BALANCING VOICES AND ENSEMBLES: METHODS FOR TUNING AND ASSESSING ADAPTABLE PERFORMANCE AND REHEARSAL SPACES

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Abstract

Acoustically adaptable performance spaces offer the possibility to actively shape their sonic response, allowing them to be *tuned* in relation to specific artistic requirements. In this sense, the space itself can be approached as an instrument, whose parameters — such as reverberation, clarity, and spatial distribution — are adjusted to support different ensembles and repertoires. A central challenge lies in defining appropriate strategies for tuning these environments, particularly with regard to perceptual aspects such as the audibility between musician groups and the balance between singers, orchestra, and choir.
This contribution examines methods for assessing and adjusting such spaces, with a focus on capturing interaction within and across performer sections. While established room acoustic metrics provide a useful foundation, they often fall short in describing the nuanced relationships that emerge in complex performance settings. The paper therefore addresses the limitations of current measurement approaches and explores complementary strategies that better reflect ensemble conditions.
In addition, the role of participative design processes is highlighted. Involving musicians and other stakeholders in the tuning and evaluation of the space can support more informed adjustments and tends to increase acceptance of the resulting acoustic conditions. The study aims to contribute to an ongoing discussion on how architectural design, acoustic adaptability, and user involvement can be integrated, and how such processes can be supported by appropriate measurement and evaluation methods.

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1. Introduction

With the means of active acoustic systems, performance spaces are no longer fixed architectural givens but can become instruments in their own right — reverberation, clarity, and spatial response can be adjusted by a push of a button. This shift raises a question that is deceptively simple to state but difficult to answer in practice: how should such a space actually be tuned? Tuning is, in part, a matter of taste — conductors, section leaders, and singers frequently disagree on what "good" sounds like for a given room and repertoire. At the same time, tuning cannot proceed by taste alone; it relies on established room acoustic parameters for orientation, most notably reverberation time, clarity, strength, and support, which give acousticians a shared vocabulary and a repeatable point of reference when moving between presets. These parameters are most widely codified in the ISO 3382 series, which remains the measurement standard for describing concert hall acoustics [1]. Kahle's return-from-experience across several halls shows, however, that this standard toolkit has clear limits: single-number values such as reverberation time can characterize a preset but repeatedly fail to explain specific, strongly perceived effects on stage — why one instrument is masked and another is not, or why a hall seems to "open up" only at certain dynamic levels [2]. ISO 3382 parameters were developed primarily to describe the audience experience and only partially capture the on-stage, performer-centred conditions that active tuning must address.

A further complication, already established in the literature, is that musicians and acousticians do not speak the same language. Beranek's comparative studies of concert halls and opera houses show that performers describe sound in experiential and often metaphorical terms — warmth, presence, blend, support — that do not map directly onto the physical quantities engineers measure [3]. Before a space can be meaningfully tuned together with its users, a common vocabulary bridging these two perspectives has to be established; without it, feedback from rehearsal sessions risks being systematically misread or discarded.

This paper addresses these questions through two case studies of active acoustic systems tuned for orchestral, vocal, and chamber use. For each project we describe the individual tuning process, the presets developed, and the acoustic and subjective results obtained, before drawing out the topics that recurred across all three. Central to this account is a design-thinking, participative approach to acoustic design: rather than tuning presets in isolation and presenting them to musicians as a finished product, acousticians, conductors, musicians, and other stakeholders are brought into a shared, iterative design process from an early stage. This paper aims to show how such a participative process can help bridge the vocabulary gap described above, and how it can be structured and documented so that a room, once tuned, continues to function reliably as an instrument for the ensembles that use it.

2. Acoustic metrics

Before a space can be tuned, there must be a shared basis for describing what "well-tuned" actually means, and this is the role played by acoustic metrics. Without them, feedback from musicians risks remaining anecdotal — a vague sense that "something is wrong" without a shared way of locating the cause or verifying that a subsequent adjustment has actually addressed it. The six metrics discussed in this section were chosen because they recur, in one form or another, across the case studies presented later in this paper, and because each addresses a distinct aspect of how performers experience a room from within it, rather than how an audience experiences it from without. Dynamic response and dynamic range describe how the room behaves across the full range of playing intensity; one's own audibility and cross-sectional audibility concern the musician's ability to hear themselves and their colleagues accurately enough to play together; orchestral balance at the conductor's place reflects the aural perspective from which rehearsal corrections are actually made; and stage acoustics ties these together as the physical basis from which the others emerge. Taken together, they give acousticians a working vocabulary that can be mapped, however imperfectly, onto musicians' own descriptions of their experience, and they provide the reference points against which the tuning interventions described later in this paper can be evaluated.

Dynamic response of the room

The dynamic response describes how strongly and how quickly a space reacts across the range from the quietest to the loudest playing, i.e. how the room's early and late energy behave under varying source levels and how audibly it "opens up" during a crescendo. Kahle notes that a room's ability to reveal successive parts of its volume as sound intensity rises is one of the more fascinating, yet poorly quantified, aspects of concert hall quality [2]. Musicians in tuning sessions frequently describe this quality directly in terms of the room "supporting" them at both climaxes and pianissimi, echoing Dammerud's finding that an audible, appropriately scaled return from the hall is essential for orchestral playing [4].

Dynamic range of the orchestra

This refers to the achievable spread between the orchestra's softest and loudest sound levels as actually perceived on stage and in the hall, which depends on how much the room's own response compresses or extends this range. Dammerud's thesis shows that excessive on-stage loudness, or a stage enclosure that returns too much energy too quickly, narrows the perceived dynamic range and can mask the room's own reverberant response [4]; Kahle's Casa da Música case likewise found that musicians could not hear any room return at all during loud tutti passages until absorption was introduced, effectively restoring the orchestra's usable dynamic range [2].

One's own audibility within the orchestra

This metric concerns a musician's ability to hear their own instrument clearly relative to the surrounding sound field — a balance in which excessive self-level distorts intonation and insufficient self-level compromises rhythmic precision. Dammerud's own laboratory and questionnaire findings confirm that the ratio of one's own sound to that of others is the single most frequently cited acoustic concern among orchestral musicians.

Cross-sectional audibility in the orchestra

Beyond hearing oneself, musicians must be able to hear players in other sections across the width and depth of the stage, a requirement complicated by the obstruction of direct sound by intervening players, stands, and instruments, and by delays of up to several tens of milliseconds across a large stage. Dammerud quantifies this obstruction effect through scale-model and computer studies of sound propagation within the orchestra and shows that the resulting attenuation and masking strongly influence whether string, woodwind, and brass sections can hear each other adequately [4]. Kahle's Auditori Barcelona case illustrates the same issue architecturally: without rear-stage absorption, brass and percussion masked the strings so severely that woodwind players could not hear the string section in front of them [2].

Orchestral balance at the conductor's place

Because the conductor's aural perspective differs substantially from that of the audience or the players, dedicated measures have been proposed to describe the balance heard at the podium. A measure reviewed in Dammerud's thesis, compares early (7–40 ms) to late (>40 ms) energy at the conductor's position and was found to agree well with conductors' own subjective impressions where standard measures did not [4]. Kahle further stresses that orchestral balance — for the conductor as much as for the audience — is frequently overlooked in acoustic design yet can be strongly shaped by decisions such as canopy height or absorption placement [2].

Stage acoustics

Stage acoustics encompasses the full set of conditions that determine how musicians experience playing together on a given platform: mutual hearing, self-audibility, the timing and level of reflections returning from the stage enclosure, and the audible presence of the main hall's reverberation. Dammerud's PhD thesis is a comprehensive treatment of this topic, combining musician surveys across twenty halls, physical modelling of sound propagation within the orchestra, and a critical evaluation of existing objective stage measures such as ST, concluding that a narrow, high stage enclosure with the stage strongly exposed to the main hall volume tends to be most favourable for players [2]. These findings inform the tuning strategies discussed in this paper and are complemented by Kahle's related case studies of stage enclosure modifications in Nancy, Porto, and Freiburg [2].

3. Venue and Tuning Session

The first venue is a 300-seat venue equipped with retractable stalls, a stage tower and an orchestra pit that can be closed to convert the space into a single-level rehearsal setting. Because of this flexibility, it serves an unusually broad range of uses: it functions as a rehearsal space for orchestra, singers, and choir, and hosts theatre, opera, chamber music, symphonic concerts, and amplified performances, all within the same room. Given this diversity of use, variable acoustics were implemented through an active acoustic system rather than purely passive architectural measures, and five distinct acoustic settings were tuned in advance, with impulse responses measured for each; the resulting reverberation times are shown in Figure 1 for the sake of completeness. To evaluate and refine these settings under real performance conditions, the orchestra was invited to a rehearsal session lasting approximately 1.5 hours, structured in three stages. First, the orchestra rehearsed alone, after which the singers joined, followed by the choir. Second, the orchestra moved into the pit, with soloists and choir joining from the stage. Third, a chamber music configuration was tested, combining piano

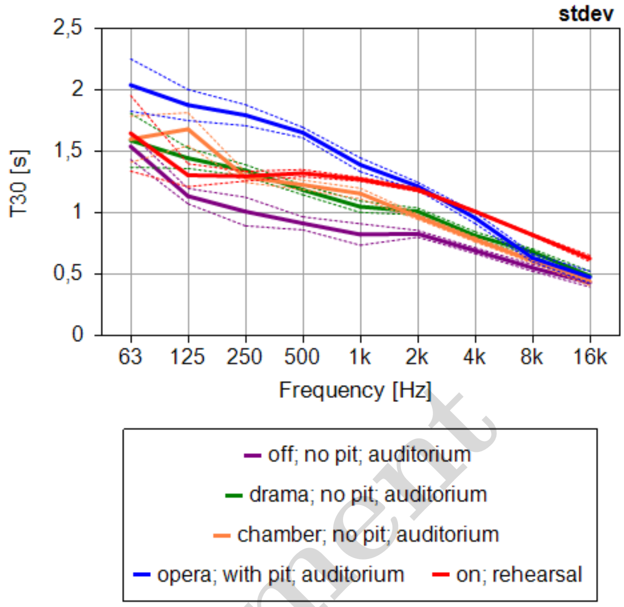

Figure 1: Reverberation times in the hall, active acoustic system turned off and on with four different settings.

and singers together with single instruments such as cello, trumpet, and xylophone. Tuning under these conditions proved challenging, as the time available with the full orchestra was limited; presets were therefore prepared beforehand and adjusted live based on immediate feedback from section leaders and the conductor, whose responses to changes in the acoustic settings were rapid and direct. Given the constraints of the session, no time remained for distributing questionnaires, so the assessment presented here relies on this immediate, spoken feedback rather than structured subjective ratings.

The second hall is an orchestra rehearsal hall located directly beneath an auditorium, a constraint that leaves the room's overall geometry far from ideal: the ceiling follows the raked profile of the auditorium seating above it, sloping down to a height of less than 4 m at the rear of the room. The tuning process was carried out in two distinct phases. A technical tuning phase was performed by the contractor and system integrator, followed by an artistic tuning phase carried out jointly by the acousticians and the orchestra. This artistic phase took place over two days, with the full orchestra present throughout and the full opera choir joining for one session. On the first day, the orchestra played a series of passages, after which the acousticians and musicians discussed their overall impressions together; the acousticians then translated these impressions into concrete physical adjustments — for instance, raising the ceiling by 500 mm or strengthening the reflection from the first violins toward the rear of the hall. On the second day, the contractor presented several pre-configured setups, which the orchestra evaluated in an A/B comparison, and the final configuration was selected on this basis.

4. Findings from the Tuning Session

The tuning session produced markedly positive feedback from both the conductor and the musicians, and each observation can be read directly against the metrics introduced in Section 2. These outcomes were not present from the beginning but emerged through an iterative tuning process in which initial shortcomings were identified, the preset was adapted accordingly, and the resulting changes were immediately evaluated by the performers. The conductor's remark that the harp was audible for the first time, together with his assessment that the balance between individual sections and between orchestra and soloists was very good, corresponds closely to orchestral balance at the conductor's place: a well-tuned early-to-late energy ratio at the podium is precisely what allows previously masked instruments such as the harp to register clearly from that position. The conductor's and musicians' shared impression that the room's dynamic range was very large reflects a favourable dynamic range of the orchestra, indicating that the tuned setting neither compressed loud tutti passages nor left soft passages under-supported — a direct counterpart to the dynamic response of the room, which governs how audibly the space "opens up" between pianissimo and fortissimo. That musicians could hear themselves clearly while remaining aware of all other instruments around them maps onto two distinct metrics simultaneously: one's own audibility within the orchestra, in the sense of a well-balanced self-to-other level ratio, and cross-sectional audibility in the orchestra, in the sense of adequate hearing across sections despite the obstruction and delay effects discussed in Section 2. This represented a clear improvement over the initial state of the session, during which, for example, the violin section reported difficulty hearing the celli. After the preset had been adjusted, this limitation was removed, and the musicians confirmed that the revised setting provided the desired level of mutual audibility. The singers' own choice of position — behind and to the left of the orchestra — and the resulting good mix and moderate choir loudness for the conductor again reflect orchestral balance at the conductor's place, this time achieved through choosing the right position rather than purely level-based adjustment. The clarity reported within the orchestra pit, where every instrument was distinctly identifiable and the concertmaster was surprised at how well he could hear the harp, is a further, more localized expression of cross-sectional audibility, confirming that the tuning succeeded even under the more constrained geometry of the pit. Finally, the singers' report of hearing the orchestra clearly across the entire stage without needing additional monitoring, together with the soloists' sense that the room's response actively supported their playing, both correspond to favourable stage acoustics as defined in Section 2 — an audible, well-balanced return from the enclosure that supports rather than competes with the performers. A particularly illustrative example concerned the trumpet, for which the players initially described the sound as appearing to stop only about 10 cm in front of the bell, indicating that the hall was providing insufficient acoustic support. Following the adaptation of the preset, the perceived sound projection and room response improved substantially, and the musicians expressed satisfaction with the resulting support provided by the hall. Taken together, these observations suggest that the tuning achieved a coherent balance across all of the metrics discussed above, as experienced directly by the performers themselves.

Another outcome of the tuning process in the second case study was that the active system contributed only a small objective change to the room's acoustic conditions, yet this change was immediately and clearly noticed whenever the system was switched off. The final system configuration retains only a single setting, optimized for the orchestra alone. When the choir joined the full orchestra, it became evident that the room was simply too small for the combined ensemble; nonetheless, musicians consistently reported that conditions with the system active, even under this oversized configuration, remained clearly preferable to conditions with the system switched off.

5. Conclusion

Both case studies illustrate the potential of active acoustic systems to turn a room itself into an instrument — one that can be adjusted and tuned much like a violin, rather than remaining a fixed architectural given. Where a passive hall offers a single, largely immutable acoustic character, an actively tunable space allows the same physical room to be reconfigured within minutes for orchestra, choir, chamber ensemble, opera, or amplified performance, and to be fine-tuned live in response to the specific musicians present on a given day. The tuning session showed that this potential is real: presets adjusted on the basis of immediate feedback from section leaders and the conductor produced audible improvements that performers could identify and articulate on the spot. Yet this same episode also confirms what the literature reviewed in this paper already suggests — that standard ISO 3382 parameters are not sufficient to fully capture or describe the sound field, particularly where subjective evaluation is concerned. Reverberation time and related single-number metrics can characterize a preset, but they cannot on their own explain why a harp becomes audible for the first time, why a choir finds one position preferable to another, or why a room "supports" a soloist. Turning a room into a playable instrument therefore raises further questions that remain open: how such spaces should be systematically tuned rather than adjusted by trial and feedback alone, how all stakeholders — musicians, conductors, singers, and technical staff — can be meaningfully included in this process under realistic time constraints, and how the resulting settings and their perceptual effects should be documented so that tuning knowledge can be retained, compared, and transferred between venues. Addressing these questions is a necessary next step if active acoustic systems are to be used as reliably and expressively as the instruments they are increasingly able to emulate.

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