Acoustic Analyses of the Singing Vibrato in Traditional Peking Opera

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Summary: China's traditional Peking Opera has four standard categories of roles: Sheng, Dan, Jing, and Chou, the singing vibrato of each displaying a different auditory effect. The audio and respiratory signals were recorded for two performers of the Qing Yi role, one of the Jing role, one of the Chou role, one of the Lao Sheng role, one of the Xiao Sheng role, and one of the Lao Dan role. The recordings gained eventually consisted of 24 representative songs from six roles. The rates and extents of vibrato, fundamental frequency, and rib cage signals were analyzed. Two findings were obtained: (1) the classical opera singing vibratos of China and Western countries are acoustically different from each other; and (2) in Peking Opera, the singing vibratos of different roles show significant acoustic differences.

Key Words: Singing vibrato–Peking Opera–Fundamental frequency–Rib cage respiration–Categories of roles.

INTRODUCTION

Peking Opera, which originated in the 17th century (Qing Dynasty), is the typical representative of China's traditional opera, and is a comprehensive performing art consisting of music, painting, literature, dancing, singing, recitation, acting, etc. Therefore, it is an embodiment of China's classical culture, reflecting the thoughts, emotions, religions, aesthetic values, and other ideological elements of the Chinese people. With "virtualization" and "stylization" as its prominent features, Peking Opera has formed four standard categories of roles, different roles possessing apparently different characteristics of voice: Sheng, Dan, Jing, and Chou.

Sheng is a male role that includes Lao Sheng and Xiao Sheng. Lao Sheng means the Old Man role, whereas Xiao Sheng is the Young Man role. *Dan* is a female role that includes Qing Yi, Lao Dan, Wu Dan, and Hua Dan. Qing Yi, as the most important role of Dan, refers to a young or middle-aged woman who specializes in singing. Lao Dan is the role of Old Woman. Wu Dan is a young or middle-aged female who specializes in martial acting. Hua Dan is a role of young and naughty girl. *Jing* refers to a middle-aged male role, called "Big Colorful Face." Sometimes, a woman plays this male role using special skills of phonation and articulation. *Chou*, also called "Small Colorful Face," refers to a young or middle-aged male role that says or does funny and silly things to amuse the audience.

More and more researchers, such as Wang and Sundberg et al, have been attracted to the art of Chinese operas, especially by that of Peking Opera, and are interested in the unique voice features of their various roles, which are considerably different from those of Western operas. Their findings mainly involve the acoustics of the voice of Peking Opera roles, such as "phonation type," "singer's formant," "long-term average spectrum," and "spectrum slope."[1,2] Through acoustic analyses, Sundberg et al pointed out that the vibrato rate of Peking Opera (about 3.5 Hz) was considerably slower than that of Western classical singing, and the spectra of vibrato-free tones contained unbroken series of harmonic partials sometimes reaching up to 17 kHz.[2] Actually, the study of vocal vibrato has a long history, which can be dated back to the 1930s when Seashore analyzed the vibrato in singers and instrument players.[3] However, the research object of Westerners was largely Western music, including Western classical opera, modern music, or pop music, and very little of their attention was paid to the Chinese traditional opera.

The present paper focuses on all the four standard categories of Peking Opera roles: Sheng, which includes the Old Man role (Lao Sheng) and Young Man role (Xiao Sheng); Dan, which includes the Qing Yi and Old Woman roles (Lao Dan); Jing, which refers to the Big Colorful Face; and Chou, which refers to the Small Colorful Face. The purpose is to gain a systematic picture of the acoustics of their vibrato voices. How such voices are related to respiration is to be investigated as well.

METHODS

Seven professional Peking Opera singers, either from the Academy of Traditional Chinese Opera or from the Chinese Peking Opera Theatre, volunteered as subjects. Of the three male roles, one specialized in singing the Young Man role, one in singing the Old Man role, and one in singing the Small Colorful Face. Of the four female roles, two majored in Qing Yi, one in the Old Woman role, and one in Big Colorful Face. Each singer was asked to sing three to five songs that could display their professional attainments in Peking Opera (Table 1).

Four channels of signals were simultaneously recorded from the seven singers. Audio signals were picked up by the Sony Electret Condenser Microphone (Tokyo, Japan) mounted off axis at a measured distance from the lips that varied between 15 cm and 21 cm for different singers. The Electroglottography (EGG) signals were obtained using an electroglottograph (Model 7050, Kay Elemetrics Corp. New Jersey, USA), and breath signals using a respitrace inductive equipment (MLT1132 Piezo Respiratory Belt Transducer, AD Instruments Ltd, Oxford, UK). One of the two respibands was placed around the rib cage below the breasts, and the other around the waist at the level of the navel. The recording of the breathing movements was made over an AC channel, and the signals from these two respibands were recorded on separate tracks. The microphone, the electroglottograph, and the respibands were connected to an ML880 PowerLab

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TABLE 1.
Information of the Seven Peking Opera Singers: Age, Gender, Number of Songs, Number of Vibrato Segments, and Categories of Roles

Roles	YM	OM	QY1	QY2	OW	CF	Chou
Gender	Male	Male	Female	Female	Female	Female	Male
Age	49	49	46	20	20	19	21
Songs	5	3	4	3	4	3	3
Vibrato segments	27	25	49	38	17	14	0

Abbreviations: YM, Young Man role; OM, Old Man role; QY, Qing Yi role; OW, Old Woman role; CF, Big Colorful Face role; Chou, Small Colorful Face role.

system (AD Instruments Ltd, Oxford, UK), which was again connected to a desktop computer, and all the four channels of signals were digitized at a rate of 20 kHz (16 bit). The recording was accomplished in the sound-treated booth at the Language Lab (about $3.6 \times 2.6 \times 2.2$ m) of the Chinese Department, Beijing University, where the background noise was below 25 dBA and the reverberation time was about 0.3 seconds.

Acoustically, vibrato is defined as a long-term periodic modulation of the fundamental frequency, and is one of the most expressive aesthetic features of singing voice. The wave files obtained were first converted into an smp format, because only signals in this format can be analyzed using the Sound Swell program (Sound Swell Core Signal Workstation 4.0, Saven Hitech, Solna, Sweden). The following parameters were extracted: fundamental frequency (F0) of each vibrato segment was tracked by the Corr module of the Sound Swell program; the rate, extent, waveform, and regularity of vibrato were measured using an *Excel* program (Microsoft Corporation, Redmond, USA) provided by Sundberg et al; the rib cage respiration values were tracked by the *Sopran* program (KTH, Stockholm, Sweden), and then transferred into *Excel* files; and the correlation analyses between the values of F0 and respiration were done using *SSPS* 17.0 (SPSS Inc, Armonk, New York, United States).

All the singing samples chosen for analyses met the following requirements: (1) Each sample must be longer than 1.5 seconds or contain over three vibrato cycles, within which there should be (2) no abrupt undulation of pitch, (3) no shift of vowels, and (4) no noise or sound produced by accompanying musical instruments.

RESULTS

Vibrato rate

Vibrato rate (VR) specifies the number of pitch contour undulations per second. It was interesting that, from the songs of Chou role (Small Colorful Face), no vibrato segments could be found that fulfilled the requirements above, namely the Chou role singers rarely used vibratos in singing. The mean, maximum, minimum, and standard deviation (SD) of the VR of the other six roles are indicated in Table 2.

As shown in Table 2, the VRs of the six roles range sharply between 2.36 Hz and 6.25 Hz, with mean VRs of different roles being respectively different. The Old Man role displays the slowest mean VR at 2.78 Hz (SD: 0.30 Hz), whereas the Colorful Face role displays the fastest at 4.95 Hz (SD: 0.58 Hz). Qing Yi 1 is 26 years older than Qing Yi 2, but the two singers display similar mean VRs—3.34 Hz (SD: 0.43 Hz) and 3.71 Hz (SD: 0.42 Hz)—suggesting that, in Qing Yi roles, VR is not strongly affected by age. The VRs of the Old Woman role range sharply from 2.73 Hz to 6.25 Hz, and therefore display the largest SD among the six roles: 1.12 Hz.

Putting together individual VRs of all six roles, we obtained the mean VR of the six roles—3.69 Hz (SD: 0.72)—from which we can see that the voice VR of Peking Opera is apparently much slower than that of Western music singing (generally between 5 Hz and 7 Hz).

Vibrato extent

According to Sundberg, vibrato extent (VE) describes how far phonation frequency departs up and down from its average during a vibrato cycle.[4] VE is also an essential aspect that reflects the characteristics of Peking Opera singing.

As indicated in Table 3, among the six Peking Opera roles, Qing Yi singers display the highest mean VEs: That of Qing Yi 2 (the younger singer) reaches ±0.81 semitones, whereas that of Qing Yi 1 (the older singer) amounts to ±0.76 semitones. Furthermore, the SDs (0.19 semitones) for the two singers are not only the same, but also higher than those of all the other roles. Among all singing samples of the two Qing Yi singers, the extent of vibrato undulation varies dramatically, with the highest spanning up to ±1.36 semitones and the lowest spanning down to ±0.42 semitones. However, according to the singing theory of Peking Opera, Qing Yi voice is often expected to sound the most graceful and leisurely among all the role categories, and its voice vibrato should theoretically be the most stable and smooth. Apparently, the result here is not consistent with the traditional singing theory regarding the Qing Yi roles.

TABLE 2.
Mean, Maximum, Minimum, and Standard Deviation of Vibrato Rate for the Six Peking Opera Singers (in Hz)

Roles	YM	OM	QY1	QY2	OW	CF
MIN VR	2.36	2.42	2.60	2.86	2.73	3.81
MAX VR	5.36	3.70	4.44	4.84	6.25	5.75
Mean VR	3.58	2.78	3.34	3.71	3.80	4.95
VR SD	0.72	0.30	0.43	0.42	1.12	0.58

Abbreviations: YM, Young Man role; OM, Old Man role; QY, Qing Yi role; OW, Old Woman role; CF, Big Colorful Face role; VR, vibrato rate; SD, standard deviation; MAX, maximum VR value; MIN, minimum VR value; VR, vibrato rate.

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