Proceedings of the International Symposium on Musical Acoustics, March 31st to April 3rd 2004 (ISMA2004), NARA, Japan

Is *Voix Mixte*, the Vocal Technique Used to Smoothe the Transition across the two Main Laryngeal Mechanisms, an Independent Mechanism?

Castellengo M., Chuberre B., Henrich N.

Laboratoire d'Acoustique Musicale - CNRS, University Paris 6, French Ministry of Culture, France.
castel@ccr.jussieu.fr

Abstract

From a physiological point of view, two main laryngeal vibratory mechanisms, M1 and M2, are used successively from the bottom to the top of the vocal range. From a musical point of view, singers distinguish many registers, most of which rely on resonance adjustements. *Voix mixte*, which is related to the area of overlap of M1 and M2, is a register found in different voice categories. Use of the *voix mixte* allows the singers to realize a homogeneous voice timber throughout their tessitura. Contradictory views have been expressed on the true nature of this register: laryngeal, or resonantial?

The present study on French *voix mixte*, carried out with 5 professional singers of both sexes, shows, on the basis of glottal open quotient (Oq) measurements, that *voix mixte* is not related to a different, or "mixed", laryngeal mechanism. *Voix mixte* sounds are always clearly produced in a given laryngeal mechanism, M1 or M2.

1 - Introduction

Within the two-and-a-half-octave range of human voice, singers and singing teachers traditionally distinguish several *registers*: regions within which the sound quality is felt to be homogeneous. One of the terms frequently used by professional singers in the French school is *voix mixte*, applied to male as well as to female voices. Similar terms found in English, *medium voice, middle, mid register,* or *mixed voice,* don't refer clearly to the same singing technique.

The professionals' definition of registers raises difficulties, as it defines a register on the basis of overall sound quality. We know that the sound results from the transformation of the glottal wave by the resonating cavities, which means that the quality of the sound depends both on the glottal source and on the adjustments within the oropharynx. In their description, singers use labels that refer to the two levels at the same time: laryngeal mechanisms, and resonantial registers.

2 – Laryngeal mechanisms

It has been known since Garcia [1] and Behnke [2] that the singers of the Western lyric (operatic) school mainly use two vibratory mechanisms.[1] The first mechanism (hereafter referred to as M1) is well adapted to sound production in the lower part of the singer's range; the second, M2, is well adapted to production in the upper part of the range. Midway through the singer's range, the two mechanisms share a frequency range of at least one octave. The exact position of this intermediate zone varies across singers; it is found somewhere between 200 and 400 Hz. These observations holds true of male and female voices.

The characteristics of each mechanism have been studied extensively [3, 4, 5]: its physiology, and its acoustical properties (intensity, spectrum).

The labels employed in the literature are notoriously varied : they differ across historical periods, across authors, and also differ according to the gender of the singer under description. Differences across languages add to the confusion, as the same terms are translated in various ways. The most often encountered terms are :
- for M1: *heavy* or *thick mechanism*; *chest*; *normal* or *full voice*.
- for M2: *light* or *thin mechanism*; *falsetto* (for men); *head voice* (for women).

3 - Vibratory mechanisms and vocal practice

The various vocal quality registers that singers learn to produce are grounded either in one vibratory mechanism or in the other: either M1, or M2. As an important requirement of the lyric voice is that a homogeneous quality of voice should be achieved over the whole tessitura, in intensity as well as in timbre, a "good" singer must devote special training to be proficient in the "ponticello", developing "medium" voice, at the transition between M1 and M2 [6][2]. During a special session on voice registers, the CoMeT members reported [7]: "In addition, we referred to yet another "register"

[1] For simplicity, we leave aside the third mechanism used by the sopranos in the upper part of their tessitura.

[2] "Most two-register teachers also speak of a middle area in both male and female voices in which either mechanism can operate, generally in cooperation with each other" p. 124

and defined it as that "register" which is described by many voice teachers as in the middle of the frequency range, as one constituting an important problem in the training of many singers (old terms : *head, mid, middle, upper*). As is obvious from the research litterature, this register is rather difficult to demonstrate empirically but as it receives so much (subjective) support, it cannot be ignored."

4 - Medium register and *voix mixte*

The issue in the study of medium register, and of *voix mixte* in particular, is thus to find out whether singers develop a special, independent mechanism that mixes M1 and M2 [8][3], or train to adjust the cavities of resonance to modify voice timbre [9][4] while remaining in one or other of the two mechanisms. The table below presents the results of four previous studies on the laryngeal mechanism being used in the medium range. Mechanism identification is conducted through electromyography (Hirano [10]), airflow measurements (Large [11]), or electroglottography (hereafter EGG) (Schutte [12], Miller [13]).

	MEN		WOMEN	
Mechanism	M1	M2	M1	M2
Hirano (1970)	head		mid	light head
Large (1970)				middle
Schutte (1993)			Middle (Belting)	middle (classic and pop)
Miller (1994)	head			

The correspondence between the terms *mid/middle* employed by these authors and the *voix mixte* cannot be stated with certainty; it was found necessary to conduct a new study on this specific topic.

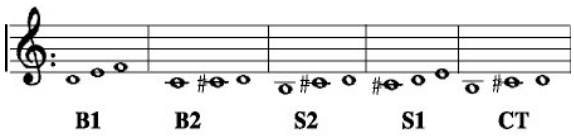
5 - An experiment focusing on *voix mixte*

B. Chuberre [14]

Experimental procedure

Five subjects took part in the experiment, all of them professional singers: 2 baritones (B1 and B2), 2 sopranos (S1 and S2), and 1 counter-tenor (CT).

Each singer first identified the three or four notes on which (s)he practises *voix mixte*. The experiment consisted in producing each of these notes in three different ways: in M1, in M2 and in *voix mixte*. The experiment was repeated with each of the five following vowels: /a/, /e/, /i/, /o/, /u/.



The recordings took place in a semi-anechoid room. The EGG signal was recorded on a Portadat PDR1000 DAT recorder, together with the audio signal from a 1/2' B&K microphone placed 50 cm from the speaker's mouth.

All of the artists who participated as subjects have a vivid awareness of which laryngeal mechanism they use. Before producing a sound, they announce which mechanism they are going to use, in the singers' traditional terminology: M1 is called *chest*, M2 *falsetto* (for men) or *head* (for women). If our auditory impression did not clearly confirm the singer's announcement, extra data was recorded: the singer was asked to produce an intensity crescendo on the note that was being investigated. The usefulness of this procedure is explained below.

Under their own description, the two baritones use *voix mixte* in M1 to "soften" the voice at the top of the range of M1, developing a timbre that is close to M2.

Soprano 1 uses *voix mixte* in the bottom part of the range of M2, to "give more timbre" to the sound *(timbrer le son)*, making it closer to M1. Soprano 2 uses *voix mixte* in M1 in order to achieve a smooth transition between M1 and M2. The counter-tenor uses both kinds of *voix mixte*; data from CT is used here to illustrate *voix mixte* in M2, along with data from S1.

Results

The EGG signal is used to get informations concerning the vibrations at the glottal source, and the audio signal to measure intensity and spectrum.

Calculation of the Open quotient (Oq)

On the whole, the shape of the EGG signal allows for a clear categorization of the laryngeal mechanism involved. But some variations are found due to anatomical differences across subjects, and also to variation in larynx height during singing, which raise interpretation problems. This is an especially crucial issue for *voix mixte*, as we must test the hypothesis that there is a *mixture of mechanisms*. Drawing on research by N. Henrich [15] which shows that Oq is a reliable cue to laryngeal mechanism, we used this parameter. The open quotient was computed from the *Derivative* of the electroglottographic signal: DEGG. (For references to the articles showing that Oq can reliably be computed from the DEGG signal, see [15]). As differences across

---

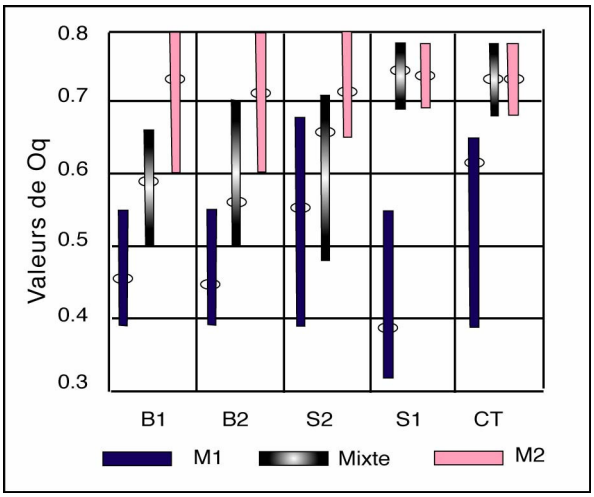
3 «There are two main registers, corresponding to sharply distinct vibratory patterns: *chest voice*, also called *heavy mechanism*, and *falsetto* or *light mechanism.* In-between these two registers is found an intermediate vibratory mode that borrows elements from the other two.» p.26.

4 A propos de voix de femme : "Le terme de *mixture* décrit toute qualité de timbre qui n'est ni entièrement de tête, ni entièrement de poitrine." p.154

vowels are not significant, we group the results by singer and by the type of performance: M1, M2, *voix mixte*.

Singers indications	M1 Oq range	mixte Oq range	M2 Oq range
Baritone B1 mixte M1	0.39 to 0.55 M= 0.46	0.5 to 0.65 M = 0.59	0.6 to 0.80 M= 0.73
Baritone B2 mixte M1	0.39 to 0.55 M = 0.45	0.5 to 0.65 M = 0.55	0.6 to 0.80 M = 0.71
Soprano S2 mixte M1	0.39 to 0.68 M = 0.55	0.48 to 0.71 M = 0.66	0.64 to 0.8 M = 0.71
Soprano S1 Mixte M2	0.32 to 0.55 M = 0.39	0.69 to 0.78 M = 0.74	0.69 to 0.78 M = 0.74
countertenor CT Mixte M2	0.59 to 0.65 M = 0.62	0.68 to 0.78 M = 0.73	0.68 to 0.78 M = 0.72

Figure 1 presents the interval of variation for Oq, as well as the mean Oq value.



For all subjects:

- M2 is characterized by the highest Oq values, ranging from 0.6 to 0.8
- M1 is characterized by the lowest Oq values, ranging from 0.35 to 0.55. It is clearly distinct from M2, except in the case of S2, where there is some overlap between M1 and M2.

The Oq values for *voix mixte* are found in two distinct regions (these two categories corresponding to the categories distinguished by the singers themselves).

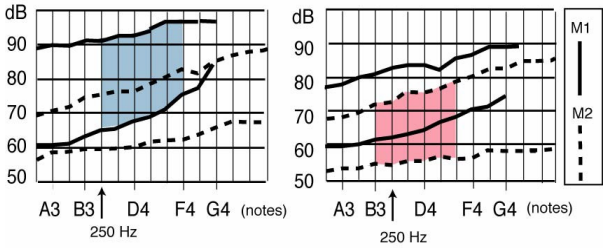
- *Voix mixte* in M2 (S1, CT): Oq values are similar to what is commonly found in M2.
- *Voix mixte* in M1 (B1, B2, S2): the Oq values are higher than what is commonly found in M1.

This raises the issue whether, in M1 *voix mixte*, the mechanism is actually different from M1 mechanism, or whether another parameter is at play.

6 - Interpretation of the results: the role of intensity in M1

Intensity range corresponding to M1 and M2

Voix mixte is used in the part of the singer's range that the two mechanisms have in common. A study of the dynamic intensity range of each mechanism was conducted by Roubeau [16]. The following data (figure 2) are averaged values from 20 male subjects and 20 female subjects.



It appears that:

- the region that the two mechanisms have in common corresponds to the same frequency range for both sexes.
- the dynamic range (defined as the interval between highest level and lowest level in one given mechanism) is greater in M1 for men and in M2 for women.

The region where *voix mixte* is used is indicated in grey in figure 2. These data make it clear that in order to simulate the characteristics of another mechanism, an adjustment in intensity must be made: -10 dB to simulate M2 while in M1, and +5dB to simulate M1 while in M2.

Our own intensity measurements show that the two baritones diminish the intensity by about 10 dB when in M1 *voix mixte*, in conformity with the prediction. By contrast, the singers who use M2 *voix mixte* (S1 and CT) increase intensity less than expected: only 2 to 3 dB. This can be interpreted as indicating that the physiological limitations of M2 mechanism do not allow for a full compensation to simulate the intensity values of M1. But it was noted that the sound produced by S1 and CT in M2 mixed voice has greater harmonic richness than is generally found in M2, arguably increasing the perceived intensity; this is one of the central topics of our ongoing research.

A link between Oq and intensity

Oq values vary according to the laryngeal mechanism, but other parameters also influence Oq: fundamental frequency, and the vowel (supraglottic articulation), are known to have some influence on Oq. N. Henrich [17]

showed a strong inverse correlation between open quotient and intensity, which holds true in M1 only. In data from B1 and B2, a 10 dB decrease in intensity was found to correspond to a 10% decrease in Oq. This result is in keeping with the observations in figure 2.

This warrants the conclusion that singers B1, B2 and S1 produce *voix mixte* in mechanism 1. This conclusion fits neatly with their own comments on their use of laryngeal mechanisms in vocal technique.

Lastly, concerning the cases in which the singers were not sure which laryngeal mechanism they use, the intensity crescendo that they were asked to produce on the note under invertigation proved to be a very useful test: if a change of laryngeal mechanism is found in the course of the crescendo, this indicates a lapse into M1, and indicates unambiguously that the singer was using M2 *voix mixte.* The change of mechanism is evidenced clearly by the recordings, and perceptible by the trained ear. In the absence of such a break, it can be concluded that the singer was in M1 from the beginning, producing M1 *voix mixte.*

Incidentally, it was noted that these cases were assessed by the singers themselves as very successful instances of *voix mixte*.

7 -Conclusions

Voix mixte is a vocal technique developed in the Western lyric school of singing. It is found in the region of the singer's range which is common to both laryngeal mechanisms.

It is possible to conclude, on the basis of the measurements of open quotient, that 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.

The aesthetic finality of *voix mixte* is to simulate the sound quality of another mechanism (M2 when in M1, M1 when in M2). This adjustment is realized by various means: adjusting sound intensity and modifying sound spectrum, especially the singer's formant. The modifications of the spectrum, and the variety in the use of the *voix mixte* according to the singer's category (baritone, soprano...) are the subject-matter of an article in preparation.

Acknowledgments - The authors thank A. Michaud for the English translation and for insightful suggestions.

References -

[1] Garcia M., (1840), Mémoire sur la voix humaine. *CR Académie des Sciences de Paris*; Duverger Ed., Paris, (1847)

[2] Behnke E. (1880) - The mechanism of the human voice, Curwen & Sons Ed., London, 156p.

[3] Hirano M. (1982) - The Role of the Layer Stucture of the Vocal Fold in Register Control, in *Speech Research*, University of Jyväsjkylä, pp 50-62.

[4] Roubeau B. (1993) - Mécanismes vibratoires laryngés et contrôle neuro-musculaire de la fréquence fondamentale. Thèse de l'Université Paris-Sud.

[5] Henrich N., Roubeau B., Castellengo M., (2003) - On the use of electroglottography for characterisation of the laryngeal mechanisms. In *Proc. SMAC 03*, Stockholm.

[6] Miller R. (1977) - English, French, German and Italian Techniques of Singing; The Scarecrow Press, Metuchen (N.J.).

[7] Hollien H. (1983) - Report on vocal registers, In *Proc. SMAC 83* , Stockholm, p.27-35.

[8] Cornut G. (1983) - La voix. Ed. P.U.F, "Que sais-je", Paris, 124 p.

[9] Miller R. (1986-1990) - La structure du chant. Editions Ipmc, Paris.

[10] Hirano M. Vennard W., Ohala J.; (1970) – Regulation of register, pitch and intensity of voice : An electromyographic investigation of intrinsic Laryngeal Muscles. *Folia Phon*. **22** p.1-20.

[11] Large J., Iwata S., von Leden H. (1970) - The Primary Female Register Transition in Singing. *Folia Phoniatrica*, **22**, pp 385-396

[12] Schutte H., Miller D., 1994 - Belting and pop, non classical approaches to the female middle voice: some preliminary considerations. *Journal of Voice*; 7 (2), 142-150

[13] Miller D.G., Schutte H.K. (1994) - Toward a definition of male "head" register, passaggio, and "cover" in western operatic singing. *Folia Phon. Logop.* **46**; 157-170

[14] Chuberre B., (2000) - Les registres et passages dans la voix chantée. Thèse de médecine, Univ. de Nantes.

[15] Henrich N., (2001) - Etude de la source glottique en voix parlée et chantée. PhD dissertation, Université Paris 6.

[16] Roubeau B., Castellengo M., Bodin P., Ragot M., Phonétogramme par registre laryngé. *Accepted for publication in Folia phoniatrica*, April 2002.

[17] Henrich N., d'Alessandro C., Castellengo M., Doval B., Open quotient measurements in singing. *Accepted for publication in J.A.S.A.,* Feb. 2003