CHAPTER 7

The Phonetics of Formosan Languages

Yu-An Lu and Kristine M. Yu

 | DOI:10.1163/_005

7.1 Introduction

While a sizeable body of literature has documented and analyzed the phonological and morpho-syntactic characteristics of Formosan languages, phonetic descriptions of these endangered languages are relatively scarce, and few of these phonetic studies have involved instrumental investigations. This chapter provid[illegible] comprehensive review of each of the major languages described in Chapte[illegible] ncluding phonetic characterizations of vowels, consonants, and word prominence, with the goal of identifying areas awaiting further research. Each section presents one language, and the sections are arranged in alphabetical order.

Although the phonetic studies reviewed in this chapter were not conducted on the same bases, each with its own research goals and methods, our aim is to make generalizations across these Formosan languages, including ones about the dispersion of vowels according to the size of vowel inventory (Amis, Seediq), speakers' characteristics, and adjacent consonants (Atayal, Saisiyat), and realization of word-level prominence. These generalizations are discussed in § 7.16.

We reproduce the phonetic plots from previous works using comparable scales across languages, based on the raw data either provided by the original studies or extracted from the original figures using WebPlotDigitizer (Rohatgi 2017). For comparability, we present all vowel space plots with logarithmically-scaled axes to approximate auditory vowel space (Calamai 2005), even if in some cases the original plot from previous literature was linearly scaled. We address the gaps in the literature regarding vowels and word-level prominence by conducting exploratory acoustic analyses using data extracted from the online dictionaries of Indigenous languages (henceforth e-dictionaries). We alternatively "stress" or "pitch accent" if the studies being reported committed to these t s; "word-level prominence" is otherwise used to stay non-committal to the phonological status of these languages (also see discussion in § 8.5 (H. Huang this handbook)). Tokens from e-dictionaries are described as having penult or final stress, under the assumption of a linking hypothesis that a stressed syllable has higher F0 than an unstressed one when uttered in isolation in a declarative. We provide only F0 information to describe word-level prominence, as intensity may be affected by recording quality and background noise, and duration may be affected by final lengthening and other boundary effects in the elicitation. The F0 contours were obtained using the Straight algorithm in VoiceSauce (Kawahara et al. 2008, Shue et al. 2011). Mean F0 values were computed over each of 10 equally spaced time slices from each syllable, as well as from each onset+nucleus and coda within CVC syllables. Formants were computed using the Burg algorithm with the default settings in Praat (Boersma & Weenink 2017). All figures were produced using the ggplot2 package (Wickham 2016) in R (R Core Team 2017). The extracted data, scripts, and output files used in both our literature review and our analyses of the e-dictionary data can all be found in the OSF repository at https://osf.io/w9u67/.

7.2 Amis

Central Amis has four vowels /i a u ə/ and eighteen consonants /p t k ʔ ʔ ts m n ŋ v s (ɣ) ʜ r ɮ l w j/, though the velar fricative only occurs in a few loanwords (Maddieson & Wright 1995). Stress is described as invariably falling on the final syllable (Maddieson & Wright 1995; J. Wu 2018, p. 15).

7.2.1 *Amis Vowels*

Maddieson & Wright (1995) recorded a small group of speakers from the Central dialects of Amis (spoken in Kangko and Fengbin, also referred to as Makota'ay and Kakacawan dialects by Tsuchida (1982)) who produced 54 words with

identical penultimate and final vowels surrounding the full range of consonants (e.g., [siriʔ] 'goat', [mataʔ] 'eye', [vuŋuʜ] 'head'). The first two formants (F1 and F2) of /i a u/ in the unstressed penultimate syllable and the stressed final syllable were measured (Figure 7.1). They hypothesized that, in this language with a relatively small vowel inventory, vowels may be produced with greater variation depending on whether they are in a stressed or unstressed position, and that variation may occur due to coarticulation with the adjacent consonants.

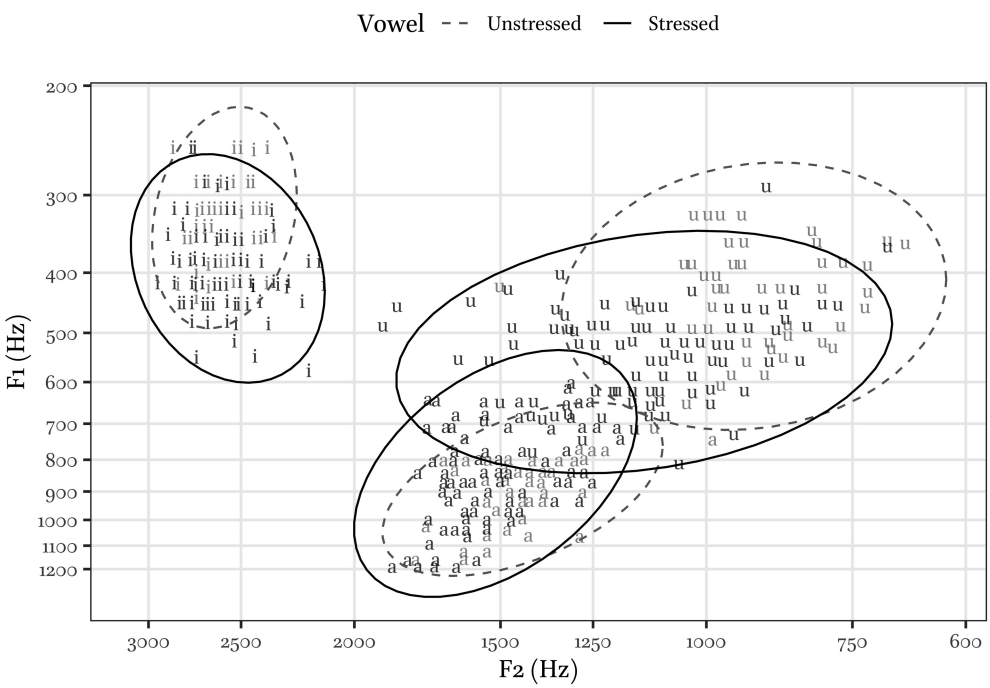

FIGURE 7.1 Amis vowel space
REPRODUCED FROM MADDIESON & WRIGHT 1995, P. 58

The results showed that the distribution stayed relatively compact and did not vary according to stress location (unstressed penult vs. stressed final) or adjacent consonants. Maddieson & Wright (1995, p. 63) concluded that "... despite possessing a small vowel inventory, Amis characteristically displays rather weak coarticulatory effects of consonants on the steady states of adjoining vowels." A similar research question was asked by W. Chiang & F. Chiang (2005b), in which they investigated the vowel space of Truku, a dialect of Seediq, that may have 3 (/i u a/), 4 (/i u a o/), or 5 (/i u a e o/) perceptually distinct vowels in the inventory, depending on the speaker (§ 7.13.1).

7.2.2 *Amis Consonants*

Two noteworthy characteristics of Amis consonants have been identified in the literature: a two-way rhotic contrast (Maddieson & Wright 1995) and glottal and epiglottal/pharyngeal contrasts (Edmondson et al. 2005, Maddieson & Wright 1995).

Amis contrasts two rhotics: an alveolar trill /r/ and a lateral flap /ɺ/, as in the near minimal pair /paro/ 'contain' vs. /paɺa/ 'field'/. Maddieson & Wright (1995) used spectrograms to illustrate that both sounds are characterized by a dipping third formant (F3, marked with solid arrows); however, the trill /r/ is typically produced with two or three contacts (Figure 7.2 right, marked with arrowheads), while the lateral flap /ɺ/ only involves a single short closure (Figure 7.2 left).

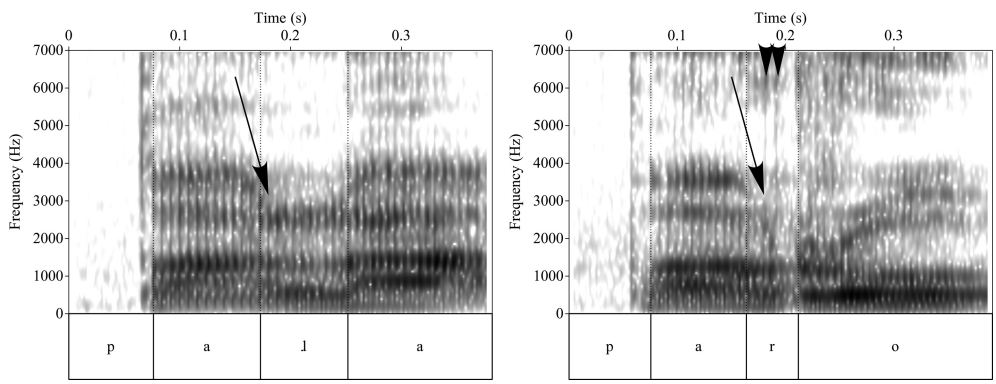

FIGURE 7.2 Rhotic contrasts in Amis: /paɺa/ 'field' (left) and /paro/ 'contain' (right)
THE SOUND FILES WERE OBTAINED FROM THE AMIS E-DICTIONARY

In a laryngoscopic study, Edmondson et al. (2005) examined activity in the lower throat to characterize glottal and epiglottal contrasts in Central Amis. They found that [ʔ], a "moderate" glottal stop, is not lexically represented but is inserted to "wrap" onset-less or coda-less syllables (e.g., *ina* [ʔinaʔ] 'mother', *kaen* [kaʔən] eat', *roma* [romaʔ] 'other'). The epiglottal stop, however, is lexically represented and is realized as [ʔ] in onset position (e.g., [ʔikoŋ] 'to bend') but as an aryepiglotto-epiglottal stop [Ꝛʜ] in word-final position (e.g., [ririꝚʜ] 'grasshopper'). They also found a parallel three-way difference in fricatives and proposed that the glottal fricative /h/ contrasts with the epiglottal fricative /ʜ/, which also has two variants: intervocalic [ʜ] and word-final [ʜħ]. The word-final variants, [Ꝛʜ] and [ʜħ] are articulatorily strengthened to /ʔ/ and /ʜ/, presumably due to final stress.

7.2.3 *Amis Word-Level Prominence*

To date, no instrumental studies have been conducted on word-level prominence in Amis. To begin to fill this gap, we examined recordings from the Amis e-dictionary of isolated C1VC2V(C3) bisyllabic words in which C1 and C2 were restricted to sonorants (/l m n ŋ w y/) to avoid segmental perturbation of the F0 contour. C3 was left unrestricted so we could examine the effect of syllable structure on the F0 contour of the stressed final syllable. Of the 77 tokens that fit these criteria, only two had penultimate stress (*lolo* 'three'/'purple'; *nima* 'five'); otherwise, stress was on the final syllable. Furthermore, patterns of F0 conditioned by the segmental make-up of the stressed syllable have been reported independently by different researchers in Puyuma (§ 7.9.3) and Saisiyat (§ 7.12.2). Two perceptually identifiable pitch movement patterns were agreed upon by the authors: for the 75 tokens with final stress, the F0 contours over the penultimate syllables were consistently low (first sections in Figure 7.3 labeled as C1V1), while the F0 contours of the stressed final syllable were either characterized as high level, sometimes with a slight fall (27 tokens) or sharp falling (48 tokens). Mean F0 contours are plotted in Figure 7.3, conditioned by syllable structure. Ribbons indicate ±1 SE about the mean, "S" stands for a sonorant consonant, and "O" stands for obstruent consonant. 6 tokens from a speaker with a very low f0 range and poor F0 tracking were excluded from the plot, and 1 CVCVS token which was pronounced with a glottal stop between the first and second syllables was also excluded due to the resulting perturbation to the F0 contour.

One important caveat must be mentioned: we do not know how recordings in the Amis e-dictionary were elicited, so it is possible that the F0 contours of the isolated words were influenced by phrase-final boundary tones or discourse context. There is also no information on the speakers in the database, so we cannot be certain how many speakers made the recordings we analyzed. Nevertheless, we found systematic correlations between the syllable structure and the perceived pitch movement on the last syllable. Namely, among the tokens ending with a sonorant coda, 31/32 were classified as having a falling pitch in the final syllable, and only one token was classified as high level. In contrast, a minority of tokens classified with falling pitch (17/48) ended with a phonetic glottal stop or word-final obstruent. Among the 43 tokens not ending with a sonorant coda, 26 were classified with high level pitch in the final syllable: 10/27 of these ended with a phonetic glottal stop and 16/27 with a word-final obstruent coda. Similar patterns of F0 conditioned by the segmental make-up of the stressed syllable have been reported in Puyuma (§ 7.9.3) and Saisiyat (§ 7.12.2).

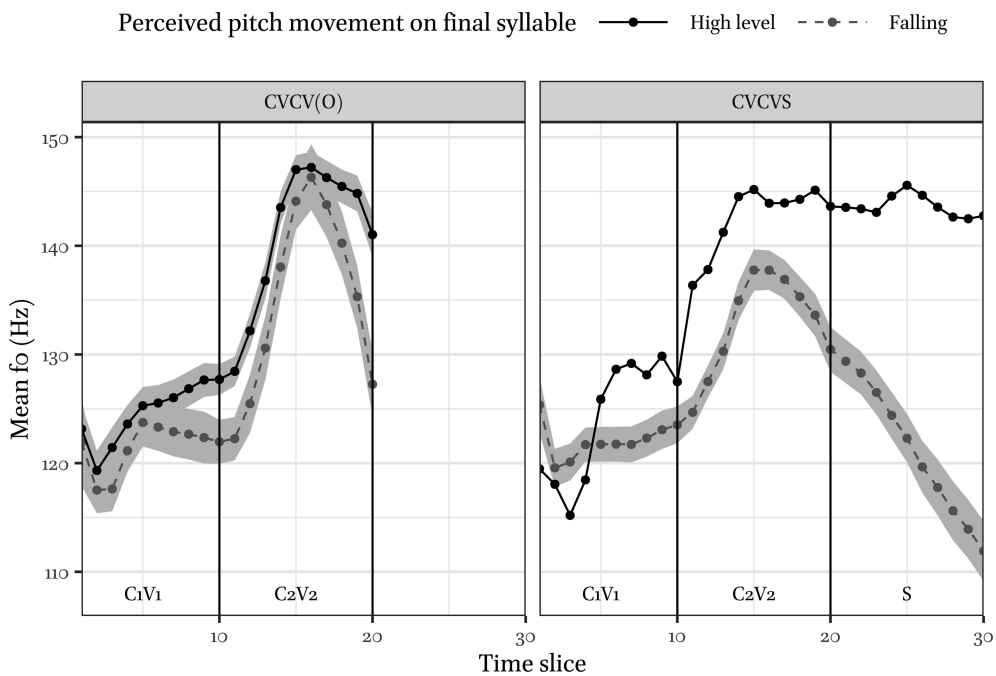

FIGURE 7.3 Amis word-level prominence
DATA OBTAINED FROM THE AMIS E-DICTIONARY

7.2.4 *Other Processes*

An emphatic process in Siwkolan Amis (also a variety of the Central dialect) has been identified whereby the consonant or vowel of the penultimate syllable of a stative verb is lengthened to show expressive intensification or contrast to one's expectation. Acoustic studies on emphasis in Amis (Hsin-yi Chen 2019) have revealed that 1) the consonants or vowels in the emphatic penultimate syllables were longer than their non-emphatic counterparts, 2) the emphatic syllables were also found to carry a rising F0 contour, comparable or even higher than the stressed final syllable, and 3) the voice quality of emphatic syllables differed from the non-emphatic ones, with spectral measures H1-H2, H1-A3, and H1-A1 lower in the emphatic syllables than in the non-emphatic ones. In an AXB identification task in which the duration of the penultimate consonants/vowels and F0 were manipulated, Y. Chang et al. (2019) showed that native Amis speakers were more sensitive to F0 peaks in the consonant-lengthening emphatic process, while both duration and F0 cues were reliably distinguished in the vowel-lengthening emphatic process. They concluded that vowel lengthening is the default emphatic form while consonant lengthening is more marked and is mainly used to signal a speaker's surprise. This finding

echoes those in other languages (e.g., Finnish, Basque, and Latin) in which consonant lengthening (or "expressive gemination") was also found for expressive purposes (Martinet 1937, Rivierre 2001).

7.3 Atayal

The Squliq dialect has 19 consonants /p t k q ʔ ts(ʃ z) x ɣ h m n ŋ r l w j/. Li (1980) reported a five-vowel inventory and the addition of /z/ in the consonant inventory for the Squliq dialect while Lu (2005, p. 22) reported a three-vowel inventory (see more discussion in § 7.3.1) and the lack of /z/ for Mayrinax. Stress in Atayal falls mainly on the final syllable (L. Huang & Hayung 2018, p. 16).

7.3.1 *Atayal Vowels*

Based on data collected from a small number of Squliq Atayal (Wufeng Township) and Mayrinax Atayal speakers (Tai'an Township), Y. Chang (2011) reported that /i/ and /u/ were produced as [e] and [o] when adjacent to /q h/, under a three-vowel phonemic analysis (/i a u/ as phonemic and [e, o] as allophones). Results showed that the formant transitions of /i u/ following /q h/ to a steady state were about 1.5 times longer than /i u/ following other consonant environments. During this transition, F1 values were higher while F2 values were lower compared to /i, u/ in other consonantal environments. During the steady state of the vowel, however, the spectral information did not differ across consonantal environments. Figure 7.4 shows the vowel data produced in h/qV context (grey) and in other context (black) provided in the study (it was not clear whether these vowels were produced by a single speaker or by multiple speakers), with formants measured at the vowel midpoint.

Y. Chang (2011) also conducted perceptual experiments in which ten Squliq Atayal listeners were asked to discriminate [i, e] and [u, o] embedded as a final vowel in CVCV stimuli and to rate how good these tokens were in their language. Four of the ten listeners performed at below-chance levels in discriminability, and discriminability was shown to decrease when the vowels followed the coarticulated environment /h/. Overall, listeners judged high vowels to be better sounds in their language than mid vowels. These results indicate that [e] and [o] may be allophones of /i/ and /u/ rather than emerging phonemes.

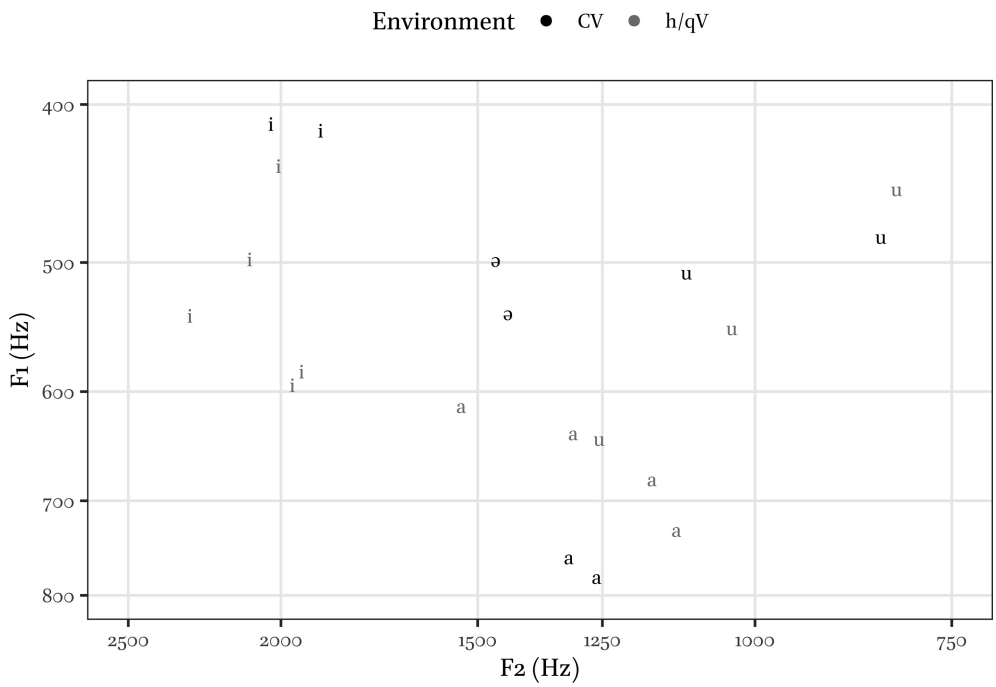

FIGURE 7.4 Atayal vowel space
REPRODUCED FROM Y. CHANG 2011, P. 4

7.3.2 *Other Processes*

C.P. Shih (2008) documented the interrogative intonation of four Plngawan Atayal (C'uli' dialect) speakers from Wanda, Wushe, Puli and Qin-ai Townships. Four types of questions were identified: yes-no, tag, alternative, and information questions.

Yes-no questions were realized using either a typical declarative intonation (final falling) with the high-toned sentence-initial question particle *ya'* or with a final rising-falling contour without the particle. Figure 7.5 shows the F0 contours of a declarative sentence (1a) and a yes-no question (1b). The rising-falling contour in (1b) was realized on the final stressed syllable *was*. The *ya'* yes-no questions (1c) displayed sentence-final F0 contours similar to those in the declarative sentence. F0 measurement points were taken at the beginning and end of each syllable for (1a) and (1b), but at syllable midpoints for (1c).

(1) Plngawan Atayal (C.P. Shih 2008)
a. *ba'=cu* *mawas.*
know=1SG. NOM AV:sing
'I can sing.' (p. 11)

b. *ba'=cu mawas?*
know=2SG. NOM AV:sing
'Do you sing?' (p. 11)

c. *ya' s⟨un⟩kisli' mawas ka' Yuma?*
QST ⟨AV⟩like AV:sing NOM Yuma
'Does Yuma like to sing this song?' (p. 101)

Another distinct final rising contour was found for tag questions with the sentence-final *'aw* (Figure 7.5, tag question, F0 peaks measured for each syllable). In an alternative question construction in which two yes-no questions are connected, the first clause had the typical yes-no final rising-falling contour while the second had a final falling contour with the sentence-initial *ya'* particle, similar to the *ya'* yes-no contours in Figure 7.5. C.P. Shih also described the *wh*-question intonation of information questions, which ended with a high rising contour.

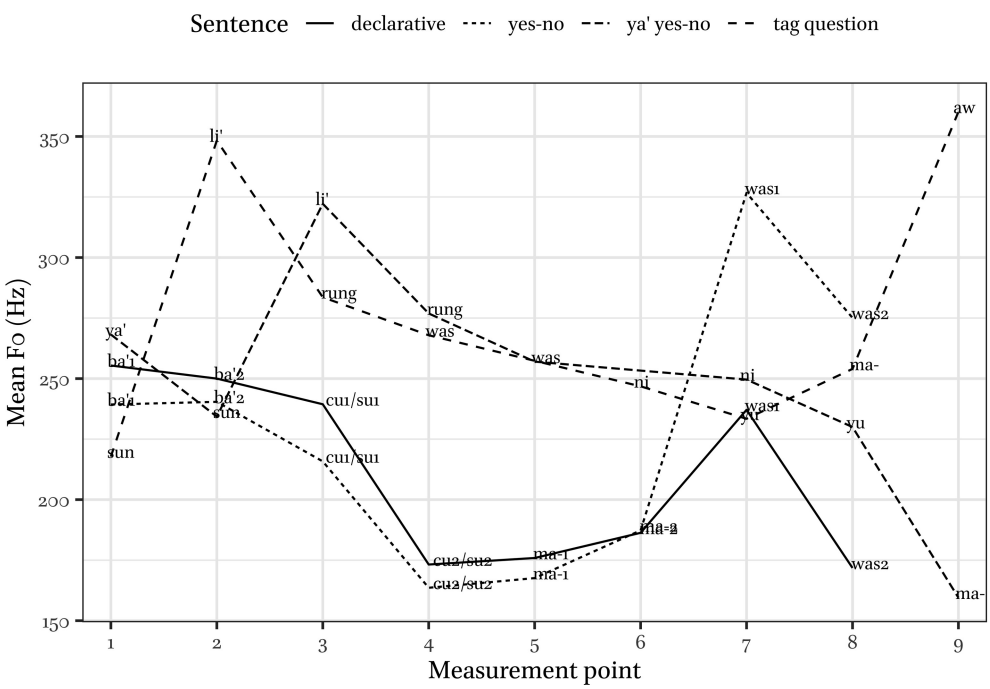

FIGURE 7.5 Plngawan Atayal question intonations
REPRODUCED FROM C.P. SHIH 2008, P. 94

7.4 Bunun

Isbukun Bunun has three vowels (/i a u/) and sixteen consonants (/p t k q ʔ b d ts v ð s h m n ŋ l/). Stress has been reported to predominantly fall on the penultimate syllable (Huang 2008, Lin 1996, Zeitoun 2000 [based on Tumpu dialect in Nantou], Yu 2009, p. 17 [based on the Isbukun dialectal variety spoken in Namasia, Kaohsiung]).

7.4.1 *Bunun Vowels*

Yu (2009) recorded 28 Isbukun Bunun speakers (14 female, 14 male) from Namasia District in Kaohsiung, producing a list of words with the three contrastive vowels /i a u/ balanced across prosodic positions (word-initial, word-medial, word-final). Mean F1 and F2 values were obtained and plotted (see Figure 7.6a). After comparing the values of the two formants from each vowel against those in Hakka, Southern Min and English, Yu (2009) concluded that the vowel spaces of these languages are similar.

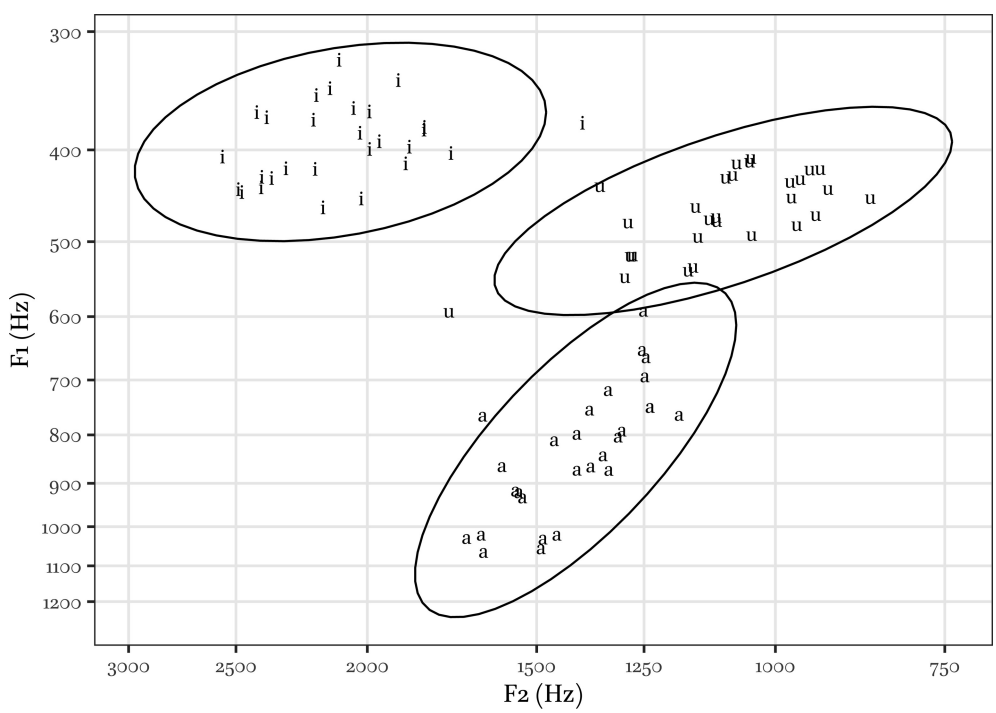

FIGURE 7.6A Isbukun Bunun vowel space
REPRODUCED FROM YU 2009, PP. 113–140

Maddieson et al. (1995) recorded 9 female speakers and 6 male speakers from Chohsi (or Zhuoxi) and Kufeng villages (Central and Southern dialects) and reported a comparable vowel space to the one in Yu (2009), as shown in Figure 7.6b. The data were estimated from the figures in Maddieson et al (1995) and are available in the online OSF repository.

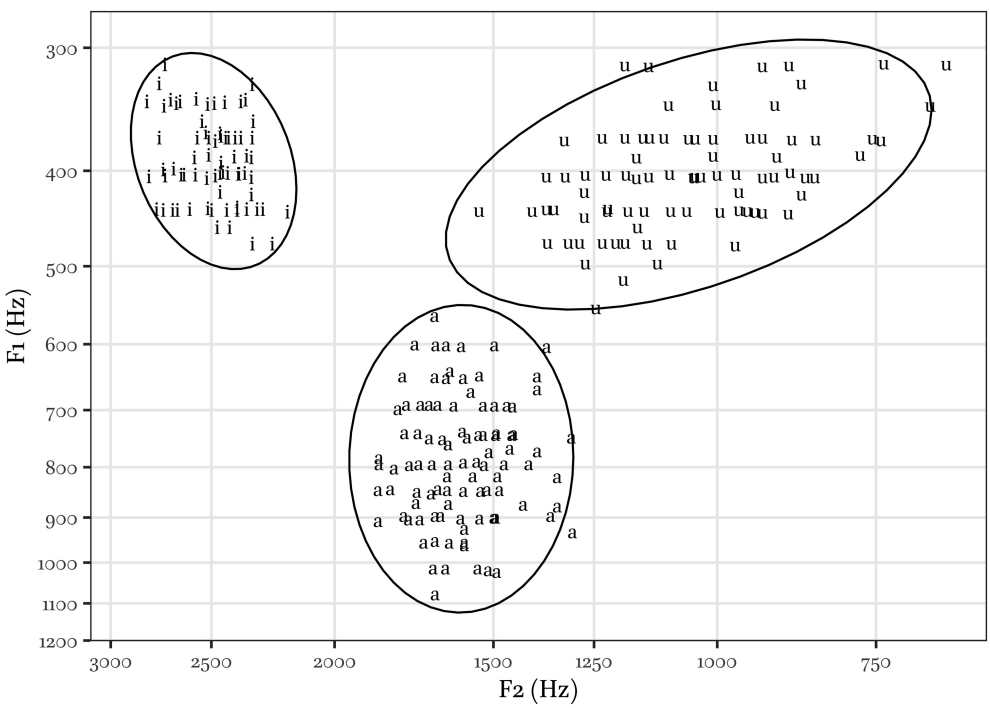

FIGURE 7.6B Central and Southern Bunun vowel space
REPRODUCED FROM MADDIESON ET AL. 1995, P. 26

7.4.2 *Bunun Consonants*

Yu (2009) recorded the same 28 Isbukun Bunun speakers producing words with one of five stops /p t k b d/ as the onset of the final or penultimate syllable. The results (Figure 7.7) showed that the contrast is best described as pre-voiced versus short-lag voice onset time (VOT). VOT also increased with more posterior places of articulation, a universally observed tendency. Acoustic analyses of fricatives and nasals were also provided.

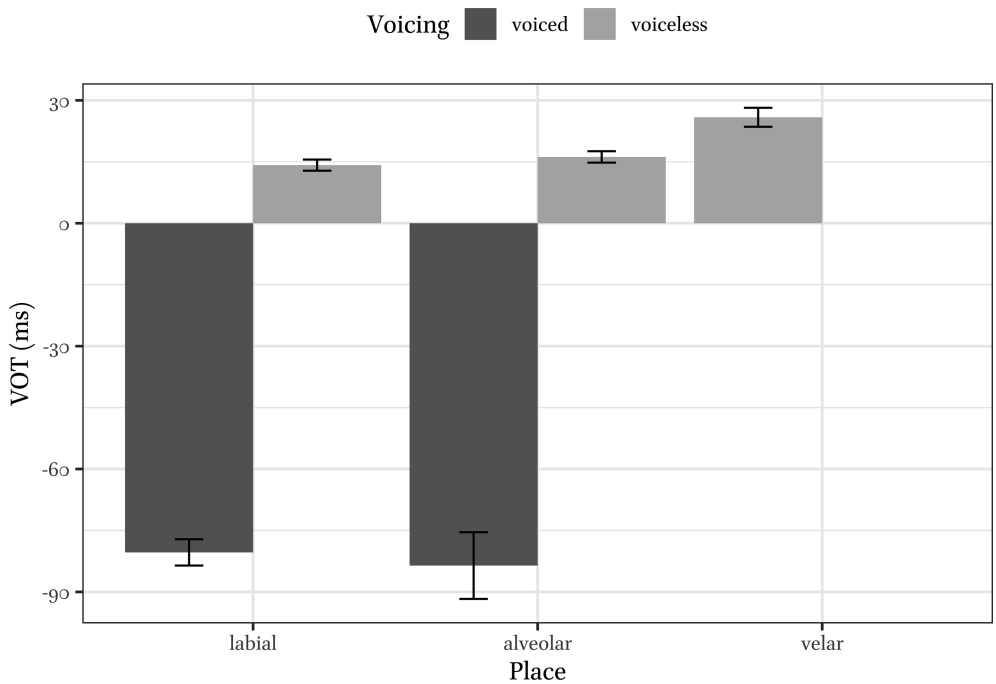

FIGURE 7.7 Isbukun Bunun stop voice onset time
REPRODUCED FROM YU 2009, PP. 113–140

Maddieson et al. (1995), recorded the same 15 Bunun speakers described above and reported similar VOT values for the voiceless stops. However, using acoustic and aerodynamic data, Maddieson et al. (1995) describe the voiced stops /b d/ as implosives /ɓ ɗ/. Variation was also observed, mainly to facilitate voicing: prenasalization was observed for /ɓ/ while lateralization was observed for /ɗ/.

7.4.3 *Bunun Word-Level Prominence*

We failed to find instrumental studies on Bunun word-level prominence and thus examined Bunun recordings in the e-dictionary of isolated words in the shape of C1VC2V(C3), in which C1 and C2 were restricted to sonorants (/l m n ŋ/) and C3 was left unrestricted, following similar selection criteria as in § 7.2.3. The resulting list of 27 Bunun tokens included words with multiple meanings (e.g., *lulu*$_1$ 'cheekbones' and *lulu*$_2$ 'wound'); each meaning variant was associated with a different recording file in the e-dictionary and were included as separate tokens. One token (*liliu* 'fly (bug)') had final stress; the remaining 26 tokens with a stressed penultimate syllable were perceived as having high level pitch on the penult. The remaining 19 were perceived as having

rising pitch on the stressed penult. Due to the small number of tokens, we show individual F0 contours in Figure 7.8 rather than the mean. There was no evidence that the category of perceived pitch movement on the penult varied systematically with syllable structure; if anything, it seemed to vary by speaker.

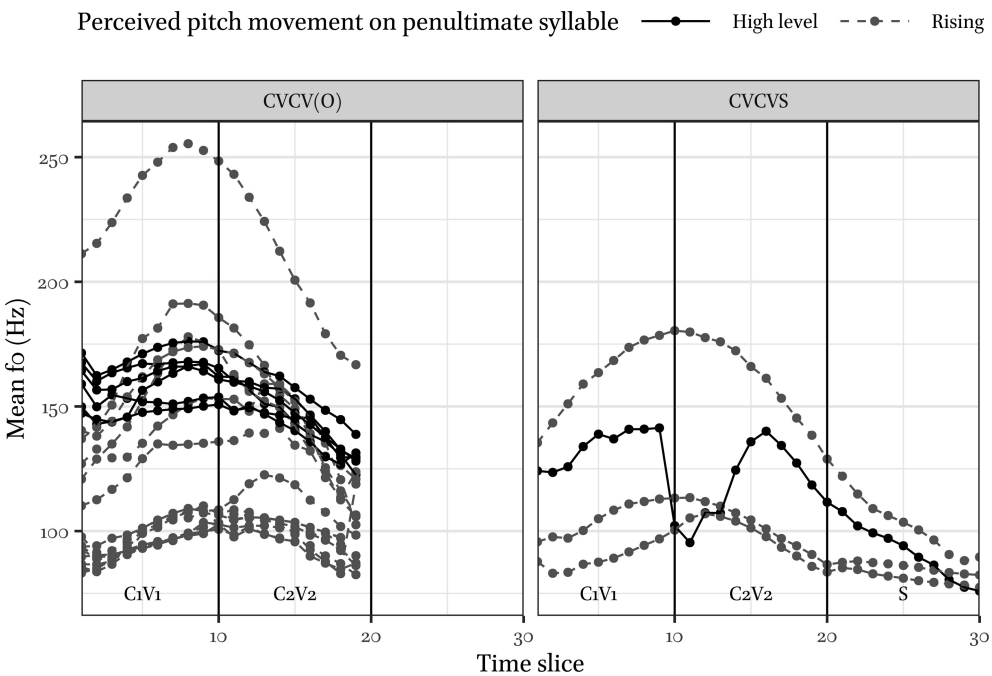

FIGURE 7.8 Bunun word-level prominence
DATA OBTAINED FROM THE BUNUN E-DICTIONARY

7.5 Kanakanavu

Kanakanavu has six vowels (/i e u o a ɨ/) and twelve consonants (/p t k ʔ ts v s m n ŋ r ɾ/) (Hsuan-ju Chen 2016, pp. 9–11). Word-level prominence has been reported to fall mainly on the penultimate syllable, though it may also fall on the antepenult or final syllable depending upon processes such as final echo vowels, monophthongization of long vowels, or vowel deletion (Hsuan-ju Chen 2016, p. 84).

7.5.1 *Kanakanavu Vowels*

No instrumental investigations of Kanakanavu vowels were found in the literature, so we selected 44 bisyllabic (C1V1C2V2(C3)) or trisyllabic (C1V1C2V2C3 V3(C4)) tokens from the e-dictionary to provide a preliminary characterization of Kanakanavu vowels. C1 and C2 were restricted to stops /p t k/ to facilitate the segmentation of the stressed vowel. /ʔ/ was excluded to avoid glottalization of the vowel. Unfortunately, very few /e, o/ exemplars met these requirements. F1 and F2 values were measured at the midpoint of the stressed vowels (Figure 7.9). (F2 and F3 data and plots are available in the OSF repository, as well, and are available in general for all languages with data for vowel space plots obtained from the e-dictionary.) All tokens were spoken by speakers we perceived to be men.

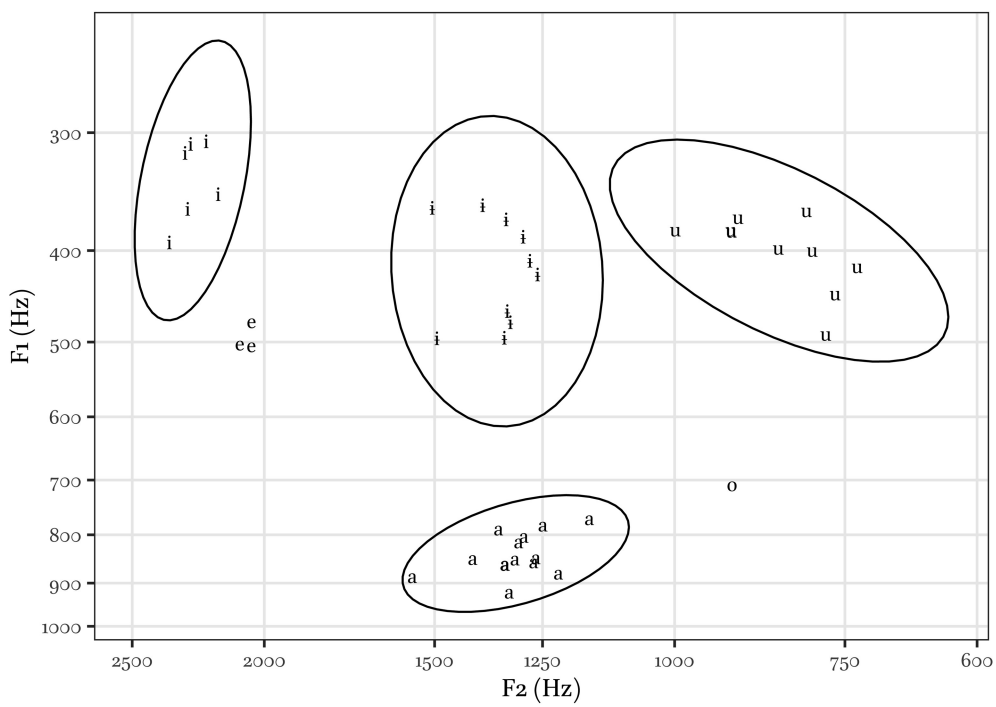

FIGURE 7.9 Kanakanavu vowel space
DATA OBTAINED FROM THE KANAKANAVU E-DICTIONARY

7.5.2 *Kanakanavu Word-Level Prominence*

S. Chen (2016) recorded six Kanakanavu speakers (3 female, 3 male) from Namasia Township in Kaohsiung producing two-, three-, and four-syllable words with prominence on the final or penultimate syllable (two-syllable words) or on the penultimate or antepenultimate syllable (three- and four-syllable words). With F0 maxima measured for each syllable, F0 peak was shown to be a consistent indication of stress (Figure 7.10). Duration may also reliably signal stress on non-final syllables, as shown in Figure 7.11).

missing matching parenthesis

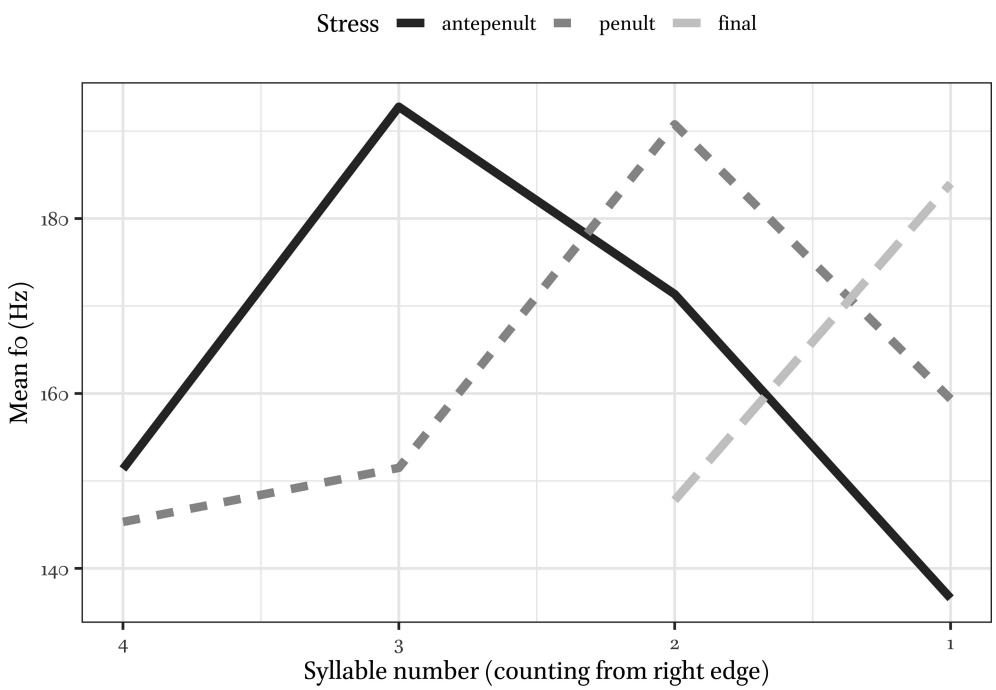

FIGURE 7.10 Kanakanavu word-level prominence signaled by F0
REPRODUCED FROM S. CHEN 2016, P. 685

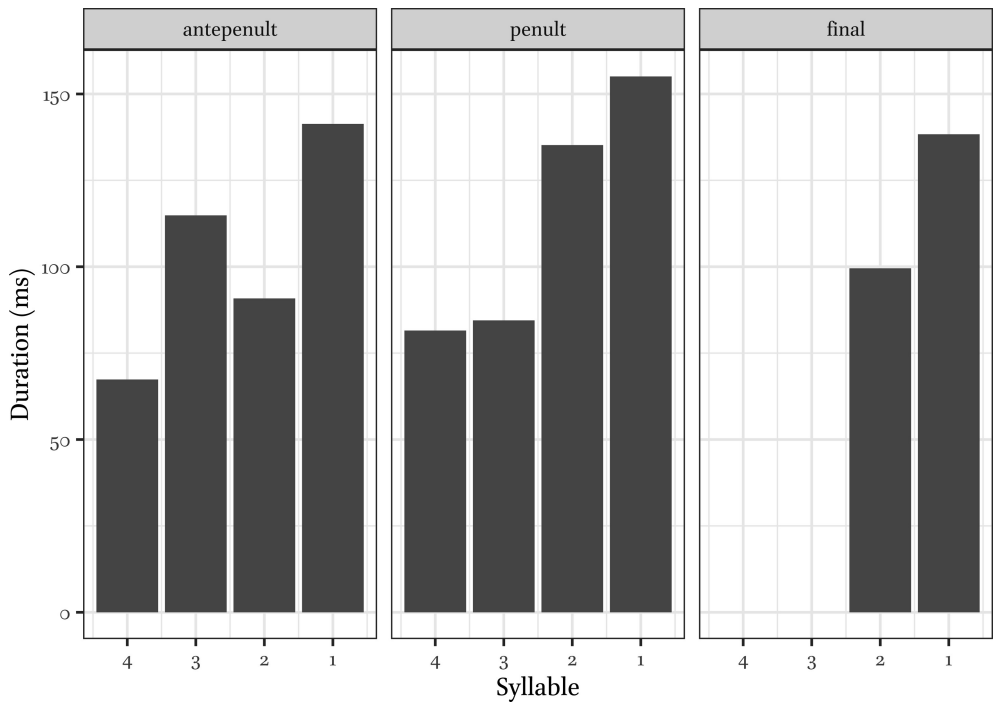

FIGURE 7.11 Kanakanavu word-level prominence signaled by duration and paneled by stress position REPRODUCED FROM S. CHEN 2016, P. 686

7.6 Kavalan

Hsinshe Kavalan has four vowels (/i u a ə/) and sixteen consonants (/p t k q ʔ β s z m n ŋ ɾ ɬ w j/) that are yet to be explored instrumentally. Word prominence has been reported to fall invariably on the final syllable (F. Hsieh 2018, p. 19).

7.6.1 *Kavalan Vowels*

To the best of our knowledge, no instrumental studies on Kavalan vowels have been conducted to date. For an initial characterization of Kavalan vowels, we selected 51 bisyllabic C1V1C2V2(C3) items from the e-dictionary with C2 and C3 restricted to /p, t, k/ and V1, V2, and C1 unrestricted. As before (see § 7.5.1), stops were chosen for clear segment boundaries between consonants and vowels. The uvular stop /q/ was excluded to avoid coarticulatory effects that have been observed in other languages (e.g., Atayal, § 7.3.1; Saisiyat, § 7.12.1). F1 and F2 were measured at the midpoint of the stressed vowel (V2). When for-

mants from multiple speakers with very different vocal tract lengths are plotted together, they are often normalized for comparability, or plotted by individual speaker. Since the e-dictionary did not identify which speaker produced which token, we could only make a rough attempt to do this by listening for different voices and noting salient differences among them, such as perceived gender. Figure 7.12 shows the vowel space based on our sample set from the e-dictionary.

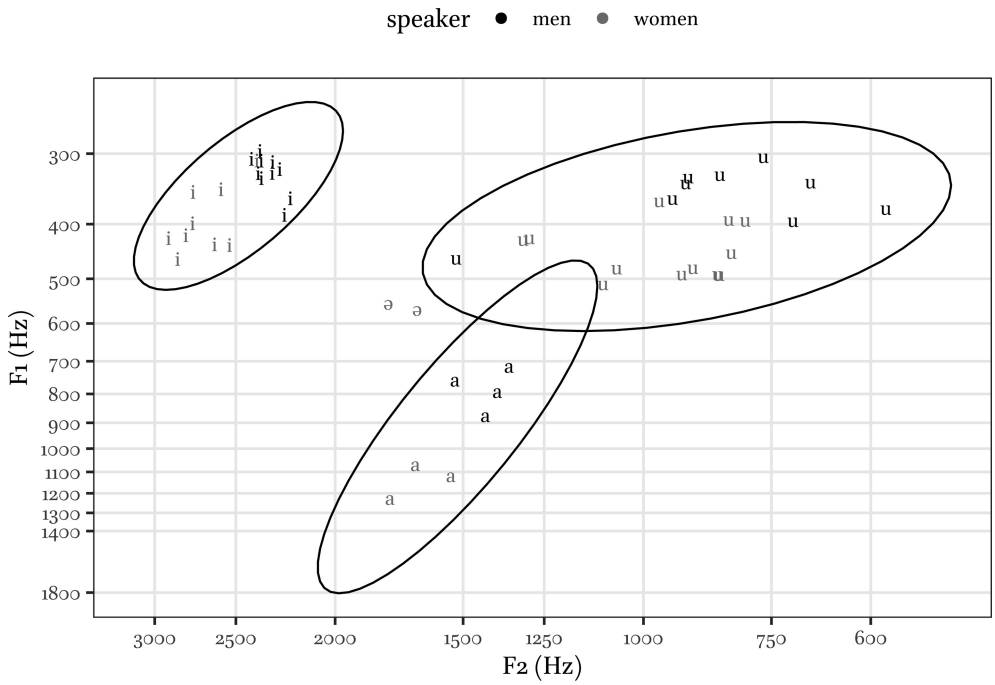

FIGURE 7.12 Kavalan vowel space
DATA OBTAINED FROM THE KAVALAN E-DICTIONARY

7.6.2 *Kavalan Word-Level Prominence*

Many of the sound files obtained from the e-dictionary that met the requirements described in §7.2.3 were obviously produced with rising listing intonation (especially those of one particular speaker), rather than typical falling declarative intonation. We selected 33 tokens with falling intonation; of these, only one had penult stress (*wama* 'only'), which was excluded from the analysis. Individual F0 contours are shown in Figure 7.13. Among the remaining 32 tokens, the stressed final syllable was perceived as having falling pitch in all but four tokens. These four tokens were all CVCV tokens produced by (a) speaker(s) with a low F0 range (possibly male speaker(s); note that the identification of

the speakers was not possible from the e-dictionary), which were perceived to have high level pitch on the final syllable. The other speaker(s) with a higher Fo range (possibly female speaker(s)) did not produce any tokens perceived to have high level pitch on the final syllable. Note that one token perceived as high level (*mali* 'ball') had tense voice quality at the end of the second syllable, which may have contributed to the sharp drop in Fo there as estimated by the Straight algorithm.

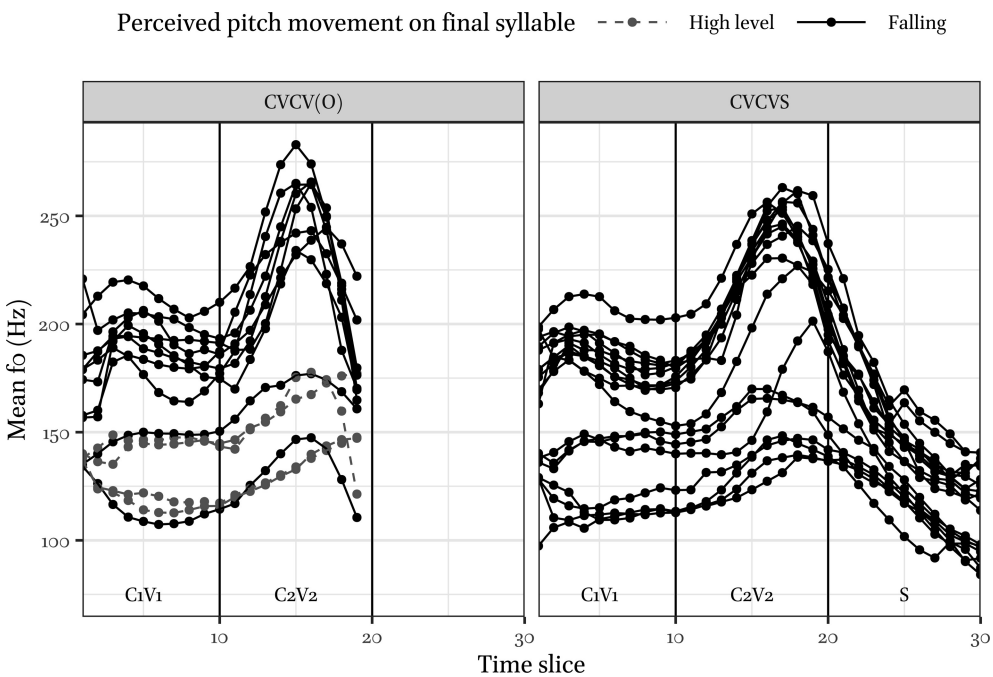

FIGURE 7.13 Kavalan word-level prominence
DATA OBTAINED FROM THE KAVALAN E-DICTIONARY

7.7 Paiwan

Piuma Paiwan has four vowels (/i u a ə/) and the largest consonant inventory among the Formosan languages, with 23 consonants (/p t c k q ʔ b d ɖ ɟ g s z m n ŋ r ɭ ʎ w j/). Stress is described as falling on the penultimate syllable, unless the penultimate vowel is a schwa (which repels stress) or the final vowel is long (which attracts stress), in which case stress is on the final vowel. (C. Chen 2009, S. Shih 2019, Yeh 2011).

7.7.1 *Paiwan Vowels*

Maddieson et al. (2004) presented data from two Southern Paiwan speakers (Mudan dialect) and presented vowel formants from the steady state and their corresponding durations. The formant results (Figure 7.14) from 1 woman and 1 man showed that, among the four phonemic vowels, /i/ was the least variable, /u/ was produced with a lower tongue height, indicated by higher F1, and /a/ was a low central vowel. Furthermore, the results showed that /ə/ was most affected by consonant context, indicated by the dispersed space in Figure 7.14.

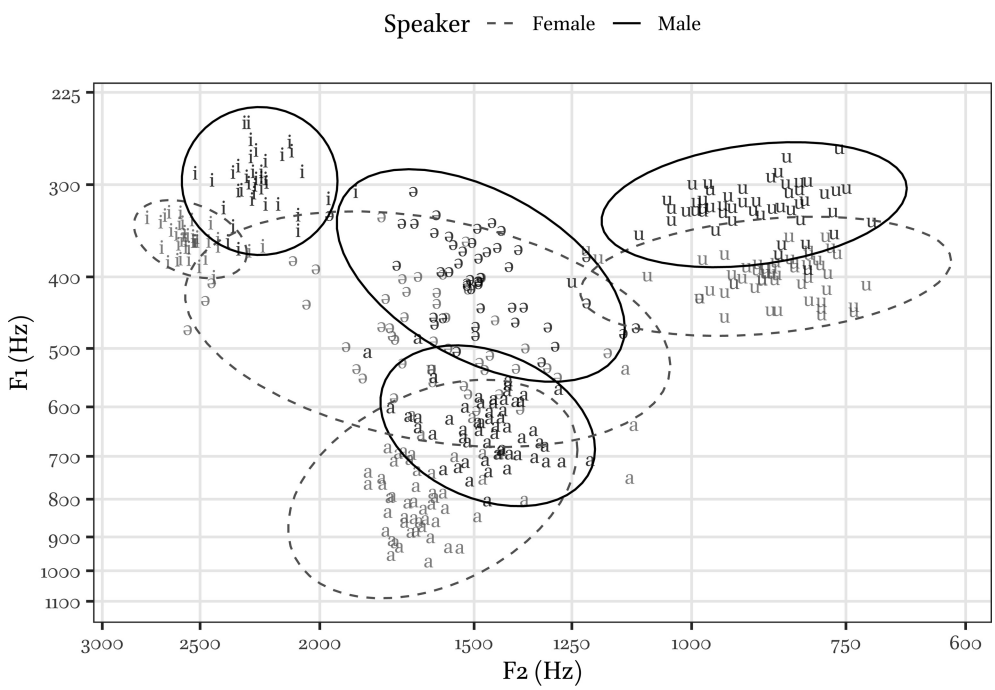

FIGURE 7.14 Paiwan vowel space
DATA OBTAINED FROM MADDIESON ET AL. 2004

Maddieson et al. (2004) attributed the high variability of /ə/ partly to its relatively shorter duration, as shown in Figure 7.15.

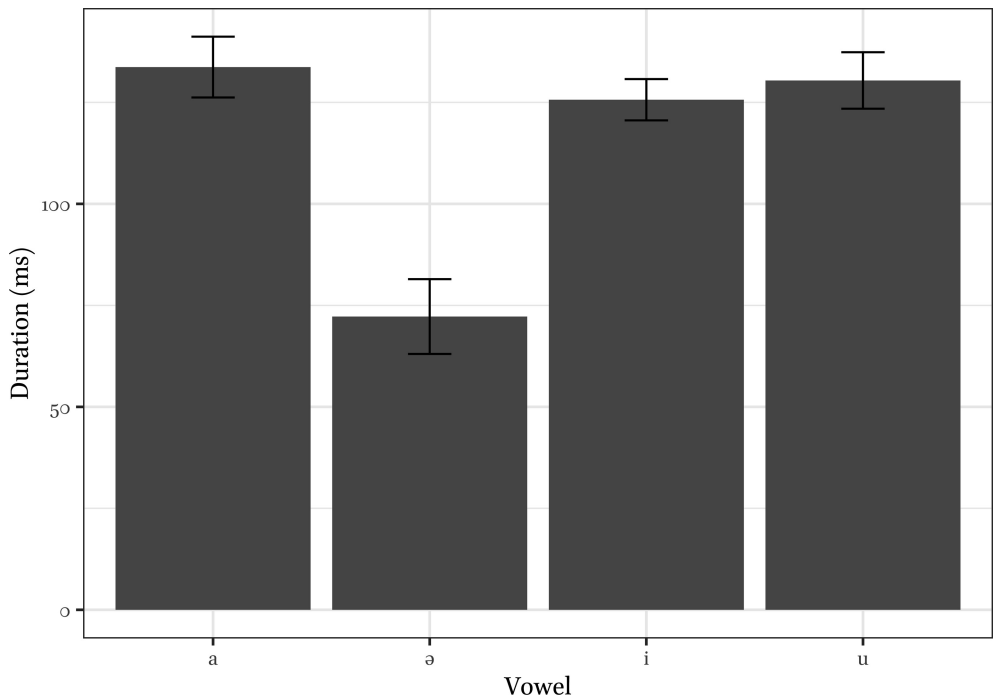

FIGURE 7.15 Paiwan vowel duration
DATA OBTAINED FROM MADDIESON ET AL. 2004

S. Shih (2018, 2019) further identified three types of schwas in Piuma Paiwan based on their prosodic status: 1) non-moraic schwas which repel stress (e.g., [kᵊ(rí:)] 'small'), 2) bimoraic schwas which occupy the head of a foot (e.g., [[ˀᵊ(ʎə́:t] 'lip'), and 3) monomoraic schwas which occupy the non-head of a foot (e.g., [(tú.lək)] 'to direct'). This three-way contrast among schwas was based on a three-way durational difference compared with a control vowel /u/ in comparable positions. S. Shih (2018) recorded two native Piuma Paiwan female speakers who produced 50 disyllabic words with either /ə/ or /u/, and with stress on either the penultimate or final syllable. The results (Figure 7.16) showed that there was only a two-way duration contrast for /u/ but a three-way contrast for /ə/.

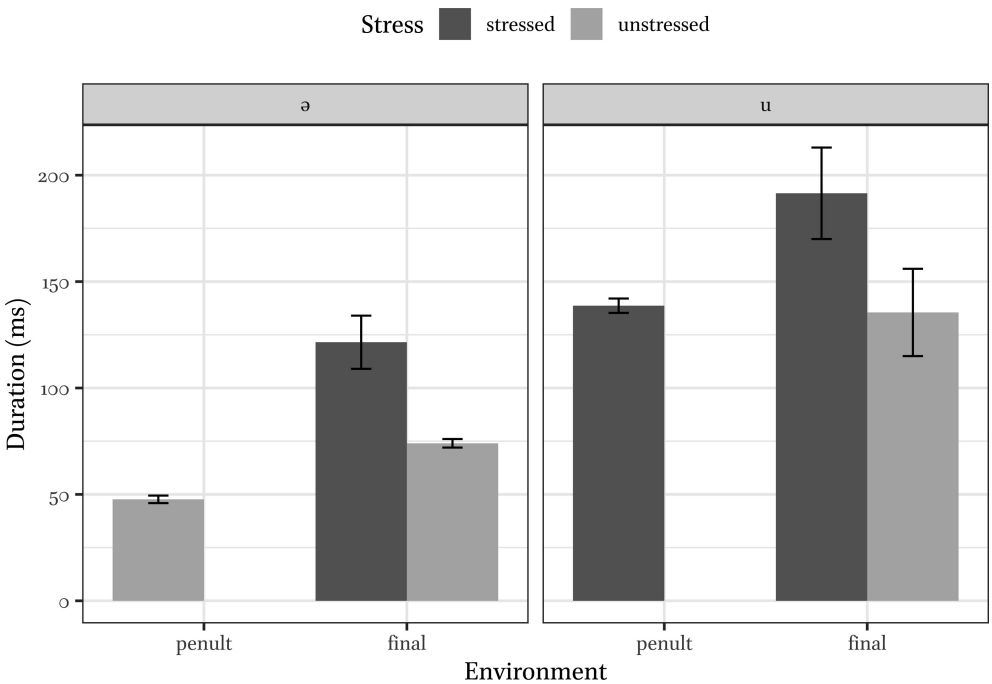

FIGURE 7.16 Three-way duration contrast of Piuma Paiwan schwas
DATA OBTAINED FROM S.H. SHIH 2018, PP. 96–110

7.7.2 *Paiwan Consonants*

Paiwan has a three-way coronal contrast /d ɖ ɟ/. Maddieson et al. (2004) used spectrograms to show that vowel transitions into these consonants are all characterized as F2 rises and F3 and F4 lowering. The releases, however, are distinct for all three consonants. The dialect described in Maddieson et al. (2004) is Southern Paiwan spoken in the township of Mudan. The data below were obtained from the Paiwan e-dictionary, which is based on Northern Paiwan, a variety that also has the same three-way contrast.

Maddieson et al. (2004) showed that velar and uvular stops /k, q/ are distinct acoustically as well (in some Central and Southern dialects). Vowel transitions into the velar stop are characterized by velar pinch of F2 and F3 and low F1 while transitions into the uvular stop are characterized by diverged F2 and F3 and higher F1, as shown in Figure 7.18. The sound files below were obtained from personal communication with Shih-Chi Yeh. These data were collected for Yeh (2018).

As in Atayal and Saisiyat, vowels preceding uvular consonants exhibit strong coarticulatory effects not observed in other consonant contexts (Maddieson et al. 2004).

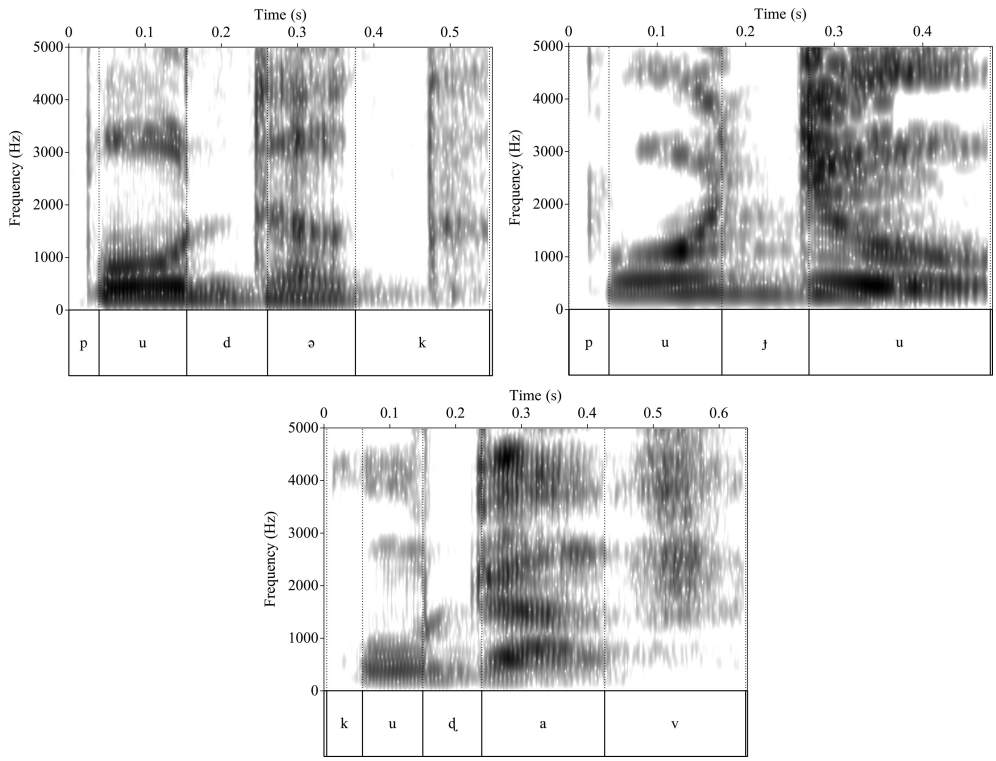

FIGURE 7.17 Three-way coronal contrast of /d ɖ ɟ/ in Northern Paiwan: /pudək/ 'belly button' (top left), /puɟu/ 'mat' (top right) and /kuɖav/ 'ten thousand' (bottom)
DATA OBTAINED FROM E-DICTIONARY

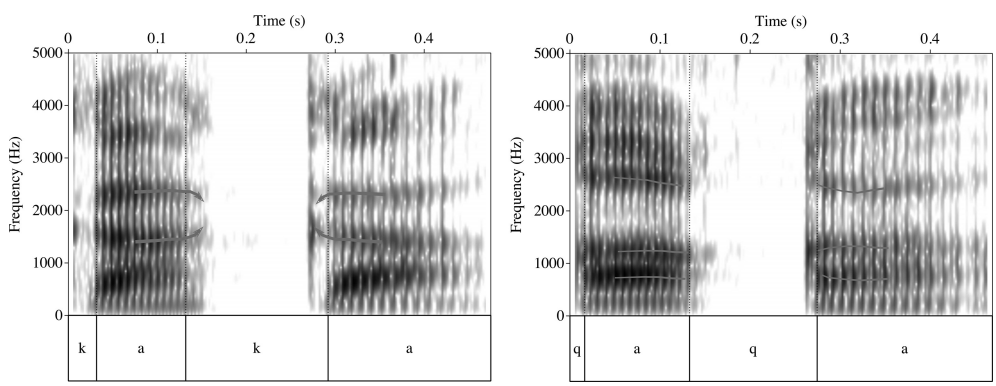

FIGURE 7.18 Velar and uvular stops in Southern Paiwan: /kaka/ 'sibling' (left) and /qaqa/ 'crow' (right)
DATA OBTAINED FROM YEH (2018)

7.7.3 *Paiwan Word-Level Prominence*

C. Chen (2009) recorded 30 disyllabic tokens from a Piuma Paiwan woman speaker to investigate acoustic correlates of word-level prominence. The results showed that F0 is a reliable indication of prominence in isolated words (F0 mean for stressed syllables = 222 Hz and unstressed syllables = 179 Hz) while duration is generally not, due to final lengthening. C. Chen (2009) further compared three Paiwan dialects by recording six speakers from the Sandimen, Piuma, and Mudan villages. Based on their recordings of 48 items, F0 was again shown to be a consistent correlate for word-level prominence while duration was not. S.H. Shih (2018) measured F1, F2, F0, duration and intensity of /u, ə/ in prominent and non-prominent positions, confirming C. Chen's (2009) finding that F0 is a strong correlate of prominence (Figure 7.19). However, contrary to what was found in C. Chen (2009), S. Shih (2018) reported that duration is a reliable cue for prominence in comparisons of word-final stressed and unstressed vowels (Figure 7.16, final stress). Additionally, stressed vowels were found to be produced with greater intensity. In the two vowels examined by S. Shih (2018), stressed /ə/ was lower in intensity than unstressed /ə/, while /u/ did not show acoustic differences due to stress.

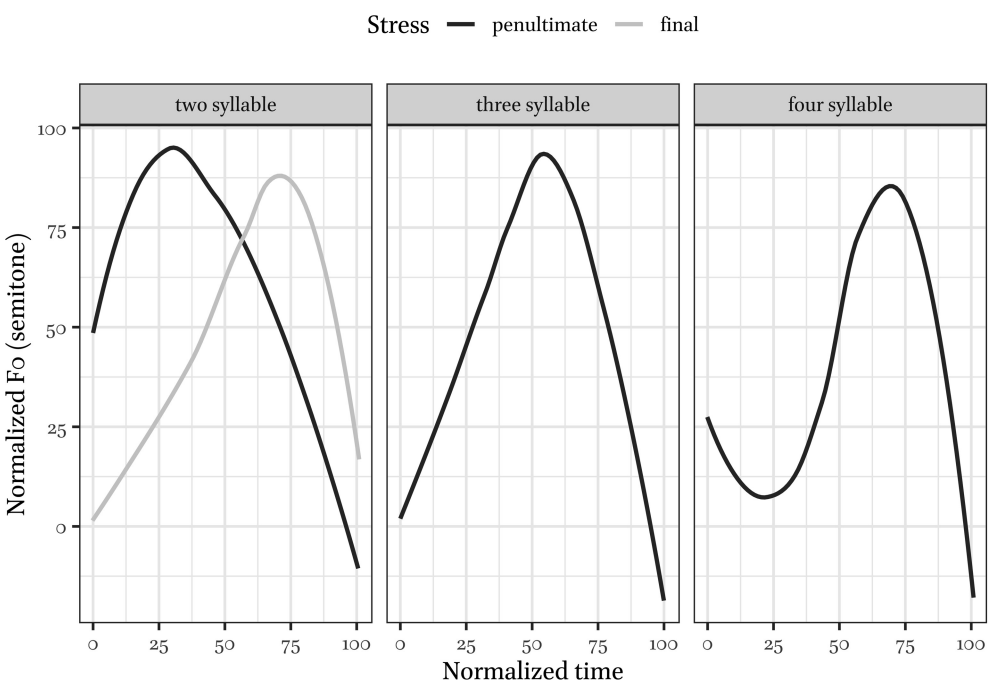

FIGURE 7.19 Normalized F0 trajectories in tokens with penultimate and final stress in two-, three-, and four-syllable words in Piuma Paiwan schwas
REPRODUCED FROM S.H. SHIH 2018, PP. 89–92

7.8 Pazeh and Kaxabu

Pazeh and four vowels (/i u a ə/) and eighteen consonants (/p t k ʔ b d g x ħ m n ŋ ɾ l/). Stress is described as falling on the final syllable (Li & Tsuchida 2001, p. 3). Except for the loss of /ɾ/, the phoneme inventory of Kaxabu is identical to that of Pazeh. Since no instrumental studies have been conducted on Pazeh, nor is there an available e-dictionary, we report some measurements of word-level prominence in Kaxabu, a dialect close to Pazeh (Lim 2016, p. 85).

Lim (2016) consulted 10 native Kaxabu speakers and reported three F0 contour shapes for word-final prominence: Speakers aged 80–90 implemented word prominence as high, whereas older speakers (90+) realized it as falling. Some speakers, however, irregularly realized word-final prominence as either high or falling. One of the most fluent speakers consistently realized all final syllables as high except for ones ending in fricatives, which were realized as falling. Figure 7.20 shows two smoothed F0 curves of this speaker plotted based on two disyllabic words ending in fricatives (low-fall type) and eleven disyllabic words ending in non-fricatives (low-high type). The first syllables were consistently realized as low

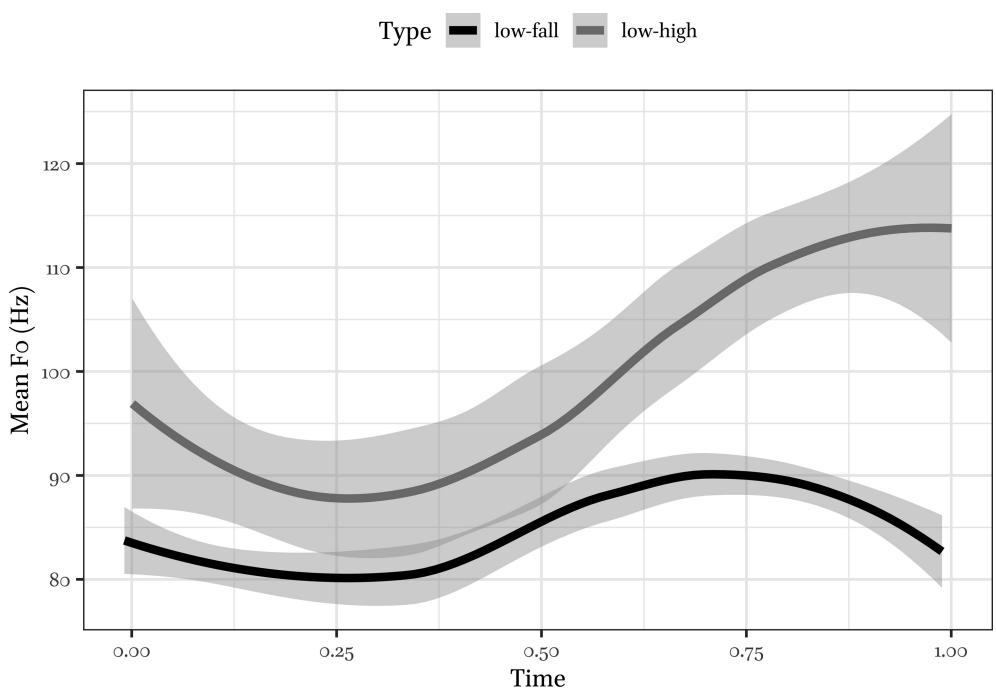

FIGURE 7.20 High and falling realizations of word-final prominence in Kaxabu
REPRODUCED FROM LIM 2016, PP. 91–96

Beyond word-final prominence, Lim (2016) also observed quantity-sensitive stress assignment. Specifically, when an initial syllable is heavy (i.e., long vowels or diphthongs), it is realized as high

7.9 Puyuma

Nanwang Puyuma has four vowels (/i u a ə/) and eighteen consonants (/p t ʈ k ʔ b d ɖ g n ŋ r l ɭ w j/). Stress consistently falls on the final syllable (Teng 2008, p. 22).

7.9.1 *Puyuma Vowels*

We provide an initial characterization of Nanwang Puyuma vowels based on 79 bisyllabic C1V1C2V2(C3) tokens obtained from the e-dictionary. C2 and C3 (if present) were restricted to stops /p t k b d g/, and the rest of the segments were unrestricted. F1 and F2 were measured at the midpoint of the vowel in the stressed final syllable. All tokens were produced by speakers we perceived to be women.

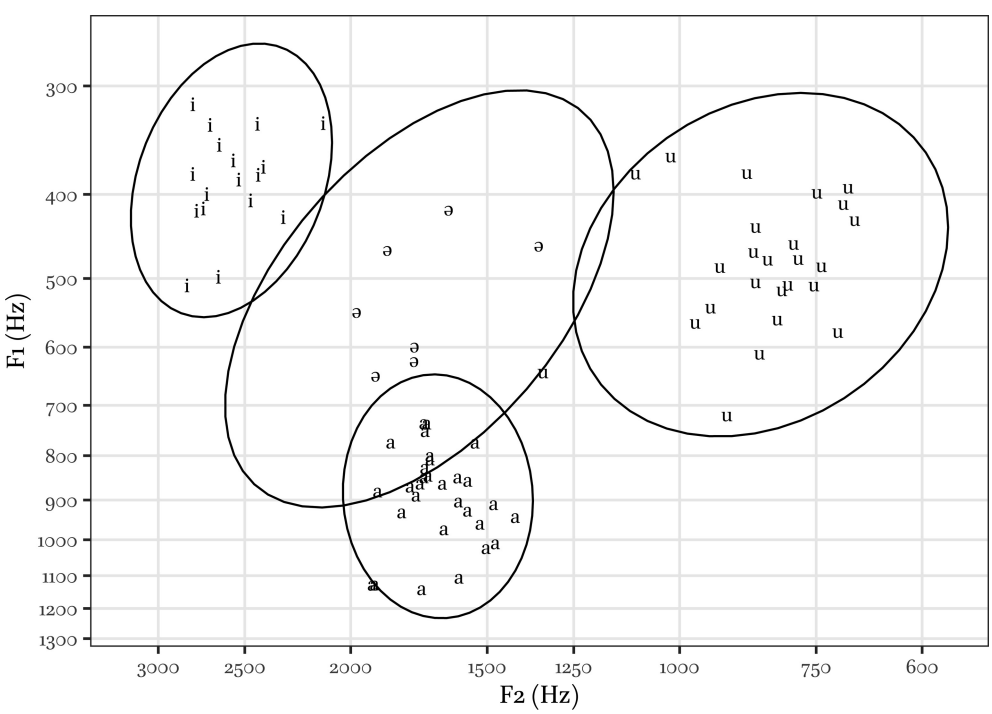

FIGURE 7.21 Puyuma vowel space
DATA OBTAINED FROM THE PUYUMA E-DICTIONARY

7.9.2 *Puyuma Consonants*

Hsu (2018) reported that the contrast between the two laterals /l ɭ/ in Nanwang Puyuma may be reliably categorized by their F3 and F4 values. In one speaker's production of the two laterals, the values of these formants for /l/ were higher (F3: 3100 Hz; F4: 3850 Hz) than those for /ɭ/ (F3: 2700 Hz; F4: 3530 Hz).

7.9.3 *Puyuma Word-Level Prominence*

In measurements of F0, intensity, and duration for some representative Nanwang Puyuma tokens, Teng (2008, pp. 22–23) showed that intensity and duration serve as consistent correlates to word prominence, while F0 correlates may be obscured by other intonational factors. Upon further examination using data (also from the Nanwang dialect) obtained from the Puyuma e-dictionary using selection criteria similar to those described in § 7.2.3, we found 5 ([ɭima] *lima* 'hand', [luwaʈ] *lruwatr* 'five', [maməs] *mames* 'easy', *manay* 'what/who', *numa* 'sometimes') out of 61 tokens that had penultimate stress (i.e., higher F0 on the penultimate syllable than final one); we classified all other tokens as having either high or falling pitch movement over the final stressed syllable (Figure 7.22). Among the words not ending in a sonorant coda, 16 with a final open syllable and 14 that ended with an obstruent coda were classified as having high level pitch on the final syllable; the remaining 8 were classified as having falling pitch on the final syllable. All 18 tokens ending with a sonorant coda were perceived as having falling pitch on the final syllable. (F0 values past the 22nd time slice of 5 of these—*liyay* '(be) drunk', *walay* 'thread', *wanay* 'whisker', *yanay* 'brother-in-law', *yawan* 'leader'—were excluded due to misleading, sharp jumps to the F0 contour at the end of the word from background noise.) As noted earlier, we found similar patterns according to the segmental make-up of stressed syllables in Amis (§ 7.2.3) and Saisiyat (§ 7.12.2).

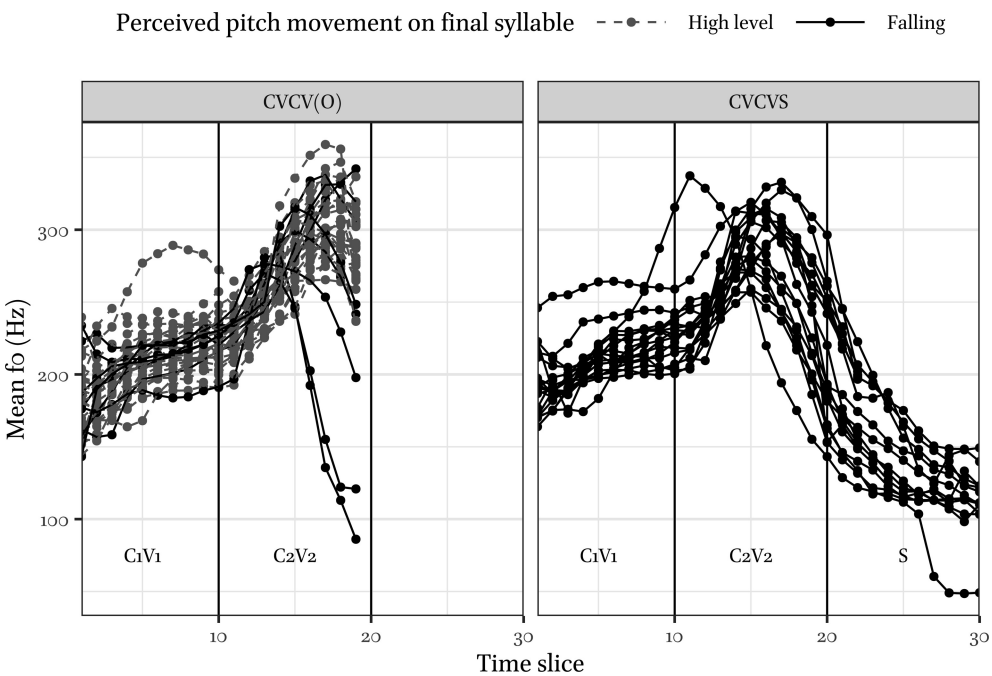

FIGURE 7.22 Puyuma word-level prominence
DATA OBTAINED FROM THE PUYUMA E-DICTIONARY

7.10 Rukai

Budai Rukai has four vowels (/i u a ə/) and twenty consonants (/p t k b d ɖ g v θ ð s m n ŋ r l ɭ w j/) (Zeitoun 2000). Stress falls primarily on the penultimate syllable and less frequently on the final or antepenult syllable (Li 1995, Zeitoun 2000, p. 50).

7.10.1 *Rukai Vowels*

We selected bisyllabic C1V1C2V2(C3) items from the e-dictionary (also from the Budai dialect) with C2 and C3 ranging over all stops except /ɖ/ due to possible coarticulatory effects from retroflexion. Eight items with extreme background noise were discarded. F1 and F2 values were obtained at the midpoint of the stressed penultimate vowel (V1) for the remaining 59 items. Vowel spaces were plotted according to speaker characteristics that we speculatively identified (Figure 7.23). Note that the tokens for /ə/ on the left panel (men) were not sufficient to draw an appropriate ellipse.

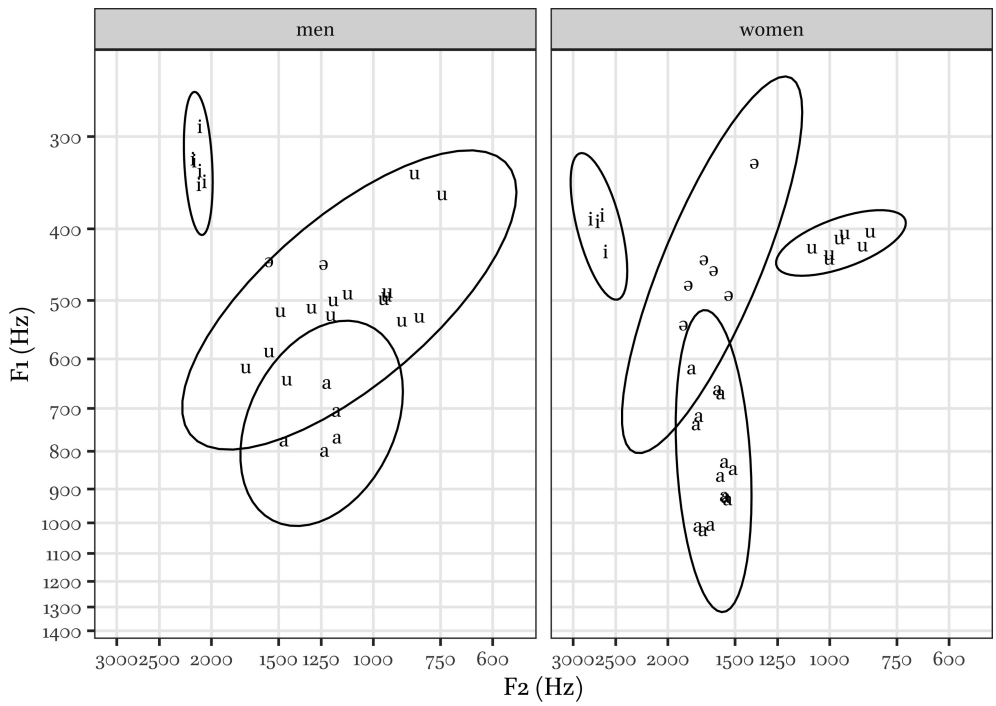

FIGURE 7.23 Rukai vowel space
DATA OBTAINED FROM THE RUKAI E-DICTIONARY

7.10.2 *Rukai Word-Level Prominence*

C. Chen (2011) reported stress regularization from antepenult to penultimate due to frequent contact with Paiwan, a language with regular penultimate stress. Eight speakers of Budai Rukai (4 female, 4 male) were recruited, half of which were from Budai Village, the other half from Sanhe Village, where Paiwan is the dominant language. Their productions of 11 disyllabic words with penultimate stress and 15 trisyllabic words with antepenultimate stress were recorded in isolation. The results showed that both groups of speakers consistently produced disyllabic words with higher F0 on the penultimate syllable. The production of trisyllabic words, however, differed by group. Both man and woman speakers from Budai Village implemented a higher F0 for the antepenultimate syllable, while the men from Sanhe Village shifted the high F0 to the penultimate syllable (Figure 7.24, lower-left panel). In addition, the duration of the (stressed) penultimate syllable was longer than the duration of the final syllable for Sanhe speakers, but the opposite was true for the Budai speakers.

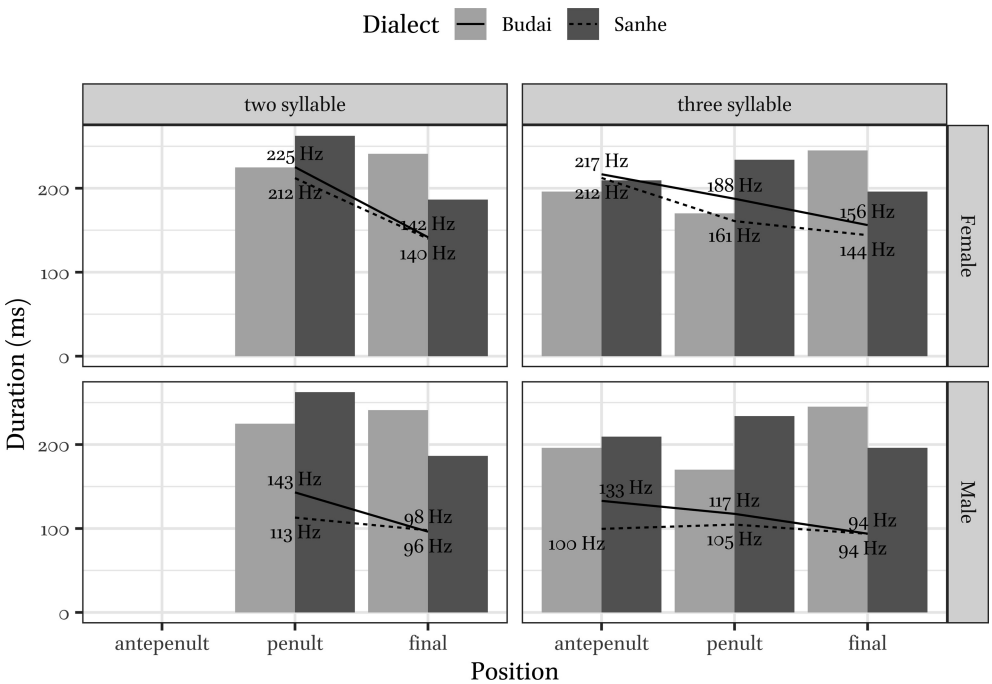

FIGURE 7.24 Word prominence correlates in Rukai
REPRODUCED FROM C. CHEN 2011, PP. 142–143

7.11 Saaroa

Saaroa has six vowels: /i u a (ɛ) (ɔ) ɨ/, with those in parentheses only occurring in loanwords. There are thirteen consonants in Saaroa (/p t k ʔ ts v s h m n ŋ r ɾ ɬ/). Saaroa has been reported to contrast vowel length (e.g., /kiːra/ 'yesterday' vs. /kira/ 'step on'; /sɨːkɨ/ 'male name' vs. /tɨkɨ/ 'heart'; /vuːru/ 'bow' vs. /vuru/ 'give (UVP)' (Pan 2012, p. 31). Stress primarily falls on the antepenultimate syllable with words longer than three syllables but on the penultimate syllable in disyllabic words, which are less common (Pan 2012, p. 33). To the best of our knowledge, no instrumental studies on Saaroa have been conducted, so our preliminary characterization of Saaroa vowels and word-level prominence based on e-dictionary data is provided below.

non-matching parenthesis

7.11.1 *Saaroa Vowels*

We selected all the trisyllabic words (C1V1C2V2C3V3C4) with C1 and C2 restricted to stops (/p t k/). Trisyllabic words were chosen as they are the most common word size. Among the 52 tokens that fit our requirements, 6 had

penultimate stress and were excluded, resulting in 46 tokens in total. F1 and F2 values were measured at the midpoint of the stressed vowel (V1) (Figure 7.25). All tokens were produced by speakers we perceived to be men. From the vowel space, the /ɨ/ vowel transcribed in the literature may be better transcribed as a mid-central /ə/.

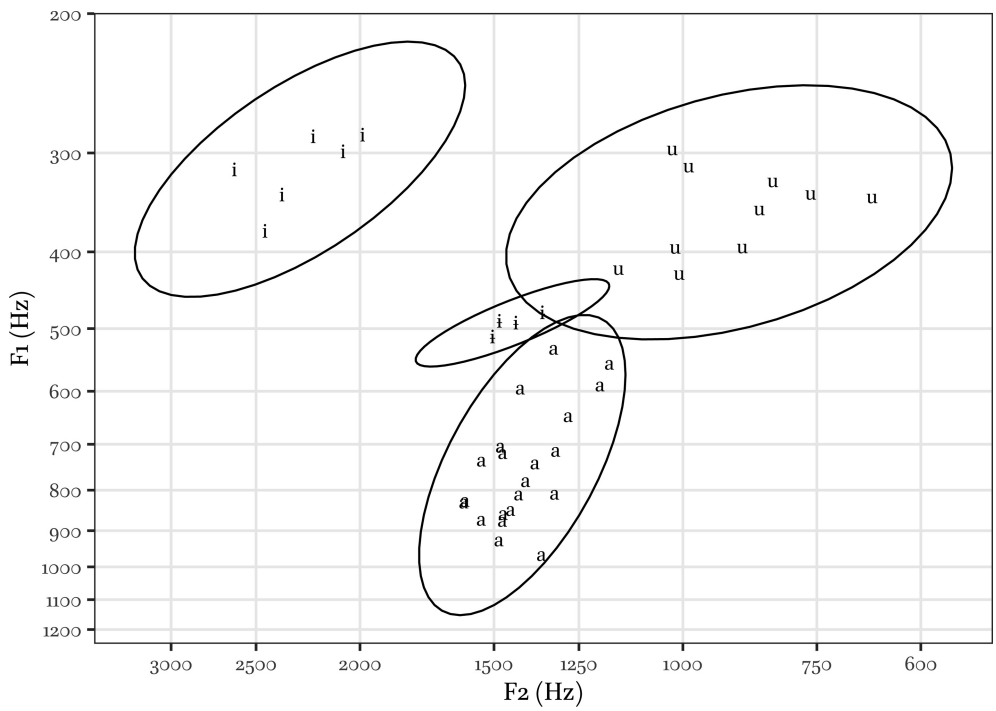

FIGURE 7.25 Saaroa vowel space
DATA OBTAINED FROM THE SAAROA E-DICTIONARY

7.11.2 *Saaroa Word-Level Prominence*

We examined all the recordings of bisyllabic and trisyllabic words in the e-dictionary with the shapes of C1V1C2V2(C3V3C4) in which C1 and C2 were restricted to sonorants to avoid segmental perturbation of the F0 contour, resulting in 11 bisyllabic and 61 trisyllabic tokens. Although the majority of the selected bisyllabic tokens clearly exhibited penultimate stress (8 out of 11), the F0 contours varied (i.e., 2 tokens with falling-low, 5 with high-low, and 1 with high-mid). We also observed 3 bisyllabic tokens that seemed to have final stress (mid-high). The majority of the trisyllabic tokens (52 out of 64), on the other hand, consistently exhibited a high-mid-low pattern, signaling antepenultimate stress as described in the literature (Figure 7.26). That

being said, 9 tokens were observed with penultimate stress, realized as mid-falling-low (1 token) or mid-high-low (8 tokens).

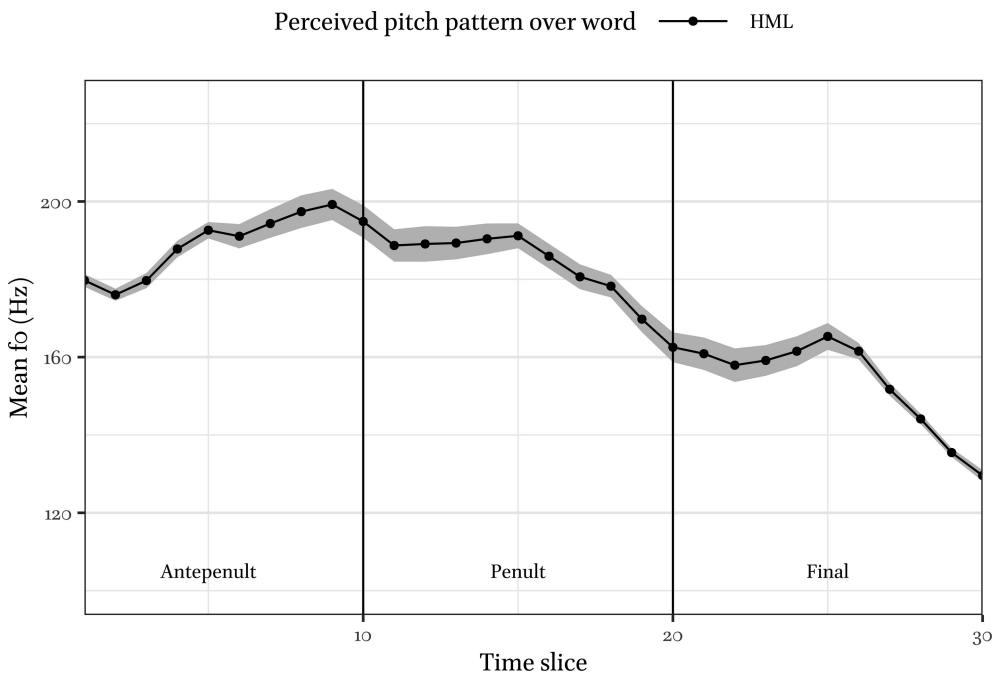

FIGURE 7.26 Saaroa word prominence
DATA OBTAINED FROM THE SAAROA E-DICTIONARY

7.12 Saisiyat

Saisiyat consists of two dialects, Ta'ai and Tungho. Tungho Saisiyat has been reported to exhibit four to seven vowels: /i (e) a (æ) o ə (œ)/ (Deng 2007 and Tsuchida 1964, among others); the Ta'ai dialect, on the other hand, has the following six vowels: /i a o ə œ æ/ (Hsieh 2008, p. 11). There are sixteen consonants in Saisiyat (/p t k ʔ β θ ð ʃ ħ s m n ŋ r w j/). Word-level prominence falls on the final syllable (Y. Chang 2011, Hsieh 2008, p. 20).

7.12.1 *Saisiyat Vowels*

The controversy over the number of underlying vowels stems from the existence of /œ/ and the status of [e] and [æ]. The two vowels, [e] and [æ], are largely in complementary distribution with /i/ and /a/, and their distribution seems to be partially limited to be adjacent to /h ʔ/. Y. Chang (2009) collected

tokens from three speakers of the Tungho dialect. The tokens included vowels adjacent to various consonants including /h ʔ/. The F2 values for the central vowels /ə, a/ were higher around /h, ʔ/, suggesting that the tongue was fronted in this context (Figure 7.27). However, /e, æ/ seem to occupy a region of the vowel space distinct from that of /i a/. One alternative hypothesis is that, rather than tongue fronting around/h ʔ/, pharynx could be constricted, mimicking the acoustic effect of fronting (cf. Amis).

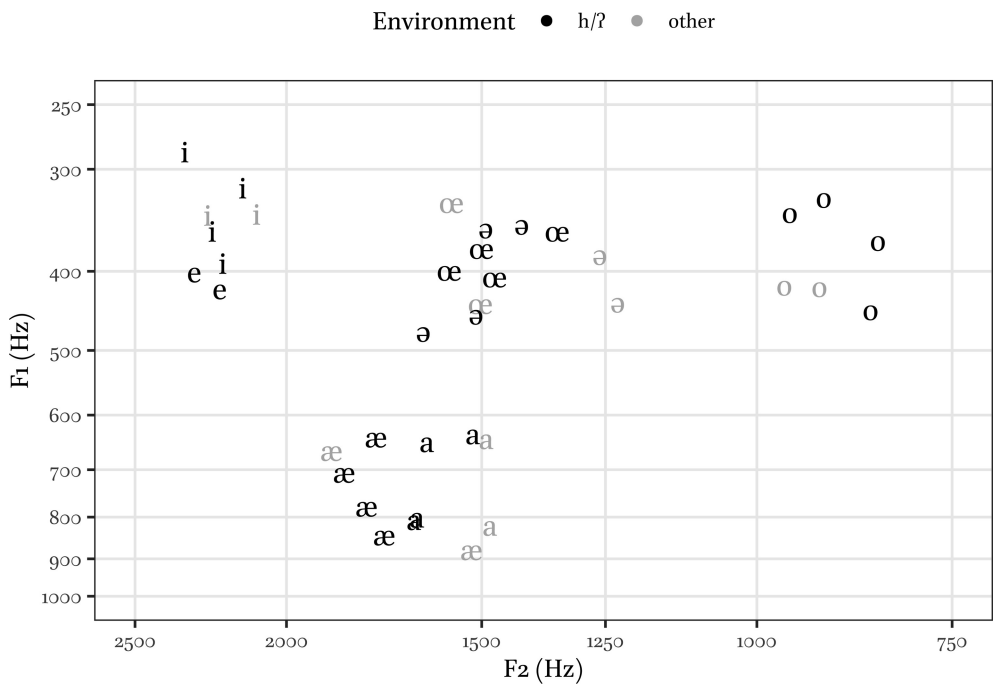

FIGURE 7.27 Saisiyat vowel space
REPRODUCED FROM Y. CHANG 2009, PP. 4–5

Y. Chang (2009) reported a possible vowel length contrast from the loss of */ɾ/, e.g., *ɾimaʔ →/_imaʔ/ →[iːmaʔ] 'hand'. Two speakers of the Tungho dialect were recorded producing a list of disyllabic words with the lost */ɾ/ as an onset or coda in the first syllable. The results showed that vowels with the lost */ɾ/ were significantly longer than those without it (1.25: 1). This difference was treated as non-phonemic because the durational difference, though significant, was small in comparison to those in languages with clear vowel length contrasts (see also Tsuchida 1964, Li 1978, and Zeitoun et al. 2015).

7.12.2 *Saisiyat Word-Level Prominence*

W. Chiang & F. Chiang (2005a) recorded two men (1 from northern Saisiyat, 1 from southern Saisiyat) producing 34 words balanced in length (2–5 syllables) and prominent final syllable coda type (no coda, nasal coda, stop coda). The results (Figure 7.28) showed that when the final syllable has a stop coda, prominence (which they typologized as pitch accent) is realized as a high tone, while a falling tone was observed on final syllables with either nasal codas or no coda. Duration, too, was found to be longer for the accented syllable, but Chiang & Chiang (2005a) noted that it may be due to final lengthening. Intensity was not found to be stronger for the accented syllable relative to the unaccented syllables.

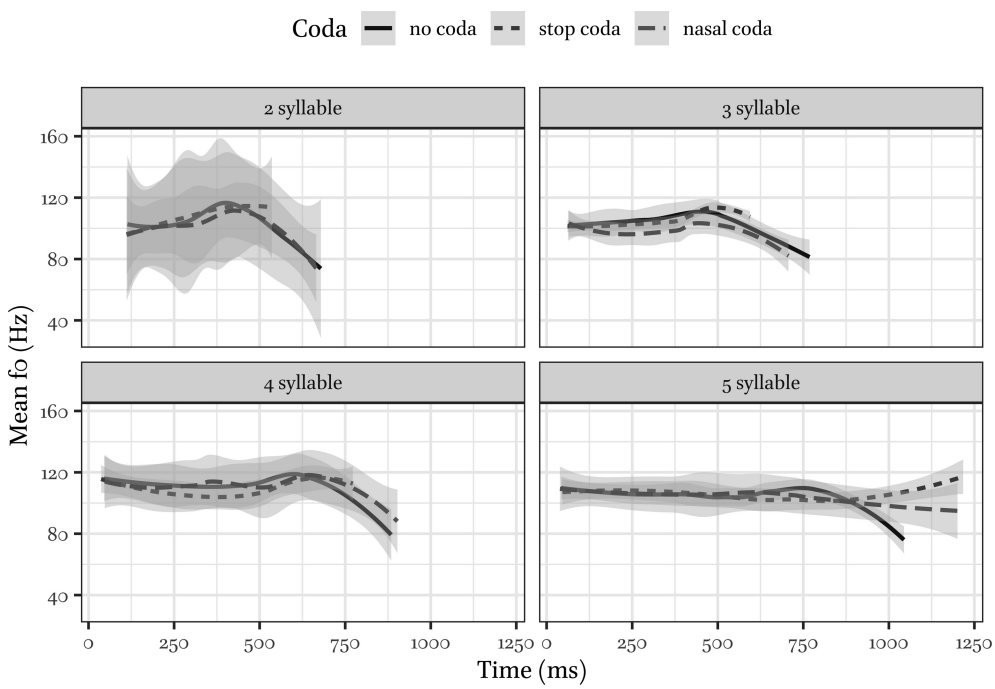

FIGURE 7.28 Saisiyat realization of word-final prominence
REPRODUCED FROM W. CHIANG & F. CHIANG 2005A, P. 412

7.12.3 *Other Processes*

W. Chiang et al. (2006) investigated the realization of F0 patterns in negative and affirmative sentences. Two Saisiyat speakers (1 from northern Saisiyat, 1 from southern Saisiyat) recorded 15 affirmative (2a) and negative sentences (2b) in a question-and-answer paradigm due to the lack of a writing system in this language.

(2) a. *ʔoβaj minatiniʔ.*
Obay elder.sibling
'Obay is (someone's) elder sibling.' (W. Chiang et al. 2006, p. 188)

b. *ʔoβaj ʔokik minatiniʔ.*
Obay NEG elder.sibling
'Obay is not (someone's) elder sibling.' (ibid)

The results Figure 7.29 showed that the subject (e.g., *Obay* in (2ab)) consistently carried the highest F0 and intensity in both sentence types, while the sentence-final element carried the lowest F0 and intensity.

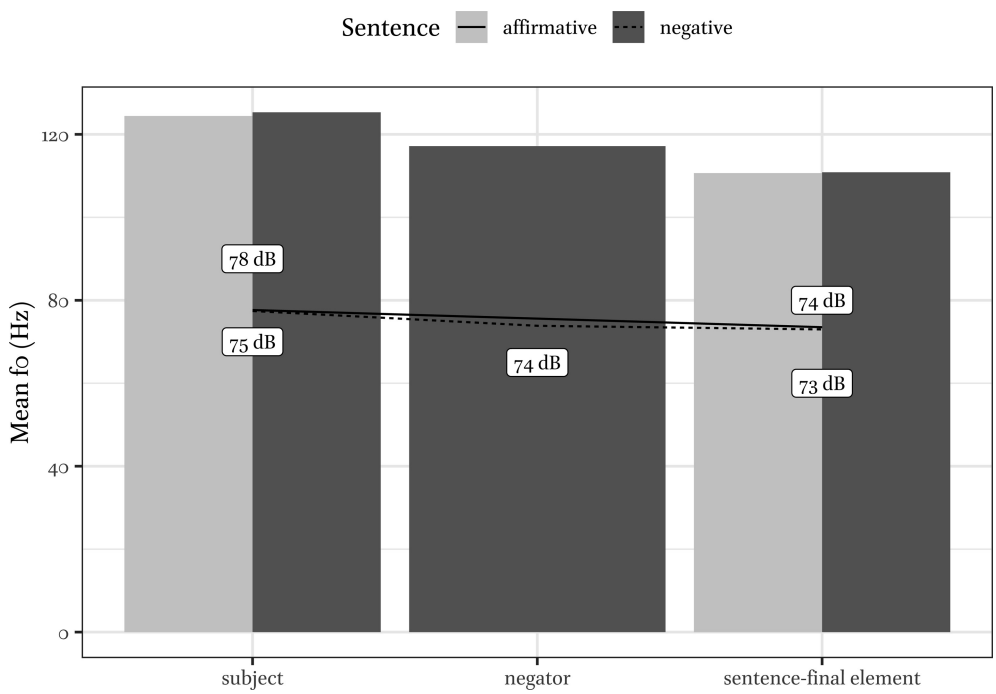

FIGURE 7.29 Saisiyat F0 and intensity patterns of affirmative and negative sentence
REPRODUCED FROM W. CHIANG ET AL. 2006, P. 121

7.13 Seediq

Tɑdaya Seediq has five vowels (/i u a e o/) and eighteen consonants (/p t k q b d g s x ħ m n ŋ ɾ l w j/). Word-level prominence invariably falls on the penultimate syllable (H. Chang 2000, p. 48, Li 1991). Truku Seediq has a slightly smaller vowel inventory (/i a ə u/) and a slightly bigger consonant inventory (/p t c k q b d ɟ ʔ s x ɣ ħ m n ŋ ɮ ɾ w j/).

7.13.1 *Seediq Vowels*

W. Chiang & F. Chiang (2005b) recorded six native speakers (3 females, 3 males) of the Truku dialect of Seediq who perceptually categorized native vowels into three (/i u a/), four (/i u a o/) or five (/i u a e o/) different categories. They investigated the degree of dispersion in the vowel space and whether it was related to the number of vowels in the inventory that these native speakers identified. F1 and F2 were measured at steady state in the stressed penultimate vowels and the unstressed final vowels in 77 disyllabic words. The results (Figure 7.30) showed that 1) the 3-vowel inventory (top two panels) exhibits a larger vowel space than the 5-vowel inventory (bottom two panels), 2) greater distance occurred between vowels in the 3-vowel inventory than in the 5-vowel inventory, 3) stressed vowels were more dispersed than unstressed vowels and 4) front vowels produced by the women speakers were more fronted than those by women speakers. Note that these vowels were categorized by the informants themselves, and not by the phonological distribution. From visual inspection of the vowel space, there is some indication that vowels in unstressed syllables reduce to a three-way contrast for all speakers. But even for stressed vowels, what were classified as /o/ and /u/, or /i/ and /e/ are non-distinct acoustically. As previous studies generally reported a five-vowel inventory for Seediq, it is worth examining if the above mentioned two set of vowels have undergone merging.

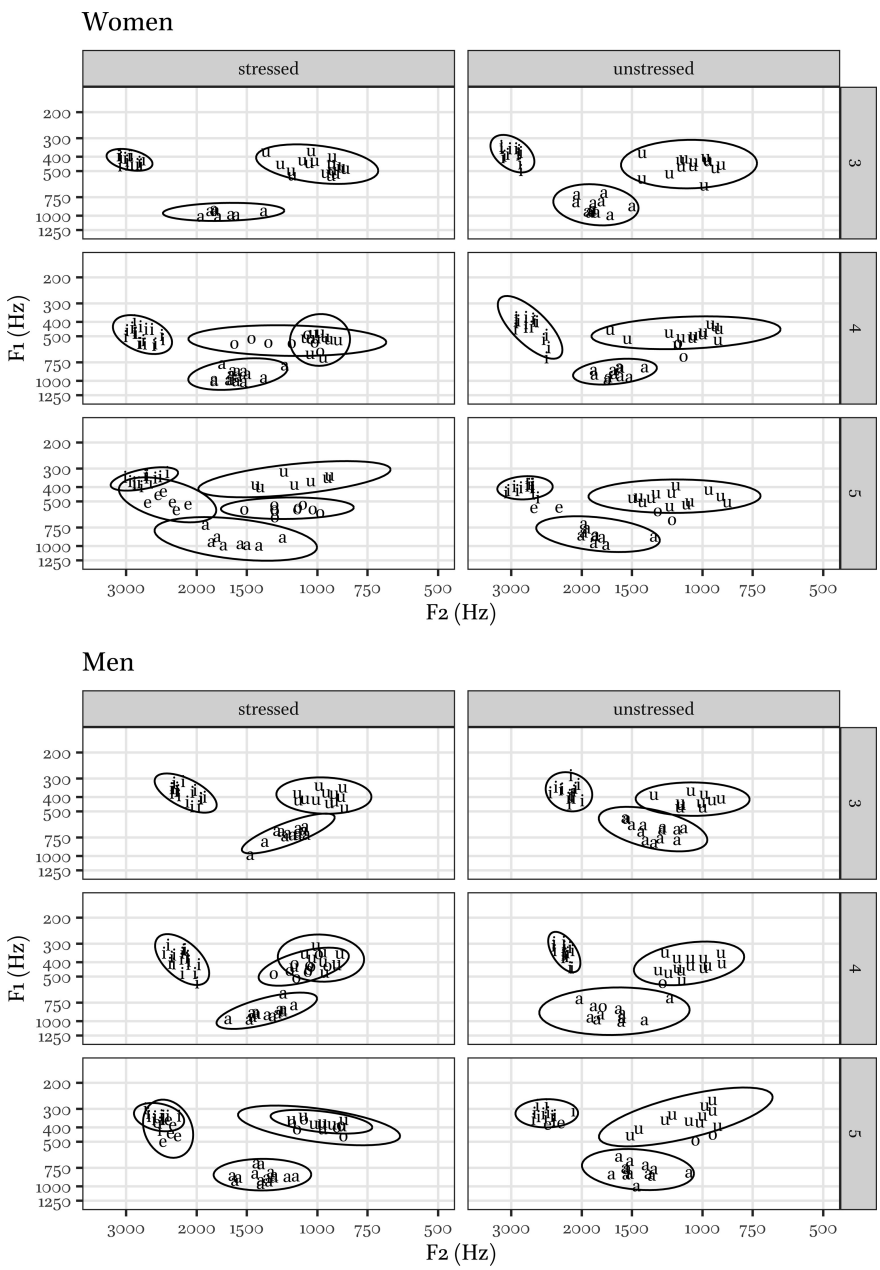

FIGURE 7.30 Truku Seediq three- (top), four- (middle) and five- (bottom) vowel space in stressed (left) and unstressed syllables (right)
REPRODUCED FROM W. CHIANG & F. CHIANG 2005B, PP. 31–36

7.13.2 *Seediq Word-Level Prominence*

As no instrumental studies have been conducted on Seediq word-level prominence, we provide our own preliminary characterization. We obtained 46 bisyllabic tokens from the e-dictionary (Tgdaya dialect); as in § 7.4.3, C1 and C2 were restricted to /l, m, n, ŋ, w, y/, and C3 was limited to /s/ (but not other fricatives due to their effect on voice quality that made it difficult to extract F0 from the preceding vowels). The stressed penultimate syllable was consistently realized as rising on all the tokens, as shown in Figure 7.31.

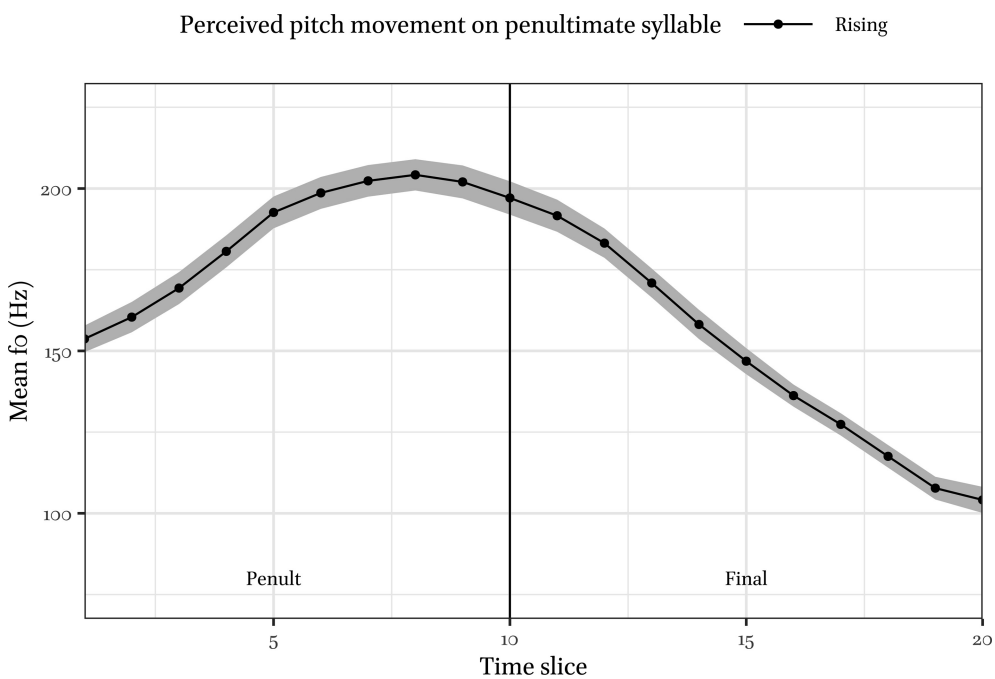

FIGURE 7.31 Tgdaya Seediq word-level prominence
DATA OBTAINED FROM THE SEEDIQ E-DICTIONARY

7.14 Thao

Thao has three vowels (/i u a/) and a relatively large consonant inventory of twenty-one[1] (/p t k q ʔ ᵑb ⁿd ɸ θ ð s ʃ h m n ŋ r l ɬ w j/). Word-level prominence falls on the penultimate syllable (Tseng 2009, p. 57).

7.14.1 *Thao Vowels*

For our preliminary characterization of Thao vowels, we used the same selection criteria as in § 7.10.1 for Rukai. 17 tokens were obtained from the e-dictionary.

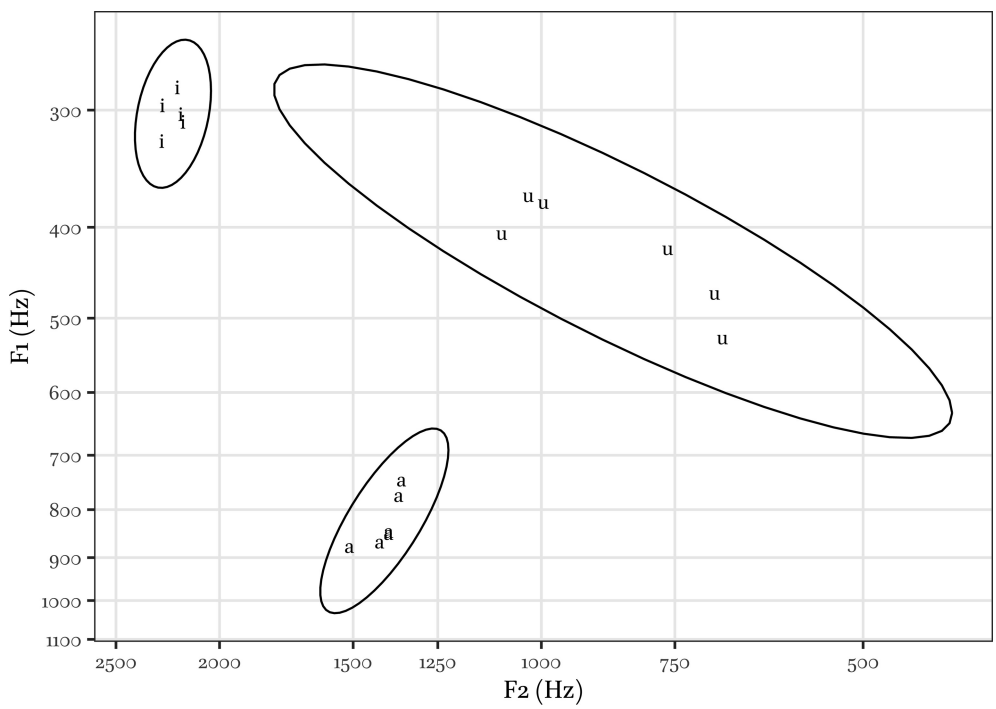

FIGURE 7.32 Thao vowel space
DATA OBTAINED FROM THE THAO E-DICTIONARY

1 Some authors consider that /ŋ/ is actually a loan phoneme, but we will not discuss this issue here.

7.14.2 *Thao Word-Level Prominence*

Blust (2003, p. 35) noted that word-level prominence is marked primarily by greater intensity and secondarily by duration. Additionally, we obtained 15 tokens fitting similar criteria to those described in §7.4.3 (allowing for /l m n ŋ w y r/ for C1 and C2). Of these tokens, only one (*lalau* 'bully') had final stress based on F0. The stressed penultimate syllable in the other 14 tokens was consistently realized with rising F0, as shown in Figure 7.33.

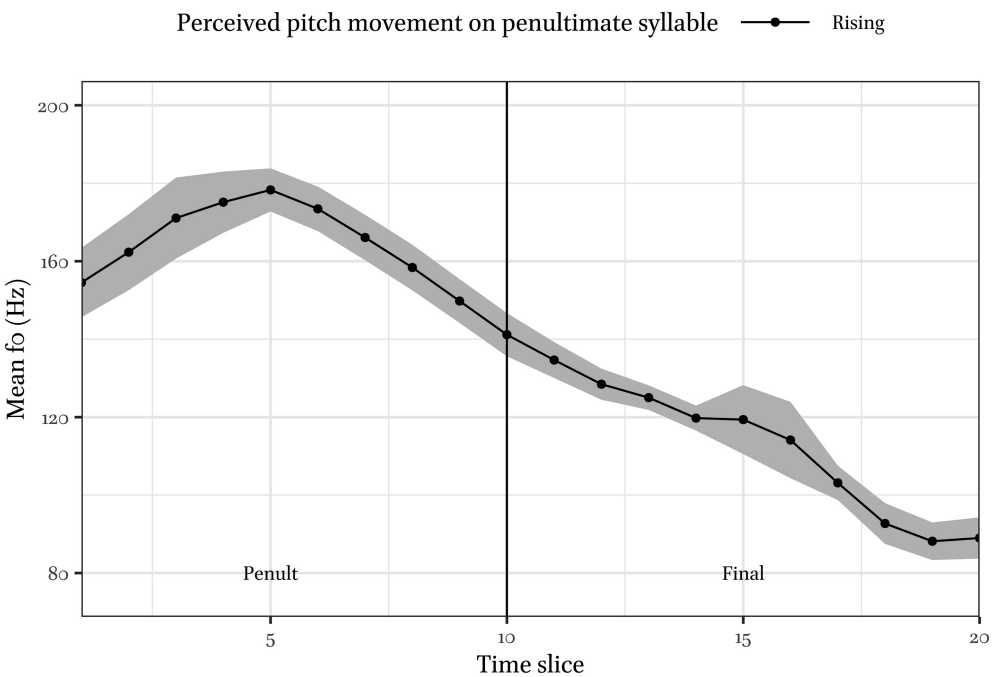

FIGURE 7.33 Thao word-level prominence
DATA OBTAINED FROM THE THAO E-DICTIONARY

7.15 Tsou

Tsou has six vowels (/i u a e o ɨ/) and seventeen consonants (/p t k ʔ ɓ ɗ ts f v s z h m n ŋ (w) j/). It has been noted, however, that /w/ has a limited distribution (Wright & Ladefoged 1997). Stress typically falls on the penultimate syllable (Wright 1994, Wright & Ladefoged 1997, Zeitoun 2005).

7.15.1 *Tsou Vowels*

Wright and Ladefoged (1997) recorded thirteen speakers (5 female, 8 male) of the Tfuya dialect of Tsou, producing eleven words (two tokens for each vowel except for /ɨ/, for which only one token was recorded due to its restricted distribution). Note that the x-axis indicating the backness of the vowel represents the difference between F2' (F2+(F3-F2)(F2-F1)/2(F3-F1)). The results (Figure 7.34) showed that what is transcribed as /e/ is more centralized and closer to high vowels than to low vowels. They also observed that the speakers tended to centralize the back vowels.

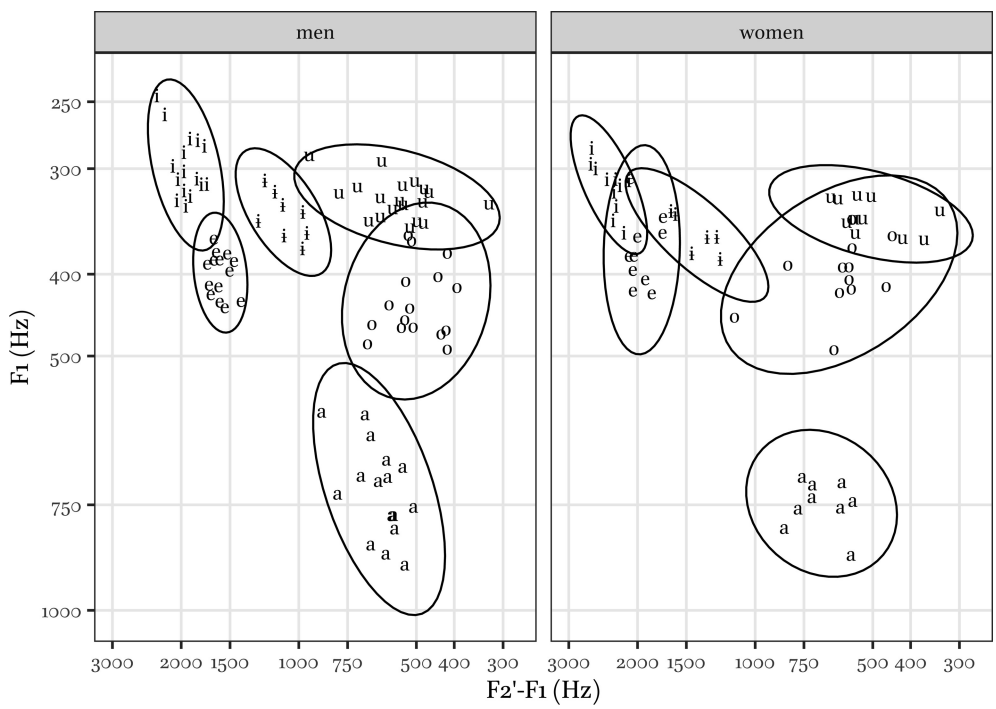

FIGURE 7.34 Tsou vowel space in stressed syllables by gender
REPRODUCED FROM WRIGHT & LADEFOGED 1997, P. 992

7.15.2 *Tsou Consonants*

Wright & Ladefoged (1997) and Wright (1996) provided detailed phonetic descriptions of Tsou consonants illustrated with spectrograms, as well as averaged VOT for the three voiceless stops (p: 11 ms, t: 17 ms, k: 28 ms). These values increase with more posterior places of articulation—a common trend cross-linguistically.

Ladefoged & Zeitoun (1993) argued against the existence of a pulmonic ingressive fricative [f] in Tsou as proposed by Fuller (1990). Using methods such

as asking informants to inhale the smoke from a cigarette, or to put a thin tube between their lips when producing words containing [f], Ladefoged & Zeitoun (1993) reported that a puff of smoke or air could be clearly observed in the production of the sound. That is, there were no signs of ingressiveness.

A special characteristic of Tsou is that it allows a wide array of consonant clusters in the word-initial position (pt, pts, ps, pn, pk, pŋ, pʔ, ph, ft, fts, fn, fk, fŋ, fʔ, fh, vts, vh, ɓn, mp, mf, mts, ms, mz, mn, mʔ, mh, tp, tf, tv, tm, tn, tk, tŋ, tʔ, th, tsp, tsf, tsv, tsm, tsn, tsk, tsŋ, tsʔ, tsh, sp, sv, sɓ, sm, sn, sk, sŋ, sʔ, nm, nt, ns, ks, kn, ŋv, ŋh, ʔp, ʔv, ʔm, ʔt, ʔts, ʔs, hp, hv, hm, ht, hts, hn, hʔ) (Wright 1996, p. 72). Wright & Ladefoged (1997) noted that clusters beginning with /ʔ h/, in particular /ʔp/, /ʔt/ and /hʔ/, are not found in other languages. Wright & Ladefoged (1997) recorded five speakers of the Tfuya dialect (1 female, 4 male) producing these clusters at different speech rates (fast, normal, slow) and reported that when the first consonant was a stop, its release rate was 100%, ensuring audibility. They also found that variations in inter-burst-interval between C1 and C2 were not significant across different speech rates; however, when C1 had internal cues, there may be a lack of release (for nasals) or an overlap with C2 (for fricatives and affricates), and consistent differences across the three speech rates were observed.

7.15.3 *Tsou Word-Level Prominence*

C.F. Huang (2003) recorded twelve speakers from the Tapangu and Tfuya dialects (3 female, 3 male from each dialect) and reported the F0 differences: 1) between the stressed penultimate syllable and the unstressed final syllable in disyllabic words, 2) across the unstressed antepenultimate, the stressed penultimate and the unstressed final syllables in trisyllabic words, and 3) across the unstressed preantepenultimate, antepenultimate, final and stressed penultimate syllables in four-syllable word. The results showed that stressed penultimate syllables in disyllabic and trisyllabic words were realized with higher F0 than the other syllables. In trisyllabic words, the F0 of the unstressed first syllable was higher than the unstressed final syllable. In four-syllable words, speakers variably produced higher F0 on the antepenultimate or preantepenultimate syllables than on the stressed penult.

7.16 Summary

In this chapter, we have summarized the instrumental studies on the phonetic features of fourteen major Formosan languages (Amis, Atayal, Bunun,

Kanakanavu, Kavalan, Kaxabu, Paiwan, Puyuma, Rukai, Saaroa, Saisiyat, Seediq, Thao, Tsou). When instrumental studies could not be found, we made our own preliminary characterizations. Despite the fact that these studies were carried out with different research questions and using different methods, several overarching generalizations could be made.

7.16.1 *Formosan Vowels*

First, as noted in Chapter 9, vowel inventories of Formosan languages are relatively small compared to the world average (4.3 vs. 8.7). One common research question pursued in these previous studies is whether vowel space would be less dispersed or the coarticulation of vowels would be more readily observable in these languages with small vowel inventories. In their investigation of (Central) Amis, Maddieson & Wright (1995) found that vowel space is relatively compact, independent of stress and adjacent consonants (§ 7.2.1). On the contrary, W. Chiang & F. Chiang (2005b) observed that stressed vowels in Truku Seediq are more dispersed than unstressed ones, indicating that dispersion in the vowel space is related to the number of vowels in the inventory. Moreover, vowels were found to be more scattered with a three-vowel inventory than with a five-vowel inventory identified by the native speakers, and there was a greater distance between vowels in the three-vowel inventory than in the five-vowel inventory (§ 7.13.1).

Along similar lines, Y. Chang (2011) investigated if vowels are more coarticulated with adjacent consonants, specifically examining two vowels [e o] in Atayal (Squliq and Mayrinax dialects) that seem to emerge when /i u/ occur next to glottal /q h/. Results showed that, despite formant transitions being longer in the glottal environment, spectral information during the steady state of the vowel did not differ across consonantal environments. Corresponding perceptual experiments were conducted, in which Squliq Atayal listeners were asked to discriminate [i e] and [u o] embedded as a final vowel in CVCV stimuli and to rate how good these tokens were in their language. Though discriminability decreased when the vowels were followed by /h/, overall, listeners rated high vowels as better sounds in their language than mid vowels, suggesting that [e] and [o] are allophones of /i/ and /u/ rather than emerging phonemes (§ 7.3.1). Saisiyat /i/ and /a/ were found to be subject to the same coarticulation effect, becoming [e] and [æ] when occurring next to glottal /q h/, resulting in a complementary distribution between the two sets of sounds. Y. Chang (2009) showed, however, that [e æ] occupy a region of the vowel space distinct from /i a/, unlike in Atayal (§ 7.12.1).

The status of schwa, whether it is a phonetic realization resulting from the resolution of consonant clusters (as in Atayal, Tsou) or it exists in the underly-

ing representation (as in Paiwan, §7.7), is also of interest in Formosan phonetics (see more discussion in Chapter 8 (§8.2.6)).

7.16.2 *Formosan Consonants*

Though Formosan languages offer rich opportunities for consonant research, instrumental studies on Formosan consonants are scarce. Further research is needed, for example, on the wide range of liquids (e.g., in Kavalan, Pazeh, Seediq, Thao, Atayal, Saisiyat, Pyuyma, Rukai, Paiwan; see also relevant discussion in §810.2.3), the retroflex stops (e.g., in Paiwan, Puyuma, Rukai), and glide-fricative alternations (e.g., in Atayal; H. Huang 2020).

Whether glides (G) enjoy an underlying status or are derived on the surface due to well-formedness requirements has been a controversial issue explored in several previous studies (Tung 1964, Ho 1976, Lin 1996, Wright & Ladefoged 1997; see also the discussion in Chapter 9 (§9.2.5)). In a cross-linguistic study of glides in Amis, Bunun, and Tsou, C. Wu (2002) measured the duration of syllables with glides (CGVC, CGV) and without (CVC, CV, CCV). The results (Table 7.35) showed that syllables with glides were significantly longer than those without, segmental durations of CG were longer than those of C, those of GV were longer than those of V, and those of GV were longer than those of G. These results indicate that the duration of glides is comparable to that of a consonant.

correct?

TABLE 7.1 Syllable durations (in ms) for Amis, Bunun, and Tsou

35 changed to 1

	CGVC		CVC		CGV		CV	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
Amis					319	8.4	214.4	1.9
Bunun	343.1	4.2	311	3.1	230.7	4.7	171.7	1.3
Tsou	284.1	2.5	250.8	4.3	264.4	1.8	165.4	2.8

C. WU 2002, P. 74

7.16.3 *Formosan Word-Prominence*

In exploring data in the e-dictionary, we also identified some patterns in word-level prominence: word-final stress tends to be realized with falling F0 when the syllable ends with a sonorant and as high when the syllable is open or ends with an obstruent, as in Amis (§7.2.3, Figure 7.3) and Puyuma (§7.9.3, Figure 7.18). W. Chiang & F. Chiang (2005b) made a similar observation for

Saisiyat (§7.12.2). The patterns (i.e., falling vs. high) observed in Pazeh, Bunun, and Kavalan, however, were based on syllable weight or speakers' idiosyncratic characteristics (Pazeh, §7.8, Figure 7.26) or had no particular correlation with syllable structure (Bunun, §7.4.3, Figure 7.8; Kavalan, §7.6.2, Figure 7.13). On the other hand, from the limited data obtained from e-dictionaries, only one kind of F0 contour shape was observed in Seediq (§7.13.2, Figure 7.31) and Thao (§7.14.2, Figure 7.33) show only one kind of F0 contour shape (i.e., rising).

7.16.4 *Final Remarks*

Finally, there are a few instrumental studies involving second language aspects of Formosan languages. For example, Lin (2011), Y. Chen (2015) and Chung (2016) examine high-school-aged speakers of Amis, Bunun and Paiwan in the vowel production of their heritage languages (L1), Mandarin (L2), and English (L3), and provide pedagogical implications, such as incorporating perceptual training into the teaching of English as a foreign language.

Acknowledgements

We would like to thank the editors of the Handbook, Elizabeth Zeitoun and Paul Jen-kuei Li, and two anonymous reviewers for their valuable comments and suggestions. We would also like to thank Ian Maddieson and Shih-chi Stella Yeh for generously sharing their unpublished data with us to complete this work, and Hui-chuan J. Huang for her insights on how to arrange this chapter. We are indebted to the scholars who put together the online dictionaries of Indigenous languages on which we based our exploratory acoustic analyses. Any remaining errors are ours.

References

Calamai, Silvia (2005). Intrinsic vowel normalization: Comparing different procedures (data from Tuscan Italian). *Italian Journal of Linguistics* **17**(2), 211.

Chang, Henry Yung-li 張永利 (2000). *Saidekeyu cankao yufa* 賽德克語參考語法 [*A reference grammar of Seediq*]. Taiwan nandao yuyan 6 台灣南島語言 6 [Formosan Languages 6]. Taibei 台北 [Taipei]: Yuanliu chubanshe 遠流出版社 [Yuan-Liou Publishing Co.].

Chang, Yueh-chin 張月琴 (2009). Taiyayu he saixiayu de yuyin yanjiu 泰雅語和賽夏語的語音研究 [A report of Atayal and Saisiyat phonetics]. Xingzhengyuan guojia

kexue weiyuanhui zhuanti yanjiu jihua chengguo baogao 行政院國家科學委員會專題研究計畫成果報告 [National Science Council Grant Report].

Chang, Yueh-chin 張月琴 (2011). Taiyayu he saixiayu de yuyin yanjiu II 泰雅語和賽夏語的語音研究 II [A report of Atayal and Saisiyat phonetics II]. Xingzhengyuan guojia kexue weiyuanhui zhuanti yanjiu jihua chengguo baogao 行政院國家科學委員會專題研究計畫成果報告 [National Science Council Grant Report].

Chang, Yueh-chin, Feng-fan Hsieh and Hsin-yi Chen (2019). Emphatically lengthened segments in Siwkolan Amis: Phonetics and phonology. Poster presented at the International Congress of Phonetic Sciences (ICPhS 2019). August 5–9, 2019. Melbourne: Melbourne Convention and Exhibition Center.

Chen, Chun-Mei (2009). The phonetics of Paiwan word-level prosody. *Language and Linguistics* 10(3), 593–625.

Chen, Chun-Mei (2011). Phonetic Evidence for the contact-induced prosody in Budai Rukai. *Concentric: Studies in Linguistics* 37(2), 123–154.

Chen, Hsin-yi (2019). Emphatic lengthening in Siwkolan Amis (Pangcah). MA thesis. Hsinchu: National Tsing Hua University.

Chen, Hsuan-ju (2016). A study of Kanakanavu phonology: Selected topics. MA thesis. Puli, Nantou: National Chi Nan University.

Chen, Sally (2016). A first glimpse of Kanakanavu word prominence. In Jon Barnes, Alejna Brugos, Stefanie Shattuck-Hufnagel and Nanette Veilleux (Eds.), *Proceedings of Speech Prosody 2016*, (pp. 683–686). Boston, MA: Boston University.

Chen, Yu Hsuan (2015). An acoustic comparison between vowels of Paiwan, Bunun, Mandarin, and English for junior high school students. MA thesis. Tainan: Southern Taiwan University of Science and Technology.

Chiang, Wen-yu and Fang-mei Chiang (2005a). Saisiyat as a pitch accent language: Evidence from acoustic study of words. *Oceanic Linguistics* 44(2), 404–426.

Chiang, Wen-yu and Fang-mei Chiang (2005b). Vowel dispersion in Truku. *Concentric: Studies in Linguistics* 31(1), 21–45.

Chiang, Wen-yu, Chang-Liao I and Fang-mei Chiang (2006). The prosodic realization of negation in Saisiyat and English. *Oceanic Linguistics* 45(1), 110–132.

Cho, Taehong and Peter Ladefoged (1999). Variation and universals in VOT: Evidence from 18 languages. *Journal of Phonetics* 27(2), 207–229.

Chung, Raung-fu 鍾榮富 (2016). Paiwan yu bunong guozhongsheng yingyu muyin de xuexi xianxiang 排灣與布農國中生英語母音的學習現象 [The production of English vowels by Paiwan and Bunun high school students]. *Taiwan jiaoyu pinglun yuekan* 臺灣教育評論月刊 [*Taiwan Educational Review Monthly*] 5(9), 31–49.

Edmondson, Jerold A., John H. Esling, Jimmy G. Harris and Tung-chiou Huang (2005). A laryngoscopic study of glottal and epiglottal/pharyngeal stop and continuant articulations in Amis—an Austronesian language of Taiwan. *Language and Linguistics* 6(3), 381–396.

Fuller, Michael (1990). Pulmonic ingressive fricatives in Tsou. *Journal of the International Phonetic Association* 20(2), 9–14.

Ho, Dah-an 何大安 (1976). Zouyu yinyun 鄒語音韻 [Tsou phonology]. *Zhongyang yanjiuyuan lishi yuyan yanjiusuo jikan* 中央研究院歷史語言研究所集刊 [*Bulletin of the Institute of History and Philology, Academia Sinica*] 47(2), 245–274.

Hsieh, Fang-yin Freda (2008). Saisiyat phonology: With special reference to vowel variations. MA thesis. Hsinchu: National Tsing Hua University.

Hsieh, Fuhui 謝富惠 (2018). *Gemalanyu yufa gailun* 噶瑪蘭語語法概論 [A sketch grammar of Kavalan]. Taiwan nandao yuyan congshu 11 台灣南島語言叢書 11 [Series on Formosan Languages 11]. Xinbei 新北 [New Taipei]: Yuanzhuminzu weiyuanhui 原住民族委員會 [Council of Indigenous Peoples]. (2nd ed.)

Huang, Chuian-Fang (2003). A study of the Tsou intonation. MA thesis. Taipei: National Taiwan University.

Huang, Hui-chuan J. (2008). Competition between syllabic and metrical constraints in two Bunun dialects. *Linguistics* 46(1), 1–32.

Huang, Hui-chuan J. (2020). Glide strengthening in Atayal: Sonority dispersion and similarity avoidance. *Journal of East Asian Linguistics* 29(1), 77–117.

Huang, Hui-chuan J. (this handbook). Phonology of Formosan languages. In Paul Jen-kuei Li, Elizabeth Zeitoun and Rik De Busser (Eds.), *A handbook of Formosan languages: The Indigenous languages of Taiwan*. Leiden: Brill.

Huang, Lillian M. and Tali' Hayung 黃美金、吳新生 (2018). Taiyayu yufa gailun 泰雅語語法概論 [*A sketch grammar of Atayal*] Taiwan nandao yuyan congshu 2 台灣南島語言叢書 2 [Series on Formosan Languages 2]. Xinbei 新北 [New Taipei]: Yuanzhuminzu weiyuanhui 原住民族委員會 [Council of Indigenous Peoples]. (2nd ed.)

Kawahara, Hideki, Masanori Morise, Toru Takahashi, Ryuichi Nisimura, Toshio Irino and Hideki Banno (2008). Tandem-STRAIGHT: A temporally stable power spectral representation for periodic signals and applications to interference-free spectrum, F0, and aperiodicity estimation. *2008 IEEE International Conference on Acoustics, Speech and Signal Processing*, Las Vegas NV, 2008, (pp. 3933–3936). doi: 10.1109/ICASSP.2008.4518514.

Ladefoged, Peter and Elizabeth Zeitoun (1993). Pulmonic ingressive phones do not occur in Tsou. *Journal of the International Phonetic Association* 23(1), 13–15.

Li, Paul Jen-kuei (1995). Rukai: Introduction and wordlist. In Tryon, Darrell (Ed.), *Comparative Austronesian dictionary: An introduction to Austronesian studies*, (pp. 297–305). Berlin: De Gruyter Mouton.

Li, Paul Jen-kuei and Shigeru Tsuchida (2001). *Pazih dictionary*. Language and Linguistics Monograph Series No. A-2. Taipei: Institute of Linguistics (Preparatory Office), Academia Sinica.

Lim, Hong-Sui 林鴻瑞 (2016). Gehawuyu yinyun yanjiu 噶哈巫語音韻研究 [A study of

Kaxabu phonology]. Shuoshi lunwen 碩士論文 [MA thesis]. Xinzhu 新竹 [Hsinchu]: Guoli qinghua daxue 國立清華大學 [National Tsing Hua University].

Lin, Hsiu-Hsu (1996). Isbukun phonology: A study of its segments, syllable structure and phonological processes. MA thesis. Hsinchu: National Tsing Hua University.

Lin, Wei-Chen (2011). Acoustic properties of Amis vowels and the implications on English pronunciation teaching. MA thesis. Tainan: Southern Taiwan University of Science and Technology.

Lu, Yu-An (2005). Mayrinax phonology: With special reference to UM affixation. MA thesis. Hsinchu: National Tsing Hua University.

Maddieson, Ian, Kivi Mavaliu, Chen-Hui Wu and Youjing Lin (2004). Phonetic characteristics of a Southern Paiwan dialect. Paper presented at the LSA Annual Meeting, January 8–11, 2004, Boston, MA.

Maddieson, Ian and Richard Wright (1995). The vowels and consonants of Amis-a preliminary phonetic report. *UCLA Working Papers in Phonetics* 91, 45–66.

Maddieson, Ian, Jie Zhang, and Richard Wright (1995). Phonetic patterns of Bunun. MS.

Martinet, André (1937). *La gémination consonantique d'origine expressive dans les langues germaniques*. Copenhagen: Levin et Munksgaard; Paris: C. Klincksieck.

Pan, Chia-jung (2012). A grammar of Lha'alua, an Austronesian language of Taiwan. PhD dissertation. Cairns: James Cook University.

Rivierre, Jean-Claude (2001). Tonogenesis and evolution of the tonal systems in New Caledonia, the example of Cèmuhî. In Shigeki Kaji (Ed.), *Proceedings of the symposium "Cross-linguistic studies of tonal phenomena: tonogenesis, Japanese accentology, and other topics"*, (pp. 23–42). Tokyo: Tokyo University of Foreign Studies.

Shih, Cindy Peiru (2008). Interrogative constructions in Plngawan Atayal. MA thesis. Taipei: National Taiwan Normal University.

Shih, Shu-hao (2018). Non-moraic schwa: Phonology and phonetics. PhD dissertation. New Jersey, NJ: Rutgers University.

Shue, Yen-Liang, Patricia Keating, Chad Vicenik and Kristine Yu (2011). VOICESAUCE: A program for voice analysis [computer program]. *Journal of the Acoustical Society of America* 126, 2221.

Teng, Stacy Fang-ching (2008). *A reference grammar of Puyuma, an Austronesian language of Taiwan*. Pacific Linguistics 595. Canberra: The Australian National University.

Tseng, Josh Chia-hsing (2009). The morphophonemic alternations in Thao phonology. MA thesis. Hsinchu: National Tsing Hua University.

Tsuchida, Shigeru (1964). Preliminary reports on Saisiyat: Phonology. *Gengo Kenkyu* [*Journal of the Linguistic Society of Japan*] 46, 42–52.

Tsuchida, Shigeru (1982). Subclassification of Ami dialects. Manuscript. Tokyo: Tokyo University.

Tung, T'ung-ho with the assistance of S.H. Wang, T.K. Kuan, T.F. Cheng and Margaret M. Yan (1964). *A descriptive study of the Tsou language, Formosa*. Institute of History and Philology, Academia Sinica Special Publications, No. 48. Taipei: Institute of History and Philology, Academia Sinica.

Wright, Richard (1996). Consonant clusters and cue preservation in Tsou. PhD dissertation. Los Angeles, CA: University of California.

Wright, Richard and Peter Ladefoged (1997). A phonetic study of Tsou. *Bulletin of the Institute of History and Philology, Academia Sinica* 68(4), 987–1028.

Wu, Chen-huei (2002). A study of glides in Formosan languages: Acoustic evidence for a constraint-based approach. MA thesis. Taipei: National Chengchi University.

Wu, Jing-lan Joy 吳靜蘭 (2018). *Ameiyu yufa gailun* 阿美語語法概論 [A *sketch grammar of Amis*]. Taiwan nandao yuyan congshu 1 台灣南島語言叢書 1 [Series on Formosan Languages 1]. Xinbei 新北 [New Taipei]: Yuanzhuminzu weiyuanhui 原住民族委員會 [Council of Indigenous Peoples]. (2nd ed.)

Yeh, Shih-Chi Stella (2011). Phonemic distinction between vowels and glides in Sinvaudjan Paiwan. *Tsing Hua Journal of Chinese Studies, New Series* 41(3), 551–586.

Yu, Lee-Jiun (2009). The acoustic characteristics of consonants and vowels in Isbukun Bunun. MA thesis. Kaohsiung: National Kaohsiung Normal University.

Zeitoun, Elizabeth 齊莉莎 (2000). *Bunongyu cankao yufa* 布農語參考語法 [*A reference grammar of Bunun*]. Taiwan nandao yuyan 5 台灣南島語言 5 [Formosan Languages 5]. Taibei 台北 [Taipei]: Yuanliu chubanshe 遠流出版社 [Yuan-Liou Publishing Co.].

Zeitoun, Elizabeth. (2005). Tsou. In Adelaar, Alexander K. and Nikolaus Himmelmann (Eds.), *The Austronesian languages of Asia and Madagascar*, (pp. 259–290). London and New York, NY: Routledge.

Zeitoun, Elizabeth, Tai-hwa Chu and lalo a tahesh kaybaybaw (2015). *A study of Saisiyat morphology*. Oceanic Linguistics Special Publication, No. 40. Honolulu, HI: University of Hawai'i Press.

Online resources and open data

Boersma, Paul and David Weenink (2017). Praat: Doing phonetics by computer (Version 6.0.26). Retrieved from www.praat.org. http://www.fon.hum.uva.nl/praat/manual/FAQ__How_to_cite_Praat.html

Council of Indigenous Peoples 原住民族委員會 (2021). Yuanzhuminzu yuyan xianshang cidian 原住民族語言線上詞典 [Online dictionaries of Indigenous languages]. Retrieved from https://e-dictionary.ilrdf.org.tw/

Hsu, Chung-Wen Akiw 徐中文 (2018). *Peinanzu yuyan diaocha baogao* 卑南族語言調查報告 [*A report on Puyuma*]. MS. http://shorturl.at/cnC09.

R Core Team (2017). R: A language and environment for statistical computing. R Foun-

dation for Statistical Computing, Vienna, Austria. Retrieved from http://www.R-project.org/.

Rohatgi, Ankit (2017). WebPlotDigitizer. URL https://apps.automeris.io/wpd/; https://osf.io/w9u67/ ■ correct?

Wickham, Hakley (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. Retrieved from https://ggplot2.tidyverse.org.