly (although not necessarily change our minds or agree with each others' conclusions). I had a theory that the SoundLab revealed a division: the brass and amplified/rock players in one listening group, and the singers and string players in another, and we heard the world differently.

Since many acousticians who work on design of performance spaces are musicians in their own right, and therefore trained listeners, it is worth asking how we can understand more about the listening process we all depend on in our work, and how we can apply that process more effectively in acoustic design. Hence these short papers, and the more expanded presentations and discussion to take place at our ISRA forum.

It is interesting that each of these papers is very personal in content. There are commonalities in the listening approach of these eminent acousticians, but also some really significant differences. The acoustic parameters that are the work tools of acousticians today are not necessarily correlated particularly closely with the writers' observations on their own listening processes. Different aspects of acoustic and musical quality are given priority by the different authors. We are challenged to understand more about the music itself before making acoustic judgments. The limits of our known acoustic parameters are challenged also, because so much of what is observed and commented on in these papers is beyond current practice in acoustics measurement and analysis. A quick review of Leo Bernanek's rankings of halls reveals halls with identical acoustic parameters that sound quite different. How do we use this knowledge to inform acoustic design?

One other interesting aspect that is implicit in these papers – but not addressed – is how we apply our listening experiences to the design of new spaces. Listening in an existing hall that needs renovation is an opportunity to apply the knowledge gained to the renovation work at hand. But taking listening knowledge to the drawing board for a new project is another level altogether. I hope that this forum will challenge us as acousticians to learn from the insights about listening in these papers, to go beyond our customary approaches, and take our own listening to a much higher level. Hopefully, too, the challenge will be taken up to expand the capability of our scientific tools to bring them much closer to modelling what we hear, learn and understand from our listening experiences.

LEO BERANEK: LISTENING TO ACOUSTICS IN CONCERT HALLS

My principal listening interest is in the music itself. I have enjoyed symphonic music since my high school years. In college I played tympani in its orchestra and also in the Cedar Rapids (Iowa) Symphonic Orchestra. In graduate school, I played tympani in the Harvard-Radcliff Orchestra. At a concert, if the piece is familiar, I pay attention to the conductor's interpretation. I am interested in the conductor's control of the orchestra and how close the musicians pay attention to his/her gestures. After I settle in at my seat and come to terms with the music, I begin to think about the acoustics.

Assume that this is a hall where I have not been before and that it houses an excellent symphony orchestra that performs there several times a week, repeating the same program each time. I try to select a concert with music I am familiar with. An ideal concert would be one presenting two of Beethoven's odd numbered symphonies or Brahms early symphonies. For three identical concerts in the same week I dicker with the box office for two seats at each which results in seat locations in six different parts of the hall.

Admittedly, one's mental state is influenced by the early approach to the hall—the size and beauty of the lobbies, the ascending steps, and the lighting. In Europe, one automatically checks one's coat—there may even be a check room with pegs numbered for every seat—and this is a pleasant experience. However, to me, the most dramatic moment is entry into the concert hall itself. Its size, the presence of a pipe organ, chandeliers, the stage with hanging overhead panels, all register at once. Then one notes the arrangement of the balconies and the presence of coffers, niches and statues. Of course, the colours of the seats, the wood, and any painted surfaces as well as any special acoustic elements, such as cubes or wildly splayed elements, or hanging disks, demand one's attention.

Now comes the acoustics. I usually pay detailed attention first to the reverberation time. How long is it at mid and low frequencies and is one enveloped by it? Does it seem to come equally from the front, centre and rear of the overhead volume, or is it only located in the upper front part of the hall?

Next is loudness. The strength of the music depends, in part, on how large the hall is—the music may be almost overwhelming on double forte passages if the room has only 1200 seats, while not strong in a hall with 3200 seats. Recent studies have shown that the reverberation time at low frequencies is less important than the strength of the sound there. This brings to the fore the stage conditions around the orchestra. In the conventional shoebox–shaped hall, with the orchestra at one end and surrounded by solid walls, the orchestra sound is probably well blended and projected evenly to the audience and into the overhead reverberant spaces. In a surround hall the music is usually weaker than that in a shoebox hall even when the reverberation time is the same and it may be less well distributed. The important thing is that the strength of the sound should be greater at low frequencies than at mid-frequencies.

My attention usually goes next to the direct sound. Am I able to determine the azimuth direction of each instrument on the stage? Do successive notes stand out? And, visually or acoustically, does the stage seem near or far away?

With these characteristics in mind, I attempt to estimate the clarity factor, C_{80}, the ratio, in decibels, of energy in the early sound to that in the reverberant sound. My thinking on this

aspect is influenced by modern recordings, where the pickup microphones are often hung at low heights above the orchestra and the reverberation is added, often with same reverberation time, but with the reverberant energy lower than in the classic shoebox-shaped concert halls. A low amount of reverberant energy is most pronounced in one type of actual hall, i.e., in those halls called "Direction Reflection Sequence Halls," of which the New Zealand Christchurch Town Hall was the first example and of which the Costa Mesa, Segerstrom Hall, is one USA example. In those halls, each listener receives a large number of early reflections from a multitude of surfaces which results in the removal of a significant amount of energy from the reverberant field without changing the reverberation time. Some think this type of acoustics is that of the future.

Then follows my attention to the early reflections. Do they come from side walls and balcony fronts? Do they seem to add spaciousness to the music, i.e., do they broaden the source? Do the early reflections sound natural or is there roughness or brittleness? Are the low frequencies in the reflected waves strong? In some halls, at some positions, there is a source shift, e.g., the violins are heard as coming from a side reflecting surface, not a desirable feature.

Next, one compares listening at different seats on the three successive days. Is one section of the orchestra emphasized at one seat location and a different section of the orchestra emphasized at another? I remember in one hall clearly hearing a harp solo at one seat location and the next day hardly hearing this same harp solo at another seat location. In another hall, the cello in a cello concerto was loud on the main floor and weak at a side-balcony seat. I try to determine where this emphasis or de-emphasis comes from. Any imbalance between sections of an orchestra may be caused by the shaping of the surfaces in the shell in which they are located. Or, the imbalance may come from shapes of the ceiling or of the side walls in the main part of the hall which reflect some parts of the orchestra to one place and a different part of the orchestra to another. I have been in a hall where the double basses seemed almost too loud on one side of the main floor and almost inaudible on the other side. In a hall with a large overhanging balcony, is the sound underneath, at the rear, greatly different from that out front?

In my book, *Concert Halls and Opera Houses* (2004) I wrote, "The worst acoustics I have ever heard in any concert hall exists in the front rows of the top balcony in Carnegie Hall in New York. The sounds from the rear of the stage rise to the curved section between the proscenium and the flat upper ceiling and focus on those seats. At a 2001 concert . . . I could hardly hear the violins and the cello [at a cello concerto with the cello player near the conductor's position] because of the overpowering strength of the sound from the back of the stage—horns, percussion, brass, and woodwinds."

Of course, noise is a serious deficiency. In two halls I have been in, the noise of the municipal subway was heard in quiet passages. In another hall, the noise was not evident, but the seats in the balcony shook whenever a heavy truck passed by outside. In some halls the air conditioning is audible in quiet passages. And squeaking seats drive me crazy.

For each three-day listening experience, I hope to have found the best locations, acoustically, in the hall, and to have catalogued the hall overall among the many others in which I have heard music. I hope to have added to my knowledge reasons as to why halls of various architectural features have differing reputations among conductors, music critics and audiences. In short, join me in Happy Listening!

J. CHRISTOPHER JAFFE: HOW I LISTEN TO CONCERT HALLS

In my many years of thinking about concert halls and listening to concerts, I have tried to train my listening to focus on these major components: 1) patterns of reflected sound energy, 2) reverberation, 3) tonal characteristics, 4) on-stage communication, and 5) mechanical system noise.

First, patterns of reflected sound energy.

This relates to assessing early and late reflections throughout the frequency spectrum. Of course, the overall sonic characteristic of the direct orchestral sound is really out of the acoustician's purview; instead, this is a function of the calibre of the orchestra and the technique of the conductor. But, as acousticians, we are basically responsible for establishing the proper relationship of this direct sound to the reflected energy in the hall. These reflecting energy patterns will affect the capability of the sound source (the orchestra) to create a qualitative ensemble sound.

Second, reverberation.

By carefully listening to the decay rate of a sound source in a concert hall, I can aurally evaluate the reverberation times of a room, sometimes within a few tenths of second. With my ears I try to filter the orchestral source to evaluate the mid range and the low range ends of the spectrum separately so I can then assess the bass response of the room. This method also reveals acoustic flaws such as echoes and focusing.

Third, tonal characteristics.

When listening to a concert orchestra, I try to evaluate the mid frequency reverberation times of a room by listening to the decay of stop chords. It's harder to evaluate low frequency reverberation during orchestral performances since the high-powered, mid frequency brass instruments dominate massed orchestral sound and the timpani generates its own reverberation which can mask hall return. In addition, the human ear is not as sensitive to low frequency sounds as it is to mid frequency sounds. But with this technique, I try to detect the warmth of the hall. In a good hall, this desirable characteristic will be clearly audible during fully scored orchestral moments. You do not want to see the cellist bowing and not be able to them.

In a small volume room, the persistence of high frequency information is aurally apparent in terms of the orchestra taking on a shrill, so called "hi-fi" sound. I find that this is often due to the lack of sufficient high frequency air absorption in the space. In addition the orchestral sound will overload a small room resulting in a harsh dry sonic environment.

Fourth, on-stage communication.

As an acoustician, I am keenly concerned with the quality of sound on stage. Can the musicians hear themselves and other members of the orchestra? This is the key to great ensemble playing. For example, the performances of the Cleveland Orchestra have been compared to that of a chamber quartet, which is quite a compliment. The perfect timing of their entrances and the balance between sections is remarkable. This can in part be attributed to a very tight orchestral formation, relatively low ceiling reflectors, and a fairly dry hall.

Therefore, I try to spend some time on stage during orchestral rehearsals and obtain my own aural perception of orchestral sound at different locations on stage, including at the conductor's podium. In this manner, I can add my own aural per-

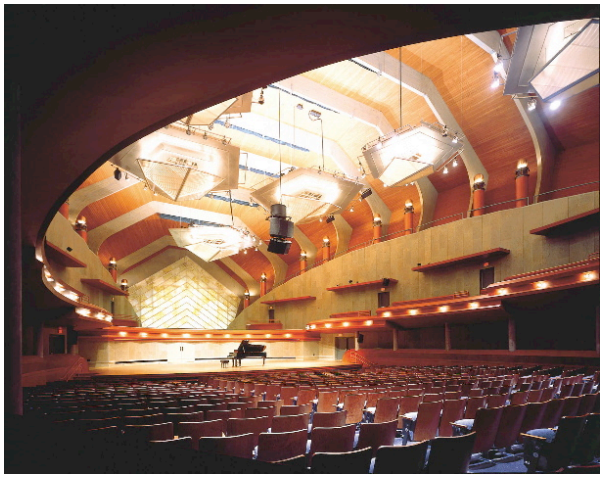
ception of stage sound to that of the musicians and better understand their aural reactions.

Fifth, mechanical system noise.

A quiet background sound is imperative to a good concert hall design, so this factor must be attended to. When working on the renovation of Severance Hall for the Cleveland Orchestra, I was able to evaluate mechanical and electrical noise as never before. Thomas Morris, the Executive Director of the Orchestra, was very sensitive to extraneous noise and he organized his own version of critical listening.

All the architects, engineers, and acousticians as well as hall administrative and maintenance personnel were assembled in the Hall at five o'clock one morning a month before the opening concert. All the mechanical and electrical systems were turned off and then one by one turned on. The participants were spread around the hall and instructed to call out if they heard any intrusive noise. If something was heard, the offending equipment was singled out for additional noise control work. Actually, most of the noise heard in the hall by the listeners would have faded into the background of a hall filled with 2,000 patrons. Still it was a unique way of ascertaining the effectiveness of noise control design in a hall.

Last, but not least, I also try to enjoy the concert. Listening should be fun and enjoyable, too.



(Source: J. Christopher Jaffe)

Figure 1: Winspear Hall, Murchison Performing Arts Centre, North Texas University, Denton, Texas.

Winspear Hall, Murchison PAC, incorporates the following characteristics required for good symphonic listening experiences on stage and in the audience chamber (see Figure 1):

- Sufficient volume for the development of proper reverberation times throughout the spectrum.
- Thick and dense wood ceiling and side walls to make sure low-frequency reverberation is slightly higher than mid-frequency reverberation. (Air absorption of higher frequencies also helps us here.)
- Narrow rectangular shape, under-balcony and side wall horizontal side wall shelving, and overhead reflectors all contribute to the arrival of early reflected energy to the audience. These reflections provide clarity, intimacy, definition and transparency.
- Stage enclosure for proper ensemble sound.
- Overhead reflectors for improved on-stage hearing.

TATEO NAKAJIMA: HOW DID I SOUND? COULD YOU HEAR ME?

Anyone who has worked with musicians in a hall will recognize these questions: How did I sound? Could you hear me? In whatever language, wherever one is around the world, answering these questions (and the monumental number of similar questions) is a significant challenge to the auditorium designer – and provides some insight into the complexity of the task we face when we listen.

In my early days as a conductor, I had the privilege of studying with Charles Bruck, a Hungarian French conducting professor of some renown, at his school in the US. Although his teaching method included many signature ways of getting students to conduct better, one in particular is memorable to this day; he would stop the orchestra and the hapless young conductor mid phrase and ask the dreaded question – "What did you hear?"

It was understood that you *should* have heard that a key instrument hadn't played correctly (or at all), or that some balance issue was obscuring an important feature of the writing – and of course, this meant that you *should* have known well enough to have been listening for it, or perhaps been aware enough to have understood that it was important.

Most of the time, at least in the early days of our studies, we hadn't. We had heard a lot of sound, of course, but the dreaded question demanded we know exactly what we were supposed to be hearing at that particular moment in time. And it took each of us some time before we could be in the middle of that wash of (hopefully) glorious sound and know what we should be hearing and what we were not.

There, as here in the acoustics world, knowing what we are listening to and how something should sound is a vital part of being able to evaluate what one is hearing. After all, the hardest challenge before us is to distinguish between what is due to the writing, what is due to the playing and what is due to the hall.

What are we listening to?

As we all know, what we hear depends on many factors, and the nature of the work of music is perhaps the first major factor. Some factors are more obvious than others, of course, such as the size of the ensemble – a large symphony orchestra, a string orchestra or a violin recital obviously does and should sound differently in a given space.

The types and combinations of instruments being played is another such factor. Here it would be helpful (not to say important) for the listener to actually know what the differences are between viole de gambe and modern cello or German rotary trumpets versus the more common piston trumpets are in terms of how they should sound if one is to be able to finely evaluate what one is hearing.

But what of the style of composition, and the performance practices that are associated with it? We should have at least a basic understanding of those differences too, lest we apply expectations about balance, impact and instrumental colour that are inappropriate.

And what of the nature of the composition itself? What should we know about the writing styles of different composers and their (hopefully) related expectations in terms of how the music should sound? One famous example is the use of dynamic markings in Schumann symphonies where the composer has not indicated any nuance between different instrumental groups – thus creating not only endless debate

amongst musicians, but, rather more importantly, a clue for those of us listening, that a balance problem between the brass and string sections may be somewhat endemic to the writing of the music, or the artistic decisions of the conductor, and not necessarily due to the acoustics of the hall.

Who are we listening to?

Equally important is an understanding of the individual performer(s) and what one can tell about how they should be sounding.

As even a cursory comparison of the mellifluous oboe sound produced by Maurice Bourgue and the edgier sound of Heinz Holliger would show, each individual musician brings a certain variation and a personal touch to the definitions above. In most cases the differences are fairly subtle – in others, such as in the case of the two artists named here, the differences can be more dramatic: Baseline knowledge of what each musician or musical ensemble is looking for can be essential to being able to judge the quality of a hall.

In a good hall, all these differences should be heard well, but if one doesn't know what is "characteristic" of the sound desired by a given musician or ensemble it is very difficult to judge how well the hall works.

A more delicate issue is one of skill, and to a lesser extent, physical health. Whether or not the sound that a musician wants the audience to hear is actually heard depends primarily not on the acoustics, but on their skill level. And in some cases – perhaps most acutely, though not exclusively, in singers – the health of the musician on the given day may also have a dramatic impact on whether the characteristics sought after can be heard and appreciated in the hall.

"How did I sound? Could you hear me? "

So let's go back to where we started from.

The principal difficulty with these questions is that any answer spawns a raft of other questions which need answering first. Is the questioner referring to a specific passage? Or perhaps a specific context where they themselves had the impression that they could not be heard? Was there any passage in the works where you could hear this individual musician – or should have, and didn't? Was she worried about loudness and impact, or the nature of the sound?

While I think we can probably all agree on the various metrics (reverberance, strength, clarity, etc) that we, as acousticians, use to evaluate a hall – I suggest that in order to understand whether what we are hearing is, in fact, appropriate, a strong background knowledge of what we are hearing *should* sound like is a vital part of the knowledge base needed to do our work.

ECKHARD KAHLE: HOW ACOUSTICIANS LISTEN

When listening to a concert hall – or any performance in a space – I first listen to the performance itself, in just the same manner as a regular audience member. I am of the firm belief that *all* listeners can – and do – judge the acoustic quality of a space, whether it be consciously or subconsciously. The acoustic quality of a space is, together with the quality of the performance, the adaptation of the performance to the space and other aspects, part of the global concert experience. And an excellent and adapted acoustic quality contributes to a positive concert experience for the general audience member in just the same manner as for a professional acoustician.

Where the difference between the professional acoustician and the regular concertgoer comes into play is when trying to explain *why* the acoustic quality is good – or bad – and *what* the acoustic problems are.

Acoustic quality is, by nature, a multi-dimensional phenomenon, when it comes to the *perceptual aspects* (or *perceptual factors*) that describe the different subjective aspects of the acoustic quality, when it comes to *objective measurements* (or *objective criteria*) that characterize the acoustic quality of a space, and when one considers the *architectural criteria*, the dimensions (such as distances, surfaces and volumes) and architectural features that create the acoustic quality of a space. Being aware of the different aspects, having integrated a semantics for the description of acoustic quality, and having studied the relationships between *perceptual factors, objective criteria* and *architectural criteria* obviously allows a more thorough description of the acoustic quality of a space. And it helps when trying to explain why the room sounds as it sounds – and when asking the question what could be improved in the sound of a space and how it could be improved.

In my case, I started my involvement in acoustics (other than being a musician and physicist) when, at the beginning of my PhD thesis, I organized structured listening tests using questionnaires during lives performances in several European concert halls and opera houses[1,2]. The IRCAM-questionnaire had five pages and more than 30 questions, deliberately overdefined in order to allow a reduction of the semantic redundancy during the analysis. See Figure 2. One of the first outcomes of the analysis of the questionnaires was that the influence of the musical work – and especially the orchestral forces – could hardly be dissociated by listeners from the acoustic quality.[3] The influence of the musical work therefore always has to be considered when evaluating the acoustic quality of a space. Another result of this finding is that "good acoustics" do not actually exist as such, one should rather talk of "perfectly adapted acoustic quality".

The final analysis of the questionnaire allowed a reduction of the many questions to a limited number of independent perceptual attributes, and these attributes I still find relevant and helpful when listening in a structured way (see as well [4,5,6,7] for alternate complete lists of perceptual attributes):

- Reverberance (decay, as perceived both during running music and stopped chords).
- Source presence (loudness and presence of the sources).
- Room presence (loudness and audibility of the room).
- Definition of attacks and clarity.
- Orchestral balance, especially balance between the different orchestral sections.

- Tonal balance and tone coloration.
- Echoes and effects of delayed reflections.

Other important aspects, interestingly not revealed in the analysis of the questionnaires, are spaciousness and especially listener envelopment, i.e. to what degree we feel surrounded by the music and the room effect. Yet another aspect I find important is "openness" and "respiration", to what degree there is space around the musical instruments and around the music (the opposite being "compressed"). This is linked to a good separation between the early part of the acoustic response (related to source presence) and the late part of the acoustic response (related to room presence).

IRCAM STANDARD LISTENING SURVEY QUESTIONNAIRE

Hall:	**Seat:**
Occupancy (%):	**Orchestra size:**
Listener initials:	**Date:**
Musical work / Composer:	

Part 1 – PERCEPTION OF THE HALL

Subjective loudness (perceived amplification of the hall)

very weak weak quite weak quite strong strong very strong
(01) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - - - - - - 5 - - - - - - - - - 6 - - - - >

Subjective dynamics (perceived difference between *pp* and *ff*)

very small small quite small quite big big very big
(02) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - - - - - - 5 - - - - - - - - - 6 - - - - >

Reverberance (sense of temporal decay of the sound)

very weak weak quite weak quite strong strong very strong
(03) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - - - - - - 5 - - - - - - - - - 6 - - - - >

Subjective hall size (auditive impression of the size of the hall)

small quite small quite big big
(04) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - >

Subjective envelopment (auditive impression of being surrounded by sound)

weak quite weak quite strong strong
(05) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - - - - - - 4 - - - - >

Coloration

lack of intimacy some intimacy intimate
(06) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - >

lack of warmth some warmth warm
(07) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - >

dry some liveliness lively
(08) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - >

lack of brilliance some brilliance brilliant
(09) < - - - - 1 - - - - - - - - - 2 - - - - - - - - - 3 - - - - >

(10) muddy [ ] yes [ ] no

(11) heavy [ ] yes [ ] no

(12) acid [ ] yes [ ] no

(13) aggressive [ ] yes [ ] no

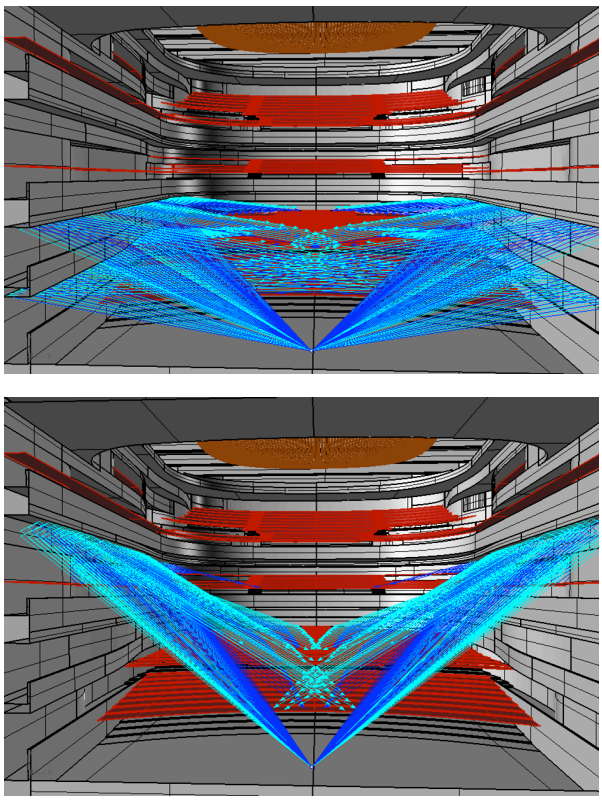
(14) hard [ ] yes [ ] no

page 1/5

(Source: IRCAM/Kahle Acoustics)

Figure 2: Page 1 of the IRCAM questionnaire. Subsequent sections covered perception of the sound sources, spectral balance, and general impressions.

All these perceptual aspects can be linked to both objective criteria and architectural criteria. Just as a complete description of the acoustic quality is possible in terms of perceptual aspects, it would – or should, unluckily less research has been performed for these aspects – be possible in terms of objective criteria and architectural criteria. Reverberance is linked to total volume, volume per person and the quantity of acoustic absorption; source presence is linked to early reflections and especially the presence of "downkickers", elements that can send reflections back down to the audience (see Figure 3); orchestral balance is linked to the stage surroundings; and tonal balance and colorations are linked to materials and surface treatments, as well as sometimes to the number of reflections created. As the links between perceptual factors, objective criteria and architectural criteria are less than perfect, it is interesting during listening and evaluation of rooms to switch between the different descriptions, in this way trying to "complete the picture" as much as possible.



(Source: Kahle Acoustics)

Figure 3: The action of downkickers, that direct reflections down to the audience and hence are important is a sense of source presence.

We all know that taste and personal preferences are another important aspect when listening to rooms, but the first step should always be structured evaluation of the room and the listening experience. Before going to the question of "good" or "bad", one needs to evaluate – as objectively as possible, even when the subject is perception – the different aspects of the acoustic quality of a space, and the adaptation of the space to the musical performance.

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R. LAWRENCE KIRKEGAARD: HOW DO I LISTEN?

The term *tabula rasa* seems appropriate to describe the freshness of mind that I try to bring to exploring a hall. Rarely do I use a checklist to guide my listening. It is more a matter of patiently getting to know the hall, the conductor and the orchestra, and how they all interact.

I listen with curiosity and an open mind - without preconceptions, and with enthusiasm and appreciation for the power and subtlety of music. I listen with eyes closed and open.

I listen actively *to rooms* with both ears, 'aiming my ears' to track reflections. I listen directly *to surfaces* with one ear pressed against walls, floors and other materials seeking resonances that absorb sound energy and color the acoustic.

To understand the unique qualities of an orchestra in its hall, I try to obtain the conductor's permission to listen onstage during rehearsal. Before the musicians arrive I make various sounds onstage and listen to the hall's response. Time-variant and pitch-variant handclapping help me understand the structure and directionality of strong reflections; in this I take advantage of the side-lobe sensitivity of my ears.

I listen from various areas of the stage and hall as the musicians warm up. During rehearsal I listen to the conductor's comments to musicians and their responses. How often does the conductor stop the orchestra to deal with balance issues? Do the musicians and conductor have to work hard for sound quality and ensemble, or is the process relatively easy?

I listen for any surprises. Is the sound transparent or congested? Can I hear the high strings and deep bass sounds across stage during *tutti* passages? Does sound get overloud? How many musicians wear earplugs or use screens? Are these issues musician or acoustics-related?

Having sensed sound on stage, I move into the hall, starting close to the conductor for aural perspective on balance and timbre. I move back in the hall, listening as the 'adolescent' sound gradually becomes the 'mature' sound of the hall. I listen to whether the hall accurately conveys the sound I heard on stage or if there is distortion or coloration. Can I still understand what the conductor is saying to the orchestra (a good indication of clarity)?

If I close my eyes can I localize individual sounds and sections within the overall ensemble sound? Are soft sounds supported by the hall? Are loud sounds exhilarating or uncomfortable? Can I hear the full orchestral spectrum in balance during loud passages as well as during quiet ones? Is the sound compelling?

As I explore the hall, l listen for acoustic anomalies - sounds that cause me to pause and analyse - changes in timbre or loudness, or in spatial/temporal qualities. Are there acoustic 'zingers' – disembodied sounds appearing from odd directions? Often the causes of anomalies are obvious. If not, I explore their causes after rehearsal. During breaks, I talk with conductors and musicians about their observations and concerns, which may lead me to more listening onstage.

All this serves to inform my listening during the performance. I already have a strong understanding of the nature of the acoustics of the unoccupied hall, so the effect the audience and the energy of performance simply overlays earlier observations.

Listening during performances, I am drawn into the wonder and fullness of the music, returning intermittently to the acoustics. My mind is constantly reacting to qualities of sound and seeking to understand what determines those qualities - good and bad. I am also struck by the acoustic realms that are as yet not fully explained, the acoustics mysteries we cannot yet understand.

A Challenge for our Futures as Acousticians

I am determined to advance my abilities to solve these challenging and perplexing mysteries involved in what we do as acousticians!

How do we find our relevance in an impoverished economy that cannot support the types of projects for which we have developed our skills? To be relevant, future halls will need to be home for many audiences and a proliferation of performance types. I believe we can meet this challenge and create halls that are truly excellent for the widest variety of events – not good for one and poor for the rest, but acoustics that convey the full essence and impact of the creators' intent across the genres. These halls will need to be efficiently and adeptly adaptable.

This will require our full commitment to achieve the highest levels of excellence and flexibility that our skills and wisdom can produce. Those who trust us to produce the best, deserve the best.

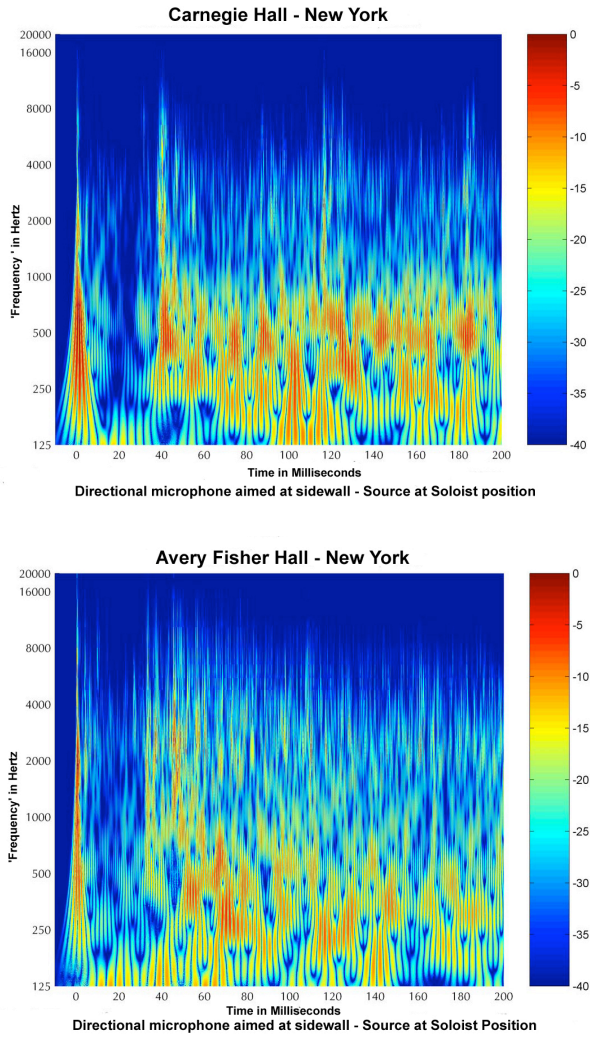
I am convinced that we need to work with the **whole spectrum of human hearing –** we must not ignore the universes of very high and very low frequency sound that are presently unattended and ignored in our data gathering and analysis. Half the instruments of our orchestra have their fundamental pitches below 125Hz. We need to design for strength in the fundamental sounds of those instruments. We must not believe that overtones can fully compensate. Fundamental pitches of low frequency instruments support intonation and bloom for the full orchestral sound. Fundamentals are fundamental!

And why do we limit high frequency consideration to 4000Hz? While that limit encompasses much of the musical spectrum that concerns us, it ignores the potentially treacherous universes of harshness and over-brightness contained in the frequencies above 4000Hz. We have encountered many listening spaces that are seriously flawed because of high frequency distortion. Most often the distortion is caused by diffraction effects from elements of acoustic and/or architectural shaping.

Willy-nilly we have accepted conventional wisdom that abundant surface shaping is a pre-requisite for great concert hall acoustics. This wisdom is partly right, but mostly wrong! The great halls that have helped to define our acoustics understanding do indeed have significant surface shaping, but that shaping is most often in the upper volume. These great halls have relatively flat surfaces at the lower levels, where they direct the lateral reflections from the stage to the listeners. Most of these wall surfaces are modulated only by the imperfections of the masons and plasterers who built them.

The high-frequency havoc resulting from diffraction from over-diffused surfaces can be seen in Figure 4, which compares the reflection structure from Avery Fisher Hall (an extreme example of diffusion over-indulgence) with Carnegie Hall (which has simplicity of form for walls and ceilings). The multiple cross-room reflections at Carnegie Hall show full-spectrum energy, faithfully retained at each successive reflection. In Avery Fisher, none of the reflections – even the earliest – carries any sense of authenticity, and the amount of

energy in the higher frequency regions is extraordinarily dense and polluted.



(Source: Kirkegaard Associates)

Figure 4: Reflection structure of Avery Fisher Hall (highly diffused) compared with Carnegie Hall (plain surfaces). Where Carnegie has a gentle infill of high frequency sound up to about 4K, Avery Fisher has an impenetrable veil of harmonically unrelated high frequency energy extending strongly to 10K and above.

We share a rich and extensive acoustics legacy for which we should be deeply grateful. We also share a profound need to shape that legacy for those who will follow.

We risk becoming both complacent and complicit in limiting the depth and breadth of our investigations. Today our acoustics practitioners work within a framework of computers, test data, electronic simulations and closely defined acoustic parameters. Ironically, almost by virtue of their accuracy and sense of certainty, these tools constrain our imaginations and limit our search for knowledge. We have taken on unnecessary limitations in our acoustic explorations.

The full range and subtlety of our listening needs to inform our analyses. We need to ask more of our measuring processes so that we explore all the acoustics goals that really matter not just those that are easy to pursue. Without such direction, our testing and research can only provide partial truths.

We need to reassess what is important and, notwithstanding the challenges, pursue with passion and conviction the expansion of acoustic knowledge. What is yet to be learned could be more important than what we already know.