

The realization of lexical tones in Sichuan opera

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The interplay between speech melody and song melody in tonal languages, especially that in Chinese songs, has been of interest to scholars because of the close relationship between pitch and lexical meaning. However, previous studies have mainly focused on popular songs in Standard Mandarin and Cantonese, and research on other Chinese dialects and traditional Chinese opera is scarce. In fact, the tonal-melodic mapping prescribed by the compositional principles of traditional opera differs from the approach taken by popular songs, thus tone-melody correspondence in this form of musical genre and the listeners' strategies for extracting the lexical meaning of the lyrics worth to be investigated.

Pitch sequences, in popular songs, would abandon the ratio scale of fundamental frequency (F_0) of the vocal tones in the lyrics and instead use an ordinal scale [1]. For example, a higher pitch in speech can be realized as any higher F_0 in music, but never a lower F_0 . However, the compositional principle of Chinese traditional opera, "yi zi xing qiang (Tunes Following Lyrics)", does not strictly follow the patterns of ordinal mapping [2]. This principle states that ordinal mapping is only reserved when the tone sequence is rising or falling. When the tone sequence is consistent, the melody direction will manifest as falling instead of remaining plateaued.

The previous study of traditional opera employed the Suzhou Tanci, a traditional Suzhou opera, as a test case [3]. The study showed that Suzhou Tanci was not in high concordance with the compositional principle (the degree was only 49%). This may be related to the tone sandhi in Wu dialects. In addition, the study did not consider the strategies used by listeners to access the meaning of the lyrics. Therefore, our study has two goals: the first is to add to the body of studies on tone-melody mappings in traditional opera, and find a suitable sample of greater adherence to the composition principle for the perception experiment; the second is to explore the relationship between tone-melody interaction and listeners' perception.

We first calculated the frequency of tone-melody mapping in 30 pieces of Sichuan opera and Beijing opera respectively. Then, a perception experiment was conducted to test whether this principle would affect listeners' accurate recognition of lyrics.

Table 1 shows the tone-melody correspondence data of 30 Sichuan operas chosen. The numbers in parentheses are the percentage of occurrences relative to the total number of cases included in the matrix. The frequency of compliance with composition principle occurred 76.90% of the time (the sum of the grey cells in **Table 1**) in these 30 Sichuan operas.

		Musical sequence		
		Up	Down	Same
Tone sequence	Up	491 (32.78%)	34 (2.27%)	36 (2.40%)
	Down	41 (2.74%)	470 (31.37%)	32 (2.14%)
	Same	60 (4.00%)	191 (12.75%)	143 (9.55%)

Table 1. Number of tone-melody relation in Sichuan opera

This frequency reached only 46.17% in Beijing Opera (**Table 2**), indicating lower frequency than that of Sichuan opera, same as the Suzhou Tanci (49%).

		Musical sequence		
		Up	Down	Same
Tone sequence	Up	125 (18.80%)	87 (13.08%)	40 (6.01%)
	Down	89 (13.38%)	96 (14.44%)	48 (7.22%)
	Same	51 (7.67%)	86 (12.93%)	43 (6.47%)

Table 2. Number of tone-melody relation in Beijing opera

This may be due to the limited diachronic variation in Sichuan Mandarin tones [4]. Furthermore, to avoid sacrificing musicality, it could be desirable to properly abandon strict adherence to the tonal-melodic correspondence [1]. To this end, Sichuan opera was chosen as a test case for the perception experiment.

In the perception experiment, 214 participants were invited. The participants should understand Sichuan Mandarin and possess normal hearing. This experiment followed the design of Wong and Diehl's perception experiment [1], with some modifications. Instead of using a carrier phrase that can carry all potential words, we directly took musical segments from a Sichuan opera excerpt sung by a professional Sichuan opera singer. We measured listeners' perception accuracy as a function of composition principles compliance, which was adjusted by manipulating the melody trend. As the frequency of tone-melody mapping of single sentence in Sichuan opera was concentrated above 50% ($M = 0.783$, $SD = 0.185$), the ordinal mapping ratings of chosen stimuli were 100%, 83.3%, and 66.7%. We chose 3 sentences from each scale to compose the 9 original stimuli. These 9 original samples were then resynthesized by the PSOLA method in Praat [5], to obtain the musical variant sample at the other 2 scales. This controlled the variables and ensured a relatively high level of naturalness of sound. A total of 27 clips were obtained, and participants were invited to listen to 9 music clips (random 1 variant stimuli of a sentence * 9 different sentences) and transcribe the lyrics.

A chi-square test of independence found a significant association between the correct recognition of the lyrics and ordinal mapping rate of the stimuli (100% vs. non-100%), $\chi^2(1, N = 1926) = 6.350$, $p = .012$. This implied that listeners of Sichuan opera use the principle of traditional opera composition to attain the lexical meaning of the lyrics.

In conclusion, we found that Sichuan opera is composed with a high degree of adherence to the principle of "Tunes Following Lyrics", a partially conforming ordinal mapping. This could be rare in a tonal language with four tones, as it offers limited options for pitch variation [6]. Correspondingly, we found that when listening to Sichuan opera, listeners applied this compositional principle in identifying the lyrics. Although, this principle does not strictly adhere to ordinal mapping, this descending processing is similar to the downdrift contour observed in ordinary conversational speech [7]. Thus, the result of our perceptual experiment may also reflect listeners' experience of ordinary speech patterns.

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