Period-doubling occurrences in singing: the "bassu" case in traditional Sardinian "A Tenore" singing.

Nathalie Henrich[(1)], Bernard Lortat-Jacob[(2)] , Michèle Castellengo[(3)], Lucie Bailly[(1)], Xavier Pelorson[(1)]

(1) Institut de la Communication Parlée (ICP)
46, Avenue Félix Viallet, F-38031 Grenoble Cedex 1 - France

(2) Laboratoire d'Ethnomusicologie du Musée de l'Homme
17, pl du Trocadéro
75116 Paris

(3) Laboratoire d'Acoustique Musicale
CNRS - Université Paris 6 - Ministère de la Culture
11, rue de Lourmel
75015 Paris

Introduction

The human vocal-folds vibratory system is known to be a non-linear dynamical system (Herzel 1993; Titze et al. 1993). Evidences of bifurcation and chaotic behaviours have been found in the study of pathological voices, infant vocalizations, etc. In singing, period-doubling occurrences are commonly found in Asian vocal cultures, such as Mongolian Kargyraa throat singing or Tibetan Dzo-ke chants (Lindestad et al. 2001). A very low-pitch bass-type sound is produced by the combined vibrations of the vocal and ventricular folds (Fuks et al. 1998; Sakakibara et al. 2001; Sakakibara et al. 2004). In this study, we focus on a low-pitch singing technique found in a Mediterranean vocal culture, the Sardinian "A Tenore" singing. This traditional singing is still practiced nowadays in the central and mountainous part of Sardinia (Lortat-Jacob 1998). It is sung by a quartet of male singers, in an attempt to produce a single voice (Lortat-Jacob 1993). The lowest voice of the quartet, called "bassu", usually sings with a fundamental frequency of about 200 Hz but the perceived tone is half the fundamental frequency, i.e. around 100 Hz. We aim at describing the period-doubling phenomenon which occur in this phonation, discussing its similarities with the Kargyraa throat singing, and briefly exploring phonetic and aeroacoustics correlates for period-doubling sound generation.

Material and method

To this end, a Sardinian quartet was recorded in an anechoic chamber. An electroglottograph was placed on the bassu's neck to get more information about glottal period and vocal folds' contact area (Henrich et al. 2004). In addition, the audio and electroglottograhic (EGG) signals were also recorded for several vowels sung by a French singer trained for imitating the bassu's vocal technique. A videostroboscopic examination of both his normal and low-pitch phonations was performed.

Results and discussion

As illustrated in Figure 1 for the Sardinian bassu, and in Figure 2 for the French trained singer, the analysis of EGG signal and its derivative show typical period-doubling features. Vocal-folds contact area is modified from one glottal period to another for both singers. The EGG pulse shape is similar to what was observed by (Fuks et al. 1998) during "vocal-ventricular mode" phonation. The derivative EGG signal (DEGG) presents glottal closing peaks of alternating amplitudes, suggesting a rapid closing movement on one glottal cycle followed by a slower one on the next cycle. The videostroboscopic examination conducted on the French subject confirms that, during the period-doubling phonation, the ventricular folds are touching every two glottal cycles. This observation is in agreement with the findings of (Fuks et al. 1998; Lindestad et al. 2001; Sakakibara et al. 2001; Sakakibara et al. 2004).

The phonetic context seems to be helpful for producing these low-pitch sounds. The Sardinian singer always starts his musical sentences with the sonorous consonant /m/ or /b/, and the subharmonic vibratory pattern establishes very quickly, giving the perceptual impression of a very low-pitched attack. He always ends his musical sentences with the sonorous consonant /m/, and, as can be seen on Figure 1, the period-doubling phenomenon vanishes. The French singer takes advantages of the vowels to alternate between his normal and low-pitch phonations.

What would induce the period doubling ? According to (Gibiat and Castellengo 2000), period doubling scenarios would be favoured by very relaxed vocal folds and low subglottal pressure. This is in line with singers' laryngeal sensations. For obvious reasons, the subglottal pressure could not easily be measured in-vivo on the two singers. The relation between vocal folds tension, subglottal pressure and period-doubling occurrences has then

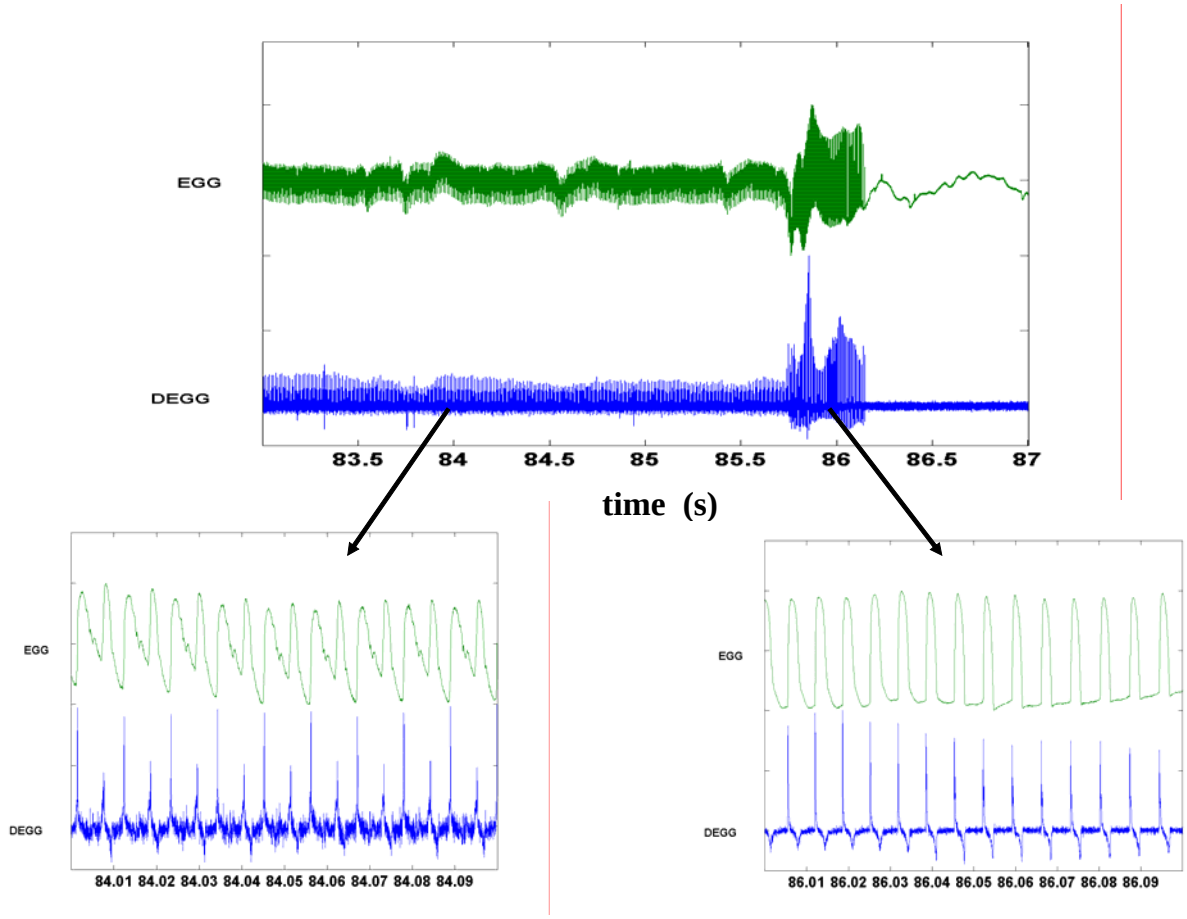

Figure 1: ***musical sentence sung by the Sardinian bassu. Bottom left panel: a period-doubling phenomenon can be detected on the EGG signal and its derivative (DEGG). Bottom right panel : at the end of the sentence, the period-doubling phenomenon vanishes.***

been tested in-vitro, by the use of a self-oscillating replica of vocal folds coupled to a fixed replica of ventricular folds.

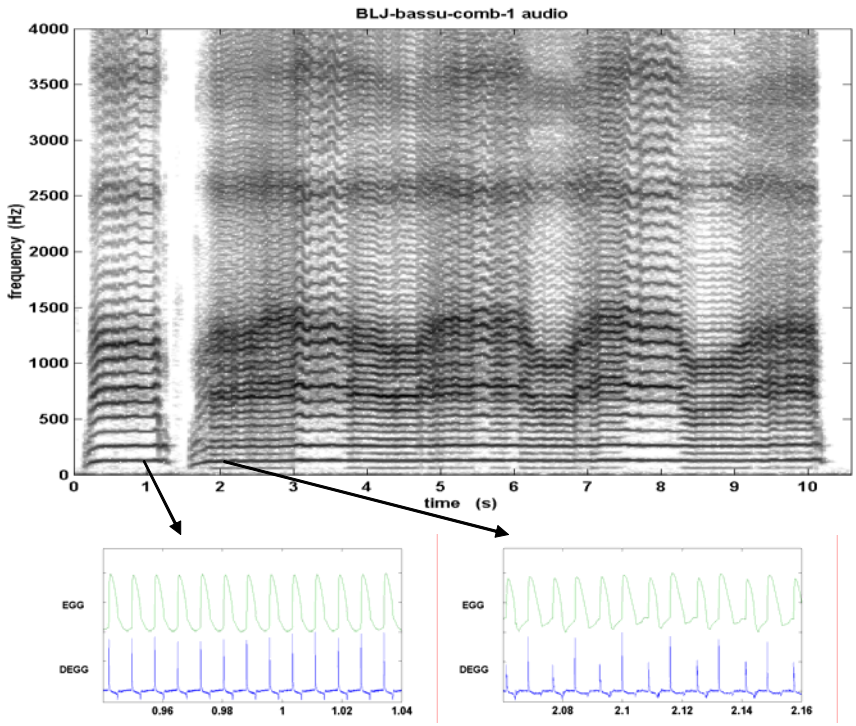

Figure 2: Sustained tone sung by the French trained singer, alternating between his normal phonation and the low-pitch one.

REFERENCES

Fuks L., Hammarberg B. and Sundberg J. (1998). "A self-sustained vocal-ventricular phonation mode: acoustical, aerodynamic and glottographic evidences." TMH-QPSR **3**: 49-59.

Gibiat V. and Castellengo M. (2000). "Period doubling occurences in wind instruments musical performance." Acta Acustica **86**: 746 - 754.

Henrich N., d'Alessandro C., Doval B. and Castellengo M. (2004). "On the use of the derivative of electroglottographic signals for characterization of nonpathological phonation." J Acoust Soc Am **115**(3): 1321-32.

Herzel H. (1993). "Bifurcations and chaos in voice signals." Applied Mechanical Revues **46**: 399-413.

Lindestad P.A., Sodersten M., Merker B. and Granqvist S. (2001). "Voice source characteristics in Mongolian "throat singing" studied with high-speed imaging technique, acoustic spectra, and inverse filtering." J Voice **15**(1): 78-85.

Lortat-Jacob B. (1993). "En accord, polyphonies de Sardaigne : quatre voix qui n'en font qu'une." Cahiers de musiques traditionnelles **6**: 69-86.

Lortat-Jacob B. (1998). Chants de Passion. Au coeur d'une confrérie de Sardaigne. Paris.

Sakakibara K.-I., Imagawa H., Niimi S. and Tayama N. (2004). Physiological study of the supraglottal structure. International Conference on Voice Physiology and Biomechanics, Marseille.

Sakakibara K.-I., Konishi T., Kondo K., Murano E.Z., Kumada M., Imagawa H. and Niimi S. (2001). Vocal fold and false vocal fold vibrations and synthesis of khoomei. International Computer Music Conference.

Titze I., Baken R. and Herzel H. (1993). Evidence of chaos in vocal fold vibration. Vocal Fold Physiology: Frontiers in Basic Science., Singular Publishing Group, San Diego.