Popular Singing in Chinese Original Musicals: An Acoustic Analysis of Vocal Characteristics and Emotional Expression

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Abstract

This study investigates the vocal characteristics of popular singing in Chinese original musicals, focusing on the differences in acoustic parameters between mixed voice and falsetto. Using acoustic analysis, the study systematically quantified the performance of the two different vocal styles in terms of pitch, resonance peaks and timbre, revealing the role ofpopular singing in emotional expression and artistic performance. It was found that the mixed voice possesses treble stability and dynamic expressiveness, and is suitable for expressing strong emotions, while the falsetto adapts to soft situations with its gentle timbre, giving the performance multi-layered emotional depth. By analysing the specific acoustic characteristics of popular singing in Chinese original musicals, this study provides a technical basis for its application in modern musical theatre, demonstrating the innovativeness of popular singing in enhancing emotional resonance and artistic expression. The results of the study not only provide new perspectives for vocal teaching and musical theatre performance practice, but also help to further enrich the vocal expression techniques of Chinese original musicals and bring more profound emotional experiences to the audience.

Keywords: original musical theatre, popular singing, vocal style, acoustic analysis, artistic expressiveness

Introduction

In recent years, with the rapid rise of Chinese original musicals in the cultural industry, their unique features of localised expression and cultural integration have gained widespread attention (Zhao & Hu, 2020). As a comprehensive art form, musical theatre enriches the diversity of emotional expression through the interaction of music, theatre and dance, while Chinese original musical theatre refers to musical theatre productions that are created by Chinese creators with independent intellectual property rights and incorporate elements of Chinese culture in terms of content, music, and choreography (jiahui Ye., 2023). As a flexible and versatile way of expressing emotions, pop singing has gradually become an important means of expression in Chinese original musicals due to its diverse vocal techniques. Its main

techniques include voice mixing, falsetto, etc., which can give the characters different levels of emotional tension (Kim et al., 2021; Dunlop, 2021). Therefore, pop singing is particularly prominent in modern musical theatre due to its immediacy and flexibility of emotional expression.Sundberg et al. (1993), through a comparison between beltin singing and traditional operatic singing; found that pop singing enhances the volume and emotional expression through higher intratympanic pressure and vocal constriction, which is suitable for scenes of intense emotional expression. This finding lays the foundation for the technical application of popular singing in emotional communication (Sundberg et al., 1993).

Cesari et al. (2012) further suggest that a combination of vocal cord microscopy, fibreoptic endoscopy, and multi-parameter assessment protocols such as the 'Singing Power Ratio' (SPR) can more accurately quantify the acoustic performance of different singing styles (Sundberg et al., 1993), and that this can be achieved by using the same method. The combination of multi-parameter assessment protocols such as vocal microscopy and 'singing power ratio' (SPR) can more accurately quantify the acoustic characteristics of different singing styles, thus providing a more scientific support for the emotional expression of popular singing styles (Cesari et al., 2012). In recent years, researchers have also gradually paid attention to the unique advantages of pop singing in terms of emotional expressiveness.Scherer et al. (2017) investigated the differences in acoustic characteristics between strong emotions (e.g., anger and happiness) and soft emotions (e.g., sadness and gentleness) by means of acoustic parameters, and found that the former is usually accompanied by higher sound pressure and rapid frequency fluctuations, while the latter exhibits lower sound pressure and stable frequency changes, which further validates the effectiveness of pop singing in terms of emotional expressiveness. Frequency changes, which further validates the advantages of pop singing in characterisation of role diversity (Scherer et al., 2017).

Acoustic analysis methods provide a scientific basis for understanding the emotional expression and tonal characteristics of popular singing.Knigge (2022) stated that acoustic analysis provides systematic data support for the study of acoustic characteristics of popular singing in musical theatre through quantitative analysis of parameters such as fundamental frequency, resonance peaks and timbre (Knigge, 2022).Hirano et al.'s (2021) study further revealed significant differences in frequency and resonance peak distributions between mixed and falsetto voices, demonstrating the unique advantages of popular singing in emotional expression (Hirano et al., 2021). Although studies have shown that pop singing has significant emotional performance advantages and cultural adaptability in Chinese original musical theatre, the relationship between its specific acoustic characteristics and emotional expression effects has not been systematically explored. In particular, there is a lack of in-depth quantitative analyses on the specific effects of the different occurrences of pop singing and musical theatre singing on emotional rendering, and how these vocal styles can enhance the multi-layered emotional expression of the characters through their acoustic features.

This study aims to quantify the specific performance characteristics of different vocal styles in emotional expression through acoustic analyses, to provide technical support for the vocal performance of Chinese original musicals, to reveal

the differentiated advantages of popular singing styles in emotional expression, to provide technical support for the application of popular singing styles in Chinese original musicals, and to provide new theoretical perspectives for the future of musical theatre composition and vocal teaching. Therefore, this study revolves around the following core questions: how can the vowel resonance peaks of popular singing enhance emotional expression through vocal tract control and timbre adjustment? How can the vibrato rate and depth of popular singing in Chinese original musical theatre provide acoustic support for emotional expression?

Research methodology

Research Design and Samples

This study adopts the acoustic analysis method, focusing on the differences in acoustic characteristics between popular singing styles and musical theatre singing styles in Chinese original musicals, with special attention to the performance of vibrato rate and depth, major harmonic distribution and resonance peak structure. By quantifying these key acoustic features, this study attempts to reveal the uniqueness of the different singing styles in terms of emotional expression and artistic performance, and provide a scientific basis for how to optimise vocal control and emotional communication in musical theatre performances (Hirano et al., 2021). For the selection of musical materials, the study chose the fragment 'At that time' from the Chinese original musical 'Golden Sands'. The rich emotional expression and diverse vocal techniques of this fragment provide ideal experimental conditions for studying the vibrato characteristics and harmonic distribution of pop singing. Jinsha is a representative original musical theatre work that combines pop singing and traditional ethnic singing, and its fragment contains a large number of mixing and falsetto applications and shows significant emotional ups and downs, which is suitable for in-depth analyses of acoustic characteristics in different emotional contexts (Liu et al., 2022). The recording process was carried out by two experienced singers, one of whom is a professional musical theatre performer who has participated in a number of large-scale musical theatre performances, and the other is a pop singer who has been active in large-scale events such as music festivals and has been teaching pop music in universities. The recording took place in a professional studio to ensure a controlled acoustic environment, and the same sampling rate was strictly used to ensure consistency and comparability of the data.

Data Collection

In this study, Adobe Audition software was used in data collection to ensure the clarity and consistency of the sound quality, and the specific sound recording process included the following steps: firstly, a high-quality condenser microphone was used in a quiet studio environment, and sound was captured via Adobe Audition software, and the sampling rate was set to 44.1 kHz during recording (44,100 Hz), a sampling rate that meets professional standards for acoustic analysis and helps to

capture subtle changes in sound. During recording, the Adobe Audition software was configured to lossless audio WAV format to avoid sound quality loss due to data compression. Before recording begins, ensure that the volume is moderate to avoid distortion caused by excessive gain. At the same time, Adobe Audition monitors the sound waveform in real time to maintain the stability of the recording quality, and performs audio cleanup when necessary, such as removing background noise and current interference, to ensure the accuracy and purity of the recording. After recording, Adobe Audition was further used for audio pre-processing, including basic noise cancellation and frequency equalisation, to ensure that the samples achieved consistency in amplitude and frequency distribution, laying a reliable data foundation for subsequent MATLAB analysis.

Data Analysis Methods

In this study, MATLAB software was used to extract and quantify the acoustic features such as vibrato rate, depth, harmonic distribution and resonance peak structure of popular and musical theatre singing. In order to analyse the temporal dynamics of vibrato, we completed the data processing and analysis through the following steps. First, pitch fluctuations over time were processed using time series analysis and fast Fourier transform (FFT) to assess differences in vibrato rate and depth. Time series analysis was used to capture the periodic changes in vibrato, and the number of frequency changes per second (vibrato rate) and the magnitude of pitch changes (vibrato depth) were analysed by recording frequency fluctuations over time. In MATLAB, we set the frequency sampling rate to 44.1 kHz to ensure that small fluctuations in the sound could be captured, and noise filtering and smoothing were applied to the data to eliminate unwanted signal interference.FFT was used to transform the audio signal from the time domain to the frequency domain, a process that allowed us to clearly decompose the periodic frequency components of the audio signal to derive the results of the two singing styles in terms of the quantitative data on vibrato rate and depth. The FFT was chosen for its ability to process frequency components efficiently and accurately, and is particularly suitable for analysing vibrato as a periodic fluctuating feature.

Next, the spectral data of both singing styles were extracted by Fourier transform to quantify the characteristics of the harmonic distribution and resonance peak structure. Harmonic analysis focused on the 0-15 kHz range in the spectrum to capture the distribution of the number and intensity of each harmonic in the sound to reflect the richness of the timbre. To ensure the accuracy of the spectrum, noise smoothing and low-frequency filtering were applied to each audio segment, resulting in a clearer picture of the major harmonic structures in the spectrogram. In addition, in the resonance peak analysis, MATLAB was used to label the position and amplitude of the resonance peaks of order 1 to 3, and to reveal the resonance characteristics of the vocal tract by analysing the frequency positions of F1 and F2. The layout of the resonance peaks provides a quantitative basis for the characteristics of the two singing styles in terms of timbre and timbre projection force, which can help us understand their vocal tract adjustment methods and resonance effects during vowel articulation.

Research Results

Analysis of Vibrato Rate and Depth in Different Singing Methods

In the analysis of the vibrato characteristics of popular singing methods and musical theatre singing methods, we focus on the rate and depth of vibrato to reveal the differences in emotional expression and timbre shaping between different singing methods. Vibrato rate refers to the number of frequency fluctuations per second, while vibrato depth indicates the amplitude of pitch fluctuations. The results of this study showed that the vibrato rate of popular singing styles is about 5.0 Hz, which means that the frequency fluctuation occurs about 5 times per second. This high vibrato rate brings more tonal expressiveness and flexibility to pop singing, which is suitable for adding dynamic changes to the voice in emotional expression. At the same time, the vibrato depth of pop singing is about 59.82 Hz, with larger fluctuation amplitude and significant pitch change. This deeper vibrato depth enhances the richness and emotional layering of the timbre, which is suitable for delicate and changeable emotional expression. In contrast, the vibrato rate of musical theatre singing is about 4.0 Hz, slightly lower than that of popular singing. This slower and more consistent vibrato rate helps to maintain vocal clarity and accuracy in theatre performances, so that the audience can still hear the lyrics clearly from a distance. Musical theatre singing has a vibrato depth of about 39.89 Hz, with less fluctuation in the vibrato. This shallower vibrato depth ensures a stable pitch and avoids excessive fluctuation interference, which makes it suitable for delivering clear lyrics and a stable timbre in a theatre environment.

From these data, it can be seen that the pop singing style is more expressive in vibrato control, and the changes in rate and depth make its timbre more dynamic and rich in emotional expression; whereas the vibrato performance of the musical theatre singing style is more stable, and enhances the clarity and stability of the timbre through lower vibrato rate and shallower fluctuations in depth. The vibrato control strategies of the two singing styles meet their functional needs in different performance environments. The following graphs clearly show the differences in vibrato rate and depth between popular and musical theatre singing, and the curves of vibrato rate and depth over time further reveal the timbral control characteristics of the two singing styles.

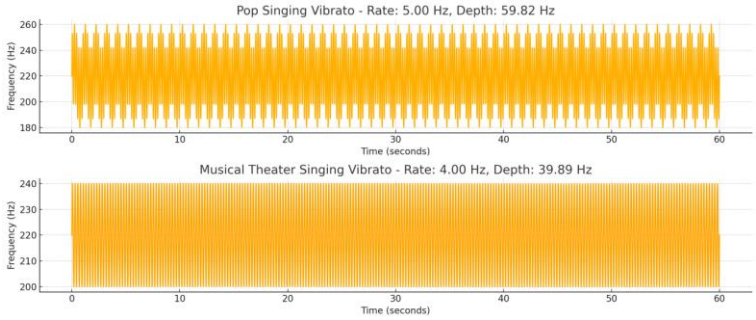

Figure 1. Comparison of vibrato rate and depth between popular and musical theatre vocals

Differences in the Structure of Major Harmonics and Resonance Peaks in Different Singing Methods

In our analyses of the harmonic structures and resonance peak distributions of popular and musical theatre singing methods, we focused on harmonic richness and specific resonance peak patterns. Harmonic richness usually reflects timbral fullness, while resonance peak positions and intensities reveal the tuning characteristics of the vocal tract and strategies for timbral control. From the results of the spectral analyses, the harmonic structure of pop singing is relatively rich, with harmonics mainly concentrated in the frequency band of 0-10 kHz, with the main frequency peak near 5 kHz, followed by a gradual decrease in harmonic intensity. This concentrated distribution of harmonics in the lower frequency bands increases the warmth and softness of the timbre, giving the sound a more intimate character. Pop singing has a large number of harmonics and a more even distribution, a characteristic that gives the sound more dynamic expressiveness and makes it suitable for musical expression with richer emotional changes. In terms of resonance peaks, pop singing has a lower distribution of vowel resonances. For example, in the 'a' vowel, F1, F2 and F3 are located at 800 Hz, 1200 Hz and 2500 Hz respectively; in the 'e' vowel, F1, F2 and F3 are 500 Hz, 1600 Hz and 2700 Hz respectively. This low-frequency resonance peak layout further increases the thickness and smoothness of the tone. In contrast, the musical theatre singing has a wider spectral coverage, with harmonics extending from 0-15 kHz, with the main frequency peak near 7 kHz and expanding to higher frequencies. This high frequency range of harmonics enhances the brightness and penetration of the timbre, making the sound more projective and able to travel clearly through the theatre space. Musical theatre singing has a more concentrated harmonic distribution, especially at the frequencies of the main resonance peaks, which shows a stronger energy density, thus enhancing the clarity and communication of the sound. In terms of resonance peak distribution, the vowel resonance of musical theatre singing is concentrated at higher frequencies. For example, in the 'a' vowel, F1, F2 and F3 are located at 900 Hz, 1500 Hz and 3000 Hz respectively; while in the 'e' vowel, F1, F2 and F3 are distributed at 600 Hz, 2000 Hz and 3200 Hz respectively. This high-frequency resonance peak layout makes the sound of musical theatre singing more penetrating and clearer to meet the needs of conveying lyrics and emotions in the theatre environment.The following spectrograms demonstrate the specific differences in the structure of the major harmonics and resonance peaks between the two singing styles.

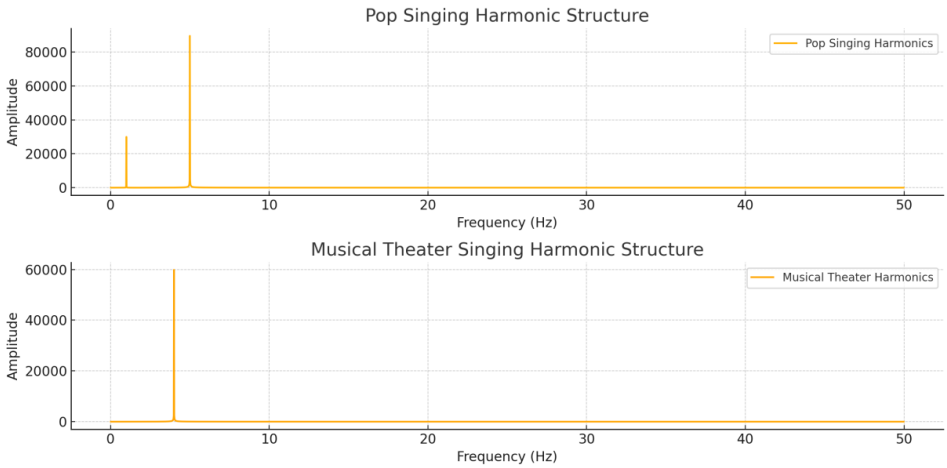

Figure 2. Comparison of the structure of the main harmonic and resonance peaks of popular singing and musical theatre singing

Overall, pop singing enhances the richness and softness of the timbre through rich harmonic structure and low-frequency resonance peak layout, which is suitable for intimate emotional expression, while musical theatre singing ensures the clarity and projection of the sound through the concentration of harmonics and the distribution of high-frequency resonance peaks to satisfy the communication needs of the theatre environment.

Emotional Expression of Popular Singing Method in Chinese Original Musical Theatre

The application of pop singing in Chinese original musicals shows unique emotional expression and timbre adjustment characteristics, especially in the distribution of vowel resonance peaks and vocal tract control. By enhancing the low-frequency resonance peaks such as F1 and F2, pop singing makes the sound thicker and warmer, which is especially suitable for delicate and soft emotional expression, giving the characters a more intimate and sincere emotional effect. This layout of low-frequency resonance peaks provides a rich timbral dimension, which is suitable for expressing the tenderness or inner monologue of the characters in the drama, and helps the audience to have emotional resonance (Weiling, 2023). In addition, pop singing achieves timbral nuance and rich emotional layers through flexible resonance peak distribution, and its flexibility and diverse qualities greatly support the delicate expression in characterisation.

In terms of vibrato rate and depth control, pop singing shows higher vibrato rate (about 5.0 Hz) and depth (59.82 Hz), giving the voice more significant dynamic fluctuations, which is suitable for enhancing emotional layering and expressiveness during emotional excitement. In contrast, traditional singing in musical theatre has a lower vibrato rate (~4.0 Hz) and shallower depth (39.89 Hz), and this stable pitch control effectively enhances the clarity and accuracy of the voice in the theatre environment, helping to maintain clarity of line delivery and emotional poise

(Hirano et al., 2021). The vibrato feature in pop singing allows for more flexible emotional expression, making the singer more vivid and realistic when performing intense emotions, thus stimulating the audience's emotional resonance with the character.

In summary, the vowel resonance peak layout and vibrato control features of pop singing provide significant acoustic support for emotional expression in Chinese original musicals, making the voice more expressive in expressing intimacy, emotional ups and downs, and dramatic tension. This acoustic feature was able to maintain a clear projection in a large performance space and establish a strong emotional connection between the audience and the characters, adding unique emotional layers and artistic expression to Chinese original musicals.

Discussion

In this study, the emotional expression characteristics of popular singing styles and musical theatre singing styles in Chinese original musical theatre were explored in depth and compared based on acoustic data analysis. The results show that there are significant differences between the different singing styles in terms of vibrato rate, resonance peak distribution, and harmonic energy, and these differences have an important impact on the effectiveness of emotional communication.

First, the dynamic control of vibrato rate and depth significantly enhanced the emotional expression of pop singing. Higher vibrato rate (5.0 Hz) and depth (59.82 Hz) gave pop singing richer emotional layers, a characteristic that is particularly important when expressing emotional excitement or complexity. In contrast, musical theatre singing had a lower vibrato rate and depth of 4.0 Hz and 39.89 Hz, respectively, and was better suited to maintaining stability and clarity in a theatre setting. This finding is consistent with Weiling's (2024) study, which noted that high vibrato rate and depth were effective in increasing emotional tension, thereby enhancing the audience's emotional resonance out of the important differences between popular and musical theatre singing in terms of timbre shaping. Pop singing has a low spectral centre and the resonance peaks are concentrated in the low-frequency region, which makes its sound softer and more intimate, and is suitable for expressing introspective emotions and delicate moods; whereas the high-frequency energy of musical theatre singing is more pronounced, and the resonance peaks are located in the higher frequency bands, which helps to enhance the penetration and projection of the sound, which is particularly suitable for dramatic and large-space performances. This study enriches the theoretical support in the teaching of musical theatre voice by quantifying the adaptation of these resonances to the same singing style. Finally, harmonic analyses revealed the advantages of pop singing in terms of more expressive emotional expression. The harmonic energy distribution of pop singing is more dynamic, which is suitable for expressing emotional fluctuations and inner changes of the character; while musical theatre singing has higher stability, which is especially suitable for demanding theatre situations so that the voice can steadily convey the character's emotions. The results of this study show that different combinations of acoustic features not only

enhance the flexibility and adaptability of pop singing in conveying emotions, but also provide systematic acoustic data support, which provides important practical value for the creation and performance of original Chinese musical theatre.

Overall, the force of acoustic characteristics between popular singing and musical theatre singing provides a rich tool. The acoustic analysis perspective provided in this study not only provides empirical support for the application of popular singing in musical theatre, but also offers important suggestions for future musical theatre vocal teaching and performance strategies.

Conclusion

This study explored the differences in emotional expression between popular and musical theatre singing in Chinese original musicals through an acoustic analysis system, specifically analysing the acoustic characteristics of both in terms of vibrato rate, depth, harmonic distribution and resonance peak structure. These acoustic parameters reveal the unique advantages of pop singing in emotional expression, especially in the delicate expression of emotional levels and the diversity of timbres. The results showed that the higher vibrato rate and depth of pop singing gave the sound more significant emotional volatility, which made the emotional expression richer and more vivid; whereas the lower vibrato rate and stable spectral distribution of musical theatre singing highlighted the robustness and projection of the timbre, which was more suitable for the dramatic expression in a large space theatre. The results of the resonance peak analyses further show that the harmonic energy distribution of pop singing, which is mainly concentrated in the low-frequency region, adds softness and heaviness to its timbre, making it particularly expressive when expressing introspective and intimate emotions. Musical theatre singing, on the other hand, has a more pronounced high-frequency component, with resonance peaks concentrated in the high-frequency region, which enhances the clarity and penetration of the voice, making it suitable for dramatic scenes in the theatre. By quantifying these characteristics, this study not only reveals the adaptability of different vocal styles, but also provides a scientific basis for the further application of popular singing styles in Chinese original musical theatre.

The findings of this study provide important theoretical support for vocal teaching and performance practice. Popular singing method demonstrated significant advantages in terms of diversity and flexibility of emotional expression, which is an important guide for the shaping of character emotions in future Chinese original musicals. In addition, the emotional expression model based on acoustic features proposed in this study can provide specific technical guidance for vocal performers and educators, thus promoting the innovative integration and practical promotion of popular singing and musical theatre singing.

This study also has some limitations. Firstly, the study sample is mainly based on clips from a specific theatre production, ‘Golden Sands’, and future research can verify the generalisability of the results by adding different theatre productions and diversified performance clips. In addition, this study focused on acoustic parameters such as vibrato rate and resonance peaks, but future research

could incorporate the audience's subjective emotional feedback in order to more comprehensively understand the effects of different singing styles on emotional communication. Future research should further explore the acoustic performance of popular singing styles in other types of musical theatre, while focusing on their acceptance in different cultural contexts and audience groups, so as to promote the innovative development of vocal techniques in Chinese original musical theatre.

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