

Anechoic recordings of Italian opera played by orchestra, choir, and soloists^{a)}

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Abstract: Auralisation-based research needs anechoic recordings. Where opera is concerned, anechoic material is limited to a few recordings. Using the approaches of previous recordings, the present work shows methods and results of a recording set focused on the Italian melodrama period. The chosen motifs come from scores of Donizetti, Verdi, and Puccini in order to consider the most performed composers and the peculiarities of their styles, which span from the early 19th century to the 20th century. Excerpts from three operas have been played by professional musicians and soloists with an array of twelve microphones in a damped room, which can be considered anechoic. The multi-track files of the recorded materials are freely available for academic purposes.

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1. Introduction

Anechoic recordings were used since the 1970s for listening tests based on auralisations.¹ Nowadays, several research fields need anechoic recordings for: preference ratings, obviously,^{2,3} but also heritage preservation,^{4,5} acoustical design,⁶ phenomenological issues,⁷ and more.

Earlier anechoic recordings were recorded in a BBC anechoic chamber⁸ consisting of compositions for small orchestras. Despite its low dynamics, these recordings were widely used in early subjective investigations on room criteria.¹ In 1988, a large orchestra was recorded in a damped concert hall.⁹ The study was mainly oriented towards the comparison of different miking techniques and the subjective evaluation of convolution techniques. In the years 1987–1992, the *Archimedes* project recorded excerpts for soloists (speakers and musicians) in various acoustic conditions (anechoic chamber, listening room, studio, church).¹⁰ The goal of the project was to quantify the “subjective influence of listening room acoustics and loudspeaker directivity on the reproduced sound.” In the *ERATO* project, which investigated the acoustics of the ancient theatres, ancient Greek singing pieces were recorded¹¹ by scholars of Ferrara University. The same research group was involved in the *CHARISMA* project, which was focused on ancient Islamic and Byzantine intangible heritage.¹² The small ensemble or soloist was recorded for the first time using an array of five omnidirectional microphones.

In almost all of the previous works, musicians were recorded while playing together, as in an ensemble. On the contrary, Vigéant *et al.*¹³ used multichannel techniques to record musicians playing solo, following a video recording of the conductor as sync source. The musicians were recorded individually in the anechoic room with the same cubic array used by ERATO and CHARISMA projects. Two or three tracks were recorded for each string part, with one track for the remaining parts. Some years later, Pätynen *et al.*¹⁴ recorded symphonic and opera music by using an approach similar to the previous study but extended the number of musicians and the miking spatial resolution: the orchestra parts and a singer were recorded individually in the anechoic room of Aalto University using an array of twenty-two microphones. Anechoic pieces for choir were also recorded by Freiheit;¹⁵ the pieces spanned several centuries of choral music production, but the voices were recorded simultaneously as an ensemble.

The most recent years’ trends follow the Vigéant-Pätynen multi-track workflow: Pedrero *et al.* recorded coral pieces from Mozarabic tradition;¹⁶ Woïrgardt *et al.* recorded Flamenco, Blues, and Pop pieces for guitar and voice;¹⁷ Böhm *et al.* recorded Beethoven’s 8th Symphony;¹⁸ Théry and Katz recorded string quartets, jazz “manouche,” and standard jazz pieces for the little

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ensemble.¹⁹ It should be noted that recently the recording quality was increased in order to achieve a pleasurable listening experience, high dynamics of the signal, and low noise levels. All of these aspects are critical to obtain realistic auralisations. For these reasons, Patýnen’s recordings were denoised and re-distributed in 2016.²⁰

A partial taxonomy of anechoic recordings provided by previous projects is summarised in Table 1. Table 2 lists the musical terms in Italian and Table 3 lists the anechoic recordings of the present work.

The present work aims to extend the availability of recorded anechoic material by introducing three multitrack recordings of voice parts of an Italian opera. A dodecahedral array of microphones with a 1.1 m radius were set in a listening room damped with porous material. The

Table 1. Partial taxonomy of previous released anechoic recordings. “Solo” means that performer(s) was (were) recorded one by one, “ensemble” means that performers were recorded together. “Multi-tracks” column show which recordings are available as multiple tracks.

Reference	Type	No. of mics	Location	Music materials	Multi-tracks
8	ensemble	1	BBC	Gibbon: <i>Royal pavane</i> Mozart: <i>Symphony KV 551</i> Arnold: <i>Sinfonietta, opus 48</i> Haydn: <i>Symphony no.102</i> Wagner: <i>Siegfried Idyll</i>	no
9	ensemble	29	Osaka	Haendel: <i>Water music</i> Mozart, <i>Le Nozze De Figaro</i> (Ouv.) Beethoven: <i>Symphony no.9</i> Mendelssohn: <i>Symphony no. 3</i> Glinka: <i>Ruslan And Lyudmila</i> (Ouv.) Verdi: <i>La Traviata</i> (Preludio) Brahms: <i>Symphony no. 4</i> J. Strauss: <i>Pizzicate-Polka</i> Bizet: <i>L’Arlesienne</i> , Minuet Bruckner: <i>Symphony no. 4</i> Debussy: <i>l’Après-midi d’un faune</i> Mahler: <i>Symphony no. 5</i> Mussorgsky: <i>Pictures at an exhibition</i> Šostakovič: <i>Symphony no. 5</i>	no
10	solo	1	DTU	Speech and excerpts for solo	no
11	ensemble	6	Ferrara	Ancient Greek singing pieces	no
12				Ancient Islamic and Byzantine pieces	
13	solo	5	DTU	Brahms: <i>Symphony no. 4</i> Mozart: <i>Symphony no. 40</i> Stravinsky: <i>Circus Polka</i>	yes
14	solo	22	Aalto	Mozart: <i>Don Giovanni</i> , aria Beethoven: <i>Symphony no. 7</i> Bruckner: <i>Symphony no. 8</i> Mahler: <i>Symphony no. 1</i>	yes
15	ensemble	24	3M	Stanford: <i>Beati Quorum Via</i> Thompson: <i>Alleluja</i> Ferguson: <i>Who is this</i> Aguiar: <i>Psalm 150</i> Willam: <i>Kyrie</i>	no
16	solo	32	RWTH	Mozarabic chants	yes
17	solo	1	FH-Köln	Two Flamenco pieces Blues A Hell of a guy	yes
18	solo	1	TU–Berlin	Beethoven: <i>Symphony no. 8</i>	yes
19	solo	1	Sorbonne	Bach: <i>BWV1068</i> Aria Bach: <i>BWV1080/15</i> Canon Vivaldi: <i>RV315 “Summer”</i> Reinhardt: <i>Minor Swing</i> Ellington: <i>Don’t mean a thing</i> Bechet: <i>Si tu vois ma mère</i>	yes

Table 2. List of the musical terms in Italian and German used in this paper. Notations of tempo (e.g., “larghetto,” “andantino”) are not reported.

aria	solo vocal piece with instrumental accompaniment
belcanto	style of singing characterised by beauty of tone rather than dramatic power
cabaletta	final section of an aria, having a fast pace
cadenza	a virtuoso solo passage occurring near the end of a piece of music, formerly improvised by the soloist but now usually specially composed
colla voce	an indication that the vocal part sings in a free manner and the other instruments should follow
crescendo	gradual change of the volume to louder
libretto	text written for and set to music in an opera
ouverture	an orchestral piece at the beginning of an opera
preludio	synonym of ouverture, but shorter
Siciliana	slow 6/8 time with lilting rhythms
recitativo	style of delivery in which a singer is allowed to adopt the rhythms of ordinary speech
romanza	a short piece of song-like character
tempo	overall speed of music
tone cluster	musical chord comprising at dissonant tones

excerpts were recorded by musicians and soloists one track by one track under the supervision of a conductor, who listened and re-recorded each track until a proper orchestral sound was reached. The noises not produced from instruments, such as hisses, breathes, and body movements, were manually erased in the post-processing phase. All the tracks of the array were exported in .wav format and uploaded to a free repository.

2. Music materials

In order to select representative opera material to be recorded, a preliminary study was conducted analysing the statistics of opera performances in the 2015–2016 season in the most important opera houses.²¹ Taking into account these statistics, the search domain of music material spans from the early 19th century to mid 20th century, in which the opera was progressively “standardising.” Before this period, the baroque opera included *recitativo* parts written for cembalo only and less instruments. After this period, modern and contemporary compositions are protected by copyright. The music material for the present study was chosen to represent the most performed Italian composers and their styles: Donizetti for the early 19th-century style, Verdi as the “classic form” of 19th-century opera, Puccini for the 20th-century evolution. In the following each excerpt is briefly described.

The first excerpt is an aria (“Come Paride vezzoso”) from the opera *L’elisir d’amore* by Gaetano Donizetti (1797–1848). The excerpt represents the *belcanto* in the Italian Opera: a *cavatina* for coloritura baritone. In the final *cadenza* and some agility passages which are peculiarities of the Italian opera style. In this motif there are parts of other soloists (a tenor and two sopranos) and a choir. The score shows several *tempo* variations: the “larghetto” in 3/4 then the “andantino” in 4/4, the free “colla voce,” which resolves to the initial time (“a tempo”) in the final (see Fig. 1).

The second recording is extracted from the opera *Il trovatore* by Giuseppe Verdi (1813–1901). In the *cabaletta* “Di tale amor, che dirsi” the soloist figure is a lyric soprano in whom voice weight and agility coexist. In this excerpt the Verdian orchestra is complete: strings, full woodwinds with ottavino, full brasses with bass trombone (cymbasso). The final part presents a *crescendo* with a wide dynamic range and an accelerated *tempo*.

In order to complete the temporal evolution of the Italian Opera, the third motif is the *romanza* “Oh Mio Babbino Caro” from the opera *Gianni Schicchi* by Giacomo Puccini (1858–1924). Here the soprano sings with a slight voice and the music is a *siciliana* played by a

Table 3. Anechoic recordings of the present work.

Title	Type	Composer	Year	Soloist	Choir
“Come Paride vezzoso”	aria + cadenza	G. Donizetti	1832	Baritone	yes
“Di tale amor, che dirsi”	cabaletta	G. Verdi	1852	Lyric Soprano	no
“Oh Mio Babbino Caro”	aria (Siciliana)	G. Puccini	1918	Coloritura Soprano	no



Fig. 1. Exemplum of agilities of soloist on the *larghetto* reprise and final *cadenza* (“A-mor”). Score for soloist and piano accompaniment of the final of the Donizetti’s excerpt.

large string section, a few woodwinds, and a harp. The recording also includes the initial tone clusters for strings and brasses, usually played in the recital version of the romanza.

3. Recording methods

The recording room was the listening room of the University of Bologna (dimensions: $7.5 \times 5 \times 3$ m) that was damped with high density fiberform (80 kg/m^3). Porous material covered all the surfaces, including the floor: performers played above a metallic grid. The porous materials and box-in-a-box structure made by gypsum boards allowed a negligible reverberation in a wide range of frequency—less than 50 ms at 125 Hz. The radius of dodecahedral microphone array measured 1.1 m. This distance is lower the critical radius of reverberation, allowing more than 10 dB of direct-to-reverberant ratio.

Professional musicians from a young orchestra and soloists were asked to join this research. Some musicians had previous experience in recording contemporary and pop music too. A total of twelve musicians and three soloists were involved in the recordings.

The arrangement of the recording follows the Vigeant-Pätynen framework: one musician at a time, for each instrument, played all the score parts, following a reference video of the conductor with a pianist; during the recording takes, the musicians heard the sync piano and the previous tracks through closed headphones.^{13,14} The conductor attended all the recording sessions in order to evaluate the effectiveness of the single takes on the general impression of the orchestra. Recordings were monitored from a control room, with a talk-back connection with the conductor. Double basses and cellos were recorded in session no.1, followed by second violins and violas. Only a single track of the first violin was recorded as reference for the intonation. One violinist played all the tracks of the first and second violin parts. In the second session, brasses were recorded: horns, trombones, and trumpets. From session No. 3 onward—which involved the woodwinds—the piano track has been removed from the audio monitoring heard by musicians during recordings. In the fourth session, all parts of the first violins were recorded with the right orchestral timbre and dynamics. In the last session, the harp was recorded and some takes were overdubbed. A comparison between the orchestral part of the previous recordings and the present ones is shown in Table 4.

Each musician was placed at the center of the microphone array (see Fig. 2) and played and repeated his/her part until earning the approval of the director. The tracks were recorded without stops and overdubs. The recordings were monitored in real time from both conductor and musician. The conductor was placed in a control room, listening to the real-time performance mixed with the previous tracks through near field monitor or closed headphones. Musicians could listen to themselves and to some or all of the previous recording tracks, depending on their requirements. Following musician requirements, the right channel only was powered

Table 4. Comparison between the orchestral parts of some of previous and the present multi-track recordings.

	BBC (Ref. 8)	Hidaka (Ref. 9)	Böhm <i>et al.</i> (Ref. 18)	Donizetti	Verdi	Puccini
1st violins	6	16	14	8	10	12
2nd violins	6	13	11	6	8	10
violas	4	11	11	5	6	8
cellos	4	8	6	4	6	7
double basses	2	6	6	3	4	5
flutes	1	4 + 1 ^a	2	2	2 + 1 ^a	2 + 1 ^a
oboes	2	4	2	2	2	2 + 1 ^b
clarinets	2	4	2	2	2	2 + 1 ^c
bassons	2	4	2	2	2	2
french horns	2	5	2	2	4	4
trumpets	2	4	2	2	2	3
trombones	—	4 + 1 ^d	—	3	3 + 1 ^e	—
percussions	1	4	1	—	—	—
harp	—	1	—	—	—	1
soloist(s)	—	—	—	3	1	1
choralists	—	—	—	20	—	—

^aPiccolo.

^bEnglish horn.

^cBass clarinet.

^dTuba.

^eCymbasso.

to the headphones for self-hearing. Headphone listening was individually set for each performer in order to allow an adequate self-monitoring and—at the same time—without compromising the recordings with the sound coming from the headphones. After each take musicians could speak with the conductor through talk-back connection in order to improve the execution. Each take was generally recorded three or four times until the conductor approved.

With respect to the work of Pätynen *et al.*, where each string part has been recorded once,²² in the present work the strings have been recorded several times (see Table 4). The same violinist played the tracks of the first and the second violin, performing all the different sessions. The same was done with brasses and other multi-track parts. Any digital-processing was added to increase the “chorus” effect, e.g., through phase shifting. It should be noticed that the conductor did not use a metronome during recordings, not even in the reference recordings of piano and voice, in order to keep the feeling of a “real” execution.

Audio-Technica AT4050 microphones have been chosen thanks to the good recording capability and low noise characteristics. The microphones have been used in omnidirectional configuration and have been pre-amplified and A/D converted 48 kHz 24 bit through a RME



Fig. 2. Positioning of the musicians during the recordings: around the performer the microphone array, on the left the monitor with the conductor video.

Micstasy, set with about 35 dB of internal gain. A pad attenuation of -15 dB was used for the trombone takes only.

The tracks were recorded with REAPER software,²³ and then post-processed in the same environment. The tracks were manually checked to delete breaths and hisses before the sound attacks and after the releases. Breaths during the notes were not erased, in order to preserve the instrumental timbre. Background noises during silence—due to monitoring through headphones, body movements, etc.—were manually deleted. The recorded tracks were not equalised. The tracks were exported in 12-track .wav format, at 48 kHz/24 bit, the number of each sub-track corresponding to a microphone of the dodecahedral array. Multichannel files and recording details are available for free.²⁴

4. Conclusions

Anechoic recordings of opera excerpts were presented. Soloist singers and ensemble musicians were recorded following procedures similar to those found in the existing literature. Multitrack recordings were made using a dodecahedral array of large-diaphragm microphones. The instrumental parts were performed in different sessions, recording one part at a time and then overdubbed, in order to reach a proper orchestral sound. The recorded material is free for research purposes.

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