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Development of a Technical Memorandum Describing Optimal Room Acoustic Parameter Ranges for Musical Performance and Rehearsal Spaces

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Abstract
A working group has been convened by the European Acoustics Association to develop optimum Room Acoustic Parameter (RAP) ranges for musical performance and rehearsal spaces. A Technical Memorandum, outlining the proposals of the working group is in production: the main contents are summarized in this article. The main focus has been to develop optimum parameter ranges for concert halls, as well as for other spaces for music rehearsal and performance, such as chamber music halls and orchestra rehearsal halls.

Room acoustic quality is a multi-dimensional phenomenon: multiple RAPs are therefore required to quantify acoustic quality. The RAPs as currently implemented do not however provide a robust differentiation of acoustic quality – both good and bad sounding halls can fall within the RAP ranges currently proposed in the literature. The Technical Memorandum describes a selection process for RAP ranges, with the aim of setting projects on a good path towards acoustical excellence, and to improve the quantification of the outcome.

While the possibility to develop novel parameters was at first discussed, is has been agreed that the RAPs already defined in ISO 3382 Part 1 will be used. The RAPs are physically linked; therefore, the RAP optimum ranges must form an internally consistent set, taking into consideration their variation throughout the space. Other important aspects that must be considered in the definition of optimal RAPs that are often overlooked are the orchestra/ensemble size, music type or genre, room volume available, ideal loudness during loud (forte) passages, variation of parameters with acoustic volume and with distance from the source.

It has also been established that measurement protocols should be refined to improve the differentiation between spaces of differing acoustical quality.

Keywords: room acoustics, optimal parameters

1 Introduction

It has long been recognised that acoustical quality is a multi-dimensional phenomenon. Sabine established this 120 years ago in his paper "*Reverberation*" [1] describing three necessary acoustical properties "in order that hearing may be good in any auditorium":

- sufficient loudness;
- components of a complex sound should maintain their relative intensities;
- successive sounds in music or speech should be clear and free from extraneous noises.

Various studies over the last century have indicated numerous independent subjective acoustical aspects significantly exceeding Sabine's three separately perceivable subjective acoustical qualities. In parallel, a search for measurable objective acoustical parameters, each maximally correlated with a subjective acoustical quality, has led to the commonly used set of Room Acoustics Parameters (RAP) defined in the International Standard ISO 3382 "*Measurement of room acoustic parameters*", Part 1: Performance Spaces [2]:

Strength, G
Reverberation Time, T
Early Decay Time, EDT
Clarity Parameters, C50, C80
Definition Parameter, D50
Centre Time, Ts
Early Lateral Energy Fraction, JLF
Late Lateral Sound Level, LJ
Interaural Cross-Correlation Coefficient, IACC
Stage Support, STearly and STlate

Establishing a set of optimal RAPs for a particular space is not always straightforward. While there exists a wealth of information in the acoustics literature, it has been up to individuals to combine resources from a number of places, often stretching across decades, to understand which combination of RAPs would be optimal for a particular space based on the type of space, the ensemble(s) that will use it, the type of music (and other uses) envisaged, the need for variable acoustics, along with the space and volume available (or that can be afforded). In addition, while there might be substantial information on a particular parameter for halls of a particular size, there may be a lack of information for other situations. The Early Lateral Energy Fraction and Late Lateral Sound Level are good examples of this: while there is substantial literature on large concert halls, much less information is available on the ideal ranges for smaller rooms.

Nor is it simple to discriminate between spaces and their acoustical quality on the basis of a small number of RAPs, in particular if only room-averaged values are provided. While room-averaged data may point to very fundamental issues with a space – such as an excessively long or short reverberation time (for the use intended) – rarely does room-averaged data provide enough information to indicate location-sensitive issues. Room averages can hide the fact that parts of a room may exhibit very high values of a particular parameter while others are lacking. Taking Strength as an example: the fact that the room-average Strength is in an acceptable range does not help the listeners for whom the sound is excessively loud in some seats, yet too quiet in other seats. The same logic applies to any and all parameters that are sensitive to the local acoustical conditions at particular seats or groups of seats in a hall.

For these reasons, a Working Group has been convened by the European Acoustics Association to develop optimum Room Acoustic Parameter (RAP) ranges for musical performance and rehearsal spaces. A Technical Memorandum, outlining the proposals of the working group is in production: the main contents are summarized in this article. The main contributors to the text of the Technical Memorandum are listed as authors here. A full list of the members of the Working Group is included at the end of this paper. The group is open to additional members – please contact the corresponding author of this paper for more information.

2 Current Sources for Room Acoustic Parameter Ranges

The mathematical definition of the above RAPs, along with requirements for their measurement, are contained in the Standard ISO 3382 Part 1. The standard also includes "typical ranges" for each parameter. These typical values are not optimal values, they are a record of the full range for each parameter, as measured in performance spaces. However, experience from the Working Group indicates that in some cases these parameter ranges have been come to be understood as "ideal" or "optimum" values. The “typical ranges” have appeared as requirements in briefs for new halls, unaltered from the ranges listed in the standard.

The “typical ranges” are however not optimal ranges: a performance space with room-average measured parameters within the "typical ranges" outlined in the standard could on the one hand have exceptional acoustical quality, on the other hand the space could equally well exhibit major acoustical flaws. In the current discussions to update ISO 3382, it should be considered whether the table containing “typical ranges” should be removed.

Furthermore, while it is clear that the RAPs for a particular space are physically related, it is common to see requirements for RAPs that are not physically possible to achieve in the same space. The RAP optimum ranges set out for a project must form an internally consistent set, taking into consideration the variation of the RAPs throughout the space.

Currently, accepted optimum ranges for RAPs tend to come from research papers and books. Well-known sources are, amongst others, the books by Beranek, Barron [3,4], who have independently surveyed many halls and correlated the measured parameters with the results of questionnaires into the subjective acoustical qualities. Some standards such as the German DIN 18041 [5] include recommendations for reverberation time dependent on volume, but do not provide recommendations for other parameters or indeed mention the important link between reverberation time, room volume and loudness (acoustic strength). The Norwegian Standard NS8178 [6], now adapted as ISO 23591 *Acoustic quality criteria for music rehearsal rooms and spaces* [7], has established a method for determining reverberation time, volume and strength, primarily to avoid that smaller rooms for music rehearsal are not too loud.

Previous research has tended to focus on individual RAPs, with "big picture" studies covering multiple aspects of music acoustics and the interconnections and relationships between the RAPs being much less common. Even though the relationships between RAPs - at least for a diffuse field case - are relatively simple to derive theoretically and are included in many textbooks, recommendations for RAPs tend to be "unlinked" with the mutual effects of RAPs not being taken into account (leading to the possibility, if not careful, of selecting physically impossible combinations).

Traditionally RT has been the main RAP to be set, and indeed for a long time it was the only RAP. Typically, RT is first set without reference to other acoustical aspects and as the main or only target for a project this can lead to problems, in particular if the room volume and the resulting acoustic strength and loudness are not considered in parallel. This reliance on the RT as the primary RAP is therefore to be considered.

3 Aim and Approach

The aim of the Working Group is to develop optimum ranges for RAPs for spaces for music, while simultaneously adding context to the RAPs and providing explanation regarding the implications of certain choices.

Early on in the process, it was discussed whether to expand the number of RAPs beyond those listed in ISO 3382. While there are valid criticisms regarding the common RAPs, it was decided to restrict the contents of the primary chapters of the Technical Memorandum to the parameters defined in ISO 3382. In addition, the standard does not include some commonly used RAPs such as bass and treble ratios, a chapter has been included in the Technical Memorandum to discuss alternative parameters and aspects of acoustics not covered by the common parameters.

The broader aim is to help acousticians – along with the clients, architects and artists that they work with – to put projects on a good track from the very conception of the project. In particular, the choices that are made at the start of a project are especially critical, since these fundamentally establish the acoustics and the potential acoustical quality of the space. As mentioned above, a major discussion point has been the relationship between room volume, reverberation time and strength. Room volume (as well as height, width, and other spatial attributes) is not an acoustic parameter in the typical sense, but it is critical to the acoustical quality. The balance between the size, loudness and reverberance of a space is an extremely important aspect to determine at the start of any project. Based on the approach developed in the Norwegian Standard NS8178 [6] and ISO 23591 [7], a method for establishing optimal relationships between these factors also for larger halls has been developed.

A further aim is to describe (and promote) methods and guidelines for conducting measurements, as well as for the presentation of measurement results, so that RAPs can be more effectively used to understand the detailed acoustics of a space and to discriminate between spaces of differing acoustical quality. A discrimination of many aspects of acoustical quality on the basis of the common RAPs, their implementation and presentation (typically as room averages) is extremely challenging, if not almost impossible. Experience from renovation projects, where measurements have been carried out before and after acoustical changes to a hall have been implemented provide an important insight [8]. In some cases, very significant, positive, audible changes to a hall have been made, yet the room-average RAPs indicate either a negligible change or a change in the opposite direction to that expected.

The conclusion of the Working Group is that measurements must in general be analysed and presented in a more detailed fashion, avoiding room averages. ISO 3382 Part 1 already includes a statement to this effect:

> "*The measurement results for the measures described in this annex [ISO 3382 Part 1 Annex A] should normally not be averaged over all microphone positions in a hall because the measures are assumed to describe local acoustical conditions. In the case of a large hall, it can be useful to average the results in some sections of the hall (stalls, first balcony etc.). Some measures such as sound strength, G, tend to vary with the distance, and a graphical plot of G as a function of source-receiver distance can be useful.*" [2]

In addition to plotting G as a function of distance (with comparisons to Barron's Revised Theory of Sound Level [9] providing a highly useful theoretical comparison), applying this approach to other parameters can elucidate more about the acoustics of a space. Mapping measurement results across audience and stage areas also provides a further method by which to gain understanding about the acoustics of a hall.

The intention is also to increase the reliability of comparisons made between measurements by different groups. A chapter in the Technical Memorandum is dedicated to refinements in measurement methods and the presentation of results.

A final aspect of the approach taken with the Technical Memorandum is to provide a logical framework for establishing optimal RAPs. Rather than presenting tables of parameter values, the intention is to describe methods and strategies by which optimum parameter value ranges can be determined based on the subjective aims and constraints of a particular project or space. The discussion in the Technical Memorandum is not intended to limit or restrict: it is still up to concert hall designers, acousticians, architects and clients to make their own decisions. The hope however is that with the information in the Technical Memorandum, more informed decisions can be made, based on a fuller understanding of the implications of the chosen RAP values, thereby putting the design on a good track from the start.

4 Scope and Structure

The scope of the Technical Memorandum focusses on spaces for unamplified music. At the lower limit are spaces for chamber music where a small audience can be accommodated – a lower limit of an audience of 50 has been discussed, leading to a space with a floor area of around 50m^2 and an acoustical volume of 200m^3. At the upper end of the scale, the Technical Memorandum intends to cover the largest concert halls for symphonic music with volumes up to 20,000 to 40,000m^3. Within this total range of 200m^3 to 40,000m^3 fall a whole host of room types and sizes, including recital halls, smaller concert halls, orchestra rehearsal halls and large recording spaces.

There is an overlap in the scale of rooms covered by the Technical Memorandum and the rehearsal spaces covered by the standard ISO 23591. This is intentional and members of the group who have developed NS8178 and ISO 23591 are part of the Working Group. It is intended that the documents align for these smaller spaces.

The Technical Memorandum is structured as follows, with a primary author determined for each chapter:

Introduction (Evan Green): Description of the scope of the document, aim, intent, approach and background information and definitions.

Selection of V, G, and RT (Uwe Stephenson): Discussion of the relationships between volume, strength and reverberation time leading to proposed strategies for establishing optimal values.

Reverberance (Winfried Lachenmayr): Selection of EDT and RT parameters. A point of discussion has been whether the EDT target should take precedence, with RT following the EDT.

Balance of Early and Late Sound (Michael Barron): Aspects relating to the selection of early and late energy balances and the parameters C80, Gearly, Glate.

Spatial Parameters (Louena Shtrepi): Discussion of the optimal values of Early Lateral Fraction, IACC and Late Lateral Level.

Stage Parameters (Eckhard Kahle): Analysis of stage support measurements, primarily STearly (ST1) leading to guidelines for STearly values dependent on hall volume and orchestra size and the distribution of STearly across the stage.

Variable Acoustics (Henrik Möller): Discussion regarding the range of variability for various parameters in multipurpose venues along with strategies for adjusting the acoustics.

Acoustics Aspects Not Covered by the Parameters (Tor Halmrast): Discussion of acoustics aspects not accounted for by the common parameters.

Measurement and Presentation of Parameters (Bård Støfringsdal**):** Guidelines for measurements and presentation of results, including presentation as plots with source-receiver distance and mapping.

The Technical Memorandum is in production, and additional members to the Working Group are welcome to join for further discussion and review.

5 Conclusion

We hope that the Technical Memorandum will become a useful reference for the acoustics community, leading to more assurance regarding the acoustical quality of future music spaces.

The Working Group welcomes any comments and input to the development of the Technical Memorandum.

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