The Evolution of Acoustical Technology in Concert Halls

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Introduction

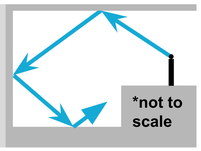
Musical performance is an integral part of many cultures through its role as a unifying force and expressive vehicle. Music is expressed in a variety of different methods and contexts, and how music is expressed profoundly impacts musical reception and composition. An important way that musical reception can be impacted is the characteristics of the performance space.

Understanding how performance spaces, such as the concert hall, have changed over time and how they are manipulated to achieve a desired result are essential in deciphering the role these spaces play in musical performance.

Key Acoustical Properties

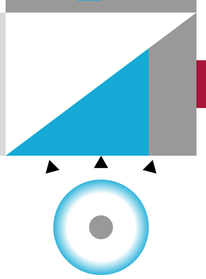
Several acoustical properties are key to acousticians today in their understanding of a hall's performance. The following properties are non-exhaustive but represent factors commonly analyzed by acousticians.

Reverberation
The continuance of a sound in a space after it has been sounded, caused by reflections

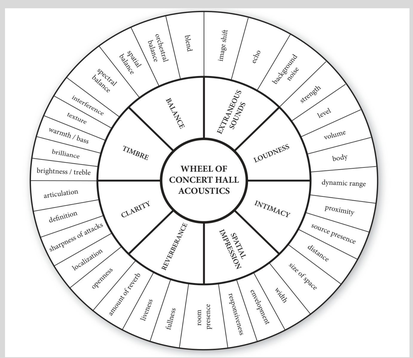


Clarity
How much an intended sound stands out from reverberant or extraneous sound

Loudness
The perceived magnitude of the sound heard



Envelopment
The subjective feeling of being surrounded by the sound



Hochgraf, Kelsey. "The Art of Concert Hall Acoustics: Current Trends and Questions in Research and Design," fig. 1.

Three Phases of Concert Hall Design

Acoustical design of concert halls can be roughly divided into three periods based on audience and techniques. The three periods below represent where music began being produced in dedicated spaces, how these spaces moved to the public, and how science influenced their design.

Phase One: Music in Court Halls

1600s to 1750s

The first quasi-dedicated spaces for music performance were halls as part of royal courts. Musicians during this period often served under a royal court, and within a court palace, music rooms were small and rectangular, differing from concert halls today principally in their size. With their small dimensions, reverberation was low, and because of the short distance between musicians and the audience, there were few performers. Composers such as Bach wrote music fitting these spaces, keeping the reverberation low to prevent the music from sounding muddy.

Royal music-making contrasts with performance in cathedrals, whose acoustical properties were of importance to religious service. The long reverberation time of these spaces support the chants and music of the Medieval period well.

Phase Two: Transition to Public Halls

1750s to c. 1890

As performances moved into public halls, the needs of concert halls changed. Public access meant greater attendance, necessitating a larger hall to accommodate additional seating. On balance, larger halls result in longer reverberation times.

This increase in hall size and reverberation is correlated with changes in the size of the orchestra and the music it played. The 1750s to c. 1890 roughly correspond with the Classical and Romantic periods, and notable Western composers like Mozart and Beethoven composed large and magnificent symphonies. These works fit well with the increased reverberation time of performance halls.

Finally, this period saw the emergence of dedicated halls such as the Boston Music Hall completed in 1863, which had a reverberation time of about 1.4 to 1.6 seconds.

Phase Three: Scientific Deisgn

c. 1890 to today

Wallace Clement Sabine is regarded as the founder of modern acoustical design. As a new professor at Harvard University, he was tasked with correcting the acoustical problems of the new Fogg Art Museum, which was caused by reverberation. In his study of the acoustics of this space, he derived a formula equating reverberation time to a room's physical properties:

$$T_{60} = 0.163\frac{V}{A}$$ where T_{60} = reverberation time, V = volume, A = absorptivity

Sabine's work introduced methods of science into the design of concert halls. In 1898, he was hired as a consultant for the construction of Boston Symphony Hall. Architects initially planned to directly scale up an existing hall design, but Sabine advised against this and advocated a redesign based on acoustical testing. Today, the Boston Symphony Hall is regarded as one of the best in the world, and acousticians continue to refine upon Sabine's work.

Acoustics and Music Composition

Shifts in acoustical design have been correlated with complementary changes in concert music.

In the Baroque period, smaller and more intimate-sounding courtrooms led to chamber ensembles, and large cathedrals benefited from the nascent orchestras. Bach is a notable example, and his Brandenburg Concertos and St. Matthew's Passion, respectfully, represent each space through their musical character. Altogether, it is generally accepted that Baroque music sounds best with a reverberation time of 1.6 seconds.

In the Classical period, a combination of more powerful instruments (such as the violin, and brass in general) as well as public concerts drive an expansion of halls. Ideal reverberation time for classical-period music is 1.8 seconds.

The Romantic period saw greater interest in reverberation and larger orchestras, and this is related to an increase in the ideal reverberation time to 2.0 seconds.

Measurement Parameters & Current Research

Acousticians have conceived of several different parameters that attempt to measure the performance of a concert hall:

- Reverberation time: the amount of time to become inaudible (often by falling 60 dB)
- Early decay time: the amount of time for intensity to fall 10 dB
- Initial time delay gap: the amount of time between direct sound and the first reverberant sound
- Clarity: the ratio between early reverberant sound and late reverberant sound
- Apparent source width: the additional perceived size of the sound source

Recent research has highlighted several different factors attempting to offer alternative viewpoints on concert hall performance, including:

- Dynamic responsiveness: how differences in dynamic contrast (loudness) vary based on the amount of lateral reflections
- Diffusion: the directness of sound reflections of surfaces, which influences reverberation

Ongoing Study & Further Research

Research in concert hall acoustics today focuses on using computer modeling and new parameters to enhance design.

Computer modeling allows for acousticians to predict how a hall will perform. Software like CATT and i-Simpa permit simulation of how sound will behave in a hall.

New parameters have also been introduced to try to gain a better measurement of a hall's performance. Parameters like the inter-aural correlation coefficient and Ando's "Theory of subjective presence" aim to capture more accurate information about how a hall sounds.

All of this, however, leads to the uncertainty of current study in the field and the need for more research. Multiple parameters have been highlighted as important in concert hall design, such as reverberation time and the initial time delay gap, but the efficacy of these attributes in the construction of a new hall is poor. Notable examples of this include Avery Fisher Hall. Sound and musical perception, being a subjective quality, is difficult to cleanly objectify, and more research is necessary to better understand how concert halls work, how they impact the music being performed, and how people process incoming sound.

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