Investigating *voix mixte:* A scientific challenge towards a renewed vocal pedagogy

Sylvain Lamesch
LAM-IJLRDA. UPMC, CNRS, Minist. Culture, Paris
lamesch@lam.jussieu.fr

Robert Expert
Professional singer and teacher
robexpert@free.fr, www.robertexpert.com

Michèle Castellengo
LAM-IJLRDA. UPMC, CNRS, Minist. Culture, Paris
castel@ccr.jussieu.fr

Nathalie Henrich
GIPSA-Lab. INPG, CNRS, Grenoble
Nathalie.Henrich@gipsa-lab.inpg.fr

Bertrand Chuberre
Professional singer and teacher

Proceedings of the third Conference on Interdisciplinary Musicology (CIM07)
Tallinn, Estonia, 15-19 August 2007, http://www-gewi.uni-graz.at/cim07/

Background in performance. Most often, the western lyrical singing technique involves the use of three singing voice registers: The chest register for the low sounds, the male-falsetto or female-head register for the high ones, and the mixed or medium register between them. According to the authors, the so-called mixed voice covers different realities: It is either a full register ranging from B3 to F5, or a narrow area around primo passagio, from A3 to F4. The purpose of practicing *voix mixte* is to homogenize chest and head voices in their overlapping area. The true nature of this *mixing* needs to be clarified.

Background in acoustics. When producing a succession of sounds, from the lowest to the highest one, two main different laryngeal mechanisms, M1 and M2, are used one after the other (Henrich, 2003). In the median part of the tessitura where the so-called *voix mixte* is found (from 200 Hz to 400 Hz), these two laryngeal mechanisms can be used, but their dynamical possibilities and the resulting sound spectral properties are very different. It has been shown that *voix mixte* register is not produced by an intermediate laryngeal mechanism (Chuberre, 2000) and that two different registers can be considered: The one produced in M1 (mx1) and the other produced in M2 (mx2) (Castellengo, 2004). It is therefore necessary to identify the phonatory adjustments which allow the singers to produce, inside a given mechanism, sounds for which timber is closer to the one obtained when using another mechanism.

Aims. The aim is to identify the mechanism in use for mixed voice productions and to compare on same-pitched sounds the spectral characteristics of mx1 and mx2 productions with the ones commonly found using laryngeal mechanisms M1 and M2.

Main contribution. The phonetogram shows that the dynamic in the overlap area is larger for sounds produced in M1 than in M2, and shifted to higher vocal intensities. Acoustics analyses confirm the spectral similarities between mixed sounds produced in a given laryngeal mechanism and the sounds commonly found in the opposite mechanism. The imitation of M2-like voice quality for mx1 is achieved by a decrease of vocal intensity, which goes with a decrease of high-harmonics spectral energy. The imitation of M1-like voice quality for mx2 requires an increase of vocal intensity, and timbre enrichment.

Implications. Literature about singing voice registers is very confused (Henrich, 2006). However, except for very few authors who defend the hypertrophy of one unique register, typical of a pedagogy historically linked to the XXth century, singing teachers recognize that managing transitions by the use of *voix mixte* is one of the most important part of a singer's education. Practicing *voix mixte* is very subtle and requires laryngeal and resonantial synergies to produce a desired sound quality while extending the physiological limits. Our investigation aims to clarify the terminology to reconcile acousticians and singing teachers in explaining the different *voix mixtes* by clearly distinguishing notions of laryngeal mechanisms and registers.

Introduction

The laryngeal mechanisms

The human voice in his fullness can cover more than four octaves. Physiologically, the perceived pitch is very closely linked with the fundamental frequency, which corresponds to the number of glottal cycles (opening and closing of the glottis) per second. To produce sounds with a fundamental frequency from 70 Hz to higher than 1500 Hz, the laryngeal vibration can be described with four different vibratory configurations (Henrich, 2003), called laryngeal mechanisms. The four mechanisms are named, from the lower to the higher, mechanisms M0, M1, M2 and M3. In the western lyrical singing, mechanisms M1 and M2 are mostly used[i].

The registers

On a musical level, singers and singing teachers define registers to refer to notes which are sung with the same quality. The identification and characterisation of registers varies a lot over the history and they depend on the geographic place (Henrich, 2006): Each author and even each treaty gives a different classification and a particular designation of registers. Therefore the pedagogy is very variable on this topic, if not confusing (Miller, 1990; Expert, 2003). The scientific research can help to clarify the concepts, to establish a precise and clear terminology and to allow the teachers to build a pedagogy based on the past knowledge but improved by the present understanding thanks to the development of modern techniques of investigation.

As an example, it is very important to distinguish in the vocal gesture what is related to the laryngeal vibration and what is related to the resonators: The characteristics of each register can be linked to specific laryngeal configuration and/or to resonantial adjustments of the vocal tract. Therefore, each singer uses (consciously or not) one of the main laryngeal mechanisms to sing in a given register. For instance, male and female singers use only the mechanism M1 to sing in chest register, the mechanism M2 being used by female singers in head register and male singer in falsetto.

The French *voix mixte*

A western lyrical singer may have to train his voice in using both M1 and M2, which is commonly the case for altos, mezzo-sopranos, sopranos, counter-tenors or even a few tenors. From A3 to F4, the singers have the possibility to choose the mechanism they want to use. This interval varies a little bit among singers, but it remains similar for men and women.

The transition from one laryngeal mechanism to another may go with a noticeable timbre modification. The singers who sing in this transition area usually have to minimize the perceptual effect of a transition in order to achieve a homogenous timbre over their whole tessitura. For this reason, they have developed a specific register called *voix mixte*, whose specificity consists on a perceptual ambiguity about the laryngeal mechanism used. The term *mixte* suggests a mixing of the different parameters characterizing chest register and head/falsetto one. The true nature of this mixing remains a controversial topic. Does it concern (1) the laryngeal level or (2) the resonantial one? In the first hypothesis, it would imply a new laryngeal mechanism to be defined, with its own vibratory patterns and biomechanical properties in terms of vibratory mass, tension, vocal folds length. In the second hypothesis, how can a singer sing using one mechanism while making people believe he's using the other one?

Previous investigations

The studies started with Manuel Garcia whose Singing method (1847) is well-known. Being an anatomist, a singer, and a great pedagogue, Garcia was the first to observe the larynx during singing, with the laryngoscope, and to report its interpretations in two scientific memoirs. He defined on a functional basis the two main laryngeal mechanisms labelled *poitrine* (M1) and *fausset-tête* (M2) (Castellengo, 2005). He described the overlapping area (G3-A4) between the two mechanisms, the sound discontinuity which occurs when shifting from a mechanism to the other on the same note, and gave exercises to smooth it. In addition he clearly stated that mixed sounds are only related to changes in timbre. Unfortunately he used the same terminology to designate both the laryngeal mechanisms and parts of the vocal range sharing the same vocal qualities, what induced high debates and lasting disagreements between scientists and artists. Today, such misunderstandings must disappear, thanks to the electroglottography, a non invasive device which allows to capture objective information on vocal chord joining, even during very subtle vocal productions as *voix mixte*.

In 2000 Chuberre conducted an electroglottographic study on five singers who were able to sing the same pitched sound in chest register (produced in mechanism M1), in head (women) or falsetto (men) register (produced in mechanism M2), and in *voix mixte*. He found that different strategies can be used to sing in *voix mixte*: Some singers use their mechanism M1, others the M2, and some are able to use one or the other. Castellengo et al. (2004) conducted another study where open quotient and vocal intensity were measured. The dynamic constraints of each mechanism were taken into account. This study showed that two types of *voix mixte* could be distinguished: One is called mixte 1 (mx1) and it is produced in the mechanism M1, and the other is called mixte 2 (mx2) and it is produced in M2.

These previous studies demonstrated that the first hypothesis could be rejected (no additional laryngeal mechanism), and they were in favour of the second one, i.e. *voix mixte* register being related to resonantial adjustments.

The present study aims to clarify the real nature of the *voix mixte* register, and to characterize the two types of *mixte* production by analysing perceptually-relevant acoustical parameters.

Investigation methods

Subjects

Two professional singers, a counter tenor (CT) and a soprano (S), were recorded. Both singers were used to sing in M1 and M2, and they were trained in singing in the *voix mixte* register. From their proprioceptive feelings, they were also able to tell in which laryngeal mechanism they were singing, even in the cases where it could not be perceived by a listener.

Material

The recordings took place in a studio room. An electrostatic microphone Neumann was placed at 30 cm of the singer’s mouth. The singer was asked to sit down on a chair in a comfortable position and to keep the distance to the microphone as constant as possible during the recording session.

At the beginning of the session, the singer was asked to sing a sound at a stable intensity level. The SPL was measured at the microphone position with a sound-level meter Voltcraft 329. This measure was used to calibrate the whole session. In a few cases, we had to modify the gain of the data acquisition chain. In those cases, a new calibration sound was recorded with the new gain.

The electroglottographic (EGG) signal was simultaneously recorded. A gel was allied on the electrodes to improve the conductivity. The acquisition was done with an M-audio FW1814 card, connected to an Apple Macintosh with the software Pro Tools M-Powered. Both signals were coded on 16 bits at 44100 Hz.

Recording protocol

In a first step, the phonetogram of CT was recorded. It representats the evolution of the vocal dynamic depending on pitch, and may also be called voice range profile. We recorded separately the different laryngeal mechanisms. The singer were asked to produce some crescendi and decrescendi on each semi-tone of his tessitura up to reach the maximum or minimum of the intensity he is able to sing on this note. The chosen vowel is the /a/.
Concerning the *voix mixte*, both singers were asked to sing crescendo and decrescendo using head (or falsetto), chest registers and *voix mixte*. The chosen vowels were /a/ and /i/. The singers also used the *voix mixte* in its musical context performing a short musical phrase they had chosen. They did it on different pitches and with the different

studied registers. After every production, the singers were asked to tell which mechanism they were using. The study of the electroglottographic (EGG) signal (more precisely its amplitude and the open quotient) allowed us to confirm the singers saying when it was necessary.

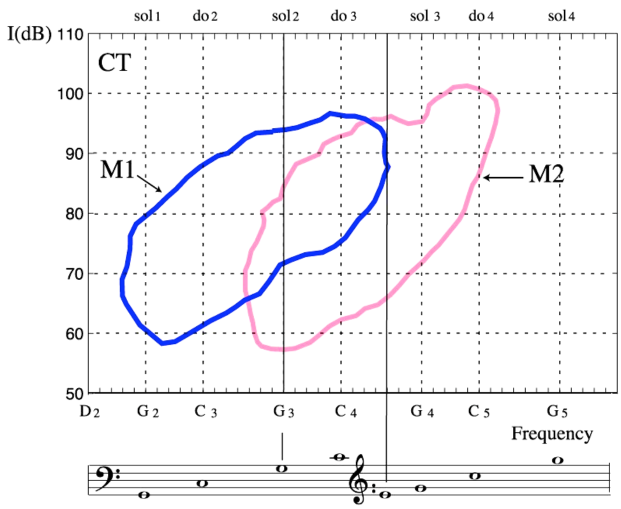

Figure 1a.

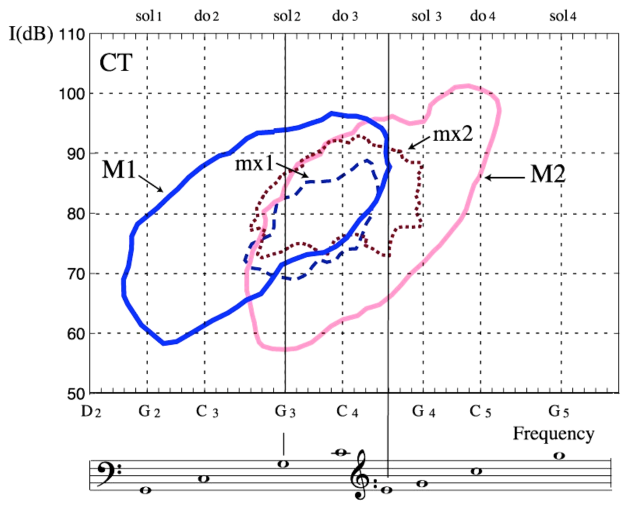

Figure 1b.

Phonetogram of CT in M1 and M2. On the figure 1b, the areas of mx1 and mx2 were added in dotted lines.

Characterization of the *mixtes* in terms of laryngeals mechanisms

Study of the phonetogram

The Figure 1a represents the phonetogram in both mechanisms M1 and M2, for singer CT. It shows a large overlapping area ranging from E3 to E4. However, on a given pitch, the vocal dynamic is characterized by higher intensities in mechanism M1 than in mechanism M2. For example on pitch C4, the mechanism M1 can be used from 75 to 95 dB, and the mechanism M2 from 62 to 82 dB, so 13 dB softer.

Therefore the overlapping area corresponds to nuances from pianissimo to mezzo-piano in M1, and from mezzo-forte to forte in M2.

The Figure 1b corresponds to the phonetogram of singer CT, with the representation of the areas of mixte 1 and mixte 2. We can notice that these areas are located in the overlapping area of the mechanisms M1 and M2.

Study of the open quotient

Figure 2 shows open quotient as a function of pitch, for M1, M2, mx1 and mx2 singing productions. The open quotient (Oq) is defined as the ratio between the duration of the open phase and the fundamental period. It is calculated at each glottal cycle. It can vary from 0 to 1, 0 corresponding to a theoretical absence of opening, and 1 to an absence of closing phase. Higher values of open quotient are commonly found in mechanism M2 than in M1. Open quotient is an indicator of the laryngeal mechanism.

It can be noticed on Figure 2 that open quotient values of mx2 productions are typical of M2 for this singer. It indicates that mixte 2 may be produced in the laryngeal mechanism M2. The open quotient area of mx1 is spread over the M1 and M2 areas.

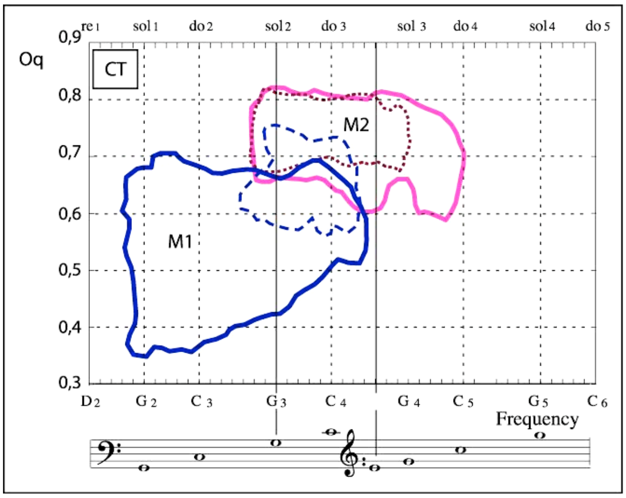

Figure 2. Pitch and open quotient variations in M1, M2, mx1 and mx2 areas.

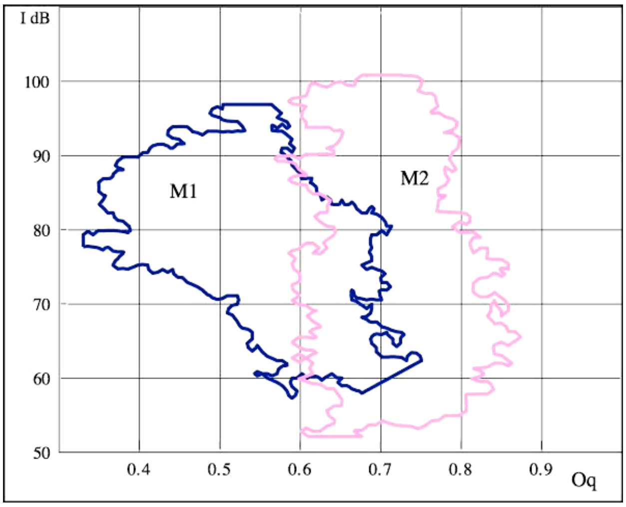

Figure 3. Open quotient and vocal intensity variations in mechanisms M1 and M2.

The Figure 3 presents the areas of vocal intensity variation as a function of open quotient. It shows that open quotient is inversely correlated to vocal intensity in mechanism M1, in other words the open quotient decreases when the intensity increases[ii].

Figure 1 shows that *voix mixte* is produced in the overlapping area of the mechanisms M1 and M2, which corresponds to the low intensities in M1. As demonstrated by Castellengo et al. (2004), mixte 1 may be a piano-to-mezzo-forte production in mechanism M1, which would explain the correlation with vocal intensity, typical of productions in M1, and the high values of open quotient.

The mixte 2: Vibrato aspects

It has been demonstrated by Castellengo et al. (2004) that mixte 2 is produced in laryngeal mechanism M2. One difference between mixte 2 and sound productions typical from laryngeal mechanism M2 is the vibrato (Lamesch, 2006).

The amplitude and the frequency of the vibrato were analyzed on the database, focusing on the interval G3-E4. The mean extent measured was 12.2 % (about one tone) in mixte 2, and 6.3 % (one semi-tone) in M2 "straight" for CT. The vibrato frequency remains similar in both cases (around 5 Hz). The use of the vibrato can be understood as a tentative to increase the perceived intensity, which could help imitating better the chest register.

Some resonantial adjustments

The glottal vibratory specificities of laryngeal mechanisms M1 and M2 allow us generally to perceptually distinguish one mechanism from the other in many cases. On a spectral point of view, a difference on the relative energy between the first two harmonics can be noticed between M1 and M2. Many authors have showed a correlation between this spectral amplitude difference and open quotient. A recent study (Lamesch and Doval, 2007) has shown that the energy is distributed differently among the spectra depending on the laryngeal mechanisms. Globally, a production in M2 has less energy in the high frequencies (from 2 kHz) than one in M1, at same pitch and intensity.

However, singers can get trained to minimize these differences, particularly when using the *voix mixte* register (Castellengo, 2007).

Figure 4 presents the spectra of sounds produced in chest, head registers and *voix mixte*. Adjustments in voix mixte 1: From chest (89.5dB) to mx1 (85.5dB), singer CT decreases his vocal intensity by 4dB. The whole spectrum translates in a direction typical to falsetto without reaching it. In the 6-8 kHz band, it could be noticed that the maximum scales down in frequency to adjust itself to that of falsetto.

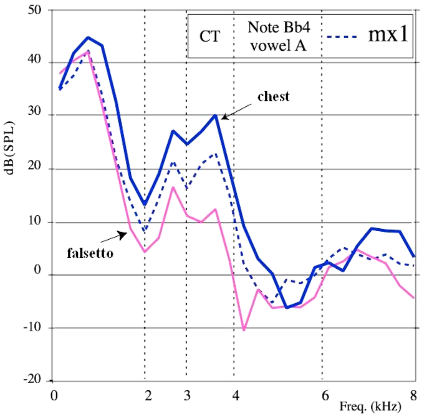

Figure 4a.

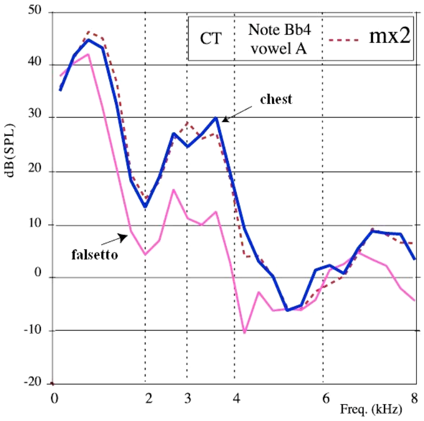

Figure 4b.

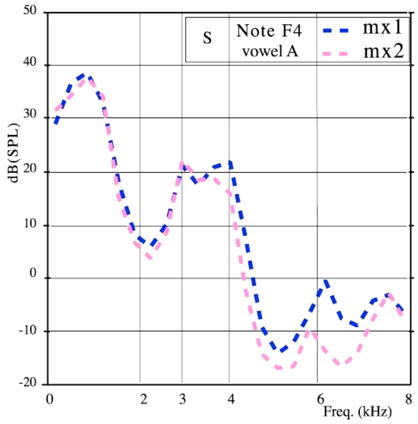

Figure 4c.

Average spectra (LTAS) of productions of chest register (using the mechanism M1), falsetto (using M2), mx1 and mx2. Every spectrum is computed with sounds on a given note and performed by a given singer.

Adjustments in voix mixte 2: From falsetto (87dB) to mx2 (90.5dB), singer CT increases his vocal intensity by 3.5 dB. The quasi superposition of the spectrum of mx2 on chest 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 4c).

Historic and teaching lengthening of the study

Evolutions of the singing practice, starting from a rather intuitive and *natural* use of a preferential mechanism, M1 for men and M2 for women, toward a widening of vocal range, led to changes in registration concept (Expert, 2003, 2007). In the baroque area, men and women take into account the two mechanisms, producing timbre shifts in agreement (in harmony) with dominant aesthetic rules: color diversity and sound contrasts. In the late 18th century, the new vocal music requires a plain and homogenous sound along the whole tessitura, and management of the passagio between the two mechanisms, as previously mentioned by Tosi (1723). Soprano and mezzo voices show a third register situated between chest and head, inside which they produce some mixing of the qualities of the two registers. In the early 19th century, the increase in room dimensions and orchestra loudness compel the singers to build a new vocal technique allowing the production of projecting and forceful sounds. This is in contradiction with the fact that a perfect equalization of the two mechanisms, without frequency break, requires to lighten the voice. So the singers turn to build their vocal range inside a sole mechanism, and to extend the area of physiological comfortable sounds. In this new situation, mixed sounds are no more used to smooth the passagio, but to push forward the limits of a given register. Mx2 allows female voices to reinforce the lower notes of M2, ordinarily too weak. Mx1 allows male voices to use higher notes without shouting, which was not acceptable in Italian bel canto. Around 1840, Duprez[iii] introduced in France the famous *copertura* which gradually led the tenors to be able to sing the highest notes of the chest register with a full voice, beyond their *natural* passagio M1/M2. So the necessity to use two different mechanisms became obsolete. This opinion is reinforced by most of the modern pedagogical views, more devoted to a museological study of romantic pieces than to creation. But in the second part of the 20th century, the rediscovery of ancient music joined to explorations of new vocal effects in contemporaneous music gave the mechanisms management a new interest. As a straight outcome of that, singers have to sing nowadays a piece from Puccini one evening and another from Monteverdi the day after.

The vocal education of the 21st century must face this new situation. What are our pedagogical options?

1. the first is the hypertrophy of the main mechanism of the young singer, which allow power and homogeneity without the complexities of mechanism transition.
2. in contrast, the second option recommend to work, from the beginning, on mechanisms change, which allow a flexible and nimble voice, but generally less powerful.

Our personal experience both as singer and teacher, leans us forward the second option. We too often meet voices blocked with bans, feeling mechanisms passagi as transgressions, and producing *mixed sounds* to supply registers lacks at their extremities, with a rather artificial voice. We propose to the young singer a functional exploration of his (her) voice in order to evaluate his (her) personal capacities and help him (her) to build his (her) own wishes. The very nature of the voice and the pupil tastes will then lead the teacher to make choice, later, between the work of a single mechanism or that of two.

Whatever the case, mixed sounds and mechanisms may become conscious matters or not, hanging on the intuitive way the pupil takes it with him or her. However we think that the objectivation of mixed sounds and mechanisms will lastly allow the pupil to become autonomous and to face to physiological and artistic evolutions of a career.

Acknowledgments

This study was financially supported by the Fondation de France.

[i] The sopranos coloraturas can also use the mechanism M3 to sing the highest notes of their tessitura.

[ii] On the opposite, such a correlation is not observed in mechanism M2.

[iii] who was famous for his *contre-ut* in chest voice in Rossini's William Tell opera.

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