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研究論文

An Acoustic Analysis of the Vowel Pattern in Taiwan Sixian Hakka *

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Abstract

This study targeted at an acoustic exploration of the vowel pattern in Taiwan Sixian Hakka (TSH). Six main vowels ([i, e, a, o, u, ɨ]) in TSH, appearing in the contexts of V, GV, VG, VN and VT (where G = [i, u], N = [m, n, ŋ] and T = [p, t, k]) and articulated by a total of 36 Hakka subjects (two genders and three generations), were recorded for formant analysis by PRAAT. Visual displays of the F_1 and F_2-F_1 values were generated for mutual comparison. The research results were shown as follows. First, for the systematicity of the vowel pattern, females' vowel space was relatively

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more expanded than males'. Moreover, back vowels and non-back vowels displayed variation in different articulatory dimensions, with the former in tongue height and the latter in tongue frontness. Next, for the variability of the vowel pattern, the glides [i, u] in GV and VG would forward, back or raise the vowel pattern, based on the intrinsic articulatory characteristics of [i, u] (i.e., high/front for [i] and high/back for [u]). More amusingly, the offglides had a stronger variability influence on vowels than the onglides. Third, in terms of VN and VT, except [k], all remaining consonant codas exhibited an effect of centralization on the vowel pattern. Because of its existence in the Checked-tone syllables and its backness in the oral cavity, the coda [k] would lower the pattern of preceding vowels. Last, the results of this study were phonologically and structurally supported, reflecting the current linguistic trend to the integration of phonetics and phonology.

Keywords: Hakka, vowel, formant, systematicity, variability, vowel pattern

台灣四縣客家話元音格局的聲學分析

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摘要

本研究從聲學角度探討台灣四縣客家話元音格局的系統性與變異性，藉以瞭解元音本身的系統性，以及韻頭、韻尾對元音所造成的變異情形與程度。本研究的語料包括四縣客家話的 6 個單元音，以及這些單元音與韻頭 [i, u]或韻尾[i, u, m, n, ŋ, p, t, k]的組合，總共 43 個單音節。本研究透過閱讀字表的方式，總共採集了 36 名客家人（男女兩性、老中青三代，共六組）的 4644 個元音樣本，接著利用 PRAAT 進行共振峰分析及 SPSS 進行測量信度分析，最後將測量所得之 F_1 及 F_2-F_1 值繪製成元音聲學空間圖以茲比較。本研究的主要發現如下。第一，就元音的系統性而言，女性的元音格局明顯大於男性。此外，因為口腔生理構造的限制，後元音及非後元音分別在不同的發音維度上變化，前者在舌位高低，後者在舌位前後。第二，對於元音的變異性而言，元音前後的滑音均會造成元音格局的變異，而元音變異的方向則受滑音本身所具備的高、前、後等發音特質的影響。有趣的是，後滑音（元音韻尾）對於元音的變異作用，其程度遠遠強於前滑音（韻頭）。第三，就輔音韻尾而言，除[k]外，其他的輔音韻尾對元音變異的最主要作用是央化。反觀[k]，因其發音位置偏後，且又處於入聲音節中，[k]對元音所產生的影響是使元音格局低化。最後，本研究的發現也獲得客家話音韻結構上的支持，充份反應了整合語音學與音韻學的語言學研究趨勢。

關鍵詞：客家話、元音、共振峰、系統性、變異性、元音格局

Introduction

Vowels are one of the significant sound classes in languages. They are articulated with periodic vibrations of vocal folds, with no obstruction to the airstream and with greater sonority and length than consonants. For the reason, they are qualified to form the peaks of syllables. Without them, it will be impossible for humans to produce speech. When it comes to vowels, two properties are of particular importance, that is, *systematicity* and *variability*. The systematicity of vowels, in accord with de Saussure (1959) and Trubetzkoy (1969), indicates that every vowel is defined by its reciprocal relation to others, and takes up a specific distributional area in a vowel space. For vowel variability, speech production is a continuous process, so vowels may vary due to the preceding or following segments. Different segment types (glides, nasals or stops) and different positions of them in syllables must lead to different degrees of coarticulation effects on vowels, which inevitably forces the vowel pattern to vary in a certain degree.[1] A great body of related literature (Cai 2007; F. Shi 2002a, 2002b, 2008a, 2008b; X. Shi 2005; Shi and Liu 2005; Shi and Liu 2006) has centered on the contextual effects upon the vowel patterns among Chinese dialects. It has been found out that the variability in these vowel patterns is rule-governed, instead of being random and chaotic. These studies help show the typological patterns of vowels among Chinese dialects (X. Shi 2006, 2007, 2010), and reflect the voices for the integration of phonetics and phonology (Beckman and Kingston 1990; Ladefoged 1992; Ohala 1997; F. Shi 2006; Wang 2000).[2]

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1 For more discussion of the coarticulation effect, please refer to Catford (2001), Laver (1994) and Pickett (1999).

2 In addition to vowels, the concept of "typological patterns" has also been extended to obstruents (Shi and Ran 2007; Ran 2008) and tones (Cai 2007; Liang 2008; Ping 2001; Shi 1994, 1998; Shi

This study targets to investigate the vowel pattern of Taiwan Sixian Hakka (TSH) from an acoustic perspective. Previous studies of vowel systems in TSH (e.g., Chung 2004; Ding 1979; Ku 2005; Lo 1990, 2007) focused mainly on the segmental configurations within syllables. Little is known about the systematicity of the vowel pattern in TSH, and about the variability effects on vowels resulting from the contextual coarticulation effects or the non-contextual age and gender difference. For this sake, this study will take the TSH rimes (i.e., V, GV, VG, VN and VT) into concern and investigate how vowels vary in different contexts. This study attempts to answer the following research questions in (1). The first one deals with vowel systematicity, and the remaining two cope with vowel variability. The understanding of the vowel pattern in TSH (i.e., systematicity) and its variability will, no doubt, be promoted by the conduction of this study.

(1) Research Questions of This Study

a. How do the monophthongs in TSH distribute (i.e., the vowel pattern)?

b. How do the onglides and offglides ([i, u]) affect the vowel pattern?

c. How do the consonantal codas (nasals and stops) affect the vowel pattern?

The rest of the study has the following structure. Section 2 provides some relevant backgrounds about the vowel inventory and the sequential constraints in TSH, and about acoustic measurements of vowel formants. Section 3 introduces the method used in this study. Section 4 presents the

and Wang 2006).

results and discusses the systematicity and variability of vowels in TSH by displaying and comparing the formant charts. Section 5 concludes this study, and suggests some issues for future research.

2. Literature Review

2.1 The Vowel Inventory and the Sequential Constraints in Taiwan Sixian Hakka

Ahead of a detailed account of the systematicity and variability of the vowel pattern in TSH, general knowledge about its vowel inventory and the phonotactic constraints is in demand.[3] There are six monophthongs in TSH, as in (2). Except [ɨ] which is an apical vowel, the remaining vowels are laminal ones. The monophthongs (V) can be preceded by onglides (G) [i, u] or followed by offglides [i, u], nasal stops (N) [m, n, ŋ] or oral stops (T) [p, t, k] to generate a number of rimes. Among these six main vowels, the apical vowel [ɨ] calls for special explanation. It only appears after [ts], [ts^{h}] and [s], such as [tsɨn] 'true', [ts^{h}ɨm] 'deep' and [sɨp] 'wet'. Like the apical vowels [ɿ, ʅ] in Mandarin Chinese, [ɨ] in TSH is hard to articulate alone. Moreover, unlike other main vowels in Hakka, [ɨ] is very restrictive to form rimes with codas. For example, though [ɨ] can appear before [p, t, m, n] in TSH, it only occurs in open syllables in Dongshi Dapu Hakka. The rimes, classified in (3), will be acoustically investigated in this study.

3 In addition to Mandarin Chinese and Southern Min, Hakka is the third largest language group in Taiwan. Hakka can be further separated into five sub-dialects, Sixian, Hailu, Dapu, Zhaoan and Raoping. Sixian Hakka takes the highest percentage of the Hakka-speaking population. For more details about the distribution of the Hakka sub-dialects in Taiwan, see Chung (2004), Ku (2005) and Lo (2007). On account of different geographic locations and several linguistic differences, Sixian Hakka can be further separated into Northern Sixian and Southern Sixian (Chung 2004). Northern Sixian is distributed mainly in Miaoli County and Taoyuan County in northern Taiwan, and is the focus of this study. For acoustic analysis of the vowels (and consonants) in Southern Sixian, please refer to Liang (2005).

(2) The Monophthongs in Sixian Hakka (Chung 2004:71)

	front	central	back
high	[i]	[ɨ]	[u]
mid	[e]		[o]
low		[a]	

(3) V: i, ɨ, u, e, a, o

GV: ui, ue, ua, ie, io, ia

VG: iu, eu, au, oi, ai

VN: im, in, un, uŋ, em, en, on, oŋ, am, an, aŋ, ɨm, ɨn

VT: ip, it, ut, uk, ep, et, ot, ok, ap, at, ak, ɨp, ɨt

Some accounts about the formation of the rimes in (3) are necessary. First, this study centers on the rimes GV, VG, VN and VT, without paying heed to the onsets. This follows the traditional view in Chinese phonology that syllables are always split into onsets and rimes, and the segments in rimes bear a strong relation with one another. Second, such rimes as GVG, GVN and GVT fall outside our concern. This is because the simultaneous coarticulation influences from pre- and postvocalic segments will blur and complicate the variability of the vowel pattern. Third, [ei], [uo] and [ou], and [iŋ, ik, eŋ, ek, ɨŋ, ɨk] and [um, up, om, op] are forbidden rimes in TSH (Chung 2004; Lo 2007).[4] At last, in accord with the sonority scale, low vowels are more sonorous than high vowels. The sonority of front vowels

[4] In Sixian Hakka, rimes formed by vowels with the same backness (e.g., [ei], [uo] and [ou]) are ruled out. The rimes [iŋ, ik, eŋ, ek, ɨŋ, ɨk] are forbidden because, phonologically, front vowels [i, ɨ, e] cannot co-occur with dorsal consonants [k, ŋ]. The prohibition of the [um, up, om, op] rimes results from a widely attested phonotactic constraint in Chinese dialects, labial dissimilation, by which the segmental combinations between round vowels [u, o] and bilabial coda consonants [m, p] are disallowed (Chung 2004).

is greater than that of back vowels, when vowels are classified as having equal tongue heights (i.e., [a]>[e]>[o]>[i]>[u]). For this sake, [ui] and [iu] are regarded as a rising diphthong (GV) and a falling diphthong (VG) respectively. Moreover, such a structural distinction between [iu] and [ui] in TSH is also acoustically supported in Hsu (2004).[5]

2.2 The Acoustic Measurement of Vowel Formants

Right after the "Bell-Sweet Model" of Bell (1867) and Sweet (1877), vowels are described in terms of tongue height, tongue advancement, lip rounding and jaw opening. This model makes a great contribution to the fieldwork transcriptions for its convenience in use. Yet, such articulatory descriptions are rarely satisfactory, for they "are often not in accord with the actual articulatory facts (Ladefoged 2001:14)." For example, both [i] and [u] are equally marked [+high], even though they did not always have the same tongue height. These articulatory descriptions are used only "as labels to specify acoustic dimensions rather than as descriptions of actual tongue positions (Ladefoged 2001:177)."

Fortunately, with the advent and advancement of modern technology, vowel qualities can now be quantified by measuring the frequencies of the lower resonance in the acoustic signal (Ladefoged 1997). Physiologically, vowels are different in their qualities on account of the different shapes of the resonance chambers. The different bodies of the vocal tract modify the airstreams from the lung and the larynx. In this period of time, a number of harmonics, so-called formants, are produced. The first two formants in

[5] Hsu (2004) focused mainly on the internal structure of [iu] and [ui] in TSH, rather than on their acoustic properties. Different from Chung (1989b), in which both [iu] and [ui] were treated as falling diphthongs, Hsu (2004) argued that [iu] was a falling diphthong (VG), while [ui] was a rising one (GV). One of her supporting arguments was the measurement of energy amplitude, with the sonority of [i] higher than that of [u].

the low frequency, abbreviated as F_1 and F_2, are well understood to have clear correspondence with articulatory properties of vowels (Catford 2001; Fry 2001; Kent and Read 2002; Ladefoged 1996, 1997; Lass 1996; Stevens 1998; Wu and Lin 1989). The F_1 and F_2 values correspond closely to tongue height and tongue advancement of vowels respectively. F_1 is inversely related to vowel height. Open vowels have high F_1 frequencies, while close vowels have low F_1 frequency values. F_2 reflects the frontness degree of vowels. A higher F_2 represents that the vowel is articulated with a more advanced tongue position. Ladefoged (2001:177) also suggested that, to fit the formant charts for the traditional articulatory descriptions of vowels and remove the effect of lip rounding on F_2 values, "the degree of backness is best related to the difference between the first and the second formant frequencies." For this reason, the plotting of F_1 against F_2-F_1 will be adopted in this study.

3. Methodology

3.1 Subjects

Thirty-six Hakka people (18 males and 18 females) living in Miaoli County, with TSH as their first language, participated in this study. They were evenly separated into six groups by age (old: over 60, middle-aged: 35-60 and young: 20-35) and gender (males and females), as displayed in (4).

(4)	Old		Middle-Aged		Young	
	Males	Females	Males	Females	Males	Females
Number	6	6	6	6	6	6
Age Average	71	68	53	51	26	25
Age Range	63-78	61-73	49-55	44-55	20-33	20-32

The subjects were randomly selected based on the following criteria. First, they used TSH at home and in daily conversations with other Hakka people. Next, the spoken TSH from these speech informants was judged to be intelligible by a qualified judge who was holding a certificate issued by Hakka Affairs Council. Third, they have been living in Miaoli County for over fifteen years. Finally, all the subjects were judged to be free from speech, language or hearing disorders.

3.2 Speech Materials

The speech data were gathered by a word list which was specifically designed to the elicitation of the vowel pattern in TSH. Besides the six monophthongs, the list contained such rimes as GV, VG, VN and VT, as shown in (5). Additionally, TSH is a tone language, so all syllables bear citation tones. As mentioned in Huang (1996), the overtone structures of vowels are rarely affected by the pitch differences. However, the current study still controls the tones of the words. The checked-tone syllables (i.e., syllables closed with [p, t, k] codas) and non-checked-tone syllables are pronounced with a Yangru tone [55] and a Yinping tone [24] respectively.[6] Besides, voiceless obstruents were adopted to be the onsets of the target syllables. The reason for this lied in the fact that different spectrographic characteristics between voiceless obstruents and vowels will be helpful for the demarcation of the vowels and for the measurement of the formant frequency values. The target syllables in the study were listed in (5).

(5) Target Syllables Adopted in This Study

V	[i]	[p^{h}i^{24}]	'quilt'	[u]	[su^{24}]	'book'
	[e]	[se^{24}]	'to lick'	[o]	[ts^{h}o^{24}]	'to sit'
	[a]	[sa^{24}]	'sand'	[ɨ]	[sɨ^{24}]	'teacher'
GV	[ue]	[ue^{24}]	'hello'	[ua]	[k^{h}ua^{24}]	'to praise'
	[ie]	[ie^{24}]	'to expose'	[ui]	[ts^{h}ui^{24}]	'to urge'
	[io]	[hio^{24}]	'boot'	[ia]	[p^{h}ia^{24}]	'to spread'
VG	[iu]	[k^{h}iu^{24}]	'uncle'	[ai]	[k^{h}ai^{24}]	'to raise'
	[eu]	[p^{h}eu^{24}]	'standard'	[oi]	[k^{h}oi^{24}]	'to open'
	[au]	[p^{h}au^{24}]	'to toss"			
VN	[im]	[k^{h}im^{24}]	'to admire'	[in]	[k^{h}in^{24}]	'gizzard'
	[em]	[sem^{24}]	'forest'	[en]	[p^{h}en^{24}	'to cook'
	[am]	[t^{h}am ^{24}]	'to reach'	[an]	[p^{h}an^{24}]	'to climb'
	[ɨm]	[ts^{h}ɨm^{24}]	'deep'	[on]	[t^{h}on^{24}]	'broken'
	[uŋ]	[p^{h}uŋ^{24}]	'bee'	[un]	[p^{h}un^{24}]	'thick'
	[oŋ]	[p^{h}oŋ ^{24}]	'to bump'	[ɨn]	[sɨn^{24}]	'to raise'
	[aŋ]	[t^{h}aŋ^{24}]	'to hear'			

6 According to Lo (2007), there are six citation tones in Northern Sixian Hakka, including Yinping [24], Yangping [11], Shangsheng [31], Qusheng [55], Yinru [32] and Yangru [55].

	[ip]	[k^{h}ip^{55}]	'to prompt'	[it]	[t^{h}it^{55}]	'special'
	[ep]	[t^{h}ep^{55}]	'close-fitting'	[et]	[p^{h}et^{55}]	'other'
	[ap]	[t^{h}ap^{55}]	'step'	[at]	[p^{h}at^{55}]	'to whisk'
VT	[ɨp]	[sɨp^{55}]	'ten'	[ot]	[t^{h}ot^{55}]	'to take away'
	[uk]	[ts^{h}uk^{55}]	'clan'	[ut]	[p^{h}ut^{55}]	'to overflow'
	[ok]	[p^{h}ok^{55}]	'thin'	[ɨt]	[ts^{h}ɨt^{55}]	'straight'
	[ak]	[p^{h}ak^{55}]	'white'			

3.3 Recording Procedures

Sound qualities of recordings play an important role in acoustic and experimental studies. For this reason, good instruments for the recordings and clear instructions to the subjects are necessary. All recordings were executed in a sound-insulated room in order to ensure high voice qualities. The unidirectional microphone (SBC-ME470) sensitive to frequencies ranging from 50 Hz to 18K Hz was placed ten centimeters away from the subjects' mouths at the chest level. All the recordings were collected by PRAAT (with a default sampling frequency of 44.1K Hz) in a notebook computer (ASUS A8Jr). The collected sound files were then transformed into WAV files for formant analysis.[7]

In the recording session, the subjects were required to read the word list. In order to ensure that subjects could familiarize themselves with the target syllables, the word list had been given to them three days before the recordings were performed. Prior to sound recordings, all subjects were instructed to produce each syllable with similar pace and intensity. Each syllable was pronounced five successive times, and the middle three were taken out for formant analysis, so each subject produced a total of 129

7 PRAAT can be used to analyze pitches and formants, and exhibit spectrograms and spectrums. It can be downloaded from the website http://www.fon.hun.uva.nl/praat/ without charge.

tokens (43 syllables x 3 times). No corrections or interruptions were given to the subjects during the recording session, so that their pronunciations could be as natural and spontaneous as possible.

3.4 Acoustic Measurement and Measurement Reliability

The collected speech tokens were measured for formant frequencies in PRAAT (Boersma and Weenink 2009). The beginning and the ending of the vowels in the target syllables were located by oscillographic and spectrographic displays. The F_1 and F_2 values in the steady-state portions were manually measured and recorded. Based on Shi (2008a), formant frequencies in the steady-state portions of vowels are stable, and contain most of the important acoustic cues for vowels. The extracted F_1 and F_2 values were plotted on formant charts for further analysis. Moreover, ten percent of the tokens in each group of subjects (464 tokens in total) were randomly chosen, and their F_1 and F_2 values were re-measured to assess intra-rater and inter-rater measurement reliability. These two tasks were, respectively, performed by the author and a research assistant having a lot of experience for conducting acoustic analysis. The Pearson correlation coefficients for F_1 (in Hz) and F_2 (in Hz) between the two measurements were 0.94 and 0.93 in intra-rater reliability and 0.91 and 0.90 in inter-rater reliability ($p < .05$ for all cases).

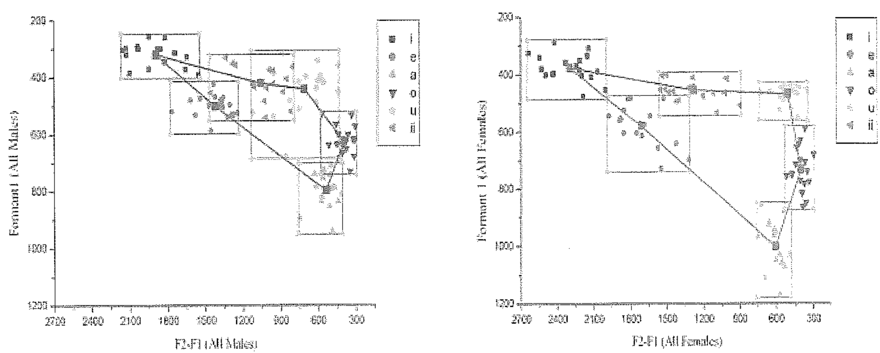
4. Results and Discussion

This section will present the results obtained from the measurement of the collected speech materials. For a well-organized exploration of the vowel pattern in TSH, the discussion is further divided into three sections: (a) the pattern of the monophthongs (i.e., V), (b) the vowel pattern in GV and VG, and (c) the vowel pattern in VN and VT. The systematicity and variability of the vowel pattern can be observed through visual displays of formant values, with F_1 plotted on the ordinate (the vertical axis) against F_2-F_1 on the abscissa (the horizontal axis). At the end of this section is a summary of the major findings of this study.

4.1 The Vowel Pattern of the Monophthongs

To manifest the systematicity of vowels in TSH, the pattern of the monophthongs functions as a good point of departure. The formant charts in (6) illustrate the patterns of the monophthongs produced by males and females.

(6) a. Males' [i, e, a, o, u, ɨ] b. Females' [i, e, a, o, u, ɨ]



On the basis of (6), each vowel takes up some specific acoustic space, as marked by squares.[8] The vowels produced by either males or females roughly correspond to the traditional description of vowels in TSH. Yet,

[8] The four angles of every square are marked by the collected maximal and minimal values of F_1 and F_2-F_1 of each vowel (i.e., [F_2-F_1^{Max}, F_1^{Min}], [F_2-F_1^{Max}, F_1^{Max}], [F_2-F_1^{Min}, F_1^{Max}] and [F_2-F_1^{Min}, F_1^{Min}]).

several explanations are called for. First, as argued in Ladefoged (2001), vowels specified as [+high] may not be equally high in real articulation. This claim is well-captured in (6) because front vowels [i, e] have higher tongue positions than their corresponding back vowels [u, o].[9] Next, as compared with females, males show more acoustic diversity in [u], with much space overlapping with [ɨ]. Third, the apical vowel [ɨ] appears as a central vowel in either gender.

In addition, mutual comparison between (6a) and (6b) gives rise to several issues. First, males' vowel space is smaller than females'. This responds to the general view in the literature (Childers and Wu 1991; Peterson and Barney 1952; Singh and Murry 1978; Titze 1989; Wu and Childers 1991) that men's and women's vowel spaces differ, with the former smaller than the latter. Next, males' comparatively small vowel space makes their vowels more congregate, and gives rise to many space overlaps in vowel pairs, like [e-ɨ], [ɨ-u] and [u-o]. This helps account for why males' speech production was sometimes not as clear as females' in the sessions of speech recordings. Third, there is a tendency that back and non-back vowels vary their positions in different articulatory dimensions. Non-back vowels display more variability in the front/back dimension (i.e., tongue backness), while back vowels in the high/low dimension (i.e., tongue height). The positional variability is attributed to the physiological limitation of the vocal tract. Compared with back vowels, non-back ones have more space ahead for the tongue to stretch. In contrast, back vowels, being restrictive to the back of the vocal tract, can only shift their tongue positions up and down along the high/low dimension.[10]

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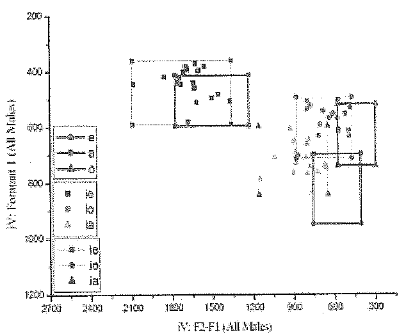
9 About this issue, also see de Boer (2010) for related discussion.

10 Readers might bear a question in mind. This study took the factor of age into account, but the effect of age on vowels was not discussed at all. In fact, the laminal vowels [i, e, a, o, u] are the most common and unmarked vowels across languages, so they may be expected to undergo less

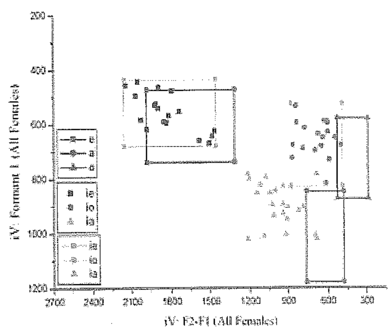
4.2 The Vowel Pattern in GV and VG

After the scrutiny of the pattern of the monophthongs in TSH, we should move to the vowel pattern in GV and VG, and identify how the vowel pattern varies under the influence of onglides and offglides. The formant charts in (7) and (8) show [ie, ia, io] and [ui, ue, ua] respectively. The acoustic space for every monophthong is marked by the thick-line square (wine color for males and olive color for females). The thin-line square is used to mark the acoustic space for the corresponding vowel after [i] and [u].

(7) a. Males' [ie, io, ia]

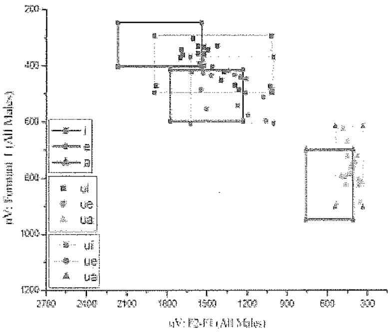


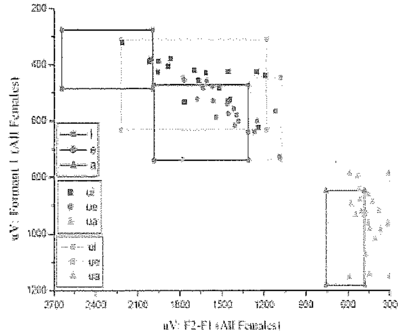
b. Females' [ie, io, ia]



change. However, the apical vowel [ɨ] actually varies with speakers' age. More specifically, [ɨ] varies gradually in the direction to [i]. The younger the speaker is, the greater approximation of [ɨ] to [i]. For more details, please refer to Cheng (2010).

(8) a. Males' [ui, ue, ua] b. Females' [ui, ue, ua]

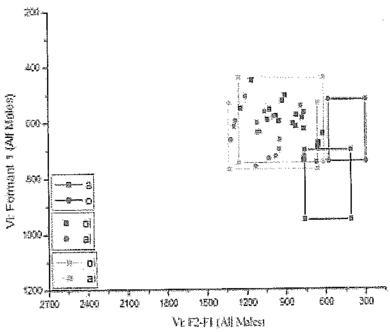




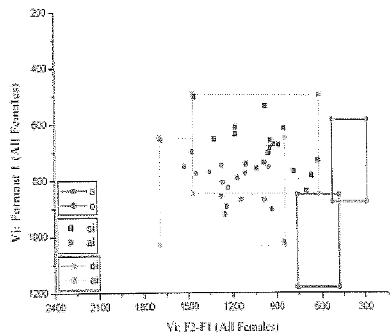
Traditionally, [i] is a high front vowel, and [u] is a high back vowel. It can be predicted that [i] and [u] will bring their intrinsic articulatory properties (i.e., front, back and high) to the vowels that directly follow them. This prediction is certified in (7) and (8). In (7), vowels following [i] undergo "tensing" (i.e., fronting and raising). Yet, in either gender, the degree of tensing is much stronger in back vowels than in front vowels. Physiologically, there is more space ahead of back vowels than front ones, so the tensing effect is much easier to emerge in [u, o] than [e]. As far as [ui], [ue] and [ua] are concerned, [u] tends to back [i, e, a] and raises [e, a]. However, [i] is lowered in [ui] in both genders. Moreover, [u] exhibits the "backing" influence upon front vowels more than on back vowels. To be specific, under the effect of the onglide [u], the more advanced a vowel is, the more retractive it will be.

The discussion about the vowel pattern in GV demonstrates that [i, u] makes the following vowels change systematically. Now, let us move to the vowel pattern in VG. The formant charts of [oi, ai] and [iu, eu, au] of both genders are displayed in (9) and (10). Like the onglides, the offglides also exhibit the same variability effect (i.e., tensing and backing) on the preceding vowels.

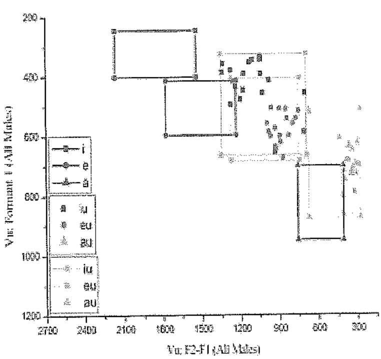
(9) a. Males' [oi, ai]



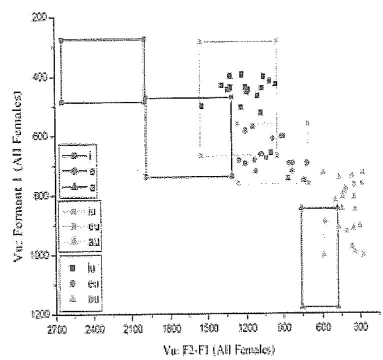
b. Females' [oi, ai]



(10) a. Males' [iu, eu, au]



b. Females' [iu, eu, au]



More interestingly, close observation of the formant charts in (7-10) illustrates a great difference between onglides and offglides. Specifically, the offglides show a far stronger degree of variability to vowels than the onglides. A similar finding was also reported in Shi (2008a).[11] Besides,

[11] Our study differed from Shi (2008a) in two aspects. First, he stated that the glide [i] in Beijing Mandarin would advance and lower its surrounding vowels. However, the phenomenon that

the different phonetic behaviors between onglides and offglides also give direct support to the traditional syllable structure among Chinese dialects (CGVX), where the offglides and the nucleus vowels form a subsyllabic constituent and have an intimate relation with each other.[12]

4.3 The Vowel Pattern in VN and VT

So far, we have discussed the vowel pattern in GV and VG. This section will focus on the vowel pattern in VN and VT. It is well-known that Hakka preserves plenty of linguistic characteristics descending from Middle Chinese, one of which is the total maintenance of the consonantal codas [-m, -n, -ŋ] and [-p, -t, -k]. However, most of the previous studies were devoted to historical comparison and phonological analysis of these codas.[13] Acoustic or experimental analyses were extremely few, much less their variability effects on vowels.

Prior to detailed discussion about the vowel pattern in VN and VT, some predictions can be made. First of all, according to Clements (1991), who has argued for the similarity between consonantal and vocalic place features, vowels and consonants could be defined through the same set of articulators.[14] For example, front vowels are implemented by the coronal articulator, and back vowels by the dorsal articulator. In view of this, [n, t]

vowels were lowered before or after [i] was not observed in our study. Second, he also indicated that onglides and offglides realized their coarticulation effects in different dimensions. Onglides function in the front/back dimension more than in the high/low dimension, whereas offglides take the reverse. Apparently, he desired to integrate phonetics and phonology, and established a link between articulatory dimensions and syllabic positions. Unfortunately, such a link failed to be established in our study. In fact, it is the intrinsic articulatory properties of the glides, rather than their syllabic positions, that play a role in the coarticulation influence on the surrounding vowels.

12 In terms of the syllable structure in Chinese phonology, the nuclei and postvocalic segments (glides or consonants) form a subsyllabic constituent, called *Rime*. Syllable rimes are further combined with the onglides to form another larger subsyllabic constituent, called *Final*.

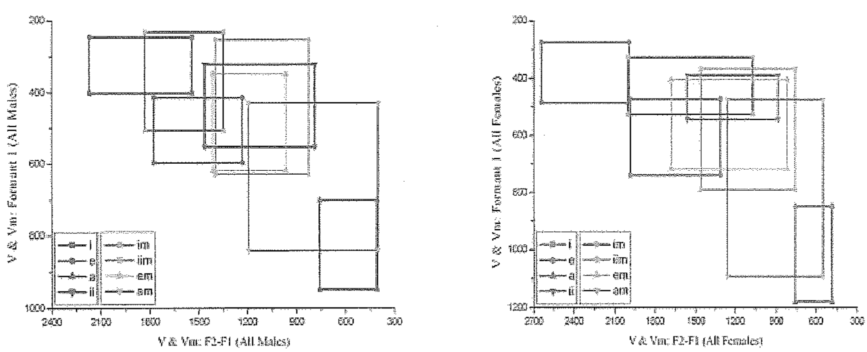
13 For a more detailed account of the related literature, please refer to Chapter 3 of Chung (2004).

14 For more discussion of the synthesis of V-Place and C-Place features, see Kenstowicz (1994).

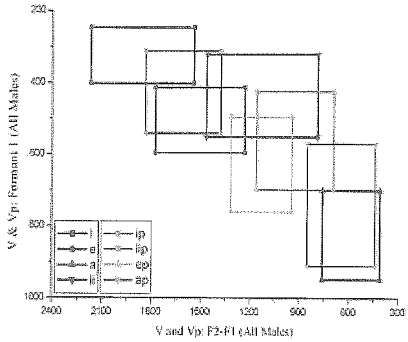
and [ŋ, k] are predicted to pattern with [i] and [u]. To be specific, [n, t] will tense the vowels, and [ŋ, k] will back the vowels. Second, to my knowledge, little is known of how the [m, p] codas affect the vowels. On account of the bilabial place of articulation of [m, p], vowels are predicted to be centralized. Now, let us explore whether the two predictions can be confirmed.

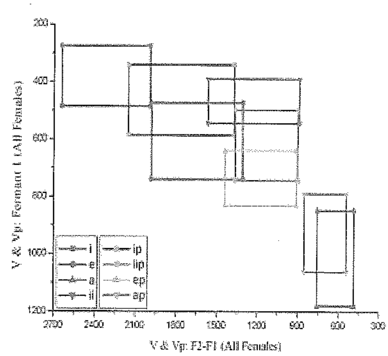
The formant charts in (11) and (12) show the acoustic space of the vowels before [m, p]. Obviously, front vowels and back vowels are all centralized in either gender. This directly supports the prediction. Another support comes from the central vowel [ɨ]. When compared with [i, e, a], the apical vowel [ɨ] remains stable around the center in the front/back dimension, even though it expands its distribution in the upper high/low dimension.

(11) a. Males' [im, em, am, ɨm] b. Females' [im, em, am, ɨm]



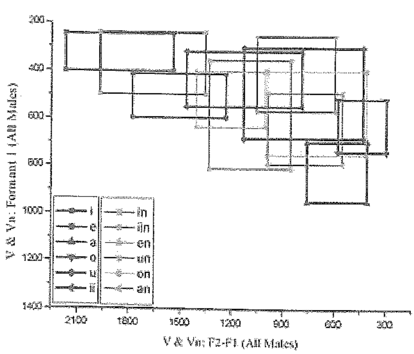
(12) a. Males' [ip, ep, ap, ɨp] b. Females' [ip, ep, ap, ɨp]

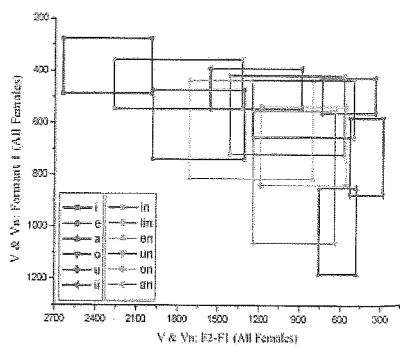




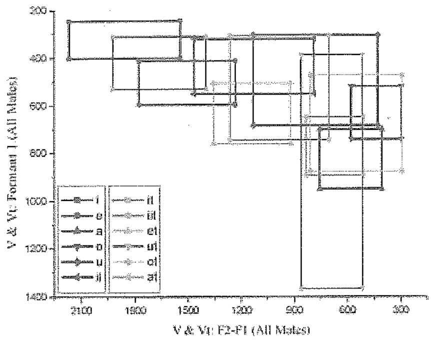
Next, how is the variability of the vowels when before [n, t] and [ŋ, k]? Can the previous prediction gain acoustic support again? To answer this question, let us first take a look at the formant charts in (13) and (14).

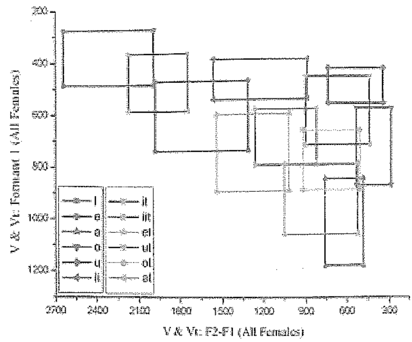
(13) a. Males' [in, en, an, on, un, ɨn] b. Females' [in, en, an, on, un, ɨn]





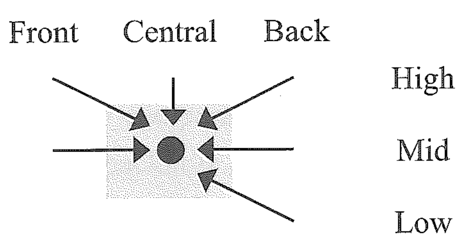
(14) a. Males' [it, et, at, ot, ut, ɨt] b. Females' [it, et, at, ot, ut, ɨt]



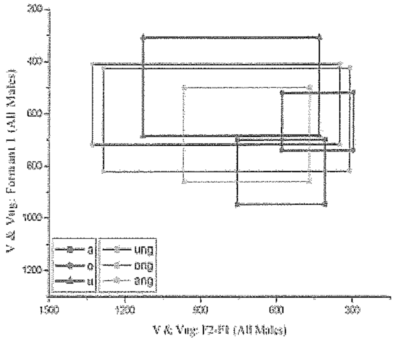


According to (13) and (14), the vowels before [n, t] do not vary in the expected direction. More specifically, the [n, t] codas do not pattern with [i] to tense the vowels. Several back vowels (e.g., [a] and [o]) apparently undergo a certain degree of tensing, but the tongue positions of the non-back vowels uniformly become low and/or back. Noteworthily, a remarkable finding will surface if we center on the overall pattern of the vowels before [n, t]. Similar to [m, p], [n, t] also introduces a centralizing effect to their preceding vowels. To be specific, the vowels before [n, t] seem to converge toward a central gathering area, as shown in (15).

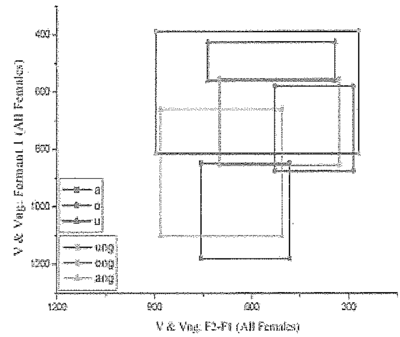
(15)



(16) a. Males' [uŋ, oŋ, aŋ]



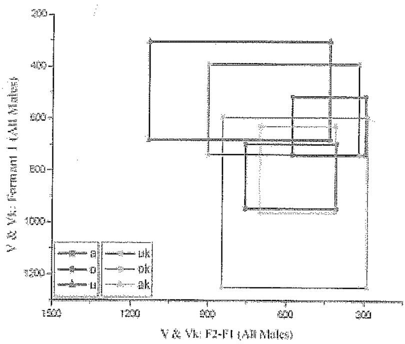
b. Females' [uŋ, oŋ, aŋ]

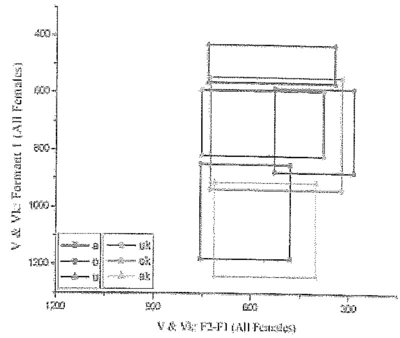


The same variability effect is also observed from the vowel pattern in [Vŋ], as in (16). The [ŋ] coda makes the vowels front and central. To illustrate, [a] is raised in the upper left direction; [u] moves in the lower left direction. The pattern of [o] is moved leftward horizontally. Moreover, the acoustic space of the vowels before [ŋ] has been expanded leftward to a great extent. As a consequence, the prediction of the variability effect from the [n, t, ŋ] codas is not confirmed. In contrast, the most remarkable variability effect on vowels from these codas is *vowel centralization*.

Up to the present, we haven't mentioned the [k] coda. Does it display an effect of vowel centralization? Unlike other consonantal codas, the [k] coda tends to lower the preceding vowels, as in (17). Apparently, as far as the variability effect was concerned, [k] differs from [m, p, n, t, ŋ].

(17) a. Males' [uk, ok, ak] b. Females' [uk, ok, ak]





But why does [k] deviate from other consonantal codas? This can be explained from two factors: (a) the backness of the segments and (b) the types of citation tones. First of all, as previously stated, back vowels show more positional variability along the high/low dimension, so the lowering effect tends to be easily realized in back vowels. Moreover, all segments in Vŋ and Vk (i.e., [u, o, a] and [ŋ, k]) are produced in the back of the vocal tract, which definitely strengthens the lowering effect. Second, as far as the citation tones are concerned, two types exist in Hakka, checked tones and non-checked tones. Checked tones exist in syllables closed by [p, t, k]. Syllables that end with [i, u, m, n, ŋ] will be accompanied by non-checked tones. Except the difference in syllable codas, checked-tone syllables and non-checked-tone syllables differ in their syllable duration, with the former comparatively shorter than the latter. The short duration, along with the backness of [k], gives rise to a strong effect of *articulatory lowering*, by which the tongue positions of the vowels will be positioned lower than their normal positions. For illustration, when [a, aŋ, ak] are pronounced successively, it can be experienced that the tongue positions are lowered successively from [a], via [aŋ], to [ak]. Both [aŋ] and [ak] demonstrate articulatory lowering, but the lowering effect is stronger in the latter than in the former because of the extra lowering effect coming from the checked tones. In fact, besides [ŋ, k], other consonantal codas, more or less, display the lowering effect on vowels. The strength of the articulatory lowering can be illustrated by (18).

(18)

Rimes	Vm	Vp	Vn	Vt	Vŋ	Vk
Backness	–	–	–	–	+	+
Checked Tone	–	+	–	+	–	+
Degree of Lowering	*	**	*	**	**	***

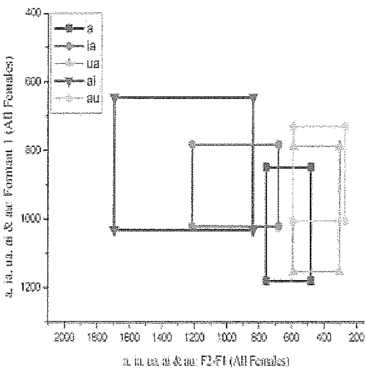
When compared with the tongue positions of the monophthongs, all consonantal codas introduce a certain degree of articulatory lowering to the preceding vowels, so all rimes in (18) will have, at least, one asterisk to represent the basic degree of articulatory lowering, in line with the notational system utilized in English rhythm (Halle and Vergnaud 1987; Kenstowicz 1994; Liberman 1975).[15] Besides, every + will give one more asterisk to articulatory lowering, and, therefore, more asterisks will exhibit a stronger lowering effect. Based on (18), a ranking hierarchy of articulatory lowering exists among these rimes, that is, Vk > Vp, Vt, Vŋ > Vm, Vn. The number of asterisks in (18) helps explain why the tongue positions of the vowels before [p, t, k] are uniformly lower than those of the vowels before [m, n, ŋ], and why [k] deviates from other consonantal codas in the variability effect on vowels (i.e., lowering vs. centralization).

[15] By Stress Rule, every vowel has a basic degree of sonority, and will be assigned one asterisk. When vowels are further stressed (e.g., word stress or sentential stress), more asterisks will be assigned.

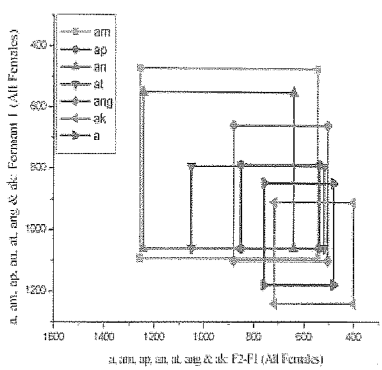
4.4 Summary

This section will make a summary about the main findings in this study. To embody the systematicity and variability of the vowel pattern in Taiwan Sixian Hakka, the formant charts of [a, ia, ua, ai, au, am, ap, an, at, aŋ, ak] in (19), articulated by the females, are adopted to exemplify the following recapitulation.

(19) a. [a, ia, ua, ai, au]



b. [a, am, ap, an, at, aŋ, ak]



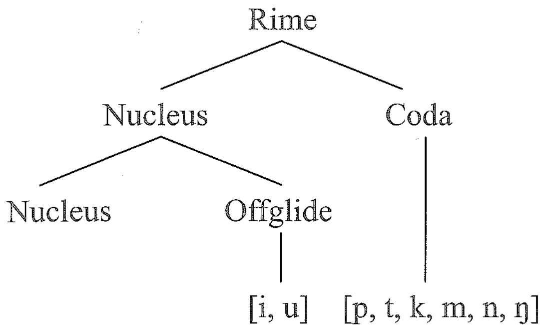
In terms of GV and VG, the intrinsic articulatory characteristics of these glides function greatly in the variability of the vowel pattern. To be specific, [i] will tense the vowels, and [u] will back and/or raise the vowels, as shown in (19a). In addition, offglides perform a much stronger variability influence on vowels than onglides. In terms of VT and VN, all consonantal codas, except for [k], tend to centralize the vowels preceding them. Because of its articulatory backness and existence in checked-tone syllables, [k] lowers the pattern of its preceding vowels. The comparison of the different articulatory influences between [k] and other consonantal codas is displayed in (19b).

Up to now, the findings of this study also lead to several insights that deserve our attention. First, all previous charts seem to show a tendency that postvocalic segments have a stronger variability influence on vowels than prevocalic glides, giving direct support to the traditional syllable structure, CGVX, in Chinese phonology, where the structural relation between V and X is far closer than that between G and V. Second, though [i, n, t,] and [u, ŋ, k] are assumed to be articulatorily implemented by the same articulators, they shown different phonetic influences on vowels on account of their intrinsic articulatory differences (vocoids vs. contoids). In the production of GV and VG, [i] and [u] cause the tongue to glide from one position to another, but no gliding is observed in the production of VN and VT.

Third, offglides and consonantal codas have different phonological behaviors when combined with vowels. For instance, V and G can not have the same specification on the [back] feature, while V and N/T can, so [ou] and [ei] are unacceptable rimes, but [im, ip, in, it, un, ut, uŋ, uk] are legal (Chung 2004).[16] These different phonological behaviors suggest that offglides and consonantal codas take up different syllable positions (Chung 1989a, 1989b, 1990). VG forms a branching nucleus, whereas VN and VT constitute a branching rime, as shown in (20). Given the phonetic result of the differences between VG and VN/VT, the syllable structure in (20) is also empirically supported.

[16] According to Chung (2004), as far as the [back] feature is concerned, nasals (as well as oral stops) in Hakka are assigned different feature values. Specifically, [m, p] and [ŋ, k] are specified as [-back] and [+back] respectively, while [n, t] are unspecified for the [back] feature.

(20) The Syllable Structure of Hakka



Finally, after de Saussure's (1959) division of *langue* and *parole*, phonetics and phonology have become two independent linguistic fields. The combination of these two fields is the current trend in linguistics, but how to integrate the gradient phonetics and the categorical phonology closely still requires plenty of constant endeavors. Obviously, this study contributes a lot to the integration between phonetics and phonology.

5. Conclusion

This study is dedicated to the vowel pattern in Taiwan Sixian Hakka, and explores the systematicity and variability among these vowels. There is no denying that variability shows in the vowel pattern, but variability is not chaotic but systematic. Onglides and offglides manifest their intrinsic articulatory characteristics on surrounding vowels, with the latter much stronger than the former. Consonantal codas, except [k], tend to centralize preceding vowels. All these findings, no doubt, reflect a central concept in modern linguistics, an orderly heterogeneity (Weinreich et al. 1968).

This study also shows several other issues worthy for sociolinguistic studies in the future. In the beginning, vowels are active in linguistic changes, but this study centers only on the patterns of the monophthongs without paying attention to those of diphthongs. Hence, little is known about whether diphthongs in TSH are changed, and, if yes, whether these changes have similar social meanings as shown in Labov's (2001) study of the vowel system in Philadelphia. Next, in addition to age and gender, there are still a great number of other social factors that should be taken into consideration, like subjects' career, socioeconomic status, social class, education background, and the like. An extensive understanding of the Hakka vowel changes calls for a full-scale survey that takes all the factors and their interaction into concern. Third, this study adopted list-reading to collect data, a way that generates the most formal speech samples. Future research can make use of other flexible methods to gather speech samples, such as article-reading, conversation, causal speech, and so forth. In this way, more informal speech data may be helpful to reveal more interesting and meaningful findings related to vowel changes. Forth, it has been 50 years since sociolinguistics first appeared in the 1960s, but sociolinguistic application into the studies of Taiwan language is comparatively fewer than formal research. It is in the hope that more research efforts can be devoted to this field. Finally, further studies are suggested to utilize vowel normalization through which vowels in different Hakka varieties can be easily compared, and vowel changes can also be observed with ease.

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