Postprint of Tone Analysis of the Meizhou Dapu Hakka Dialect

Authors: ZHANG Zhixin

Date: 2020-11-10T00:00:00+00:00

Abstract

The Dapu Hakka dialect of Meizhou belongs to the Meihui subgroup of the Yue-Tai branch of Hakka within the Sino-Tibetan language family, and possesses six tones: yinping, yangping, shangsheng, qusheng, yinru, and yangru. This study employs phonetic experimental methodology, utilizing Praat to extract and analyze speakers' speech fundamental frequency (F0), thereby summarizing the monosyllabic tone values, disyllabic tone values, and tone sandhi patterns in the Dapu Hakka dialect. The monosyllabic tone values are: yinping 44, yangping 32, shangsheng 42, qusheng 53, yinru 4, and yangru 5. Among the 36 possible disyllabic combinations, there exist 29 combination patterns, with ru-tone sandhi being not prominent.

Full Text

Preamble

A Tonal Analysis of the Dabu Hakka Dialect in Meizhou
(Department of Chinese Language and Literature, Peking University, Beijing 100871)

Abstract: The Dabu Hakka dialect of Meizhou belongs to the Yue-Tai (Yuetai) branch, Meihui sub-branch of the Hakka language within the Sino-Tibetan language family, and features six distinct tones: Yinping, Yangping, Shangsheng, Qusheng, Yinru, and Yangru. This study employs experimental phonetic methods, utilizing Praat software to extract and analyze the fundamental frequency (F0) of recorded speech samples, thereby characterizing the tonal values of monosyllabic words and the tonal coarticulation patterns in disyllabic words in the Dabu Hakka dialect. The monosyllabic tonal values are identified as follows: Yinping (44), Yangping (32), Shangsheng (42), Qusheng (53), Yinru (4), and Yangru (5). Among the 36 possible tonal combinations in disyllabic words, 29

distinct patterns emerge, with minimal tonal sandhi observed in the entering tones.

Keywords: Dabu dialect, single-character tone, double-character tone, tonal system, Hakka language

Tone represents a linguistic concept integrating multiple factors including pitch, phonation type, and acoustic properties (Kong Jiangping, 2015), and constitutes a crucial component of Chinese dialect surveys. With advances in technology, Zhao Yuanren advocated for experimental approaches to tonal research in his 1924 work "Experimental Methods for the Study of Chinese Speech Tones," subsequently pioneering the five-degree tone notation system in the early 1930s. The medical field has since developed numerous innovative techniques for speech diagnosis and therapy that have gradually been adapted for phonetic research, including electropalatography for consonant analysis, high-speed photography for vocal fold vibration studies, spiral CT and MRI for vocal tract shape and movement investigation, electroglottography (EGG) for phonation type research, and electromyography (EMG) for articulatory muscle studies.

This experimental study investigates the single-character and double-character tones of the Hakka dialect spoken in Dabu County, Guangdong Province. Dabu is a county under the jurisdiction of Meizhou City, where local dialects primarily consist of Yue dialects and Hakka dialects. Within Hakka, three main accent types are distributed: the northern "Bulao" accent (a local distinctive variety), the central "Ruansheng" accent, and the southern "Ruansheng" accent, with the southern accent resembling the Taiwan Dabu accent. According to the 1987 edition of the *Language Atlas of China*, Dabu dialect was classified under the Xinghua sub-branch of the Yue-Tai Hakka branch, whereas the 2012 second edition reclassified it under the Meihui sub-branch of the Yue-Tai Hakka branch. While adjacent regions such as Meixian have been subjects of further research, studies on Dabu County Hakka have tended to focus on comparative analyses with other Hakka varieties rather than acoustic-phonetic investigation. Consequently, this paper adopts acoustic experimental methodology to examine the tonal system of Dabu Hakka, identifying its distinctive tonal characteristics and sandhi patterns based on previous Hakka studies.

2. Dialect Point Introduction

2.1 Overview of Dabu County

Dabu County is located in northeastern Guangdong Province, along the middle and upper reaches of the Han River, at the intersection of Guangdong and Fujian provinces and bordering four municipalities: Meizhou, Chaozhou, Longyan, and Zhangzhou. It connects to Pinghe County of Fujian to the east, borders Raoping and Fengshun to the south, neighbors Meixian to the west, and adjoins Yongding County of Fujian to the north, serving as a border trade hub between Fujian and Guangdong and as a hinterland garden for the Chaoshan Plain. Human settlement in the area dates back 4,000 years, and since its establishment

as Yizhao County in the ninth year of Yixi during the Eastern Jin Dynasty (413 CE), it has undergone numerous administrative changes. The county was resettled and named Dabu in the fifth year of Jiajing during the Ming Dynasty (1526 CE), a name it has retained for 486 years. The county seat was relocated from Chayang to Huliao in April 1961. The county governs 14 towns and 1 forest farm, comprising 244 village committees and 10 community committees. By the end of 2010, the total population reached 540,900, covering a territorial area of 2,467 square kilometers, including 2.98 million mu of mountainous land and 247,590 mu of cultivated land, characteristic of a "eight parts mountain, one part water, and one part farmland" topography. Dabu is renowned as the "four districts, four townships, and four famous features" (four districts: Central Soviet Area, revolutionary old district, scenic mountainous area, and happy new district; four townships: hometown of overseas Chinese, culture, ceramics, and famous tea; four famous features: famous people, famous residences, famous temples, and famous history).

[Figure 1: see original paper] Meizhou City Dabu District Area
[Figure 2: see original paper] Dabu District Dialect Distribution

2.2 Phonological System

The phonological system of the Dabu dialect is as follows:

(1) Initials (including zero initial): 25 total
ts (姐), ts (醋), s (嫂), t (针), t (臭), (手)

(2) Finals (including syllabic /m ŋ/): 65 total
(租), (池), ə (仔, a diminutive suffix), iau (鞘), iu (流), im (琴), iam (减), ion (旋), iun (准), ioŋ (娘), iuŋ (虫), op (合), at (擦), iot (说), iut (律), iuk (叔), uok (郭), uaŋ (梗), uoŋ (狂), ap (踏), ep (涩), ip (汁), iap (眨), uat (刮), ak (百), ok (索), uk (木), iak (石), iok (勺), ŋ (吴), m (毋)

(3) Tones: 6 total
Yinping: 44 (巴)
Yangping: 11 (拔)
Shangsheng: 31 (把)
Qusheng: 53 (爸)
Yinru: 1 (法)
Yangru: 5 (侄)

3. Research Methods

3.1 Recording Setup

Recordings were conducted in November 2019 in a quiet indoor environment using a mobile phone' s built-in recording software. The sampling rate was 48,000 Hz, mono channel, with 16-bit sampling precision.

3.2 Speaker Information

This experiment selected two native speakers of Dabu Hakka, one male and one female, both born and raised in Dabu County, Meizhou City, Guangdong Province, with over ten years of continuous residence. The female speaker was 46 years old, and the male speaker was 22 years old.

3.3 Word List Design

The experimental word list was compiled based on the *Meixian Dialect Dictionary* (edited by Li Rong), the *Standard Hakka Pronunciation Dictionary* (compiled by Zhang Weigeng), and online dictionaries documenting the Meihui sub-branch Hakka phonological system. The principle for selecting monosyllabic characters was to choose those with unaspirated voiceless stop initials to facilitate data extraction.

For single-character tones, six characters were selected for each tone category, totaling 36 characters. During recording, each character was read twice in horizontal sequence, with a 2-3 second pause after completing both repetitions, yielding 144 monosyllabic recording samples. The specific character selections were:

Yinping: 租, 家, 皆, 消, 包, 煎
Yangping: 哇, 傻, 唇, 秉, 捶, 黍
Shangsheng: 紫, 手, 矮, 好, 讽, 准
Qusheng: 智, 打, 播, 叫, 秀, 放
Yinru: 法, 雀, 畜, 洁, 腹, 质
Yangru: 汁, 滴, 啄, 夹, 侄, 拨

For disyllabic tones, all 36 possible tonal combinations were included, with six example words selected for each combination, yielding disyllabic recording samples.

3.4 Data Processing

This study utilized Praat software for fundamental frequency (F0) extraction and analysis. Developed by Professor Paul Boersma and Assistant Professor David Weenink from the Institute of Language Sciences, Faculty of Humanities, University of Amsterdam, Praat is a globally recognized professional software for computer-based phonetic research. The onset and offset portions of the tones were removed in Praat, selecting the more stable intensity portions. The onset and offset phenomena are normal physiological consequences of human articulation, and removing these segments standardizes the acoustic data. The F0 extraction script was developed by the Peking University Laboratory of Phonetics and Phonology, extracting 20 F0 points from the selected range to average across speakers. For data processing, this study employed the semitone method (semitone = $12 \times \log_2(f_1/f_2)$, where f_1 represents each measured F0 value and f_2 is the minimum value in the pitch range; when f_1 takes the maximum

value in the pitch range, the resulting semitone represents the speaker' s vocal range) and the five-degree scale method (5-degree value = [(lgf - lgf)/(lgf - lgf) × 4] + 1) to analyze tonal patterns.

4. Monosyllabic Tone Parameter Analysis

4.1 Semitone Analysis of Male and Female Speakers

In phonetics, pitch refers to human perception of sound height, determined by vibration frequency. The pitch range represents the scope of pitch variation within a tonal system, unaffected by basic phonological structure but varying according to individual speakers' upper and lower pitch limits. Generally, female speakers exhibit higher pitch ranges than male speakers with relatively greater span. In 1924, Liu Fu pioneered tonal research methodology in *Experimental Record of the Four Tones* by applying logarithmic transformation to fundamental frequency, making these values correspond more closely to human auditory perception rather than representing specific acoustic parameter curves —this constitutes the semitone method.

[Figure 3: see original paper] Female Average F0 Semitone Values
[Figure 4: see original paper] Male Average F0 Semitone Values

Figures 3 and 4 reveal clear differences in pitch range between male and female speakers. The female speaker's pitch span is approximately 11.5 semitones, while the male speaker' s span is about 6.5 semitones, though their monosyllabic tonal contours show minimal differences. For the Yinping contour, both speakers' curves occupy the middle region of their respective pitch ranges: female values start at 8.49 and end at 7.63, while male values start at 5.71 and end at 5.47. The female speaker' s Yinping appears more level overall, whereas the male speaker shows a slight descending curve in the middle. For Yangping, female values range from 8.24 to 2.62, and male values from 4.77 to 1.78, with both showing relatively large spans compared to other tones. In the Shangsheng contour, the upper limits differ in position: the male speaker' s peak occurs in the middle region, while the female speaker' s occurs at the onset (female: 10.06 to 3.21; male: 5.29 to 2.26). For Qusheng, both speakers' curves begin near their pitch range maxima (female: 12.69 to 7.35; male: 7.39 to 5.34). In Yinru, female values range from 11.09 to 4.62, and male values from 6.28 to 2.69. In Yangru, female values range from 12.27 to 7.53, and male values from 7.00 to 5.10. The Yinru and Yangru contours show consistent patterns, with the female speaker' s pitch range approximately double that of the male speaker.

4.2 Overall Semitone Analysis and Five-Degree Values

After calculating all tonal semitone values, the mean F0 values across both speakers were integrated to obtain overall monosyllabic tone semitone values and corresponding five-degree values.

[Figure 5: see original paper] Overall Monosyllabic Tone Semitone Values

The specific data are presented in Table 1.

Overall Monosyllabic Tone Semitone Values

As shown in the charts above, averaging across both speakers yields an overall pitch range of approximately 11 semitones. Yinping manifests as a level tone with a slight curvature, positioned in the middle of the pitch range with values maintained between 7 and 6.5. Yangping is a falling tone with a stable linear descent in the lower-middle region, starting at 6.50 and ending at 2.20, with its endpoint representing the overall pitch range minimum. Shangsheng is a falling tone that traverses nearly the entire pitch range, descending from 10.06 to 3.48. Qusheng displays a convex contour, beginning at the pitch range maximum and fluctuating between 11 and 5. Yinru is a falling tone in the upper-middle region, starting at 8.78 and ending at 3.48. Yangru is also a falling tone in the lower-middle region, starting at 9.64 and ending at 6.31. Although Yinru and Yangru share similar starting points, their endpoints differ by approximately 3 semitones, with Yangru showing a significantly steeper descending slope than Yinru.

Based on the speakers' averaged F0 values, the maximum frequency in the pitch range is 252 Hz and the minimum is 83 Hz, yielding a total range of 10.74 semitones. Conversion to five-degree values produces the following results:

Overall Monosyllabic Tone Five-Degree Values

Summarizing the above data and referencing Liu Lili's concept of "boundary domain"(with a fluctuation range of $±$0.1) in her article "Fundamental Frequency Normalization and Tonal System Standardization in Dialect Experiments," the monosyllabic tonal values for Dabu Hakka are: Yinping (44), Yangping (32), Shangsheng (42), Qusheng (53), Yinru (4), and Yangru (5).

5. Disyllabic Tone Parameter Analysis

When syllables co-occur, mutual influence causes changes in underlying tonal values, a phenomenon known as tone sandhi. With six tones in Dabu Hakka, there are 36 possible tonal combinations in disyllabic words. Six example words were selected for each combination, with 20 F0 points extracted and processed using semitone values. Arranged by tonal pattern with data points on the horizontal axis and semitone values on the vertical axis, the results are as follows:

5.1 Tonal Patterns with Yinping as the First Syllable

[Figure 6: see original paper] Semitone Values for "Yinping + X" Combinations

When Yinping combines with Yinping, the first syllable Yinping is a falling tone with a semitone curve from 13.88 to 12.08, while the second syllable Yinping remains level, similar to its monosyllabic form, with a curve from 12.26 to 12.08 showing a slight rise at the end. When Yinping combines with Qusheng or Yangru, the first syllable Yinping remains level, maintaining a value around

12, while the second syllable becomes falling in Qusheng combinations (15.30 to 12.52) and high-level in Yangru combinations (14.22 to 13.67). When Yinping combines with Yangping, Shangsheng, or Yinru, the first syllable Yinping becomes rising: with Yangping it shows a high rising contour (starting around 11), with Shangsheng it becomes high falling (13.25 to 9.04), and with Yinru it becomes high falling (13.53 to 9.77).

The five-degree summary of disyllabic tone sandhi patterns with Yinping as the first syllable: - Yinping 44 + Yinping 44 → 44+44 - Yinping 44 + Yangping 32 → 45+53 - Yinping 44 + Shangsheng 42 → 45+43 - Yinping 44 + Qusheng 53 → 44+54 - Yinping 44 + Yinru 4 → 44+4 - Yinping 44 + Yangru 5 → 44+5

5.2 Tonal Patterns with Yangping as the First Syllable

[Figure 7: see original paper] Semitone Values for "Yangping + X" Combinations

When Yangping combines with Yinping, Yangping, or Qusheng, the first syllable Yangping is falling, with semitone curves descending to 7.82, 8.94, and 6.31 respectively. The second syllable Yinping remains level (10.92 to 10.37), Yangping becomes low-level (9.26 to 9.02), and Qusheng becomes high falling (15.53 to 13.98). When Yangping combines with Shangsheng, Yangping is mid-level (10.96 to 9.97) while Shangsheng is mid-falling (11.58 to 8.22). When Yangping combines with Yinru, Yangping is rising (12.25 to 13.61) while Yinru is mid-falling (12.26 to 9.28). When Yangping combines with Yangru, Yangping is high-level (13.51 to 13.06) and Yangru is also high-level (15.00 to 14.69), slightly higher than the first syllable.

The five-degree summary of disyllabic tone sandhi patterns with Yangping as the first syllable: - Yangping 32 + Yinping 44 → 43+44 - Yangping 32 + Yangping 32 → 43+33 - Yangping 32 + Shangsheng 42 → 44+43 - Yangping 32 + Qusheng 53 → 43+55 - Yangping 32 + Yinru 4 → 45+4 - Yangping 32 + Yangru 5 → 54+5

5.3 Tonal Patterns with Shangsheng as the First Syllable

[Figure 8: see original paper] Semitone Values for "Shangsheng + X" Combinations

When Shangsheng combines with Yinping, Yinru, or Yangru, the first syllable Shangsheng is falling, with semitone curves starting at 12.6 and ending at 8.93, 8.91, and 10.56 respectively. The second syllable Yinping is mid-level (9.99 to 9.76), Yinru is high-level (12.62 to 11.97), and Yangru is high-level. When Shangsheng combines with Yangping or Shangsheng, the first syllable Shangsheng is level, with curves from 13.10 to 11.36 and 11.16 respectively. The second syllable Yangping is falling (11.11 to 9.70) with a slight rise at the end, Shangsheng is falling (11.65 to 8.28), and Yinru is falling (11.89 to 8.44), with the second syllable' s fall slightly higher than the first. When Shangsheng combines with Qusheng, the first syllable Shangsheng is falling (13.19 to 8.23) while

the second syllable Qusheng is level (12.99 to 11.81).

The five-degree summary of disyllabic tone sandhi patterns with Shangsheng as the first syllable: - Shangsheng 42 + Yinping 44 → 43+44 - Shangsheng 42 + Yangping 32 → 44+44 - Shangsheng 42 + Shangsheng 42 → 44+43 - Shangsheng 42 + Qusheng 53 → 43+44 - Shangsheng 42 + Yinru 4 → 43+4 - Shangsheng 42 + Yangru 5 → 43+5

5.4 Tonal Patterns with Qusheng as the First Syllable

[Figure 9: see original paper] Semitone Values for "Qusheng + X" Combinations

When Qusheng combines with Yinping, the first syllable Qusheng is high falling (14.50 to 10.16) while the second syllable Yinping is level (10.16 to 10.41) with a rising tail. When Qusheng combines with Yangping, Shangsheng, Qusheng, or Yinru, the first syllable Qusheng is high-level, starting around 14.7 and ending at 15.29, 14.48, 13.84, and 14.96 respectively. The second syllable Yangping is level (10.16 to 10.41), Shangsheng is falling (11.72 to 9.11), Qusheng is high falling (14.33 to 13.19) with similar values to the first syllable, and Yinru is falling (11.84 to 9.38). When Qusheng combines with Yangru, the first syllable Qusheng is high falling (15.69 to 12.37) while the second syllable Yangru is level (11.86 to 10.65).

The five-degree summary of disyllabic tone sandhi patterns with Qusheng as the first syllable: - Qusheng 53 + Yinping 44 → 54+44 - Qusheng 53 + Yangping 32 → 55+44 - Qusheng 53 + Shangsheng 42 → 55+43 - Qusheng 53 + Qusheng 53 → 55+54 - Qusheng 53 + Yinru 4 → 55+4 - Qusheng 53 + Yangru 5 → 54+4

5.5 Tonal Patterns with Yinru as the First Syllable

[Figure 10: see original paper] Semitone Values for "Yinru + X" Combinations

When Yinru combines with Yinping, Yangping, Shangsheng, Qusheng, or Yinru, the first syllable Yinru is level, with semitone curves starting around 13-14 and ending at 12.25, 12.28, 12.23, 12.10, and 13.08 respectively. The second syllable Yinping is level (10.66 to 10.00), Yangping is concave-level (10.59 to 10.02), Shangsheng is falling (10.94 to 7.67), Qusheng is falling (13.54 to 10.82), and Yinru is falling (13.40 to 9.10). When Yinru combines with Yangru, the first syllable Yinru is high-level (14.48 to 13.08) and the second syllable Yangru is also high-level (15.72 to 14.69).

The five-degree summary of disyllabic tone sandhi patterns with Yinru as the first syllable: - Yinru 4 + Yinping 44 → 4+44 - Yinru 4 + Yangping 32 → 4+44 - Yinru 4 + Shangsheng 42 → 4+43 - Yinru 4 + Qusheng 53 → 4+54 - Yinru 4 + Yinru 4 → 4+4 - Yinru 4 + Yangru 5 → 5+5

5.6 Tonal Patterns with Yangru as the First Syllable

[Figure 11: see original paper] Semitone Values for "Yangru + X" Combinations

When Yangru combines with Yinping, Yangping, Shangsheng, Qusheng, Yinru, or Yangru, the first syllable Yangru is high-level, with semitone curves starting around 14-15 and ending at 12.02, 13.76, 12.01, 12.56, 14.74, and 12.97 respectively. The second syllable Yinping is level (10.99 to 10.11), Yangping is level (9.86 to 9.23), Shangsheng is falling (12.27 to 8.67), Qusheng is falling (14.33 to 11.35), Yinru is falling (13.63 to 10.38), and Yangru is falling (14.32 to 13.39).

The five-degree summary of disyllabic tone sandhi patterns with Yangru as the first syllable: - Yangru 5 + Yinping 44 → 5+44 - Yangru 5 + Yangping 32 → 5+44 - Yangru 5 + Shangsheng 42 → 5+43 - Yangru 5 + Qusheng 53 → 5+54 - Yangru 5 + Yinru 4 → 5+4 - Yangru 5 + Yangru 5 → 5+5

6. Discussion of Disyllabic Tone Sandhi

Based on the disyllabic tone sandhi data presented above, the tonal sandhi patterns in Dabu Hakka disyllabic words exhibit relatively clear regularities. Yinping maintains its monosyllabic value of 44 in disyllabic contexts, unaffected by the following syllable. Yangping, with a monosyllabic value of 32, typically rises by 1-2 degrees when occurring as either the first or second syllable, except when combined with Yinping. In most other contexts, the tonal contour shows a descending middle portion. As Li Xiaofan (2004) notes regarding tonal sandhi typology, Yangping sandhi belongs to the simplification type, reducing the complex contour of the monosyllabic Yangping to form one or two rising tones. Shangsheng has a monosyllabic value of 42, but as the second syllable, it consistently changes to 43 regardless of the preceding tone, representing a simplification-type sandhi that reduces the extent of the contour. Qusheng has a monosyllabic value of 53, but as the second syllable, it becomes 54, also representing simplification-type sandhi. Yinru has a monosyllabic value of 4 and generally maintains this value in disyllabic contexts, except when combined with another entering tone, where it changes to 5. Yangru has a monosyllabic value of 5 and generally maintains this value, except when combined with another entering tone, where it changes to 4.

The experimental data reveal that among disyllabic combinations, certain patterns can be merged into identical combination modes, suggesting that some Dabu Hakka tones do not distinguish Yin-Yang categories when occurring as the first syllable, exhibiting identical tonal values and contours in this position. This occurs when level tones appear as the second syllable combined with Qusheng, Yinru, or Yangru as the first syllable, where the second syllable consistently shows a value of 44. For Yinru and Yangru combinations, the tonal value is consistently 5+5 regardless of syllable position. In disyllabic contexts, Yin-Yang entering tone sandhi is not pronounced and remains unaffected by non-entering tones.

In summary, Dabu Hakka possesses six monosyllabic tones: Yinping, Yangping, Shangsheng, Qusheng, Yinru, and Yangru. The monosyllabic tonal values obtained in this experiment are:

- Yinping: 44
- Yangping: 32
- Shangsheng: 42
- Qusheng: 53

In disyllabic contexts, sandhi predominantly manifests as falling tones, affecting both first and second syllables. The specific tonal values are as follows:

Yinping combinations:
Yinping + Yinping: 44+44
Yinping + Yangping: 45+53
Yinping + Shangsheng: 45+43
Yinping + Qusheng: 44+54
Yinping + Yinru: 44+4
Yinping + Yangru: 44+5

Yangping combinations:
Yangping + Yinping: 43+44
Yangping + Yangping: 43+33
Yangping + Shangsheng: 44+43
Yangping + Qusheng: 43+55
Yangping + Yinru: 45+4
Yangping + Yangru: 54+5

Shangsheng combinations:
Shangsheng + Yinping: 43+44
Shangsheng + Yangping: 44+44
Shangsheng + Shangsheng: 44+43
Shangsheng + Qusheng: 43+44
Shangsheng + Yinru: 43+4
Shangsheng + Yangru: 43+5

Qusheng combinations:
Qusheng + Yinping: 54+44
Qusheng + Yangping: 55+44
Qusheng + Shangsheng: 55+43
Qusheng + Qusheng: 55+54
Qusheng + Yinru: 55+4
Qusheng + Yangru: 54+4

Yinru combinations:
Yinru + Yinping: 4+44
Yinru + Yangping: 4+44
Yinru + Shangsheng: 4+43
Yinru + Qusheng: 4+54

Yinru + Yinru: 4+4
Yinru + Yangru: 5+5

Yangru combinations:
Yangru + Yinping: 5+44
Yangru + Yangping: 5+44
Yangru + Shangsheng: 5+43
Yangru + Qusheng: 5+54
Yangru + Yinru: 5+4
Yangru + Yangru: 5+5

After merging equivalent patterns, Dabu Hakka disyllabic tonal combinations total 29 distinct types: 44+44, 45+53, 45+43, 44+54, 44+4, 44+5, 43+44, 43+33, 44+43, 43+55, 45+4, 54+5, 43+4, 43+5, 54+44, 55+44, 55+43, 55+54, 55+4, 54+4, 4+44, 4+43, 4+54, 4+4, 5+5, 5+44, 5+43, 5+54, and 5+4.

Overall, Yinping, Shangsheng, and Qusheng are relatively stable as first syllables, with their contours rising by 1-2 degrees at the tail compared to their monosyllabic forms. Yangping as a first syllable shows specific patterns: when combined with Yinping, Yangping, or Qusheng, it rises by one degree overall; when combined with Qusheng, it changes from falling to level; when combined with Yinru, it changes from falling to rising; and when combined with Yangping, it changes from falling to high falling. Yin-Yang entering tones show minimal change as first syllables, except when Yinru combines with Yangru, where it rises by one degree.

References

Kong Jiangping. *Experimental Phonetics Basic Course*. Peking University Press, 2015.
Chinese Academy of Social Sciences. *Language Atlas of China*. The Commercial Press, 2012.
Li Xiaofan. "Levels and Types of Tone Sandhi in Chinese Dialects." *Dialect*, 2004(1):16-33.
Liu Fu. *Experimental Record of the Four Tones*. Qunyi Book Company, 1924.
Shao Dandan. "An Experimental Study of Tones in Meixian, Fuzhou, and Changsha Dialects Based on EGG." Master' s thesis, Nanjing Normal University, 2012.
Xin Shibiao. "Evolutionary Types of Hakka Tones."School of Literature, Hainan University, 2000.
Lan Xiaoling. "The Nature of Hakka Tones." *Journal of Xiamen University (Philosophy and Social Sciences Edition)*, 1997.
Zhao Yuanren. "Experimental Methods for the Study of Chinese Speech Tones." *Science*, 1924.

Note: Figure translations are in progress. See original paper for figures.