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Acoustical properties in inhaling singing: A case-study

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ABSTRACT

A highly experienced versatile female professional singer displaying no apparent vocal complaint, developed inhaling singing, an innovative approach to reverse phonation. Although there are some reports in literature that describe the characteristics of ingressive phonation and sounds, to the best of our knowledge, no reports on actual inhaling singing are available in literature. This paper reports a case study on the acoustical analysis of inhaling singing, comparing this innovative technique with traditional exhaling singing. As this is rather undiscovered territory, we have decided to address several questions: is it possible to match the same pitches using inhaling singing compared to exhaling singing? Is the harmonic structure and energy distribution similar? Is it possible to maintain the same phonation duration in both techniques? Are there differences in volume and tessitura (vocal range)? This paper, reporting on the experience of one individual, demonstrates that a tessitura can be mastered in inhaling singing. Spectral analysis reveals a similar frequency distribution in both conditions. However, in inhaling singing the energy of the harmonics is significantly lower for the first 3 overtones, while the maximum phonation time is larger, than in exhaling singing. The singer reports that less effort is required for inhaling singing in the high register. As such, inhaling singing offers new possibilities for vocal performance.

1. Introduction

A case study comprises two experiments focussed on the acoustic properties of Inhaling Singing technique registered as ISFV is based on simultaneous control of aspiration and phonation. This study is in addition of the article by Ref. [15], which focuses on the morphology of the vocal tract in Inhaling Singing, based on MRI established on the correlation in terms of physiological processes between inhaling and exhaling vocalisation/singing, by the same singer and the differences between inspiratory and expiratory phonation revealing the inversion of the mucosal wave [25]. This prospective study contains the same notes of the MRI study from F5 to Bb5 and on the same/a/vowel. The MRI study showed statistically significant differences of the vocal tract describing the anatomical structure between inhaling and exhaling singing lying in the supraglottal morphology. The singer controls the inspiratory airflow using the breathing muscles, such as the costo-diaphragmatic breathing for stabilizing the transglottal pressure and hens vocal fold oscillation regulating the resonator capacities [15]. In this present paper, we focus on 'pure sounds', one of the three aspects of inhaling singing, comprising and defined as 'multiphonics' and 'vocal electronics'.

Breathing sounds, including sounds of aspiration often occur in daily human and animal life [4]: related to expression and emotion, for example, astonishment or laughter is sometimes produced with reverse phonation [22]; children make inhaling sounds as they imitate animals, and when crying [12]; comedians sometimes produce inhalatory voice effects [1,9]. People from Germany and Scandinavia, are known to use ingressive airstreams from time to time; and native French and Swedish speakers, for example, often phonate their respective words for 'yes' while inhaling [Fr. 'Oui'; Swe. 'Ja'] [3]. The pronunciation of both these words requires

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speakers to change the shape of the inside of the mouth, that is, to model the buccal cavity and the larynx [10]. Different types of inhaling sounds are also found in ethnic music, such as the Tibetan monks' chanting and that of the Lamas [7,19]; the Inuit use the voice and the breath simultaneously [8].

Inhaling singing (ISFV) is a specific form of inspiratory phonation, which, in turn, is a particular extended vocal technique. In the case of inspiratory phonation, vocal production is realised using an inspiratory airflow, that is, a voiced sound is made while the performer inhales [5,6].

This vocalized breathing technique which originates in speech and Inuit music making, has been explored in various musical contexts since the 1960s and is taken here as the starting point for ISFV, which we see as a contribution to the historical trend of extending and expanding expressive means in music making. Inverse phonation in speech for therapeutic and clinical applications, and acoustic comparisons have also been reported [16,18]. This technique is now considered as a new vocal extended technique in today's contemporary music platform as an extension of timbral palette for new ways of interpretation, intention and expression. The singer is capable to control intended affect and emotion, meaning and expression with this inhaling singing technique and in combination with all kinds of other singing styles. New compositions were made that demonstrate this clearly [24].

The goal of this study was to derive an understanding of the acoustic aspects of inhaling singing, by comparing recordings of ISFV with those of conventional exhaling singing. The subject for all measurements and observations in these experiments was the first author. Videostroboscopic examinations carried out before and after experimenting with this technique, showed no laryngeal pathologies.

The study sought to address several questions:

- Is it possible to sing the same pitches using Inhaling Singing as in exhaling singing, using Inhaling Singing-pure sounds?
- Is the harmonic structure and energy distribution of the resultant vocal sound similar in these two conditions?
- Is it possible to maintain the same phonation duration in both conditions?
- Are there differences in volume and tessitura between the two conditions?

2. Materials & methods

Two experiments were carried out, in which recordings of ISFV and conventional singing were made for acoustic analysis. In the first experiment, pure, sustained sounds with a controlled breath and without vibrato were recorded in the inhaling condition, with equivalent sounds for the exhaling condition. Subsequently, the spectral characteristics and energy distribution of the recordings were analysed, for comparison. The second experiment sought to examine the implications of ISFV for vocal pitch range, again, by comparison with conventional singing. A voice range profile (VRP), i.e. a schematic reproduction of the frequency range and dynamic range of the voice, is used as a measure for comparing ISFV and exhaling singing. Again, recordings made in each condition were compared and analysed.

2.1. Protocol and measurements

In the first experiment, the subject sang six separate notes with chromatically ascending pitches from F5 to Bb5, on the/a/vowel. This particular sonant eliminates formant influences on high-pitch singing [11]. This is in contrast to the case where an ascending scale on/u/, or/o/ [23]. Each note was sung for as long as possible and without vibrato, first in the exhaling condition, and immediately afterwards by the inhaling condition. The protocol is summarized in Table 1.

Sounds were recorded using two calibrated Brüel & Kjaer (type 4955) microphones positioned at a distance of 30 cm from the sound source, in a soundproofed room at the Acoustic Lab of the School of Arts, in Ghent, Belgium. Recordings were made with 24-bit digital sampling and a sampling rate of 96 kS/s. A grand piano set outside the soundproofed room was used to play the target note before the experiment, providing a reference for the subject. The two sets of six audio recordings were obtained and digitally stored as wav files. Spectral analysis was performed using the Matlab MIR-Toolbox [13].

In the second experiment the subject sang single-pitched notes on the/a/vowel across her entire pitch range, each one by exhaling-singing first followed immediately by the same pitch using ISFV during three seconds as soft and as loud as possible intensities. The voice range profile (VRP) was found using a Kay Speech Lab CSL model 4510b with a Shure SM48-LC microphone at 30 cm distance, in a quiet room. in the Maria Middelares Hospital voice laboratory, Ghent, Belgium, according to the clinical standards currently in use. It was placed at 30 cm distance from the sound source, in a silent room. The protocol is summarized in Table 2.

2.2. Experimental results

In what follows are the reported results. Pitch, duration and tone quality (amplitude, spectral content and energy distribution) were taken into consideration in analysing the recordings made in the first experiment. In the second experiment, VRPs were obtained in each condition.

2.3. Statistical analysis

For Experiment 1, pitches were extracted from the recordings using a Sonic Visualizer based on the Yin pitch tracker, using standard values (Yin threshold 0.15, 2048 samples/block with an increment of 256 samples) [2]. Using the pitch-time series (spectrogram) to establish the measurable portion of each recording, mean pitches were calculated, as well as the extent to which the pitch varied within each sung note (Table 3). The spectrogram uses a window length of 50 ms, with a 50% overlap and a Hamming window. A paired Wilcoxon and ANOVA statistical analysis was used to quantify the differences between the harmonic structures of the corresponding exhaling and ISFV pitches. For the second experiment, Voice Range Profiles were assessed by a professional speech therapist.

Table 1
Experimental setup.

N	Condition
Vibrato	no vibrato
Duration	As long as possible
Vowel	/a/
Lowest note	F5
Highest note	Bb5
Order	Chromatic ascent
Conditions	Exhaling followed by Inhaling
Loudness	Constant
Environment	Sound proof room
Microphones	Calibrated Brüel & Kjaer
Distance to microphones	30 cm
Warming up	None
Reference pitch	Piano