Teaching Singing and Technology

Filipa M.B. Lã

Summary

Meaningful feedback is vital to music pedagogy as learning to play an instrument involves the acquisition of complex multimodal skills, resulting from the integration of fine neuromotor control in response to processing visual, tactile and auditory stimuli. Both proprioceptive and exteroceptive feedbacks are applied to disentangle the underlying complexity of the information received from sensorial receptors when learning to play an instrument. Singing teachers, unlike any other music educators, face the added challenge of teaching a biological hidden instrument, which cannot be replaced if damaged. To overcome these unique conditions, technology in the singing studio has become a key asset over the past years. Here, possible applications of real-time feedback in singing lessons are discussed, integrating interdisciplinary knowledge from voice science with pedagogy, grounded on the results from previous investigations.

1. CONTEXTUALIZING FEEDBACK IN SINGING PEDAGOGY

1.1. The presuppose

Successful vocal pedagogy much depends on the fine ability of communicate effectively (Miller, 1986). This is largely achieved through the provision of meaningful feedback, which naturally is a major attribute in a singing teacher (Callaghan et al., 2001). A skilled singing teacher is expected to be able to observe, interpret and understand particular elements involved in singing (e.g. functional, musical and expressive), so that well-informed guidance can be provided to modify incorrect neuromuscular behaviours.

Feedback is vital to the control of the vocal instrument: (i) to share and discuss information (Callaghan et al., 2001); and (ii) to perceive (i.e. organise and interpret) physical stimuli received though sensations, applying interoceptive, proprioceptive and exteroceptive feedback (Welch, 1985). In a singing lesson, feedback emerges from the application of a variety of up-to-date pedagogical tools, including: (1) vocal and postural imitation; (2) the use of mirrors, charts and models; (3) verbal communication; (4) analyzes of audio and audiovisual recordings; and (5) real-time feedback displays provided by computer software. As the focus of this article is the application of technology to teach singing, the following will mainly concern the pedagogical disadvantages and advantages of such application.

1.1. Motivation

Time consuming constitutes one of the most notorious inconveniences when using technology in the singing studio. The teacher needs time to become fully acquainted with technology and to understand and to be able to translate the displays in a comprehensive manner. High organizational and creativity skills are also needed to accommodate the technology within the chosen pedagogical tools. Moreover, the student needs time to learn how to use this same technology, to understand the information underlying the displays and to apply it to the activities completed within the individual practicing sessions (Welch et al., 2005).

Taking into account these possible drawbacks, one may question whether teachers should really bother to learn about technology. After all, great singers have always existed despite the absence of these modern teaching tools. Besides, the vocal instrument has not changed that much (Nair, 1999). Albeit these may be considered valid points to consider that technology is not an important pedagogical tool, one should bear in mind that young people are probably much more accustomed to digital technology than their teachers, expecting to experiment it also in singing lessons. Additionally, and more than ever, both teacher and student need to understand that "*the singing voice is primarily a physical instrument that obeys the laws of physical function*" (in

Miller, 1986: 310). By being acquainted with these laws, a singing teacher can promote efficient learning, best preparing the developing singer to face the increasing career challenges, such as: (i) the need to sing for bigger audiences, which generally present higher expectations as compared to previous ones partially because of the perfection found in recorded versions of the repertoire easily available; (ii) the requirement to cope with louder accompaniment, resulting from larger orchestras; (iii) the need to sing in bigger concert venues, as compared to the smaller sizes of earlier days; (iv) and to cope with increasing levels of competition and sometimes less favourable conditions (Howard, 1999).

One of the most evident benefits associated with software use during a singing lesson is that the real-time display of an acoustic output corresponding to the sound generate leads to a more accurate understanding of the physical and acoustic underlying mechanisms (Nair, 1999). As both teacher and student have a visual representation of the produced voice, the diagnose of incorrect behaviours and application of effective correcting strategies is more accurate and objective (Miller, 1996). Critical points in the teaching model are avoided when using real-time displays, as the student receives quantitative feedback concomitantly to his/her vocal behaviour developing subsequent responses (Howard et al., 2004). Consequently, it monitors the acquisition of correct practicing behaviours during practice and self-regulated learning, assisting cognitive and associative stages of learning (Anderson, 1982). Technology in the singing studio also promotes the development of a student's musical identity (Hargreaves et al., 2002); it is beneficial on correcting melodic behaviour (Welch, 1985); it increases attention (Ibid.); it promotes emotional expressivity in performance (Welch et al., 1989a); and it helps the standardisation and clarification of terminology, establishing a bridge between science and vocal pedagogy (Ibid.). When combined with verbal communication, the use of feedback provided by applying technology in the singing lesson becomes more effective than verbal feedback alone (Marks, 1978; Welch et al., 1989b). Therefore, the question now is not why using technology, but rather how can it assist singing teachers as pedagogues, and students in their successful development?

2. APPLICATIONS OF REAL-TIME FEEDBACK TECHNOLOGY IN THE SINGING STUDIO

2.1 *Defining sound*

Sound results from back and forth vibrations of molecules of the medium through which the sound wave is moving. Thus, it can be characterised by four interrelated properties: duration, frequency (objective measure of pitch), amplitude (objective measure of loudness) and spectral envelope (objective measure of timbre) (McCoy, 2004). Duration is important, as the periodicity of a musical sound needs adequate duration to be perceived by the brain as pitch; periodicity is what distinguishes noise from sound, resulting in a stable frequency of the alternating high and low pressures; amplitude corresponds to the magnitude of the compressions (high pressure) and decompressions (low pressure) within a sound wave, perceived as loudness by the human ear; and the spectral envelop is the corresponding color of the sound, which acoustically results from the fundamental frequency and its harmonic partials, being the product of the voice source and the modification produced by the vocal tract resonator, with its resonances or formant frequencies (Nair, 1999). As technology transforms these sound elements from aural to visual realm, it becomes central to the provision of meaningful and less ambiguous feedback: visual displays resulting from the application of technology in the singing studio illustrate phenomena that otherwise would only be mental representations of aural perceptions (Welch et al., 2005).

2.2. Monitoring voice production

Voice production comprises interactions between ***breathing***, the power engine responsible for the vibration of the vocal folds, ***phonation***, the primary sound generated by the vibration of the vocal folds and ***resonance***, the modification of the primary sound (Sundberg, 1987). Aspects such as breathing patterns related to *vocal support*, the air pressure created below the vocal folds (i.e. subglottal pressure), the volume velocity of this airflow at the glottis, the tension and extension of the vocal folds, the glottal flow resistance (abduction and adduction forces), the shaping of the vocal tract to achieve the intended voice quality (resonance strategies), and articulation of text to make it intelligible, are of primary importance, as these constitute the basis of transformation of the human voice into a musical instrument. As the purpose of this article is not to discuss the possible combinations of different technology in teaching, here one example of a possible combination and its applications in teaching will be provided.

One possibility of recording and displaying, in real-time, four simultaneous signals revealing various aspects of voice function is to use a ***hybrid system*** (Figure 1). This particular equipment results from the combination of: (i) a laryngograph, a device that allow measures of audio signal (it comes with a Knowles EK3132 head-mounted microphone, electret condenser type with omnidirectional wide band flat response) and electrolaryngographic signal (the electrical conductivity between two electrodes placed on either side of the neck: as the contact area between the vocal folds increases, the conductivity between the electrodes also increases); and (ii) an MS-110 transducer electronics unit, which allows the recording of two channels, airflow and pressure data without an added A-D converter (a PT-2E pressure transducer is used to measure intraoral pressure via an oral pressure adapter and MA-1L CV pneumotach mask to measure air flow during voice production).

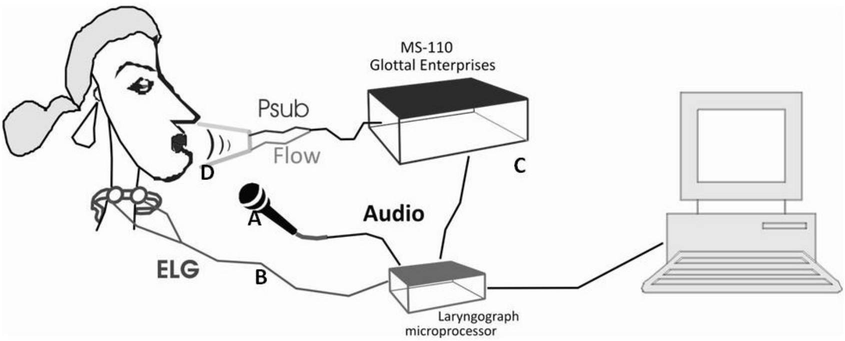

Figure 1: Hybrid system setup for studio data display and collection: omnidirectional micropone (A); laryngograph microprocessor and respective electrodes (Laryngograph Ltd.©) (B); MS-110 microprocessor (Glottal Enterprises©) (C); and pressure and air flow transducers and pneumotach mask (D).

This *hybrid system* allows the concomitant display of the four basic physiological factors affecting voice quality (Sundberg, 1987): (i) subglottal pressure (Psub); (ii) air flow; (iii) the tension and extension of the vocal folds; and (iv) degree of glottal adduction.

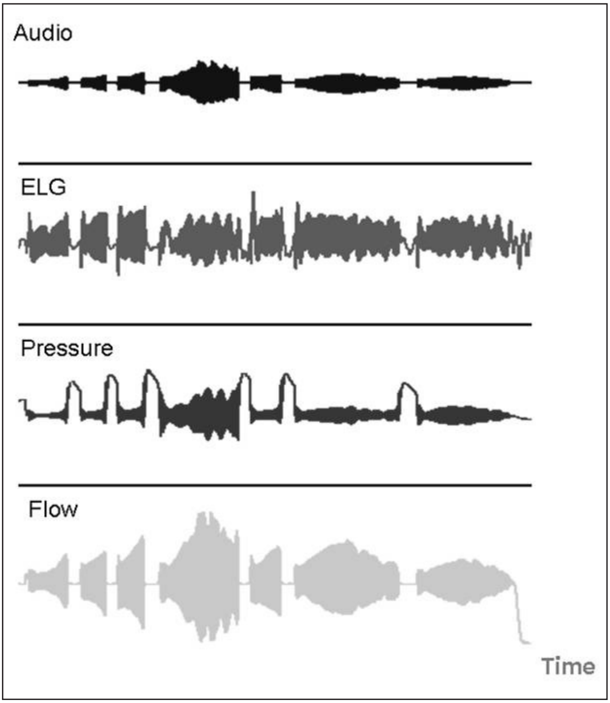

Figure 2: Speech Studio software display (Laryngograph©) of four channels (audio, electrolgaryngograph (ELG), pressure and air flow), simultaneously recorded when a soprano sung the first bars of the aria "O mio babbino caro", from Gianni Schicchi, by G. Puccini.

The above parameters can be monitored using the software Speech Studio© (Laryngograph Ltd.). It records and displays, in real-time, four different signals: (a) audio; (b) electrolaryngograph (ELG); (c) intraoral pressure peaks; and (d) air flow (see Figure 2). The importance and applications of each of these signals in providing meaningful feedback concerning the above mentioned physiological parameters affecting voice production is described below

2.2.1. Pressure and flow signals

The pattern of vibration of the vocal folds is strongly dependent on their muscle-elastic adjustments in response to the aerodynamic parameters of subglottal pressure and air flow (Schutte, 1992). Psub corresponds to the overpressure of air in the lungs (Sundberg, 1987). Psub can be estimated from intraoral pressure generated during voiceless stop consonants (e.g. [p] occlusion), as there is an equalization of lung and oral pressures. Precise descriptions on how Psub should be measured are provided elsewhere (see e.g. (Solomon, 2011)). Psub is vital to pedagogical nurturing of singing development as it is the primary variable for controlling vocal intensity. Because intensity and frequency are interdependent, Psub also contributes to the control of fundamental frequency (F0). Figure 3 illustrates this interdependence: the SoundSwell work station software, used in voice analysis, displays details of the recorded pressure signal, revealing that each note of a given piece of music (in this case, "*O mio*

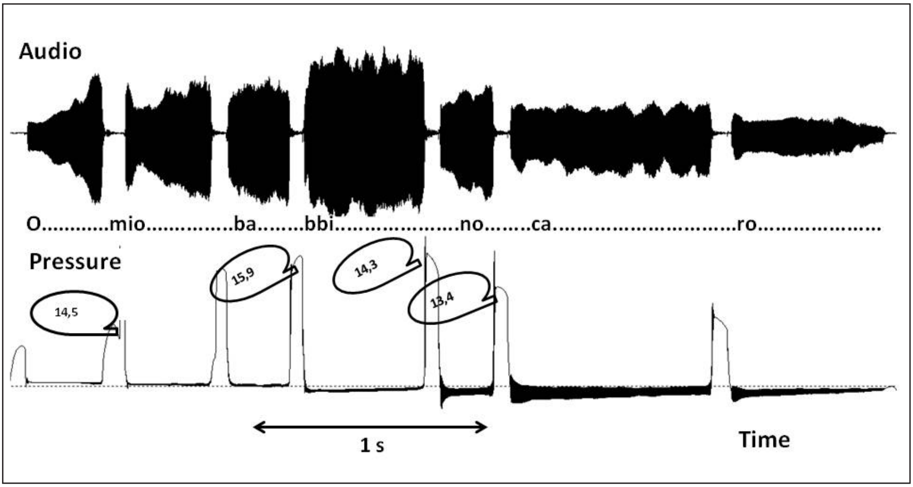

Figure 3: SoundSwell work station software (Hitech Development, Solna, Sweden) display of both audio and intraoral pressure peaks of an excerpt of "O mio babbino caro", from Gianni Schicchi, by G. Puccini, sung with the syllable [pae] instead of the lyrics. It is demonstrated that intraoral pressures are different for each note. The audio signal corresponds to the microphone signal, and pressure was determined using an intraoral tube during the [p] occlusion and by means of a flow mask.

babbino caro"), has its own pressure, depending on F0 and intensity. Psub is also crucial for regulating intonation (Lindblom and Sundberg, 2007). One might therefore conclude that learning to be at the right pressure for a specific vocal loudness and pitch before the tone starts is a key factor for efficient singing. This pre-planned fine tuning is essential for the singer (Miller, 2004). One way of automate this ability is practicing staccato and arpeggio exercises (Welch and Sundberg, 2002).

Displaying ascending and descending arpeggio exercises sung in legato can help the understanding of the concept of musical phrasing, an important aspect of expressivity in music (Friberg et al., 2006). In an ascending and descending arpeggio (Figure 4), the note which requires the highest Psub is not the top one (as a singing student might expect), but the one that follows immediately. This constitutes a key element in developing the correct vocal gesture for phrasing (Friberg and Sundberg, 1999).

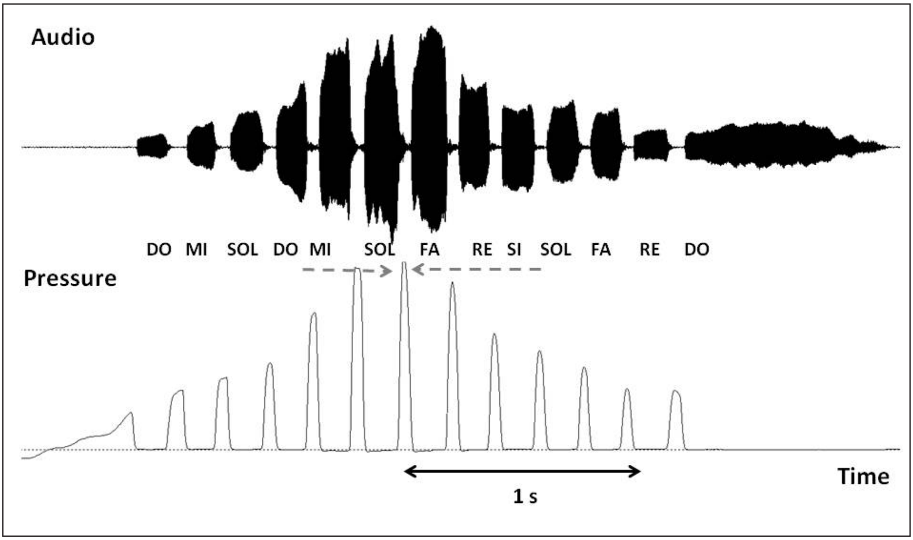

Figure 4: SoundSwell work station software displaying both audio and intraoral peaks signals of an ascending and descending nine note arpeggio, showing different intraoral pressures for each sung note. Note that the highest note does not display the highest pressure value.

The efficiency of the sound source produced depends also on the ratio between airflow rate and Psub (Sundberg et al., 2010). Psub and air flow change according to fundamental frequency, sound pressure level and sound timbre (Schutte, 1992); thus, understanding the relation between air flow and Psub, intonation and phonation types is of paramount importance for the developing singer.

The *hybrid system* above represented can assist the teacher in demonstrating how singing different *dynamics* is directly dependent on air flow and pressure. Figure 5 demonstrates that, when singing a decrescendo, both Psub and air flow diminish to a point in which sound is produced by the vibration of the vocal folds without requiring vocal fold collision. Singing a diminuendo at any pitch, and changing dynamics independently of lung volume, constitute examples of the fine control required in singing. Unlike speaking, where high pitch is generally produced with a louder voice, a classical singer needs to develop the fine ability to singing softly even at high pitches (Sundberg, 1987). This skill can be acquired by learning to control inspiratory and expiratory forces (Miller, 1996).

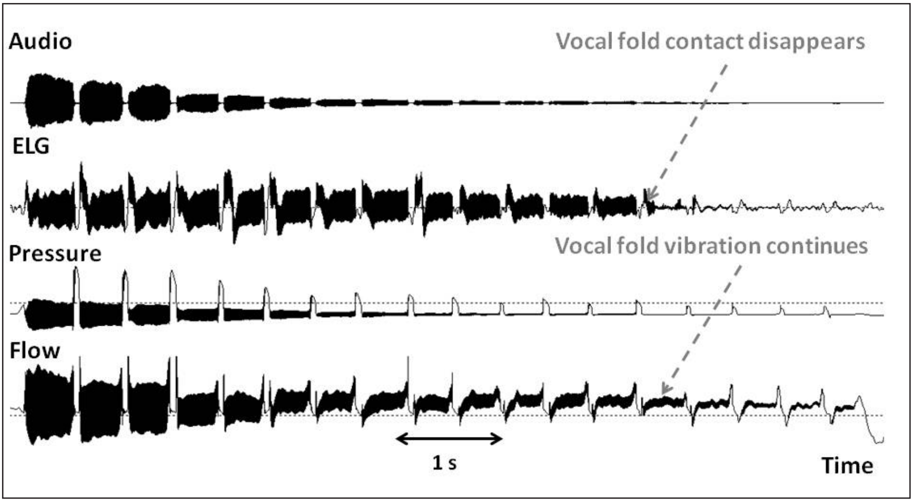

Figure 5: SoundSwell work station software display of E4 (≅329Hz) sung as a diminuendo by a baritone, using the syllable [pae]. It is demonstrated that soft phonation requires vibration of the vocal folds (as shown by the existing flow signal for soft notes) but not necessary vocal fold collision (as shown by the absence of ELG signal in softer notes).

The different breathing strategies used by singers to control Psub and air flow rate is task dependent and can be monitored using technology. For example, a Respitrace (Ambulatory Monitoring Inc., Ardsley, NY) is a portable device that allows the recording of lung volume during singing and to assess the contributions of both rib cage (RC) and abdominal muscles (AW) to change lung volume (LV). Variations of RC volume are commonly used by singers to change LV, and thus Psub and air flow (Thomasson & Sundberg, 1999). AW movements also seem to belong to singers' common breathing patterns, mainly participating in two possible ways: (i) assisting the RC in changing LV; (ii) as a stable platform for LV changes that are affected by the RC. Other studies found that at the beginning of a phrase, singers seem to change LV by activating the AW muscles, whereas movements of the RC are activated to change LV at the end of a phrase (Watson and Hixon, 1985).

2.2.2. Electrolaryngographic signal

The tension and extension of the vocal folds constitutes another physiological parameter important to the quality of the voice. It allows pitch variations: (i) to sing high notes, the cricothyroid muscle needs to contract, longitudinally tensioning the vocal fold, and the contraction of the lateral cricoarytenoid muscle is needed to further elongate and thin the vocal fold, stiffening the vocal fold edge (Sataloff et al., 2007); (ii) to sing low notes, the thyroarytnoid muscle needs to contract, shortening and thickening the vocal fold, rounding the vocal fold edge (Ibid.). The effects of these different configurations on vocal fold vibration can be monitored using electrolaryngograph displays (ELG waveform, or Lx). Changes in the vibration mass will change the contact area reflected in the ELG, as electrolaryngography constitutes a non-invasive technological aid to monitor the patterns of vibration of the vocal folds, corresponding to different physiological events (e.g. changing registers and modifying phonation types). Figure 6 displays a typical ELG waveform, showing the main phases in one cycle of the Lx.

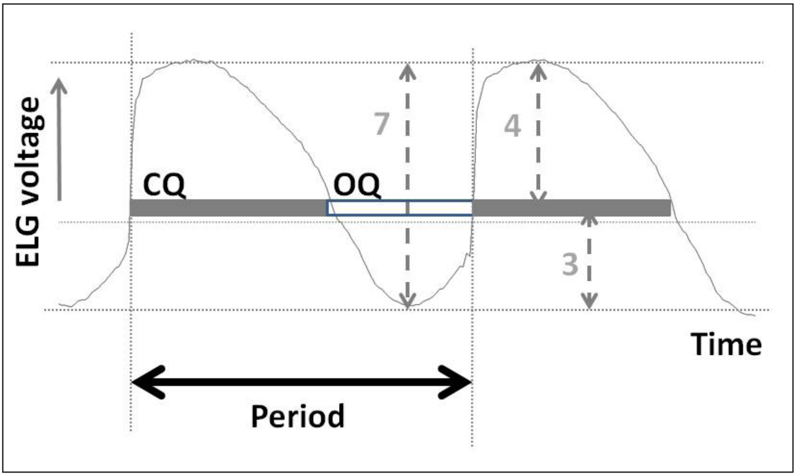

Figure 6: Speech Studio display of ELG signal (Lx), showing the main phases in one cycle: **CQ** = contact quotient – time in one vibratory cycle during which the vocal folds stay in contact; **OQ** = open quotient – time in one vibratory cycle during which the vocal folds stay open; **Period** = duration of one vibratory cycle.

Singing higher notes will require less vocal fold mass vibrating, thus producing smaller wave amplitudes in the ELG waveform, whereas low notes will involve greater vocal fold mass, thus producing greater amplitudes (see Figure 7).

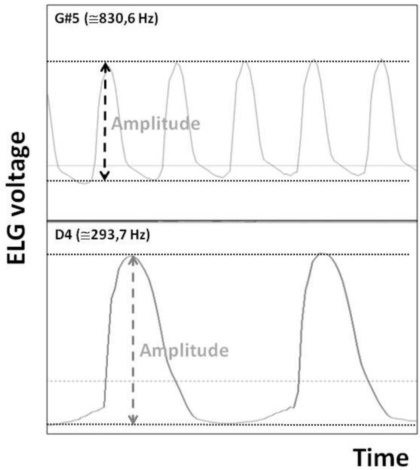

Figure 7: Speech Studio display of ELG signals for two different notes sung by a female singer, in the same vowel and for the same vocal loudness; D4 (≅293,7Hz) & G#5 (830,6Hz). The arrows point out at the amplitude of the wave form corresponding to vocal fold contact.

Another example of possible applications of ELG displays in the singing studio is the monitoring of the student's vocal evolution by comparing CQ values longitudinally. Previous investigations have shown that the time that the vocal folds are in contact can provide an estimate of degree of vocal training: the CQ tends to increase with greater expertise (Howard, 1995). Other possibilities include the display of different registers (Roubeau et al., 2009) and phonation types. The latter correspond to different degrees of glottal adduction, ranging from hyper to hypo phonation, i.e. pressed to breathy, respectively (Sundberg, 1987; Sundberg and Gauffin, 1979). Figure 8 displays different ELG wave forms, according to the type of phonation used. Flow phonation, produced by optimal relationship between Pub, glottal adduction, air flow and acoustical output, as been referred as the preferable type of phonation in classically singing (Sundberg, 1987). It typically produces a strong fundamental with many partials. On the other hand, pressed phonation is characterized by producing weaker fundamental (Ibid.). Efficient classical singing, besides using predominantly flow phonation, it also provides possibilities of using combinations of different and well controlled phonation types for communication and expressive purposes.

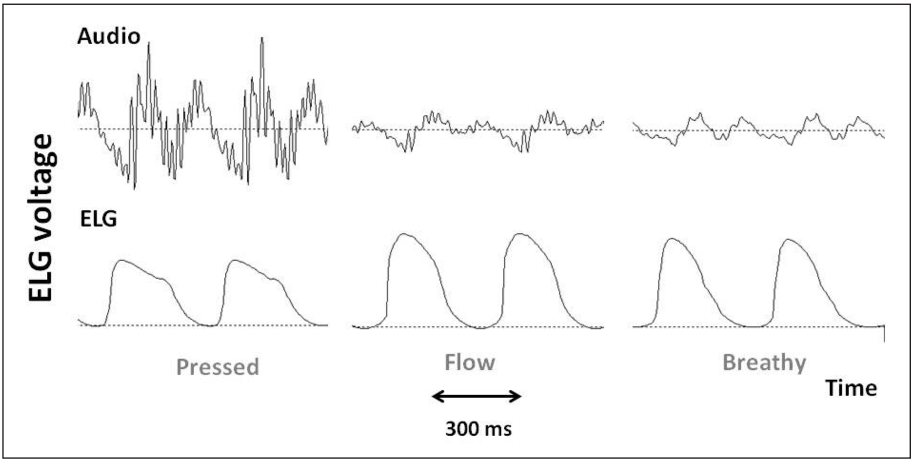

Figure 8: Audio and ELG signals for the three types of phonation of the same pitch (E3 ≅165 Hz), sung by a tenor.

2.2.3. Audio signal

As the human voice is the only musical instrument for which articulation also affects resonance (Lindblom and Sundberg, 2007), information extracted from the audio signal has been useful in many ways to singing teachers and their students (Nair, 1999). There are two types of visual representations of the sound produced by the singe: spectrograms and spectrums. The goal of such type of displays is that the student visualises a representation of his/her sound quality almost immediately after its production (hence called real-time feedback). By momentarily stopping the recording and freezing the screen, the teacher can discuss details of differences in the several attempts produced by the student. Emphasis to the repetition of the best vocal behaviour can be given, facilitating the neuromuscular memorisation of correct vocal gestures in the lesson, so these can be easily consolidated during the student's individual practicing sessions. Thus, it is of paramount importance that both teacher and student are acquainted with the information displayed on this type of displays.

The information underlying a spectrogram or a spectrum is taken first by recording the voice with a microphone; this allows the conversion of an electric sound to a digital signal, to which is then applied a mathematical formula (Fast Fourier Transform), converting sound into its component parts. The result is a graphical representation displayed on the computer screen (Howard and Murphy, 2008). Two extremely important aspects to ensure the reliability of these displays and thus their interpretations are the type of microphone used and its position in relation to the mouth of the singer. It is recommendable to use an omnidirectional flat response for a wide range of frequencies, mounted in a head set, so the distance to the mouth is kept constant and known for each student.

Nowadays, several possible options exist concerning the choice of software which provides acoustical displays of the voice. For example, there are some free options downloadable from the internet, e.g. WaveSurfer (http://www.speech.kth.se/wavesurfer/), which allows the display of both spectrograms and spectrums.

A **Spectrogram** displays time along the horizontal axis and frequency along the vertical axis. The dark colour corresponds to frequency bands with stronger energy (i.e. intensity), whereas more faith colours correspond to frequency bands with weaker energy (Howard and Murphy, 2008). There are two types of spectrograms: wide and narrow band (Figure 9). The first allows a better visualization of the formant frequency regions, as the dark coloured horizontal lines (or simply black, for cases of black and white spectrograms such as the ones displayed here) indicate the vicinity of a certain formant frequency. This change accordingly to vocal tract configurations to articulate different vowels. Narrow band spectrogram displays particular voice events in time clearly: the well defined horizontal lines correspond to single harmonic partials which have been energized by vocal tract resonances. Thus, aspects such as individual harmonic partials, voice onset and vibrato can be monitored.

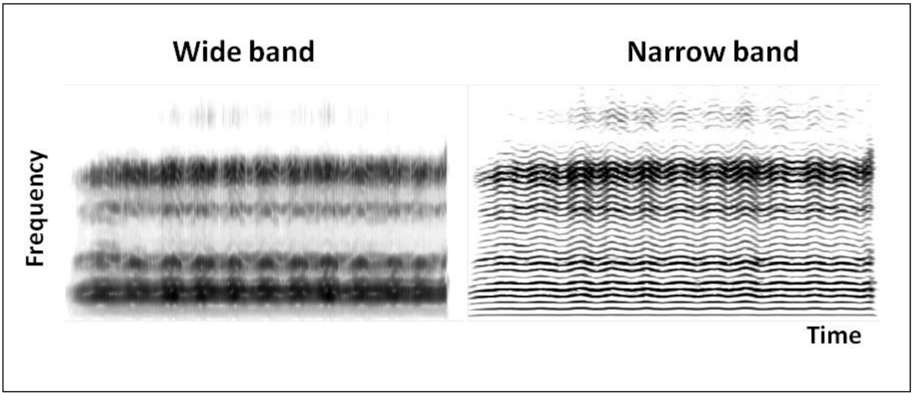

Figure 9: Wide and narrow band spectrograms for the vowel /e/. Note than on the wide band spectrogram, the black horizontal lines represent regions of formant frequencies, whereas on the narrow band, black horizontal lines correspond to individual harmonic partials. For the latter, those harmonic partials being enhanced by the vocal tract resonances will display more energy, thus a darker colour.

Spectrums, on the other hand, represent sound components during a single moment in time (some milliseconds), thus allowing the visualization of the frequency and the intensity of each harmonic partial responsible for voice quality, i.e. the spectral envelop (Figure 10).

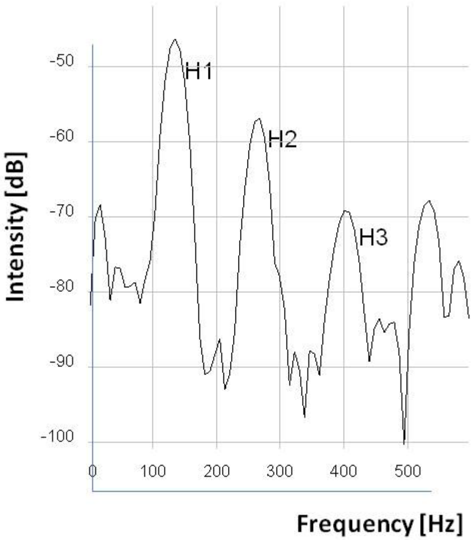

Figure 10: Spectrum of the vowel /e/ displaying the frequency and respective intensity of each harmonic partial. Note H1 is the first harmonic partial of the sound (or its fundamental frequency), H2 and H3 the second and the third harmonic partials, respectively.

A **wide band spectrogram** can display the effects of different resonance strategies applied to produce different sound qualities. Figure 11 represents the vowel /u/, sung by the same baritone, applying and not the resonant strategy of the *singer's spectrum peak* (left and right, respectively). Physiologically, this event corresponds to the modification of the shape and size of the vocal tract by lowering the larynx and enlarging the sinus *piriformes* (i.e. bottom part of the vocal tract surrounding the larynx tube). The corresponding acoustic phenomena is that the formant frequencies numbers 3, 4 and 5 (F3, F4 and F5) are lowered, producing a cluster responsible for an increment of frequencies' intensity around 2500 to 3000 Hz. This strategy, used only by male classically trained singers, results in a boost in this spectral region, facilitating the singer's voice projection over loud accompaniment, such as the one produced by a large orchestra (Sundberg, 1987).

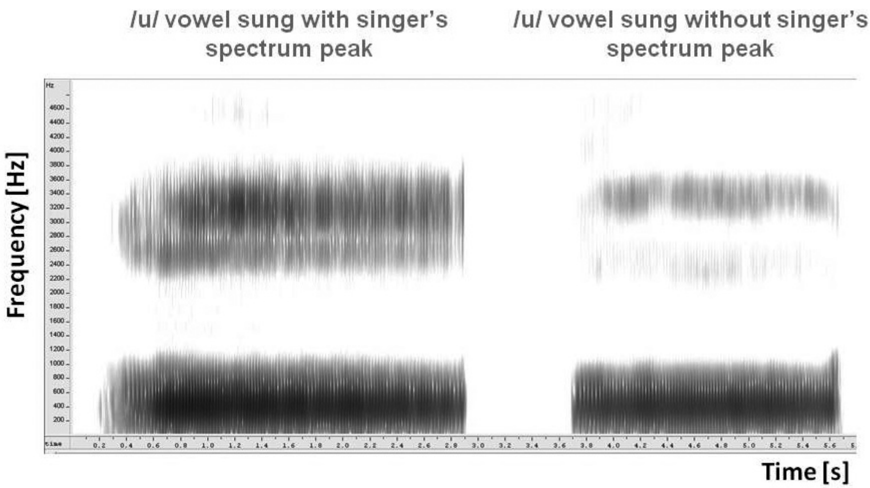

Figure 11: Wide band spectrograms of the same baritone applying the fine art of clustering the third, fourth and fifth formant frequencies (left), and not applying this resonance strategy (right). When this strategy is applied, there is a clear increase in energy between 2000 and 3000 Hz, region in the spectrogram responsible for getting heard when accompanied by an orchestra.

A **narrow band spectrogram** can, for example, display the effects of different articulation strategies in the production of vowels sung with different legato qualities. In Figure 12, two spectrograms (left and right) represent different articulation strategies used by two different sopranos singing an excerpt from the aria "*O mio babbino caro*". Legato can be monitored comparing the time spent for articulating consonants in relation to the one spent in articulating vowels. Consonants' articulation corresponds to empty spaces (or fade colors) in the spectrogram. The two sopranos used two different strategies: the one on the left sung with less legato, as the spectrogram displays longer empty spaces; on the contrary, the soprano on the right used the strategy of not spending such long time in articulating consonants (there are almost not empty spaces in the spectrum in between vowels), resulting in more legato.

Other useful information underlying these spectrograms concerns technical aspects of voice production. For example, a stronger fundamental is produced by the singer on the left, as the first harmonic possesses a darker color; the resulting effect is greater intensity also in the higher partials. Physiologically, one might argue that the singer on the left sung applying less vocal fold adduction than the one on the right, that is to say, she sung using more flow phonation.

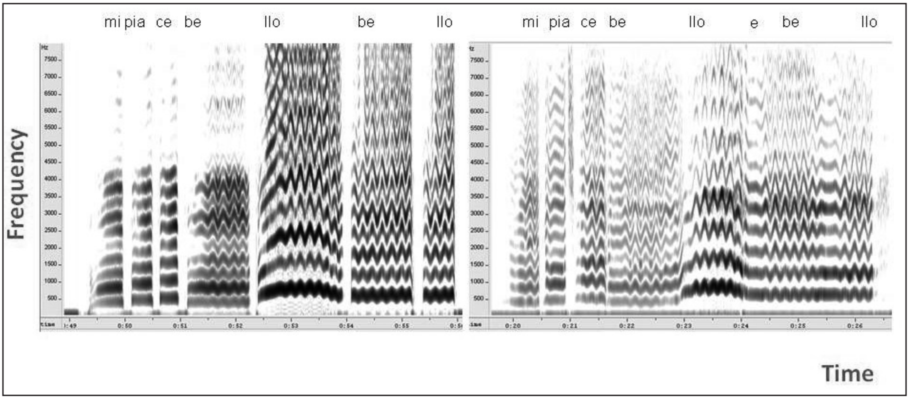

Figure 12: Spectrograms of two sopranos singing an excerpt from the aria "o mio babbino caro". The spectrogram of the right shows a clear legato than the one on the left, as there are no long and clear stops between syllables.

Another possible application of narrow band spectrograms is to monitor vocal onset and offset. Depending on whether there is synchronization between Psub, vocal fold adduction and vibration, the resulting vocal onsets can be: (i) **staccato**, when these three events initiate co-ordinately; (ii) **breathy**, if the adduction and vibration of the vocal folds follow the increase of Psub; and (iii) **hard**, if adduction occurs first, followed by the vibration of the vocal folds caused by an increase in Psub. A spectrogram of these three types of vocal onset is represented in Figure 12. For a breathy onset, non-harmonic components (i.e. noise) appear first than the harmonic components of the vowel; the hard vocal onset reveals a highly energised synchronised beginning for all harmonic partials; the staccato onset presents all harmonic partials at same time, but their maximum intensity does not occur synchronised. Voice onset has an impact on the quality of the sustained vowel, as the staccato version produces a more efficient sound, judging by the intensity of higher harmonic partials.

One might concluded that a narrow band spectrogram can be applied in a singing lesson to display both technical aspects of voice production and important stylistic, musical and aesthetic components of a singing performance.

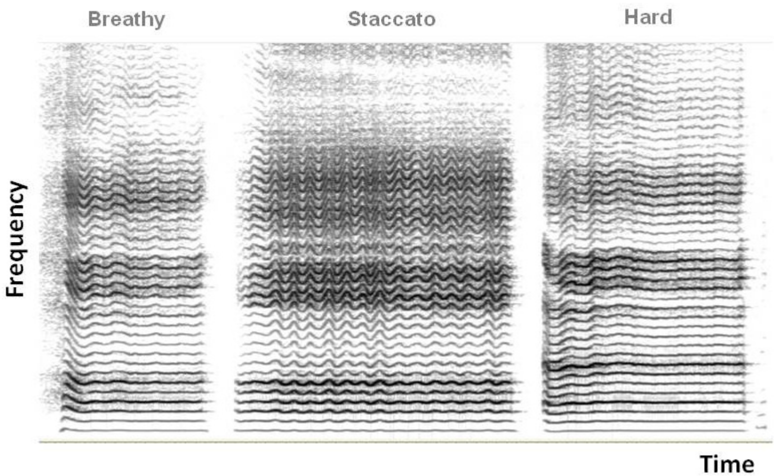

Figure 12: Narrow band spectrograms displaying the three types of vocal onset for the sung vowel /a/. These examples correspond to the same pith, and by the same tenor.

Finally, **spectrums** can be used in the singing lesson to exhibit specific vocal qualities resulting from the intensity of each harmonic partial. Figure 13 represents the spectrum of the first three harmonic partials for the same baritone applying different strategies to sing a G4 @ 392 Hz. On the left, the singer applies a resonance strategy aesthetically more acceptable for classical singing, whereas on the right he is applying a resonance strategy more appropriate for non-classical singing. It can be observed that, for classical singing, the expected colour involves higher intensity for partials H2 and H3, whereas for the case of non-classical singing, H2 is the dominant partial and H1 has slightly lower intensity.

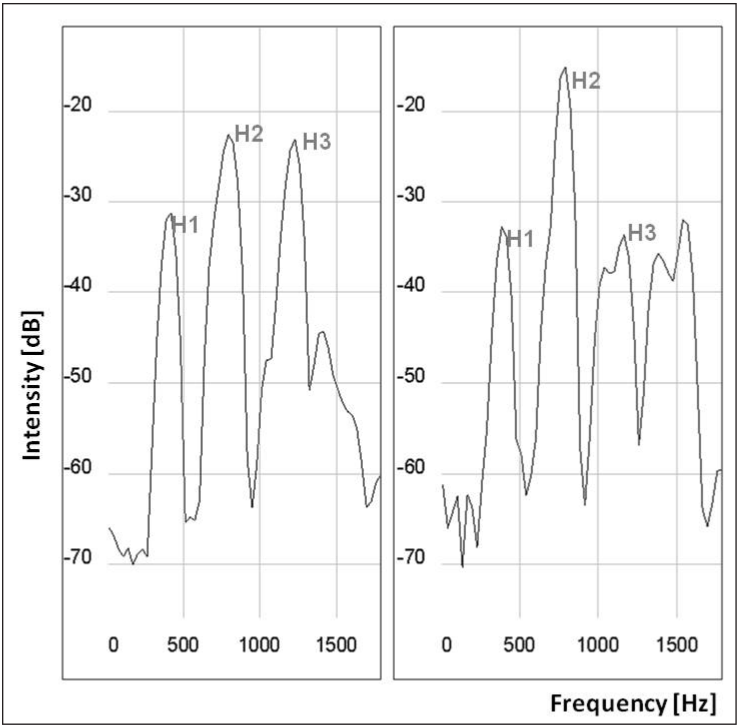

Figure 13: Spectrum displaying different intensities of the first three harmonic partials (H1, H2 and H3) when applying different resonance strategies: classical singing strategy (left); non-classical singing strategy (right).

2.2.4. *Summary*

The twenty-century singing teacher and singing student have much more in common with voice scientists than one could initially imagine. Curiosity, perseverance, organizational abilities, creativity, communication skills and looking for order constitute examples of common characteristics between these professionals. After all, they all share a common goal: to understand the complexity underlying the multiple facets of the human voice.

Nowadays, to acquire and enhance singing expertise, teachers and their students need cross-disciplinary approaches; thus, technology is not anymore exclusive to the scientific community. The advantages of using such teaching aid and their endless possible applications seem much more beneficial. Research has shown that, despite the complexity underlying interpretations of spectrograms and spectrums, singing teachers use them as an effective way of communication (Nair, 1999). When used in combination with verbal feedback, the student completes more learning cycles (Welch et al., 2005). Thus, currently increasing numbers of teachers follow the example of pioneers such as William Vennard and Ralph Appelman, in realising the potential of technology (such as, for example, spectrograms), to assist the diagnose of student's vocal malfunctions and to create efficient strategies to correct them (McCoy, 2004). Excellent teachers understand that technology can constitute an efficient pedagogical tool, but it is one amongst several others. In fact, teaching singing is rather idiosyncratic as there are different types of students: (i) kinaesthetic learners - must feel in their bodies; (ii) intellectual learners - must understand the concepts; (iii) aural learners - must model the teacher's example; and (iv) visual learners - must see in order to do. Thus, the teaching method should be chosen in accordance to the student's individual requirements (McCoy, 2004). Moreover, technology assists the observation and interpretation of details (Nair, 1999), but does not tell if the sound produced by the student is full of musical meaning and expressivity (McCoy, 2004). This is a competence that presently cannot be provided by any technology.

Filipa M.B. Lã

Department of Communication and Arts, INET-MD, University of Aveiro, Portugal

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