Singing and Science

Invited Lecture at the 7th Pan-European Voice Conference (PEVOC7),
Groningen, August 28 to September 1, 2007

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Key Words

Singing • Vocology • History

Abstract

Starting out from Manuel Garcia, attention is paid to the work of outstanding personalities having excelled both in performing arts as singers as well as in scientific elaborations. The main focus will be on two aspects: the controversies about the principles of voice production as provoked by Raoul Husson and his revolutionary ideas, and the influence of the vocal tract on the formation of the sound of the voice. Both of these topics offer the opportunity of referring to the basic contributions of the Groningen voice research pioneers Janwillem van den Berg and his scholar Harm Schutte. For the online edition, supplementary material in the form of video and audio clips contributes to a kaleidoscopic compilation of a series of selected fragments representing the fascinating field of the human voice.

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Introduction

Let us start with a group of old friends, which represents a typical constellation: phoniaticians, vocologists who like to sing. They are from Sweden (Björn Fritzell, Per Åke Lindestad, Hans Lindholm, and Sören Fex) and call themselves ‘Stimmbanditen’ (video 1; all videos are made available as online supplements at www.karger.com/doi/10.1159/000170076).

There are many ‘singing phoniaticians’, and we love them all. But they will not be in the centre of this paper. The other way around: We are out for singers eager to go into science, reflecting an old debate: does professional singing require a profound knowledge of how it works, or not – art by science or art just on its own? There is, certainly, no universal answer. We know very well that there are many excellent singers with no interest at all for what happens when they are singing. One of them is Arno Raunig, a male soprano (video 2).

Still, a whole lot of distinguished singers cannot help searching for the reasons of extraordinary voice production. They want to understand, in particular, when they are teaching. The paper will refer to some of them, outstanding personalities who excelled both in performing arts as well as in scientific elaborations.

Dedicated to Prof. Harm K. Schutte, MD, PhD, on the occasion of his retirement.

Fig. 1. The centenary portrait of Manuel P. Garcia (1805–1906) by John S. Sargent. Courtesy of S. Fernández.

Manuel P. Garcia, the Founder of Vocology

In the first place, we have to remember Manuel Patrio Garcia (fig. 1) whose performance and enormous impact was thoroughly acknowledged at PEVOC7 by the comprehensive survey from Secundino Fernández et al. [1] (fig. 2).

Garcia, the tireless promoter of the laryngeal mirror [2], highly praised by posterity for his basic studies and also blamed by contemporaries for his ‘marotte scientifique’ [3], was a painstaking observer.

Here is a special example: in his famous book *Traité complet de l’art du chant* (1847) [4], he described precisely the vocal behavior of Baskir people and peasants conducting horses in St. Petersburg in Russia – I have to thank Philippe Dejonckere for that source – who had the astonishing faculty to produce simultaneously two perfectly distinct tunes: one low pedal tone on which they let hear a high pitch melody which he called cantilena, and of which he put down a notation (video 3).

When we look at the pedal tone (set 1 octave higher for better demonstration) as the fundamental of a theoretical spectrum (fig. 3), we realize (in fact Philippe Dejonckere realized) that the cantilena in Garcia’s notation is composed of overtones to that fundamental.

As can be seen from table 1, there are slight deviations of the frequencies of partials No. 10 and 15 to the corresponding pitches for the equally tempered scale (too low, not so for the just scale) and a considerable aberration for partial No. 11, which is closer to F sharp than to F. When

we listen to the two sequences again as composed of pure tones with the partials’ frequencies, we realize that the melody is a little bit out of tune (video 4, Garcia melody synthesized).

Overtone Singing

Garcia provided not only a clear phenomenology of what we today call overtone or formant singing, he also discussed plausible approaches to physiological explanations of this phenomenon without, to his great disappointment, arriving at a satisfying concept.

In the 80s, I tried to win one of the most prominent German overtone singers, Michael Vetter [5], as a partner for some basic experiments in the field, to no avail (video 5). He is an excellent artist, but not at all interested in any physiological matters. But he recommended one of his students, Gerry Smit, who sung the Garcia passage for some real-time FFT analyses. Of course, there was full accordance as to the theoretical expectations (video 6).

Two years before, my wife Ula had worked with one of her students at the Berlin Music Pedagogic Institute, Karsten Schulze, on overtone singing, and he was kind enough to allow lateral X-ray recordings of his vocal tract whilst producing overtones. Video 7 shows the configuration of his mouth cavity for the overtone G5 to the fundamental G2. For whistling at the same frequency, the position of the tongue is exactly the same, proving that overtone singing and whistling make use of the same resonator function. Agreed, that is only a first approximation.

At the PEVOC7 meeting, there was an outstanding expert present who can tell much more and everything when it comes to overtone singing – artist and scientist Tran Quang Hai [6] (fig. 4). The audience had the chance to listen to him. I would like to present 3 short examples for his sovereign mastery of the subject: (1) basic demonstration with the fundamentals kept constant (video 8, Tran Quang Hai 1); (2) fundamentals following a diatonic scale, partials in accordance (video 9, Tran Quang Hai 2), and now the highlight: (3) fundamentals going up and down and partials going down and up, skill beyond limits (video 10, Tran Quang Hai 3).

Theory of Voice Production

In the middle of the recent century, Raoul Husson (fig. 5), a French physicist and singer, perplexed the scientific world by a ground-breaking, unbelievable idea

MANUEL P. GARCIA. THE FIRST VOCOLOGIST

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INTRODUCTION

Who is Manuel P. Garcia? Was the same person that Manuel Rodríguez Siches? Where and when was he born? In Madrid, In Zafra? Was he a Physician, a singer, a teacher? Did he discovered the laryngeal mirror?

Recently we celebrated the 200th year of his birthday and the commemoration of the 100th year of his death.

Usually Manuel Patricio Garcia is well known by Otorhinolaryngologists but in the specialised literature, books, papers, etc. We can find many errors about him. We present in this work the most important biographical aspects, his works, and a diagram of his family. We review the history of Laryngoscopy, the failed attempts, the episode of the "invention" of the laryngeal mirror. We present Manuel Garcia as the first Vocologist, his influence on laryngology and on the art of singing, his most famous students and the legacy of this great man nowadays.

The García Family diagram

The History of Laryngoscopy

- 1805 Manuel P. Garcia Was born March 17th, Madrid
- 1815 Naples
- 1816 Paris-London
- 1825 New York
- 1826 Mexico
- 1827 Paris
- 1829 Operatic career abandoned Tolon, Algiers.
- 1830 Paris
- 1840 Professor to the Paris Conservatory
- 1840 "Memoire sur la Voix Humaine"
- 1847 "Traité Complet de l'art du chant"
- 1848 Royal Academy of Music, London (1848-1895)
- 1854 September, Invention of Laryngoscope, Paris
- 1855 Communication March 22nd, Royal College of Medicine, London
- 1855 "Observations on the Human Voice", Royal Society of London.
- 1883 Royal College of Music (1883-1895).
- 1905 Centennial Celebration, March 17th Medical and Surgical Society, London

FAILED ATTEMPTS

- 1743. M. Levert, 1743
- 1789. Archibald Cleland
- 1807. Bozzini, (Frankfort-on-the-Maine) Lichtleier
- 1825. Cagniard de Latour.
- 1827. Senn, (Genebra).
- 1829. Benjamin Guy, Babington, (Guys Hospital)
- George Gibb.
- 1832. Bennelli.
- 1835. Horace Green
- 1837. Troussau y Belloc: Laryngeal Phtisis
- 1838. Jean B. Timothee Baumes, (Lyon)
- 1840. Liston, "Practical Surgery".
- 1844. Warden, (Edinburgh).
- 1844. M. Avery, (London).

The invention of the Laryngoscope

"Finally, one gloriously sunny day (September 1854), while wandering around the royal palace in Paris, as if struck by lightning I saw in my imagination the mechanism of the laryngoscope. I immediately ran to the house of Chenevier who made instruments and told him that I wanted a small mirror mounted on a long metal wire handle. Chenevier instantly showed me the small dentist's mirror that he had constructed in 1851 for to exhibit in London. This was the mirror that corresponded to what I had seen in my mind. I bought it for six francs and went running to a department store where I acquired a normal hand mirror. Impatient to begin my experiment, I arrived home, warmed the small mirror in hot water so that it should not cloud over, and I reintroduced it into my mouth until it rested on my uvula. I have a very 'foolish' throat that enabled me to perform this manipulation without any problem. With my mouth constantly open, I directed a ray of sunlight with the hand mirror to the small mirror that I had at the back of my throat. Immediately, I saw my open glottis and underneath a large portion of my trachea. The sensation that I felt is indescribable. I had made reality the idea that for so long had obsessed me! Having calmed myself after the initial impression, I observed with much attention how the glottis opened and closed, and the form and position that the chords adopted during the emission of the voice." In this way Manuel Garcia describe how "the idea dawned on him!"

Consolidation

Central figure in 19 C singing pedagogy

- Definition of registers
- "By the word register we understand a series of consecutive and homogeneous tones going from low to high, produced by the development of the same mechanical principle, and whose nature series of tones equally consecutive and homogeneous produced by another mechanical principle. All the tones belonging to the same register are consequently of the same nature, whatever may be the modification of timbre or force to which one subjects them"
- Use of laryngeal mirror in singing
- Separated for the first time the concept of register quality vs. "timbre quality"
- "closed or somber"
- "open or clear"

WORKS

- Mémoire sur la Voix Humaine, Paris 1840. (read at the Academy of Sciences in 1841)
- Physiological observations on the human voice. Proceedings of the Royal Academy, London 1855
- Physiological observations on the human voice. The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science, London 1855
- Critique of a book. The Hygiene of the vocal organs. Moret Macquenne. International Contributions for Laryngology, Phonology, etc. 1897
- Traité Complet de l'art du Chant en deux parties, Paris 1847
- Abevoau Traité Sommaire de l'Art du Chant, Paris
- Étude on Singing New York - London, 1894
- Kehrichtungen über die Menschliche Stimme, Vilen 1878

FAMOUS PUPILS

- Charles Betteille
- Julius Stockhausen
- Maria Malbran
- Paulina Vardot
- Mathilde Marchesi
- Jerry Lind
- Henriette Nissen
- Catherine Hayes
- Antoinette Sterling
- Soprano Wagner
- Barbot
- Bussine

MANUEL P. GARCIA BIOGRAPHIES

- Autobiography
- Manuel Garcia. Su influencia en la laringología y en el arte del canto. A. D. Tappa, 1955.
- García the Cantor and his Times. M. Sterling Mackinlay, 1908
- Vie Famille de Grands Musiciens. Louis Heritte de la Tour, 1923
- Homenaje del Ayuntamiento de Madrid a D. Manuel Garcia Inventor del Laringoscopio. Madrid 1924
- Homenaje a Manuel Garcia en el primer Centenario del descubrimiento de la Laringoscopia. SEDOL, 1954
- Manuel Garcia (1775-1832). Chronicle of the Life of a bel canto Tenor at the Dawn of Phonoscience. James Radinsky, 2002.

Fig. 2. Garcia poster at PEVOC7. Courtesy of S. Fernández.

Fig. 3. Theoretical spectrum.

Table 1. Frequencies of the melody as noted down by Garcia for the tempered and the just scale compared to the frequencies of the partials (numbered) to the fundamental C3 (131 Hz)

	F, Hz tempered/just	Partial No.	F, Hz
Melody			
G5	786	6	786
C6	1,048	8	1,048
D6	1,179	9	1,179
E6	1,318/10	10	1,310
F6	1,396/97	11	1,441
G6	1,572	12	1,572
B6	1,976/65	15	1,965
C7	2,096	16	2,096
Fundamental			
C3	131	1	131

Slight deviations are marked in italics, great deviations in italics and bold.

about the production of the voice. Instead of being passively set in vibration by air blowing from below, Raoul Husson claimed that the vocal folds are brought to vibratory motion by rapid contractions of the vocalis muscles themselves, following, ‘coup par coup’, nerve excitations from the recurrent nerve, that means, the laryngeal sound is produced by active movements of the glottis: la théorie neurochronaxique de la phonation [7]. After a short while of paralysis-like silence, scientists all over the world started a great variety of research programs to check this new philosophy, most of them deeply convinced that this could be nothing but a fundamental error.

To begin with, let me quote here one outstanding representative, Janwillem van den Berg (fig. 6) from Groningen, who essentially contributed to a convincing confirmation of the aerodynamic-myoelectric theory of voice production [8, 9]. Among many other profound studies, he repeated the Johannes Mueller experiments from 1840 according to his current technical possibilities and produced, together with the American singer William Vennard [10], a fascinating instructional film on the vibrating larynx in 1960 (fig. 7, 8). It is my great pleasure to present a couple of short sequences from this film, kindly provided by Harm Schutte many years ago for presentation to my students, that is why the comments are converted to German. Video 11 shows the tilting function of the musculus cricothyroideus, resulting in increasing pitch due to increasing tension of the vocal folds. Van den Berg’s scientific studies were enthusiastically supported and replenished by William Vennard from the singer’s artistic point of view, an ideal cooperation (video 12).

After Janwillem van den Berg, it is just the right place to greet Harm Schutte (fig. 9), and I would like to do so by quoting myself from my Groningen speech:

And now a few words to the celebrated retiring young man. Beste Harm: when we met for the first time, centuries ago at one of the Leipzig symposia, and you were out as a disciple of the great Janwillem van den Berg, a strong flush of admiration and respect flitted through my mind, continuing over the years. Your achievements are numerous, let me name just a few. You are playing several instruments, conducting choirs, and, without being a trained singer yourself, you have developed a great affinity to the fascinating field of the singing voice. Together with Don Miller, you have contributed extended fundamental new insight to the field, not to mention many other important topics like Groningen Voice Button, voice range profiles, and Videokymography [11, 12], and you are editor in chief of the famous international journal *Folia Phoniatica and Logopaedica*. 60 years of voice research in Groningen – that’s what the front page of the program says. A glorious era coined by two glorious names: Janwillem van den Berg and Harm Schutte. You are the voice of Groningen. Thanks and congratulations! We will return to your work when we are going to talk about Don Miller.

For the moment, we stick to the controversies about Husson’s theory, and I would like to remember here my teacher and dear friend Wolfgang Pfau (fig. 10). Parallel to his medical training with specializations in physiology, ENT and phoniatics, he had a full education in singing and, among others, an engagement at the Opera House Halle as a serious basso for two seasons (Sarastro, Pogner, a.o.). The reader may like to listen to an aria of king Lycomedes from Deidamia at the Haendel Festival in 1953 (video 13).

Fig. 4. Tran Quang Hai.

Fig. 5. Raoul Husson (1901–1967). Courtesy of E. Perelló.

Fig. 6. Janwillem van den Berg (1920–1985). Courtesy of H.K. Schutte.

Fig. 7. Voice production, situs. Courtesy of H.K. Schutte.

Fig. 8. William Vennard, situs. Courtesy of H.K. Schutte.

Fig. 9. Harm K. Schutte.

Fig. 10. Wolfgang Pfau (1920–1989). Courtesy of M. Pfau.

His interest in the singing voice led to basic investigations on its classification [13], and in the dispute over Husson's ideas, he measured the length of the vocal folds with increasing pitch with an elegant, simple procedure after Trendelenburg: the laryngeal mirror picture is par-

tially reflected by a sheet of glass, and a virtual image appears on a black velvet screen where it can be measured by a pair of compasses (video 14) [14].

It was clearly demonstrated that with increasing pitch, vocal fold length increased due to the extension caused by the frame stretching as described anatomically by Zenker and Zenker [15] in Vienna at the same time (video 15). Our photographic measurements afterwards in Berlin confirmed Pfau's results completely: pitch as a function of tension [16] (video 16).

Care of the Voice

The scene now shifts to Belgrade, to Dušan Cvejić (fig. 11). He was the father of phoniatics in former Yugoslavia with phonosurgery and care of the professional voice being his main fields of interest. In 1994, he published together with his wife Biserka (fig. 12), held in high esteem as one of the worldwide leading mezzos at her

Fig. 11. Dušan Cvejić (1923–1998). Courtesy of B. Cvejić.

Fig. 12. Biserka Cvejić.

Fig. 13. Donald G. Miller.

time, a gorgeous luxury book on singing, combining scientific as well as artistic aspects in an impressive, competent manner [17]. Video 17 provides impressions from Jules Massenet's *Werther* with records of Dušan and Biserka Cvejić. And not to forget, Duško Cvejić was the founding president of the Union of the European Phoniaticians, a professional as well as scientific organization which – against a sea of plagues – succeeded in keeping colleagues in touch from both sides of the iron curtain whilst Europe was so strongly divided during the cold war. Thank you, Duško!

The Phoniaticians' Cantus – a small segment of which can be heard in video 18 – was composed by Martin Hatung on the initiative of Wolfram Seidner.

The Vocal Tract

But now, back to Groningen. I know, talking about Don Miller and Harm Schutte in Groningen means to take matjes to the Netherlands. Nevertheless, with Donald G. Miller (fig. 13) we are naming a well-acknowledged singer as well as a vocologist of worldwide reputation: bass-baritone at, a.o., Wiener Kammeroper, singing teacher at Syracuse University School of Music, since 1984 in Groningen with van den Berg and Schutte, PhD on 'Registers in Singing', developed the acoustic analysis system 'VoceVista' [18]. I am sure that he has realized very well the enormous chances of a close cooperation with outstanding experts like Janwillem van den Berg and Harm Schutte, and so did they from their parts, an admirable and enviable example of mutual stimulation and support. Out of their numerous studies, let me just quote two impressive examples. The first one is on larynx posi-

tions and their influences on the resonator properties of the vocal tract.

First: singing with the larynx in a low position. Watch the prominentia laryngea below a little pigment spot (video 19, Don Miller 1). With the larynx elevated to a high position, simulating untrained singing, the sound of the voice changes conspicuously to a poorer quality. The changes show up impressively when we look at the VoceVista figures, displays from Don Miller's biofeedback equipment, showing a clearly richer spectrum with the larynx in a low position (video 20, Don Miller 2).

The second example demonstrates the influence of vocal tract properties on the efficiency of voice production based on studies which Harm and Don carried out together [19]. In this experiment with Don serving as the guinea pig, a mini pressure transducer was passed through the glottis to pick up the subglottal pressure during singing; the radiated sound pressure level was recorded simultaneously.

Whilst the subglottal pressure was kept permanently constant, the radiated sound pressure level increased remarkably when in a sequence of changing vowels sung at a high pitch the formant frequencies of a given vowel coincided with a partial tone offered by the glottal source spectrum. To make this power increase clearer, after a repetition, in the third sequence the tape speed is set 4 times slower, corresponding then to a pitch 2 octaves lower. Video 21 (formant tuning) shows real-time FFT analyses which we carried out in Berlin with the audio recordings from Groningen.

That means, we can get a substantial gain in loudness (increase by 10 dB corresponds to a doubling of the perceived loudness!) by just tuning the vocal tract, without any additional exertion to increase subglottal pressure.

Fig. 14. Rolf Leanderson (1933–1990).
Courtesy of J. Bergtoft.

Fig. 15. Johan Sundberg.

Fig. 16. Wolfram Seidner.

Agreed, this study reflects the classical linear source filter theory which, today, is more and more being extended to nonlinear dimensions – nevertheless, it was an important step.

The wonderful voice we are going to listen to now belongs to Rolf Leanderson (fig. 14) from Stockholm (video 22). As a well-known phoniatician from Karolinska Hospital, he dealt with cleft palate problems, and as a singer, he studied several aspects of voice production, for example breathing muscle activity and subglottal pressure dynamics in singing and speech [20]. He was not only the first author of this study, but also one of the subjects tolerating intraesophageal and intragastric pressure measurements and EMG recordings from the intercostal and diaphragm muscles.

The same is true for the second author, Johan Sundberg (fig. 15). He was also present in Groningen, everybody knows him and admires him, he is on the top. Primarily a musicologist, he was the head of the Music Acoustic Research Group at KTH Stockholm 1979–2001. His comprehensive investigations on the singing voice as summarized in his book *The Science of the Singing Voice* [21] determine one of the current standard references, including the worldwide known graph on the singing formants as drawn from his analyses of Jussi Björling's voice in 1972. As a well-trained singer himself, he made his public debut with a Lieder recital on his 50th birthday. Who has heard him singing? Here is a short sequence from Robert Schumann's 'Mit Rosen, Zypressen und Flittergold' after Heinrich Heine (video 23).

For a vivid impression of the singers' formants, here are three samples from a video by Wolfram Seidner and Dieter Mrowinski, each of the samples containing a glissando tone and a piece of an aria. First sample: full voice

sound (video 24, singing formants 1); second sample: singers' formant (frequencies beyond 2.5 kHz cutoff) (video 25, singing formants 2), and third sample: singers' formant only (frequencies below 2.5 kHz cutoff) (video 26, singing formants 3). The corresponding spectra are presented simultaneously.

Wolfram Seidner (fig. 16), too, has always combined arts and sciences in his professional career. Four editions of his book *Die Sängerstimme* and his coauthorship of our textbook [22, 23] stand for universally acknowledged competence in both fields, and 2 meetings a year over a period of 19 years of the interdisciplinary Berliner Gesangswissenschaftlichen Tagungen, which he inaugurated and conducted, are a further proof of his untiring engagement. Now, let him sing: here is the beginning of Franz Schubert's 'Der Musensohn' from 1986 (video 27).

Even at a European Voice Conference, we should not completely neglect the rest of the world. Robert T. Sataloff (fig. 17) from Philadelphia, for instance, fits perfectly in with the profile of this presentation. His professional education and career cover both science and arts in an outstanding manner. After his BA in Music Theory and Composition in 1971, he became a singer and singing teacher, a MD in 1975, and a DMA (Voice) in 1982. He currently represents ORL and HNS at Drexel, Thomas Jefferson, and Temple University, is a member of the Academy of Vocal Arts, conducts the Thomas Jefferson Choir, and is chairman of the Voice Foundation with their famous annual meetings.

Professional care of the voice at top level and professional use of the voice, his own voice as well as the voices of others, laryngologist, singer and conductor: that is his profile. To name the details would have crashed the presentation.

Fig. 17. Robert T. Sataloff.

Fig. 18. Ingo R. Titze.

Fig. 19. Turandot.

Take just *Professional Voice – The Science and Art of Clinical Care* [24] as one out of his 36 books for a summary, and listen to two recent performances: ‘Younger than Springtime’ from ‘South Pacific’ by O. Hammerstein and R. Rogers at the Voice Foundation Gala in 2007, and Joseph Haydn’s ‘Lord Nelson Mass’ at the 37th Annual Spring Concert of The Thomas Jefferson University (video 28).

When we are looking out for another outstanding representative of arts and sciences to provide us with an enchanting, captivating finale on singing and science, then, we inevitably run into Ingo R. Titze (fig. 18), a fully trained singer, performing as tenor soloist at Tulsa Opera, Seattle Opera and Fort Meade Theater, and a scientist of highest excellence: primarily in electrical engineering (BS 1963), then PhD in physics in 1972, 1990 Director of NCVS at UI, and currently Executive Director of W.J. Gould Voice Center and Denver Center for the Performing Arts – Denver Division of the National Center for Voice and Speech. His achievements are also legendary.

Out of his widespread research interests, I am just mentioning his unique model work with computer simulations which is having continuing substantial impact on current ideas about the principles of voice production [25].

As a quinta essentia of the application of his scientific insight from numerous analytic investigations to a life-long love of vocal music, let us finish with Pavarobotti, Ingo alternating with his singing robot: ‘Nessun dorma’ from ‘Turandot’ by Giacomo Puccini [26] (video 29).

How did all these people manage to excel both in performing arts as well as in scientific elaborations in such a fascinating manner? Does professional singing require a profound knowledge of how it works? These could have been other riddles to be posed by the Chinese princess (fig. 19). The author has no answer – head off – silence is the rest, in deep respect and admiration of all singers and scientists who have followed the father of vocology, Manuel Patricio Rodriguez Garcia.

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