Research on Statistical Models of Tonal Patterns in Kang County Dialect

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Abstract. This study focuses on analyzing the tonal patterns of monosyllabic words in the Kangxian dialect. By combining traditional tone research methodologies with experimental speech acoustics, it quantifies the duration and pitch values of Kangxian dialect tones, depicts their tonal structures, and aims to portray the current state of tonal pronunciation in the Kangxian dialect. The objective is to accumulate empirical insights and provide data support for future research on Kangxian dialect tones. 1) Regarding tone duration, the Kangxian dialect exhibits the following sequence: Yangping > Qusheng > Shangsheng > Yinping. Analysis based on vowel finals reveals significant differences in average duration, with nasal finals > complex finals > single finals. 2) Regarding tone values, the Kang County dialect features four tone categories: Yin Ping , Yang Ping , Shang Sheng, and Qu Sheng. After analyzing the data, the following conclusions were drawn:Level tones are further classified into Yin (even) and Yang (rising) tones, with tone values of 51 and 311 respectively.Qing initials (voiceless unaspirated initials) and unaspirated voiced initials maintain their status as Shang Sheng (rising tone), with a tone value of 54.Voiced initials in the Shang Sheng category merge with Qu Sheng (departing tone), having a tone value of 24.Ancient Qing and unaspirated voiced entering tones merge into Yin Ping (even tone), with a tone value of 51, while voiced entering tones merge into Yang Ping (rising tone), with a tone value of 311. Currently, there are no entering tone characters. This conclusion aligns with the findings of previous linguistic studies on Kang County dialect tones, with only slight variations in tone values.3) Regarding tone distribution, minimal intersection is observed between YinPing and YangPing tones, as well as between ShangSheng and QuSheng tones. This indicates a high level of independence for each tone, reducing auditory confusion.

Keywords: Kangxian dialect; Statistics; Experimental phonetics; Voice signal processing; Tone modeling.

1 Introduction

Kang County, situated in the southeastern part of Longnan City, Gansu Province, China, lies adjacent to Lueyang County in Shaanxi Province to the east, Ningqiang County in Shaanxi Province to the south, and Wudu District to the west. Across the

Xi Han River to the north lies Cheng County. Throughout history, Kang County has served as a vital corridor linking the southwest and northwest regions. Notably, the ancient Tea Horse Road within Kang County stands as one of the few documented routes in China, evidenced by inscriptions. The Kang County dialect, classified under the Zhongyuan Mandarin's Qin-Long branch, exhibits a general division into three main subgroups: southern, central, and northern. While the central and northern dialects demonstrate stronger internal linguistic coherence, the southern dialects show a more complex linguistic state due to influence from Southwest Mandarin.[1]

Research on the Kang County dialect is relatively scarce. In 1987, the "Atlas of Chinese Languages" used the modern tone categories of ancient entering tone characters as a benchmark, dividing Mandarin dialects into eight regions. Among these, Zhongyuan Mandarin was further categorized into nine subgroups, with three found in Gansu Province: Qin-Long, Longzhong, and Guanzhong. Kang County falls within the Qin-Long subgroup, known for its distinctive features including four single-syllable tones: Yin Ping, Yang Ping, Shang Sheng, and Qu Sheng. In this dialect, ancient entering tone characters with clear and unaspirated initials are pronounced as Yin Ping, while those with voiced initials are pronounced as Yang Ping.[2]In 2006, Wang Shiquan provided an overview of the phonology and tones of the Kang County dialect, identifying four tones: Yin Ping, Yang Ping, Shang Sheng, and Qu Sheng, with corresponding tone contours of low-falling, falling-rising, and high-level. [3] Research primarily relied on traditional auditory methods, focusing on comprehensive studies of phonetics and tones in the Kang County dialect, as well as comparative analyses with Beijing Mandarin. However, specialized and in-depth research has been limited. Furthermore, given that existing studies date back over a decade, they may not fully reflect the contemporary phonetic characteristics of the Kang County dialect. Foreign studies on tone, such as Acoustic Evidence for the appearance of tone Contrast in Contemporary Korean, use experimental phonetics methods to show the acoustic characteristics of tone in contemporary Korean through comparison.[4]This study aims to fill this gap by focusing on single-syllable tones in the Kang County dialect, employing both traditional tone research methods and experimental phonetic approaches. By quantifying tone duration, contour, and pitch, the study seeks to provide a detailed understanding of the tonal patterns of the Kang County dialect, thereby contributing valuable insights and data support for future research on its tones.

2   Research Methodology

2.1   Pronunciation Corpus

The single characters of the Kang County dialect used in the experiment were selected from the "Chinese Language Resources Survey Manual: Chinese Dialects"[5]. A total of 1000 commonly used characters were recorded. During the initial audio preprocessing phase, characters with mispronunciations or noise interference were excluded. After rigorous screening, 971 valid samples were obtained. These samples were then categorized based on tone: 222 for YangPing, 175 for ShangSheng, 310 for YinPing, and 264 for QuSheng tones, respectively.

2.2   Experimental Methodology

In this experiment, we enlisted a native male speaker from the urban area of Kang County's central dialect region. The speaker demonstrated fluency in the local vernacular and remained unaffected by other dialects. During the recording sessions, the speaker was instructed to articulate the word list at a natural, conversational pace. AuditionCC software was employed to capture both the speech and vocal channels simultaneously, operating at a sampling rate of 22050Hz. Following the recording phase, Praat speech analysis software was utilized to annotate syllables and extract fundamental frequency values from the tone-bearing segments (specifically, vowel segments) of each syllable. Data collection and processing were conducted using Excel 2019 and SPSS (IBM SPSS Statistics 24).[6]

2.3   Acoustic Analysis

2.3.1 Duration and Fundamental Frequency Extraction

For this study, duration data for vowel segments were extracted from annotations, while fundamental frequency data underwent preprocessing steps including five-point smoothing, interpolation, and normalization. These measures facilitated the creation of a corpus containing duration and fundamental frequency data, thereby enabling precise and quantitative analysis of tone duration, type, and value in Kang County dialect.

2.3.2 Conversion to Quint Values

The quint values calculation method, devised by Mr. Yuanren Zhao, serves as a perceptual recording system. In this study, we utilize the T-value method to transform fundamental frequency data into traditional quint values. The formula for T-value calculation is as follows:

$$T=[(\lg x-\lg \min)/(\lg \max-\lg \min)]\times 5 \qquad (1)$$

Here, lgmin and lgmax represent the upper and lower frequency limits of the pitch range, respectively, while x denotes the measured frequency point.[7] The correspondence between T-values and Fifth-degree value. is detailed in Table 1.

Table 1. Correspondence between T-Values and Fifth-degree value.

T-Values	0-1.1	0.9-2.1	1.9-3.1	2.9-4.1	3.9-5
Fifth-degree value	1	2	3	4	5

3 Tone Model Research

3.1 Tone Duration

Tone duration, recognized as a pivotal rhythmic characteristic of tones, has been underscored by Ma Qiuwu[8] , suggesting its inclusion alongside pitch in the phonetic portrayal of Chinese intonation. Traditional linguistic theory suggests that tone contour significantly impacts tone duration, with complex contour tones typically longer than level tones, and rising tones often longer than falling ones.[9] Upon statistical analysis of a dataset comprising 1000 characters in Kang County dialect, it was found from figure 1 that the sequence of tone duration is as follows: YangPing > QuSheng > ShangSheng > YinPing, providing strong support for these assertions.
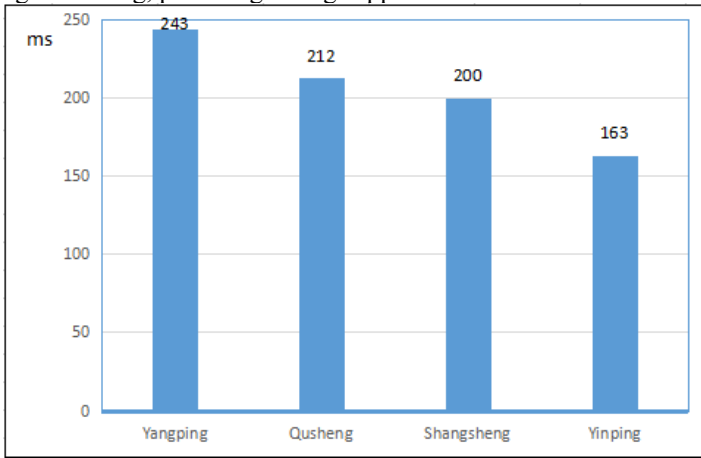
Fig. 1. Tone Duration Profile of Kang County Dialect.

Furthermore, regardless of tone category, tone duration is intricately linked to the length of vowel segments. Analysis of the vowels in commonly used characters in Kang County dialect reveals significant variations in the average duration of different vowel segments. Nasal vowels display the longest duration, followed by complex vowels, while single vowels exhibit the shortest duration.

3.2 Tone Values Analysis

Fundamental frequency data from all single-character recordings were extracted and normalized. Subsequently, the average frequencies for full-clear, partial-clear, partial-voiced, and full-voiced groups were computed for each of the four tones: level, rising, departing, and entering. Frequency curve graphs were then plotted for each tone category, illustrating variations in full-clear, partial-clear, partial-voiced, and full-voiced tones (see Figure 2, Figure 3, Figure 4, and Figure 5, respectively). Finally, the tonal range for each tone was determined based on these analyses.

3.2.1 Level Tone

In historical phonology, it's common for dialects to undergo a phenomenon known as "yin-yang split," where ancient clear initial consonants in level tones shift to yin level tones, and voiced initial consonants shift to yang level tones. [10] Figure 2 illustrates the fundamental frequency curve for the level tone in Kang County dialect, demonstrating this shift where clear initial consonants have evolved into yin level tones and voiced initial consonants into yang level tones.
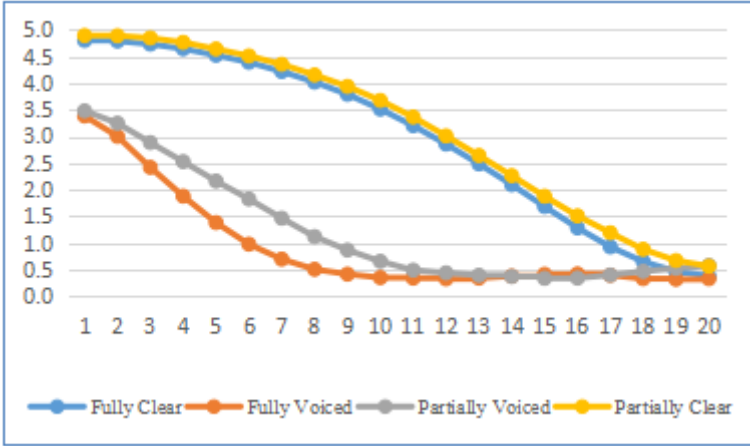

Fig. 2. Fundamental Frequency Mean Curve for Level Tone in Kang County Dialect.

3.2.2 Rising Tone

In Figure 3, the fundamental frequency mean curve for the rising tone in Kang County dialect illustrates a division into two distinct tones. Ancient clear and partially voiced rising tones have transitioned into rising tones, while ancient fully voiced rising tones have transformed into departing tones.
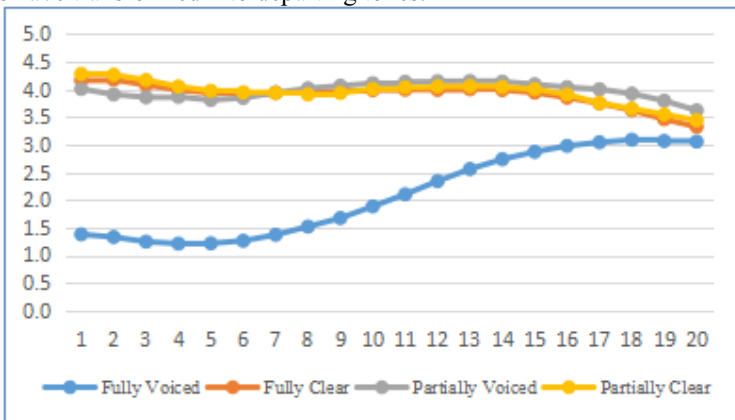

Fig. 3. Fundamental Frequency Mean Curve for Rising Tone in Kang County Dialect.

3.2.3 Departing Tone

In Figure 4, we observe the fundamental frequency mean curve for the departing tone in Kang County dialect. It's clear that the ancient departing tone has persisted as the departing tone in present-day Kang County dialect.
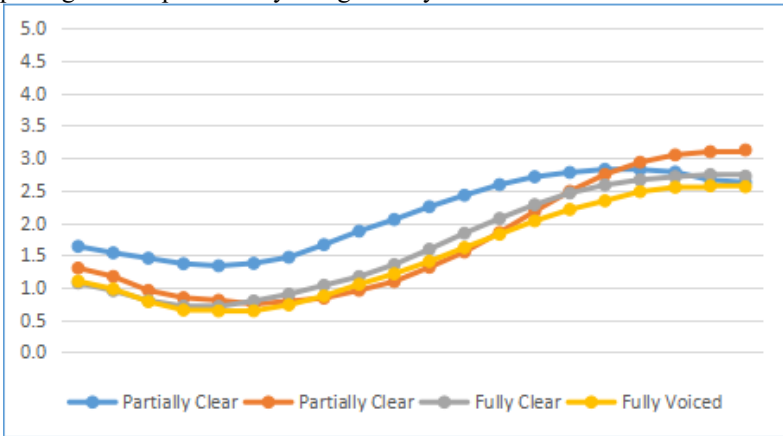

Fig. 4. Fundamental Frequency Mean Curve for the Departing Tone in Kang County Dialect.

3.2.4 Entering Tone

In Figure 5, we present the fundamental frequency mean curve for the entering tone in Kang County dialect. It's noteworthy that ancient entering tone characters with ancient clear or partially voiced initials typically correspond to yin level tones, while those with ancient fully voiced initials generally manifest as yang level tones.
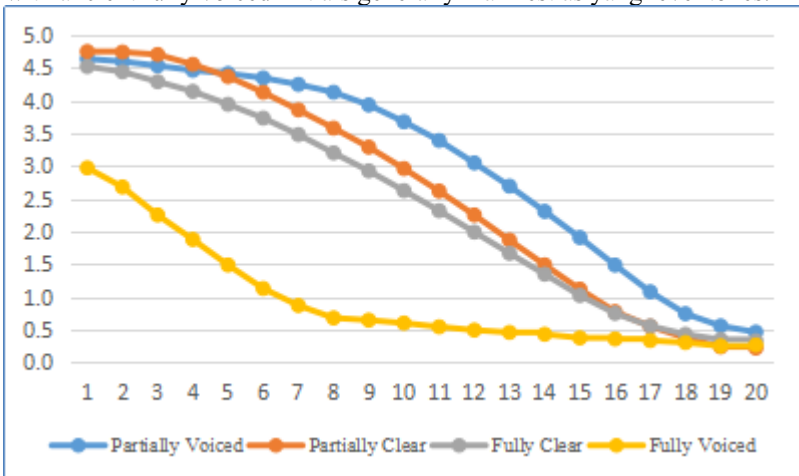

Fig. 5. Fundamental Frequency Mean Curve for Entering Tone in Kang County Dialect.

Utilizing Mr. Shifeng's T-value method, we input the fundamental frequency values of 20 points extracted from each single character into the formula for T-value

calculation. Subsequently, the resulting data is plotted in an Excel sheet to draw the T-value curve for the level, rising, departing, and entering tones in Kang County dialect. Here, the x-axis represents the number of tone points, while the y-axis signifies T-values.[11] Through quint value analysis and perceptual tests with speakers, we confirmed the existence of four single-tone categories in Kang County dialect. Figure 6 illustrates the T-value curve for these tones.
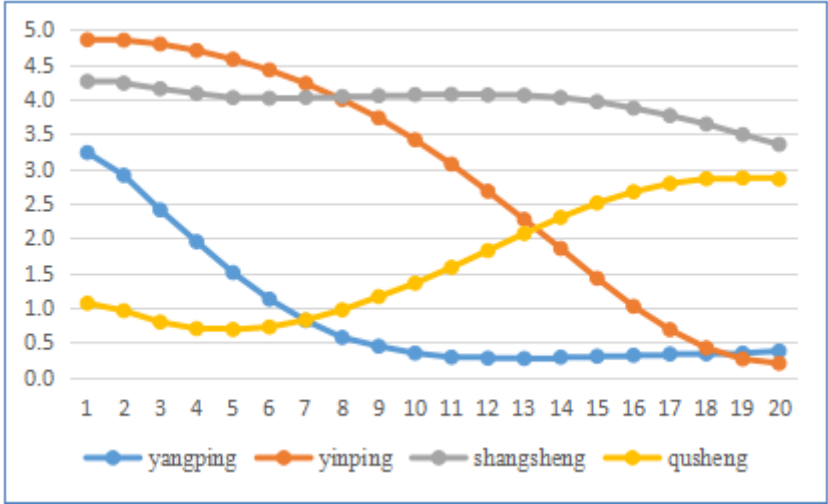

Fig. 6. T-Value Curve for Single-Tone Categories in Kang County Dialect.

Through acoustic analysis and experimental data statistics and calculations of single-tone categories in Kang County dialect, it can be seen from Figure 7 that: Kang County dialect employs a quaternary tone system. Level tones are differentiated into yin and yang categories, with values of 51 and 311, respectively. Clear initial consonants and partially voiced initial consonants retain their rising tone status, with a value of 54. Fully voiced initial consonants have merged their rising tone with the departing tone, resulting in a value of 24. Ancient clear and partially voiced entering tones have merged into yin level tones, with a value of 51, while fully voiced entering tones have merged into yang level tones, with a value of 311. Currently, there are no entering tone characters in use. These findings are consistent with previous linguistic research on Kang County dialect tones, albeit with slight variations in tone values.
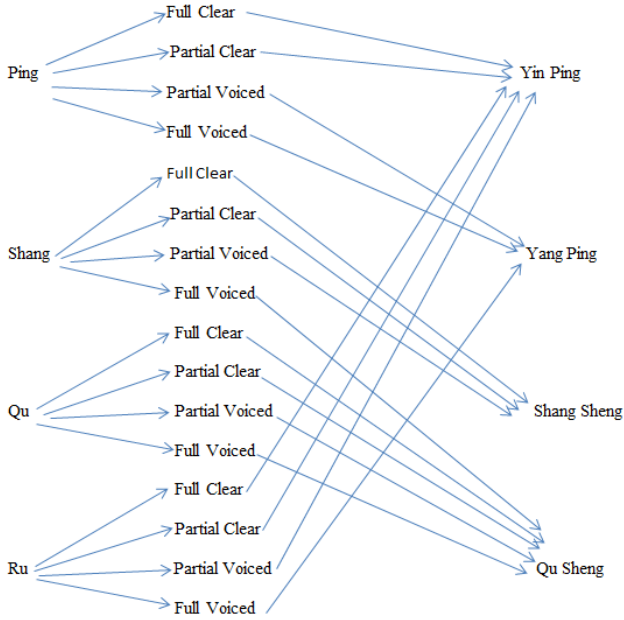
Fig. 7. Single-Tone Categories in Kang County Dialect.

3.3   Tone Distribution Model

Previous analyses and studies on tones have typically relied on limited speech data from a small number of speakers. However, in this study, we utilized a corpus of 1000 single characters to establish a comprehensive fundamental frequency database. This approach not only facilitated the examination of tone characteristics such as type, value, and duration in Kang County dialect but also enabled us to explore the distribution of tones using the extensive database. By doing so, we aimed to gain insights into the distribution relationship between different tone categories and the stability of each tone category, ultimately establishing a robust tone distribution model.
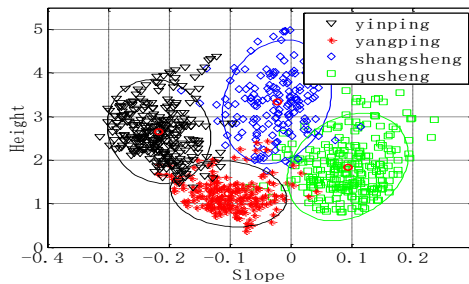

Fig. 8. Tone Position Distribution Map for Kang County Dialect.

This study analyzed the distribution of tones in Kang County dialect using the method proposed by Peng Gang [12], plotting scatter graphs with slope and height as the horizontal and vertical coordinates, respectively, as shown in Figure 8. Each point in the graph represents a single syllable, and the four regions correspond to the distribution of four tone categories. Ellipses covering 90% of the points were used to represent each region. Negative slope indicates a falling tone, zero slope represents a level tone, and positive slope indicates a rising tone

As shown in the graph: 1) YinPing and YangPing intersect with very few points, indicating excellent independence between the two tones and no auditory confusion. Both tones exhibit negative slopes, indicating falling tones. YinPing's scatter points are concentrated at higher frequencies, suggesting a high-falling tone, while Yang-Ping's scatter points are lower and closer to zero, indicating a level-falling tone. The vertical elongation of Yin Ping's ellipse suggests better stability in tone type but poorer stability in pitch. Conversely, the horizontal elongation of Yang Ping's ellipse, along with high scatter point concentration, indicates better stability in pitch. 2) ShangSheng and QuSheng also intersect with few points, indicating good independence between the two tones and no auditory confusion. Shang Sheng's ellipse is vertically elongated, suggesting better stability in tone type but poorer stability in pitch. ShangSheng mostly exhibits negative slopes, suggesting its actual tone value is a level-falling tone. Conversely, QuSheng has a positive slope, indicating a rising tone.

4   Conclusion

After statistically analyzing Kang County dialect tone data, we've outlined the tone patterns regarding tone length, tone value, and tone distribution model. Here's a concise summary of the key findings:

1)Tone Length: In terms of tone type, Kang County dialect exhibits the following sequence of tone duration: Yang Ping > Qu Sheng > Shang Sheng > Yin Ping. Additionally, the average duration of tones varies notably based on finals, with nasal finals having the longest duration, followed by complex finals, and then single finals.

2)Tone Value: the Kang County dialect exhibits four tone categories: Yin Ping , Yang Ping , Shang Sheng , and Qu Sheng . After analyzing the data, Level tones are further categorized into Yin (even) and Yang (rising) tones, with values of 51 and 311 respectively. Qing initials and unaspirated voiced initials retain their status as Shang Sheng tones, with a value of 54.Voiced initials in the Shang Sheng category merge with Qu Sheng, resulting in a value of 24.Ancient Qing and unaspirated voiced entering tones blend into Yin Ping with a value of 51, while voiced entering tones merge into Yang Ping with a value of 311. No entering tone characters exist currently.This conclusion aligns with prior linguistic studies on Kang County dialect tones, albeit with minor variations in tone values.

3)Tone Distribution: Regarding tone distribution, minimal intersection between Yin Ping and Yang Ping suggests excellent independence between the two tones, minimizing auditory confusion. Both tones exhibit negative slopes, indicating descending pitch, with Yin Ping clustering at higher frequencies, indicating a high-

falling tone, while Yang Ping clusters at lower frequencies, resembling a level-falling tone. The elongated shape of the Yin Ping distribution ellipse suggests better stability in tone type but poorer stability in pitch. Conversely, the high clustering of Yang Ping's scatter points implies better stability in pitch. Moreover, minimal intersection between ShangSheng and QuSheng indicates clear independence between these tones, preventing auditory confusion. The elongated shape of the ShangSheng distribution ellipse suggests better stability in tone type but poorer stability in pitch. ShangSheng mostly exhibits negative slopes, indicating that its actual tone value is a level-falling tone, while QuSheng slopes positively, indicating a rising tone.

Acknowledgments

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