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VOICE, MUSIC AND ACOUSTIC SPACES AT THE ROYAL ABBEY OF FONTEVRAUD

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ABSTRACT

How do singers adapt to different acoustic spaces? Can we interpret through acoustic criteria the preferences of singers for specific positions in a room? How do singers hear each other according to different acoustic spaces and positions? Experts in different fields such as medieval music, musical iconography, performance, voice and room acoustics are working together on a pluri-disciplinary project gathering the Collegium Musicæ institute of Sorbonne University and the Royal Abbey of Fontevraud in France. In relation with the liturgical function of the different spaces studied within the abbey, experiments were carried out in several spaces in the abbey, several positions and several configurations between singers. The measurements include sound recording at the ears of singers and impulse response measurements. Subjective evaluation by the singers was also included, using both scale surveys and explanatory interviews. Singers from Dialogos Ensemble with a high command on medieval music took part in the experiment, as well as singers from the Sorbonne University students choir. Based on the analysis of the data collected, the paper will discuss relations between mutual hearing of singers, acoustic spaces and positions, acoustics criteria and preferences of the singers.

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1. INTRODUCTION

This paper relates the results of a unique experience that was staged by the Collegium Musicæ of Sorbonne University in collaboration with the Cultural Centre at Royal Abbey of Fontevraud. At Easter 2023, an artist in residence, Jean-Yves Bernhard, created an *a cappella* vocal performance based on a two years experimentation for the placing of singers in reverberant spaces. The performance made use of different spaces of the Abbey, namely the cloister and the abbey church, in order to make the listeners perceive the different resonances of these spaces. Starting with a static performance in the garden and under the arches of the cloister, the public was taken in procession to the abbey church where different singer groups made resonating the different parts of the church – nave, transept, and apsidal chapels – before they gathered at the end of the nave for the final chorus. The choreography was based both on liturgical practice and on acoustical measurements, which we now relate.

2. MOTIVATION

The problematics of the voice and acoustics part of the research project "Voice, Music, and Acoustic Spaces" is summarized by the question: where to place a group of singers singing in a religious space? Behind the question lurks another one concerning 21st Century's concerts in an abbey, and the question of the repertoire. The methodology we followed was: 1/ gathering information and questions

from surveying the acoustical literature on musician and singers placement on stage, from analysing medieval iconography on the placement of monks and nuns when singing the hours, and filming and interviewing two singers specialised in medieval music when discovering the different spaces of Fontevraud Abbey while singing alone or together; 2/ measuring the room acoustic parameters, estimating how singers do hear each other in different spaces and positions through measurements and questionnaires; 3/ sharing the results with the composer, the choir chief and the singers.

3. WHAT DOES ICONOGRAPHY TELL US

Medieval musical iconography allows musicologists to better understand the different modalities of vocal practices in cathedrals, abbeys and churches and the possible interactions with architecture. A significant sample of the representations of monks, canons or nuns in their stalls is accessible on the Musiconis site (https://musiconis.huma-num.fr). It should be noted that the arrangement of the liturgical choir with the celebrants varies according to times and places and also according to the feasts of the religious calendar. If we do not have sufficient iconographic sources to describe musical practices in Fontevraud in the Middle Ages, it is reasonable to think that the nuns entered the choir through the cloister, and sometimes singing, and that they settled in the stalls, two rows on each side of the choir, facing the other side, for psalmody and response during services (illustration).

Figure 1. Nuns in stalls (London, BL, Cotton ms. Domitian A XVII f. 74v.)

Around the central lectern in the middle of the wooden stalls were grouped singers who could read the music on the large manuscript and direct their voices towards the altar and the apse. The diffusion of sound also depends on the height of the woodwork, the thickness of the albs and liturgical clothes and sometimes even the hangings hung above the stalls. The voices react to the sounds of the bells which punctuate daily life and the services and we must not neglect this strange polyphony produced at the time by the masses "dépêchées, à voix hautes ou basses", which priests had to celebrate in the small apsidioles in virtue of vows and foundations. It is undoubtedly necessary to imagine significant contrasts between moments of silence and more agitated periods with a kind of intense humming which could make one think of a beehive, especially if there is traffic of pilgrims and processions in the ambulatory (déambulatoire). We must however remain cautious with these hypotheses because the data may vary from one place to another but the recurrence of certain information such as the numbers, the placement of the singers, the direction of the voices, and the decorations, are very useful for the studies on acoustics.

4. WHAT ARE SINGERS TELLING US

The two singers form the Dialogos Ensemble explained us in the interviews what they are looking for when discovering a room for the first time:

- first they told us that they imagine how the public will receive their voice. For that purpose, they walk around the room, singing and listening to the response of the room.
- when alone, they love to “play with the room”, using its resonance as a kind of polyphony. The resonance helps them maintaining accurate tuning, and is therefore favourable for modal music. On the other hand, it forces them to sing more dryly to avoid “soup”: in less reverberant spaces like the cloister, they have to recreate the resonance themselves. This gives them indications on an adequate repertoire to sing and on interpretation choices to make.
- they look for “support” from the space by preferring positions near to the walls, especially near corners. This is coherent with supporting lateral reflections. However, acoustical measurements do not reveal these strong reflections.
- when in ensemble, they look for positions close to each other, especially when the reverberation is

loud. This is consistent with better hearing the others. It is also coherent with the iconography that represents singers very close to each other.

The two singers have tested a large amount of configurations in the different places (cloister, refectory, church), moving or still, facing or turning to an imaginary public, distant or very near each other, etc. Finally their favourite choice for a concert of Middle Age music would be either in the abbey church, at the bottom of the stairs below the main nave entrance, or near the end wall of the refectory.

Unlike the traditional approach (e.g. [1] and references within), we did not assess musical quality with recordings, but only through the self-perception of the singers and their recollection of it. Note also that they did not link pitch accuracy to support, as in 1, but to resonances, that is, to reverberation.

5. WHAT DOES ROOM ACOUSTICS TEACH US

There exists a huge room-acoustical literature on listeners' perception of space, but not so many papers concerning musicians' perception of space. As perception of space is based on reflections [2], we have focused on dealing with the perception of early reflections. Among those, Seraphim's papers [3,4] were deemed as most relevant since they focus on the perception of few reflections, both without and with reverberation, because monastic spaces are characterised by a predominant reverberation with very few early reflections. Seraphim's teaching is summed up in Fig. 2 (from [2]) for incoherent reflections, which shows that masking by the direct sound quickly vanishes, but that a subsequent reflection masks all reflections preceeding it if they are 10 dB below the direct sound level.

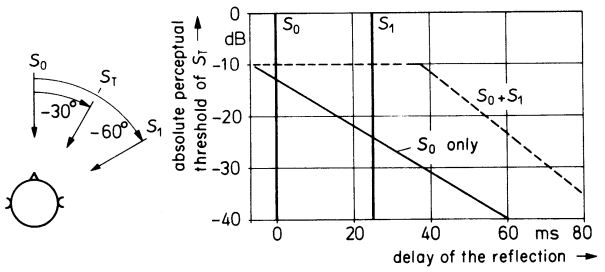

Figure 2. Perception threshold for reflections (reproduced from [2]).

More recent studies have basically confirmed Seraphim's results while considering longer reflection delays [5], or finding lower masking levels just after the direct sound in case of coherent repetition of the direct sound [6,7]. Further, the literature says that musicians appreciate the presence of a wall at a distance comprised between 3 and 6 meters [8] .

We therefore applied these ideas to the different spaces of Fontevraud Abbey. Fig. 3 represents the reflectogramme measured between a source and a receiver at 3.25 m distance, and located at one extremity of the refectory. The decreasing straight line corresponds to Seraphim's threshold of detection; most reflection comes from the frontal direction, except the strongest one, which is lateral. According to Fig. 2, this strong lateral reflection therefore masks most of the other ones, either preceding it or following it, confirming that monastic spaces are almost exclusively reverberant.

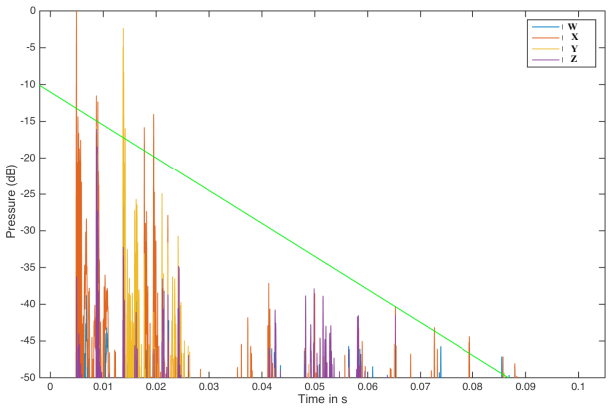

Figure 3. B-format reflectogramme at 3.25 m distance, with directions W (omni), X (front), Y (side), Z (vertical).

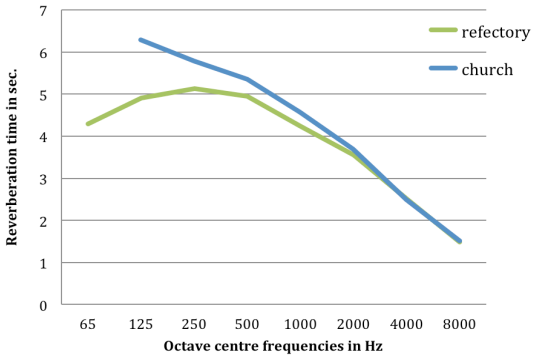

Figure 4. Reverberation times of refectory and abbey church in octave bands.

As Marshall and Meyer [9] showed that "the singers' auditory impression is dominated by reverberation rather than the early reflections", we measured the reverberation time in all spaces. Fig. 4 presents the reverberation times of the refectory and the abbey church. They are characterized by very long durations at all frequencies, as is typical from monastic structures.

Fig. 4 does not display reverberation times for the cloister, as it is a diffusing space where reverberation changes with distances to the source [10]. But from Fig. 3 and the volume of the refectory (3,700 m^3) and the nave of the church (12,700 m^3), we derived the critical distance, that is, the distance from the source at which the direct sound and the reverberation (i.e., the diffuse field) have the same level. They are displayed in Tab. 1 for the refectory and the abbey church, as function of frequency.

Table 1. Critical distances (m) in the refectory and abbey church.

freq. Hz	125	250	500	1000	2000	4000
refectory	1.6	1.6	1.6	1.7	1.9	2.2
nave	2.5	2.6	2.7	2.9	3.3	4.0

Critical distances remain of the order of 2 m at all frequencies in the refectory, and 3 m at all frequencies but 4 kHz in the nave or the abbey church. We therefore expect singers to prefer such distances between each other if they want to achieve some balance between intelligibility and ease of singing. Note the longer critical distances in the nave of the church, despite the longer reverberation times. This is simply due to the larger volume of the church, implying larger equivalent absorption areas. Indeed, the critical distance is proportional to the square root of the equivalent absorption area.

6. WHAT ARE SINGERS HEARING

When applied to the perception of one's voice by singers, Ternström et al. [11] proposed to consider the *self-to-other ratio* (SOR), measured with two microphones at the ear of the singers: the sum of the two microphone signals corresponds to the *self* signal; and their difference to the *other* signal. By monitoring the running level ratio, an indication of the ease of singing is obtained.

Therefore in Easter 2022, 3 female singers of the Dialogos ensemble were recorded in different places of the refectory and the abbey church while singing a piece of Middle Age music. Their SOR were measured and analysed, and showed the following results: when singing the same melody, their SOR are very similar (between 10 and 12 dB) and in agreement with the literature; but when they sing 2 or 3 different voices their SOR differ, which can be related to the interpretation choices of distinguishing between leading and accompanying roles. However, in all the measurements, the mean SOR increases when the mean distance between singers increase.

In autumn 2022 we then made a more systematic experiment to measure the relation between the SOR and the distance between singers, and how this relation can be influenced by the room acoustics. We asked 6 male singers and 6 female singers to sing an extract of Jean-Yves Bernhard's composition at several distances in the refectory and we measured their SOR. The results show that the SOR is indeed increasing with the distance, but presents a saturation effect further apart than the critical distance. An element of explanation is that at larger distances, the reverberation of the room is the main contribution of the "other" part of the SOR, and that the room response is quite independent of the position of the source, as is known from room-acoustics.

Beside the acoustical measurements, we wanted to know how the singers perceive the SOR. We asked them to fill a questionnaire on a scale ranging from "the others are too loud", over "well balanced", to "I don't hear the others" for each distance. The results show a strong relationship between the perceived SOR and the distance (high correlation), confirming the relation between the measured SOR and the distance. But most interesting, the singers perceived "well balanced" SOR at distances comparable to the critical distance. Fig. 5 schematically sums up those results.

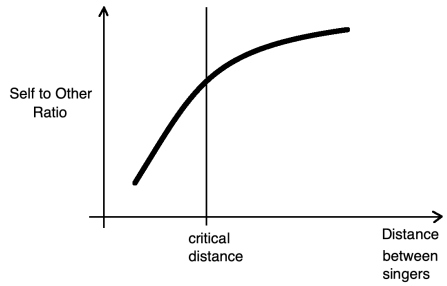

Figure 5. Schematic representation of the Self to Other Ratio (SOR) vs distance between singers in a reverberating room.

Finally, a preliminary experiment for assessing the number of singers needed to make a choir section was made in the abbey church. 2 to 6 soprano singers, in random order, sung the same phrase in front of the altar in the middle of the choir. Three of them wore the microphone system at their ears. The public, located in the transept, was turning its back to the singers to avoid visual clues, and had to fill a questionnaire on ensemble quality (including pitch accuracy), quality of voice blending, and vocal balance. The results show that the SOR is decreasing when the number of singers increases, and that when listeners are further apart than the critical distance, it is very hard to determine how many singers are singing.

7. CONCLUSION

The major result form the present experience is the preference by the singers to cluster at distances shorter that the critical distance. This is in agreement with both the iconography and the measurements of the SOR, which levels at a maximum for distances larger that the critical distance. The singers of the Dialogos Ensemble were quite adamant about it, with expression like: "*Here* I prefer". However, reverberation is useful for them, as it helps accurate tuning; they must nevertheless adapt their diction to it in order to maintain intelligibility. Whereas these two last effects are well known in the room-acoustical literature, the former one is more innovative.

While elements of the structure of his musical composition were inspired by liturgical and musicological data, discussions with the composer Jean-Yves Bernhard at different stages of the research project allowed, on one hand, to include experiments based on questions raised by the composer (i.e. influence of the number of singers), and, on the other hand, to adapt the musical writing including experimental results (i.e. absolute and relative positions of singers). As a result, the project can be seen as combining scientific and artistic research.

8. ACKNOWLEDGMENTS

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