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VOCAL REGISTERS AND LARYNGEAL MECHANISMS, A CASE STUDY: THE FRENCH "VOIX MIXTE"

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ABSTRACT

When producing an ascending scale, e.g. from C2 to E5, two different laryngeal mechanisms, M1 and M2, are used one after the other. To smooth both laryngeal and timbre transitions, singers develop a vocal technique called "Voix mixte". Contrary to the general opinion, "Voix Mixte" register is not produced in an intermediate laryngeal mechanism, but is either produced in laryngeal mechanism M1 (mx1 voix mixte), or in laryngeal mechanism M2 (mx2 voix mixte). A study has been conducted on two professional singers, a countertenor and a soprano. A voice range profile, or phonetogram, has been established in each laryngeal mechanism. Inside the overlapping frequency region where M1 and M2 can both be used, we recorded acoustic and electroglottographic (EGG) signals for musical sentences produced on the same pitches in different vocal registers: chest, male-falsetto or female-head, and "voix mixte". Since dynamic is larger in M1 than in M2, and shifted to higher vocal intensities, the imitation of the M2-like voice quality for mx1 is essentially achieved by a decrease of vocal intensity, which goes with a decrease of high-harmonics spectral energy. On the other hand, the imitation of an M1-like voice quality for mx2 is achieved by timbre enrichment, which goes with an increase of loudness.

1- THE HUMAN VOICE, A COMPLEX ACOUSTIC SOURCE

The human voice of a given individual can range over 5 octaves (from 40 Hz to 2000 Hz). From the lowest to the highest pitched note, the vocal organ transforms itself, bringing on changes of vocal quality perceived differently depending on the cultures. It is known that the quality of sound perceived by a listener is the result of the complex elaboration of sound on two levels: on the one hand, the laryngeal vibration, on the other hand the whole of the resonance cavities run through by the vibratory source. Song treaties have always partitioned the extent of the human voices into zones called "registers", but there is no consensus on the number nor on the denomination of these registers. Regardless of the variables linked to the diversity of the aesthetic conceptions of the vocal quality, the main difficulty comes from the confusion between the two levels of vocal elaboration. Even when he wants to, a singer cannot always discriminate on himself whether the changes in quality are due principally to the laryngeal vibration or to the resonance cavities, which is the case of the so-called "voix mixte". We have therefore undertaken this research thanks to the active complicity of high-level singers who wish to better understand certain aspects of their vocal technique. To achieve this we must on the one hand characterise with a maximum of certainty the laryngeal configuration, source of the sound vibration, on the other hand, adopt a vocabulary referring to this source, which is neutral and unambiguous.

2 – LARYNGEAL MECHANISMS AND REGISTERS : THE PROBLEM OF THE THIRD REGISTER.

The concept of *laryngeal mechanism* relates to the production of the laryngeal sound. Within the medium range of lyrical voices going from 100 to 1000 Hz, men and women alike, two laryngeal vibratory mechanisms are used: M1 for sounds going from low to medium pitch (modal, heavy or thick mechanism) ; M2 for sounds going from medium to high pitch (loft, light or thin mechanism).

The concept of *register* is based on the perception of a sequence of sounds of homogeneous sound quality. The number and the denomination of the registers differ depending on whether one deals with male or female voices, and vary over time. Authors who take into account only two registers in the voices tend to implicitly assume an equivalence between the 1st register (sometimes called chest*)*, and M1, and between the 2nd register (called also *falsetto* or *head)* and M2. The use of a unique word «register » referring to two different levels of sound elaboration generates ambiguities of thought, which have been of great importance in the history of vocal techniques since Garcia [6, 2]. The problem becomes more complicated as soon as there are more than two registers.

The *third register and the « voix mixte »*. The French song treaties of the beginning of the 19th century [13] offer systematic exercises to equalise the transition between « chest-falsetto » for men, and « chest-head » for women. At the same time the concept of a third register generalises, ensuring the transition between the two others called « medium voice », mainly for women, responding to a search of the homogenisation of the vocal quality on the whole tessitura[1]. The expression « voix mixte »[2] appears in 1840 after the famous vocal performance of Gilbert Duprez in William Tell[3] and subsequently generalises to its current meaning[4]. In the anglo-saxon tradition the 3rd register is called « mid, medium, middle ». Richard Miller [15,p154] uses the term *mixture* to designate « any quality of timber which is not entirely of head, nor entirely of chest [5]». The « mixture » doesn't seem to be a vocal register like the « medium », but rather a technique of adjustment of the vocal timber.

The question that must be addressed is the following. Does the work of a mixed register consist of “mixing” two vibratory mechanisms, or does it only consist of adapting the resonantial system ?

3 – STUDY OF THE VOIX MIXTE.

Prior Studies

Most research dealing with « middle, medium » registers that we reported in 2004 [1] lack objective documentation identifying with certainty the vibratory mechanism involved, or do not pertain to the mixing proper. In 2005 [14] D.G. Miller publishes different analyses on the chest-falsetto transition of the female voice. If the EGG data allow to check the change of laryngeal mechanism, the absence of information on the intensity of sounds, of which we will see the importance in this article, does not allow the author to decide on the glottal or resonantial nature of the ambiguous sounds that can be « mixed ».

Definition of “voix mixte”

According to the numerous singers we worked with, the voix mixte denotes a reduced portion of the vocal tessitura, between a fourth and a fifth, situated in the shared zone of both mechanisms M1 and M2. In this zone the singer pays particular attention to the adjustments of dynamics and spectral quality with a double objective: on the one hand to perfect the equalisation of the voice at the transition of the two mechanisms; on the other hand to have equal use of the same sounding capacities in one or the other mechanism, so that the listener cannot distinguish which mechanism is used.

Research objectives

In 2004 [1] we showed that the production of voix mixte clearly belonged to one or the other of the two laryngeal mechanisms. Here we resume the in-depth study of the mechanisms with

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1 to the extent that some authors claim that voice must have no register (or should only have one register over its whole range)

2 more precisely the « sombrer mixte », which Gilbert Duprez denotes as « mixte fort » in his singing method [4].

3 it then shows what will be known later as the « cover » in the M1 male high pitch

4 let's cite Mandl: some sounds, by their intonation, belong to both registers and can be given in chest or head voices. Voix mixte consists of the highest-pitched sounds of the chest voice, softened and sunken and for women, medium or falsetto, the beginning of the higher register. » [12] p.39

5 The *voce mista* is typical to male singers. Female singers uses two mixtures : the head mixture for low pitches and the chest mixture for medium ones.

two singers working the voix mixte electively, in fully controlled recording conditions, so as to objectivise the sound equalisation perceived from an acoustical point of view.

Experimental protocol

Subjects: the study is conducted with two professional singers, a countertenor (CT) and a soprano (S) using the voix mixte both in M1 and M2.

Data : the recording took place in a semi-anechoid room. The EGG signal was recorded on a Macintosh computer through an audio-digital card (Digidesign M-audio FW1814, sampling frequency of 44.1 kHz on 16 bits), together with the audio signal from a condenser microphone placed 30cm from the speaker ‘s mouth. Each session started with an intensity calibration signal. Singers produced isolated tones with different intensities and different vowels, and representative musical examples. The numerical data were analysed according to the procedure described in Henrich et al. [8]. From the EGG signal we derived DEGG signal, fundamental frequency (fo), and and open quotient (Oq). From sound files we calculated the intensity curve and several spectral analyses : sonagrams, and intensity in spectral frequency bands FB2 and FB3 [11].

4 - RESULTS : CHARACTERISATION OF THE LARYNGAL PRODUCTIONS: M1, M2

The singers with whom we work are fully aware of the laryngeal mechanism they use, except for the production of certain low-intensity mixed sounds. It is therefore important to gather as much data as possible allowing to objectively characterise the vibratory mechanisms. We shall first list the phonetograms.

4a/ Phonetogram M1-M2 and CT's Mixed Zone (Figure 1)

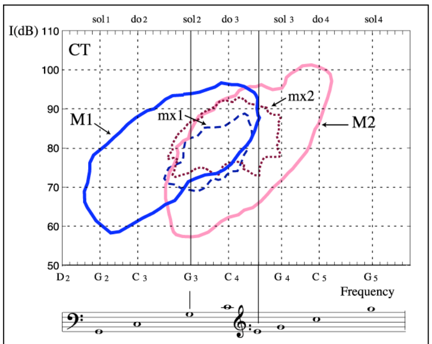

Figure 1 - Contretenor voice; phonetograms of M1 and M2 tones.

The phonetogram provides the existence zone of the sounds produced in M1 and M2 associated with their dynamic possibilities. It is fundamental for our purpose to separate M1 and M2 cf. [17]. Figure 1 shows in blue the area of M1 and in red that of M2. Mechanism 1 covers the range 87-330 Hz (F2-E4). Mechanism 2 covers the range E3-D5. (165-580 Hz). After the phonetogram recording, the singer recorded a sequence of sounds produced in *voix mixte*, differentiating « the chest mixed from the head mixed ». The mixed sounds (dotted line) are respectively located in M1 and M2, in the intersection area of both mechanisms located between G3 and E4. The two mixed zones overlap, and we previously mentioned, the singer could sometimes be unsure of the mechanism. We then rely on the characterisation of the laryngeal mechanism by the EGG data.

4b/ Open quotient in M1 and M2 (Figure 2)

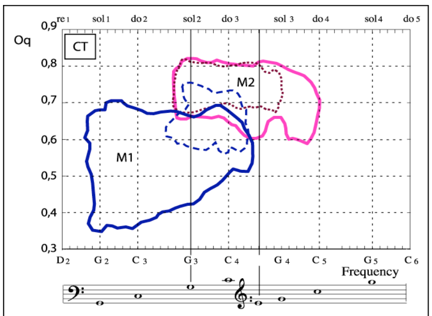

Figure 2 - Oq values for M1, M2, mx1 and mx2 tones.

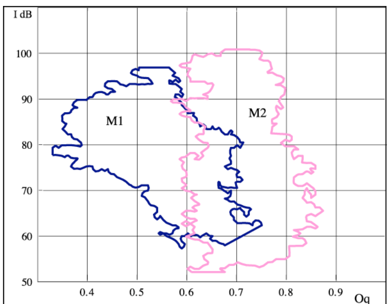

Figure 3 - Variation of Oq values with Intensity

The open quotient Oq is a good indicator of the laryngeal mechanisms [9]. For this singer (CT), the values of Oq varies between 0.35 and 0.7 in mechanism 1 and between 0.6 and 0.8 in mechanism 2. The mixed sounds of mechanism 2 (fine dotted line) are totally embedded in the M2 area but it is not so for the mixed sounds of M1 (dashed line), of which a large proportion has Oq values in common with M2. Now, for some singers and depending on the laryngeal mechanism, Oq can vary with the intensity of the emission [7].

4c/ Variation of the open quotient with the intensity in M1 and M2 (Figure 3)

The drawing in figure 3 shows a visible effect of the intensity on the open quotient, for the sounds of mechanism 1 : Oq varies as the inverse of the sound intensity. These variations must therefore be taken into consideration for the interpretation of the sounds sung in mixte 1.

4d/ Vocal intensity variations in the common zone in M1 and M2 (Figure 4)

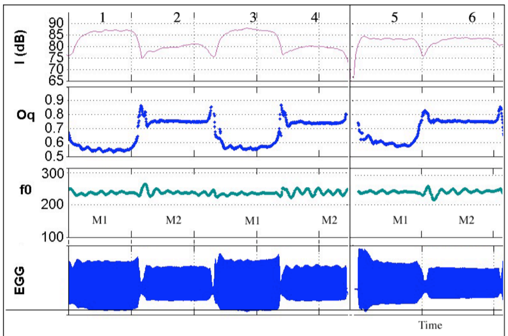

Figure 4 - IdB, Oq, fo, EGG for M1 and M2 tones

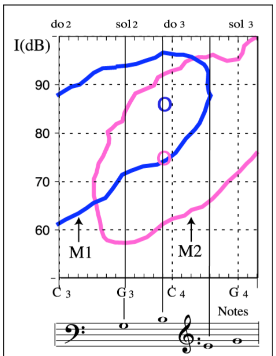

Figure 5 - Phonetogram M1-M2

Singer CT was asked to go rapidly from M1 to M2 on a common note, first in a “spontaneous” way, without making any adjustment. The results are shown in Figure 4, sounds 1 to 4. Great vocal-intensity variations can be noticed : the intensity in M1 is greater to that in M2 by about 8 to 10 dB. Simultaneously we observe variations in the amplitude of the EGG, and in the values of Oq : here from 0.55 (M1) to 0.75 (M2). The singer was then asked to equalise the loudness in M1 and M2. The results are shown in Figure 4, sounds 5 to 6. The EGG-amplitude and open-quotient variations, well diminished, still give a good discrimination of the laryngeal mechanisms.

4e/ Equalise the intensity in the common zone for both mechanisms (Figure 5)

Figure 5, which represents the central part of the phonetograms of Figure 1, corresponds to the zone of work of the mixed sounds of CT. If we ask the singer to sing the note B3 in a “comfortable” way for the emission, we remark, as before, an important difference of intensity depending on whether he emits the sound in M1 : 85dB, or in M2: 75 dB. In order to have in this zone the same variations of dynamics without risking to change the mechanism suddenly, the singer works the Mechanism 1 in the way of piano blend : mx1, and Mechanism 2 in the way of forte blend : mx2.

5 – RESULTS : ACOUSTICAL AND PERCEPTIVE CHARACTERISATION OF THE M1, M2, MX1, MX2 SOUNDS

5a/ Intensity and spectrum (Figures 6a, b, c)

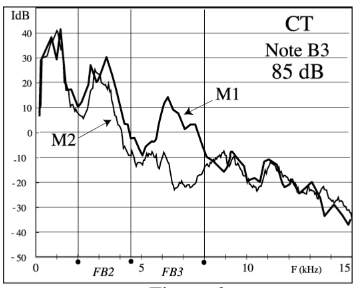

Figure 6a

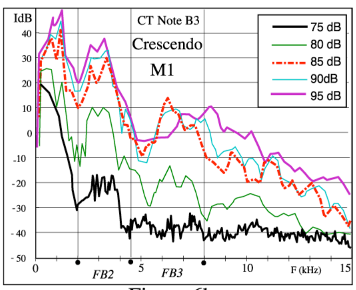

Figure 6b

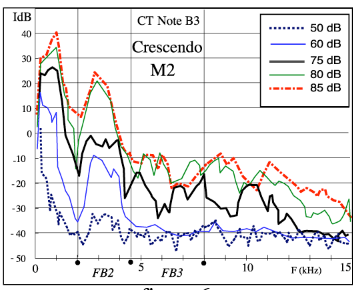

figure 6c

When listening to sounds produced in M1 and M2 with the same intensity, the listeners note that the sounds of M1 seem stronger, and that they seem to have a “richer” timber, more “brilliant”. Let's compare the spectrum of the B3 note, vowel A, sung with the same intensity (85 dB), in the common zone for both mechanisms. We have here characteristic sounds of both mechanisms, without a mixed register. Figure 6a underlines great differences in the spectral content of M2 with regard to M1 : (-10 dB) in the zone 2 – 4.5 kHz (FB2 [1]), that of the singing formant, and (-20dB) in the zone 4 – 8 kHz (FB3, [11]) already shown by Pillot [16]. These noticeable spectral differences explain the changes perceived.

We made a sequence of spectrums of this same note, sung at different intensities during a crescendo. One sees that with a comparable intensity, the energy in the frequency bands do not evolve in the same way in M1 and M2. The work of the voix mixte consists precisely in equalising, not only the intensity, but also the perceived sound quality.

5b/ Sonority equalisation : mixed sounds (Figure 7a, b, c)

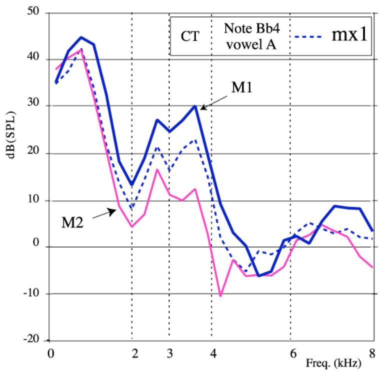

Figure 7a

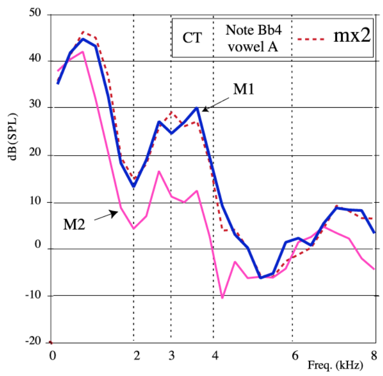

Figure 7b

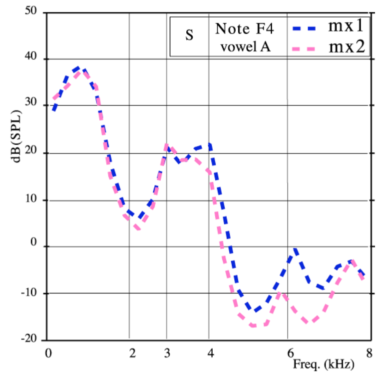

Figure 7c

During working sessions the singers made a series of sounds of similar quality but produced in different laryngeal mechanisms. In Figures 7a and 7b we can see the long-term average spectral analysis (LTAS) of the mixed sounds and mechanisms of reference produced by CT.

Adjustments in voix mixte 1. From M1 (89.5dB) to mx1 (85.5dB), singer CT decreases his vocal intensity by 4dB. The whole of the spectrum translates in the direction of M2 without reaching it. In the 6-8 kHz band one notes that the maximum scales down in frequency to adjust itself to that of M2.

Adjustments in voix mixte 2. From M2 (87dB) to mx2 (90.5dB), singer CT increases his vocal intensity by 3.5 dB. The quasi superposition of the spectrum of mx2 on M1 shows the perfect mastery of this counter-tenor.

The female singer S has just made a couple of sounds produced respectively in mx1 and mx2, with the same intensity, of which the spectral similarity is visibly very complete (Figure 7c).

These analyses confirm the fact that, in spite of obvious disparities between both mechanisms: as much in intensity (Figure 5) as in spectral distribution (Figure 6), the singers manage to adjust their emission so as to equalise the sounds to the point that listeners can be fooled. However there is one remaining difference, that of the vibrato.

Vibrato and mechanisms

The vibrato plays an important role in the perception of sound intensity and in the global appreciation of the sound quality [5]. In mechanism 2 the singer CT uses systematically a larger vibrato when he is in a mixed register. If we specify by fo the medium frequency and by fM and fm the higher and lower levels of the frequency modulations, the value of the ratio fM-fm/fo is between 0.04 and 0.09 in M2, and of 0.20 in mx2, which corresponds respectively to the intervals of 76, 168 and 340 cents.

6 - CONCLUSIONS AND PERSPECTIVES

The analyses presented here confirm the conclusions of our previous study [1]. Singers produce voix mixte either in mechanism 1 or in mechanism 2. This is in keeping with the singers' own intuition concerning the laryngeal mechanism that they use.

So as to be able to simulate in M1 the sound quality of M2 – and vice-versa – the singers make in voix mixte several kinds of adjustments. At the source the intensity is adapted so as to compensate the gap between the dynamics of both mechanisms in the common zone of the phonetogram. But the perceived intensity which only counts for the listener, depends also on the energy distribution in the spectrum, as well as the vibrato characteristics. In spite of the spectral constraints inherent to each mechanism, the singers play simultaneously on the spectral maxima frequency and amplitude, without however changing the formants responsible of the vowel “soundness”. The fine and complex spectral adaptations of the voix mixte essentially pertain to resonantial adaptations. We also observed precise laryngeal adjustments [11], but which are only nuances of the main mechanism which is always perfectly identifiable. A precise study of the EGG signal, taking into account of the double peaks, together with the observation of the laryngeal vibration using high-speed cinematography seems necessary, and it is the object of our current research. This is a work of time as the voice adaptations of the *voix mixte* change depending on the intensity, the vowel, and evolve rapidly with the emission frequency. The alto voices of which the heart of the tessitura is the zone of transition between both mechanisms are *the goldsmiths of the vocal art* [3].

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