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On the assessment of the multiplicity of spaces in the acoustic environment of cathedrals: The case of the cathedral of Seville

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ABSTRACT

Depending on the type of configuration to be adopted there are multiple forms of occupation of a cathedral which can significantly influence the acoustic environment. As a result, several activities with different acoustic requirements, including preaching and the musical performance of a song or piece can coexist during the same ceremony. Therefore, the requirements needed to achieve suitable acoustic conditions may vary depending on the type of configuration.

This article presents the development of the multiple spaces inside the cathedral of Seville, the largest Gothic church in the world. The aim is to evaluate the acoustic environment of the cathedral, which has an exceptional multifunctional character, in terms of the different configurations generated inside for concerts and other unique ceremonies, as well as the varied arrangement of the sound sources to meet the requirements of these events. The in situ acoustic measurement carried out in the cathedral enabled the assessment of the current acoustic conditions. In addition, the use of virtual simulation tools made it possible to recover the sound of past times and to establish its potential in future intervention projects. The evaluation of various configurations established the effects of the occupation, of decoration in the acoustic environment, and of different choral and instrumental musical motifs. This analysis was carried out taking into consideration the objective acoustic parameters contained in ISO 3382 and a subjective approach to the temporal and spatial factors. According to this analysis in a large multifunctional building such as the cathedral of Seville there is no general preference for a specific music motif given that the subjective perception of the sound field depends on the type of configuration, while occupation varies depending on the purpose of the event.

1. Introduction and objectives

The acoustic complexity of cathedral spaces is due partly to their geometry, materials, and multifunctional character. The wide range of options for the occupation of a cathedral requires the potential evaluation of the suitability of these churches as venues for events, depending on aspects such as the position of the sound source [1], the configuration of the space [2], the percentage of occupation [3] and the decoration [4,5], as well as the type of activity carried out [6,7], both choral and instrumental [8]. In recent years, there has been an increase in the number of studies on the acoustic conditions of worship spaces [1,2,9], mainly examining their current state [10–12]. However, there is little research analysing the behaviour of these spaces in the past, taking into account the multiple configurations within the single space [6].

From an architectural perspective, the choir of the cathedral is crucial in generating and transforming interior church spaces. On occasion, the shape and location of the choir lead to major modifications of the interior spaces, as in the case of Seville cathedral, which follows what is known as the “Spanish configuration” [13]. Several Spanish cathedrals, following the recommendations of the Council of Trent, moved the choir space from the centre of the nave to other locations around the presbytery, prompting major spatial and acoustic transformations [2]. In other European typologies the positioning of the choral space marks the main difference in relation to the Spanish model. Unlike the Spanish model, the other two European models allow for the occupation of large audiences along the central nave in all kinds of celebrations, with the source located on the Main Altar.

In the cathedral of Seville, the choir is located in the centre of the church, dividing the central nave into two differentiated areas. One of the areas in front of the presbytery creates a space for preaching where the voice can carry from the pulpits reaching the audience in an acceptable manner. As analysed in a previous study [14], the position of the choral space prevents the depth of the central nave from being used making it necessary to find a configuration that can accommodate a large audience. The different forms of occupation in the cathedral have

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created multiple spatial configurations to adapt the acoustics of the space to the necessary requirements to ensure suitable acoustic conditions [15].

An acoustic model was used for the development of the study, and was calibrated based on onsite measurements inside the cathedral, following the methodology established for this type of large historical space [8,16,17]. In addition, virtual simulation tools were used to create past configurations, allowing the recovery of sound from past eras [14,15,18], and the discovery of a method for achieving suitable acoustics in future intervention projects, obtaining the results of the acoustic parameters analysed.

The main aim of this article is the objective and subjective assessment of this acoustic environment for music in the multiple spaces that are part of a Spanish cathedral, in this case Seville, the largest Gothic church in the world. Given the multifunctional nature of the cathedral, the results are evaluated for different configurations with various source positions established. Equally, this paper analyses the influence of the occupation and the ephemeral architecture incorporated for individual events, the performance of different pieces of music for the same scenario, and the adaptation of several spatial configurations for the same piece of music, which will allow the optimal configuration for this typology to be determined.

2. Multiplicity of spaces

Since its construction, the cathedral of Seville has become the most emblematic representative of the cultural heritage of the city, even being used as the model of the Spanish cathedral type exported to Ibero-America. This exceptional model promotes the celebration of great ceremonies, especially liturgical-religious ones, indoors. Although the cathedral was conceived as a space of great historical and heritage value, this is no impediment to its multifunctionality, which allows for the development of individual civil events. In this regard, the cathedral of Seville should be understood not as a single space, but as a series of different spaces with their own acoustic characteristics and function, both liturgical and cultural.

The interior space of the cathedral is articulated around two main longitudinal and perpendicular axes: the central nave and the transept. In addition, the central position of the choir stalls breaks up the space in the main nave, generating a new space, the *trascoro*. Fig. 1 shows how the different zones inside the cathedral are organised. For centuries, the multifunctionality of the cathedral space has meant that numerous events have been held in each of the zones generated within the cathedral. In this study, numerous existing configurations have been analysed in different historical stages and in past, present, and future forms. Each configuration corresponds to a virtual model (M) acoustically analysed in the results section.

Fig. 1 provides an understanding of the two ways in which the liturgical space can be analysed. These ceremonies have been developed fundamentally along the two main perpendicular axes of the interior cathedral space: the central nave and the transept. Different zones were used depending on the type of event held, as well as the occupation and space requirements. Fig. 2 shows the configurations adopted inside the cathedral of Seville for the main celebrations that have taken place up to the present and analysed in this work. The sound source positions most frequently used throughout history in the most common events celebrated inside the cathedral are as follows:

- Source S1: Main Altar [19]: During the 16th century, the few documented events were held mainly in the Main Altar. This configuration follows the traditional way in which the liturgical space was used. This source position is the one used in the calibrated model reproducing the current state of the cathedral.
- Events at S1: this source was used for spatial transformations carried out centuries ago for major festivities such as the Royal Coronation in the 17th century (Model M1), and Easter, in the 16th century (Model M2) [20,21]. It is also important to note the luxurious displays set up for these festivities, transforming the inner space of the cathedral and noticeably affecting the acoustics.
- Source S2: *Trascoro*: this area was originally occupied by the congregation, who remained separate from the presbytery and choir and did not take part in the liturgy.
- Events at S2: Liturgical celebrations held, both ordinary and annual [22], evaluating the occupation and the position of ephemeral architecture (Models M3 and M4).
- Source S3: Transept [11]: this source position noticeably increases the areas suited to the presence of the audience, taking advantage of the depth of the transept nave.
- Events at S3: it should be noted that at present configurations are adopted for holding massive concerts, with an audience of up to 2000 (Easter Miserere model M5 and the Messiah model M6) [23]. Two configurations conceived as future interventions and incorporating proposals for improvement compatible with the heritage character, are also analysed (Models M7 and M8).

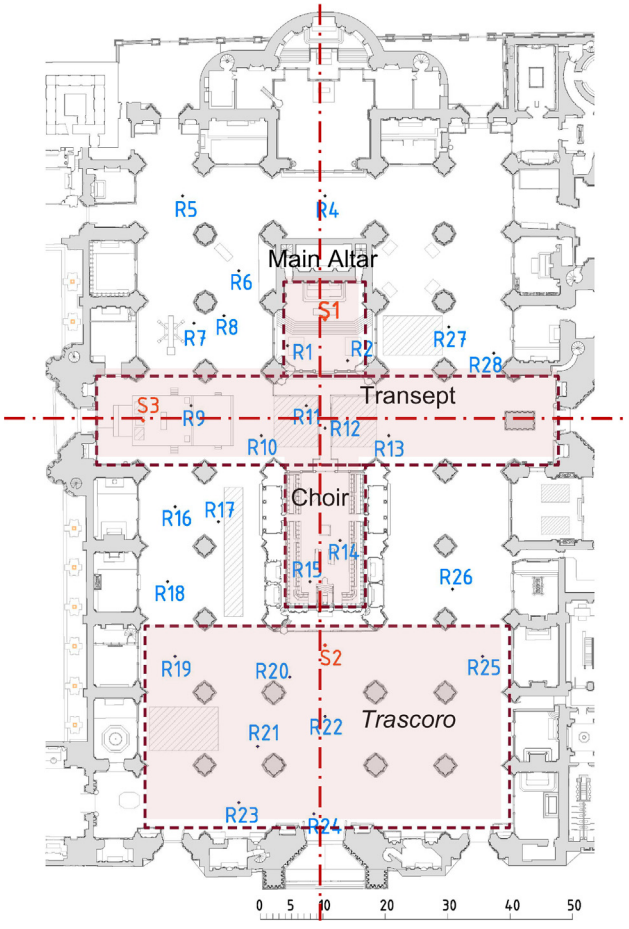

Fig. 1. Plan of cathedral of Seville with delimitation of zones. Location of sound sources (S) and receiver points (R) during in situ measurements.

3. Methodology

Acoustic simulation based on acoustic measurement results is a highly useful tool for predicting the indoor acoustic environment of a space where it is impossible to reinstall ephemeral interventions used in the past. Thus, this technique also allows historic acoustic behaviour to be assessed by offering the chance to recover the sound field of a centuries-old space.

The methodology followed in this work begins with the development of an experimental technique that enables the evaluation of