Effects of Melody and Technique on Acoustical and Musical Features of Western Operatic Singing Voices

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Summary: Objective. The operatic singing technique is frequently used in classical music. Several acoustical parameters of this specific technique have been studied but how these parameters combine remains unclear. This study aims to further characterize the Western operatic singing technique by observing the effects of melody and technique on acoustical and musical parameters of the singing voice.

Methods. Fifty professional singers performed two contrasting melodies (popular song and romantic melody) with two vocal techniques (with and without operatic singing technique). The common quality parameters (energy distribution, vibrato rate, and extent), perturbation parameters (standard deviation of the fundamental frequency, signal-to-noise ratio, jitter, and shimmer), and musical features (fundamental frequency of the starting note, average tempo, and sound pressure level) of the 200 sung performances were analyzed.

Results. The results regarding the effect of melody and technique on the acoustical and musical parameters show that the choice of melody had a limited impact on the parameters observed, whereas a particular vocal profile appeared depending on the vocal technique used.

Conclusions. This study confirms that vocal technique affects most of the parameters examined. In addition, the observation of quality, perturbation, and musical parameters contributes to a better understanding of the Western operatic singing technique.

Key Words: Operatic technique–Singing–Acoustical analysis–Vibrato–Energy distribution–Vocal perturbation.

INTRODUCTION

The vocal technique used in singing differs depending on musical style. The Western operatic singing technique is used by classically trained singers. Such singing requires a highly refined use of physiological components such as the laryngeal, respiratory, and articulatory muscles.[1–6] These components lead to a complex combination of acoustical parameters,[7] which differs from natural or untrained singing.[8–10]

The concept of good vocal quality is naturally very difficult to define as it consists of various components. Among the acoustical parameters observed in the operatic singing technique, particular attention has been paid to vibrato and energy distribution.

Vocal vibrato has been the subject of several acoustical and perceptual studies since the beginning of the 20th century and is highly correlated with overall vocal beauty.[11,12] It can be defined as a slightly tremulous effect imparted to vocal tone and corresponds to a quasiperiodic modulation of the frequency of a tone. Vibrato is mainly characterized by two parameters: rate and extent. Vibrato rate (VR) specifies the number of frequency fluctuations per second and ranges between 5 and 7 Hz depending on the singer.[13] Observing the variability in VRs across 10 prominent artists singing in the western classical music tradition, Prame[13] found an average rate of 6 Hz, with a mean variation from the singer's average of 8%. More recently, the values were defined between 4.55 and 6.25 Hz for classical voices[14] and between 6.28 and 7.14 Hz for operatic singing voices.[15] However, other authors found a mean VR of 5.7 Hz with this particular technique, slower than for the Broadway style of singing (6.1 Hz).[16] Note that mean VR is considered to be a constant for a singer.[17] It does not depend on the context of solo or choir performance[18] but can be slightly modified deliberately[19] or by musical training[20] or warming up.[21] Vibrato extent (VE) describes how far the frequency fluctuates around the pitch of the tone. Unlike VR, VE varies considerably for individual singers[22] and between singers.[23] The variability pointed out by Seashore[24] has been confirmed since then, with, for example, a mean extent of 71 cents[22] and a variation of between 0.38 and 3.26 semitones[25] or between 0.54 and 1.66 semitones.[14] Mean VE has been found to be greater for the operatic singing style (±98 cents) than the Broadway style (±78 cents).[16]

The long-term average spectrum (LTAS) provides information on the spectral distribution of the sound. Operatic singing is associated with an increase of energy of between 2 and 4 kHz.[6,26,27] This frequency range has been identified as being of primary importance for opera soloists' vocal projection and is often associated with good quality, as it allows the audibility of the voice to be optimized against an orchestra.[28,29] Note that energy distribution can be developed with training[8,27,30] and depends on the sound level of the performance[31,32] as well as on the vocal technique used.[16,33] Several parameters, such as the singing power ratio,[27] the energy ratio,[6] the α coefficient,[32] and the difference in energy between different frequency bands, have been proposed to quantify the spectral balance from

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an LTAS. Although these measurements are not intended to provide information about the singer's formant, they illustrate differences in energy distribution.

In addition to these acoustical parameters describing the operatic singing technique (ie, VR, VE, and spectral distribution), one can apply perturbation analysis to these voices. By comparing 26 recordings of different singers and singing styles, some authors have observed that the operatic performances had "normal" jitter and "high median" shimmer values (but still in the "normal" range).[34] Despite the limitations regarding the control of the musical samples, these results suggest that perturbation analysis (ie, parameters such as jitter, shimmer, and signal-to-noise ratio [SNR]), which is commonly used for evaluating voice disorders,[3] is relevant for operatic voices.[35–37]

As well as investigating the vocal and quality parameters of the operatic singing technique (ie, VR and VE, spectral distribution, and vocal perturbation), this study examined some musical characteristics such as the loudness of the voice and fundamental frequency (F_0) of the starting note and tempo. In a comparison of the performance of a popular song with and without an operatic singing technique, a particularly slow tempo was observed when the song was performed with an operatic singing technique.[38] To observe the operatic singing technique, the present study investigated the effect of technique on the commonly examined acoustical parameters but also on vocal perturbation and the musical parameters mentioned above, as well as the relationship between the various parameters.

Previous studies had compared the physiological and acoustical parameters of different vocal techniques. They applied three kinds of methods: the comparison of a single professional singer in different musical styles[5,16,33,39–42]; the comparison of different groups specializing in one particular musical style[14,43–45]; or the examination of one melody performed by one group of participants with two different vocal techniques.[46–48] However, all these experimental designs have their limitations. First, an investigation that focuses on a single subject makes it difficult to generalize the effect of vocal technique and calls into question the general validity of the findings. Second, the use of different musical material, representing different musical styles, does not allow one to control for the effect of melody on the acoustical parameters of the vocal performances. Third, when the same musical material is performed by a group of participants, with different styles, only one melody is considered and the replicability of the findings for other melodies cannot be examined. To sum up, previous studies provided useful information on the Western operatic singing technique but further investigations, with more participants, the observation of several parameters, and the control of melodic effects, would allow for a better understanding of this particular singing technique.

The present study examined the effects of melody and technique on quality, perturbation, and musical parameters among a large panel of Western professional singers. For this purpose, we analyzed the sung performances of singers performing two different melodies (a popular song and a romantic melody from the participants' musical repertory), with and without an operatic singing technique. This experimental design allows one to observe which features are attributable to the musical material used and which to the technique used. One can then develop a theoretical model clarifying this particular singing technique.

METHOD

Participants

Fifty singers (38 women and 12 men) aged between 19 and 66 years ($M = 36.94$ years) participated in the study. They had all received a classical music education in higher institutions such as music conservatories and regularly engaged in classical solo vocal performances. They began their singing lessons between 6 and 49 years of age ($M = 20.18$ years) and they had between 5 and 51 years of singing experience ($M = 19.86$ years). They reported practicing with their vocal instrument for 13.68 h/wk on average.

Material and procedure

The sound recordings were made in a quiet room (background level < 30 dB(A)), using a head-worn microphone (Sennheiser HS2; Sennheiser, Wedemark, Germany) positioned at a constant distance of 2 cm from the right corner of the subjects' lips and a Marantz Professional Solid State PMD67 Recorder (Marantz, Kanagawa, Japan). Note that the recording equipment was never removed during each participant's recording session to keep a constant distance between the mouth and the microphone and limit potential bias due to differences in the recording environments.

Before taping, participants were asked to produce two glissandi to warm up their vocal organs and encourage a lack of inhibition in front of the experimenter and the recording equipment. Then, each one produced four vocal performances: the popular song "Happy Birthday" without any particular technique, for example, while imagining a festive and friendly context (birthday); a romantic melody of their choice without any particular technique (romantic); the same melody with a Western operatic singing technique (ROMANTIC); and finally, the birthday song with a Western operatic singing technique (BIRTHDAY). Concerning the romantic melody, the participants had to choose a melody in their musical repertory (eg, Lieder of Schubert or Schumann). Except for the chosen melody, no particular starting note was given so each participant could perform in his/her comfortable range. The performances were sung a cappella to avoid altering the auditory signal with musical instrumentation and recorded with a sampling frequency of 44.1 kHz and a 16-bit resolution (ie, sufficient to extract normal vocal perturbation measurements).

Acoustical analysis

For the 200 performances (birthday, romantic, ROMANTIC, BIRTHDAY from the 50 participants), 10 variables were observed, grouped into quality, perturbation, and musical parameters. All the acoustical analyses were run on a Macintosh (Mac OS X, Version 10.6.8, Apple, Cupertino, CA).