Saisiyat as a Pitch Accent Language: Evidence from Acoustic Study of Words

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This paper investigates the acoustic realization of lexical-level accent in Saisiyat, an endangered aboriginal language of Taiwan. Accent in Saisiyat usually falls on the ultimate syllable of content words. This phenomenon has been described in previous studies as either "stress" or "accent." Our measurements and analysis of various prosodic parameters of syllable rhyme (Fo height at onset, offset, peak, and valley, as well as pitch range, duration, slope, peak alignment, and intensity peak) suggest that accent in Saisiyat should be classified as pitch accent, because lexical accent is realized by means of specific Fo patterns, rather than duration and intensity. Thus, among three typological categories that have been proposed for languages (lexical tone, lexical stress, and lexical pitch accent), we propose that Saisiyat belongs to the category that has lexical pitch accent.

1. INTRODUCTION.[1] This paper investigates the acoustic realization of lexical-level accent in Saisiyat, an endangered aboriginal language of Taiwan. Based on the results of this study, we propose that Saisiyat should be classified as a pitch accent language. Accent in Saisiyat content words is fixed on the final syllable, a property that it shares with certain other Taiwanese Austronesian languages. Yeh (2000) formulates the Saisiyat stress rule as follows:[2]

$$V \rightarrow V\,[+\text{stress}] \quad /\ \_(C)\#$$

This rule, however, does not apply to function words or place names.[3]

1. An earlier version of this paper was presented at First Workshop on Discourse and Cognition, National Taiwan University, May 29, 2004. This study was sponsored by National Science Council grant number NSC92-2411-H-002-079 in Taiwan. We would like to thank the two informants, Paway a tahis and Oebay a oemaw, who enthusiastically provided native speaker judgments and other relevant information, and the other two research assistants in the NSC Saisiyat Intonation Project, I Chang-Liao and Hung-chun Tung, for their helpful comments and discussion. Special thanks go to Tanya Visceglia and two anonymous reviewers for their insightful comments. Any remaining errors are our own.

2. Previous studies of Taiwanese Austronesian languages have usually referred to acoustically prominent syllables as "stressed" (e.g., Yeh 2000). The distinction between "stress" and "accent" will be clarified in the following sections.

3. We observed that the prosody of function words in Saisiyat was much less regular than that of content words. Many function words are either monosyllabic or disyllabic and bear neither stress nor accent, unless they are emphasized for pragmatic reasons. As for place names, too few tokens occurred in our data to discern any patterns.

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Zorc (1993) proposes a classification system for Austronesian languages based on their criteria for accent assignment.[4] According to this system, accent may be assigned on the basis of: (a) phonemic length and shortness; (b) phonemic accent (quantity or stress) as secondarily introduced, generally due to consonant loss, analogical leveling, or borrowing; (c) length contrasts in the ultima, resulting from compensation for the loss of a consonant; (d) phonemic length, as the result of coalescence (or crasis) of vowels, which does not correspond with stress (pitch accent); (e) phonemic length or shortness, retained sporadically as remnants of a preexisting system; (f) consonant length following a short vowel; (g) oxytone, with accent (with or without secondary vowel lengthening) falling regularly on the ultima; (h) paroxytone, with accent falling regularly on the penult; (i) proparoxytone, with accent falling regularly on a prepenultimate syllable; (j) PAN *e influences accent in a different way from the other vowels; (k) accent is used inflectionally, that is morphemic accent. Zorc categorized Tungho-Saisiyat[5] as belonging to category (d) and Saisiyat to category (g). This categorization of Saisiyat accent is congruent with previous observations that accent falls regularly on the ultimate syllable, and that vowel length does not affect pitch accent assignment.[6]

No previous phonological description of accent/stress in Saisiyat has measured the acoustic properties of prominent syllables. The present study aims to provide a detailed acoustic analysis of Saisiyat accent by measuring the following parameters of syllable rhyme: F0 height at onset, offset, peak, and valley, as well as pitch range, duration, slope, peak alignment, and intensity peak. Analyzing these parameters will allow us to distinguish accented from unaccented syllables, as well as among the accents realized on different syllabic structures. The results of this study provide support for the classification of Saisiyat as a pitch accent language, because lexical accents are made prominent by means of specific F0 patterns rather than by means of duration and intensity.

The remainder of this paper is organized as follows: section 2 reviews definitions of pitch accent, describes the acoustic parameters to be investigated, and reviews the literature on the influence of accent and coda types on the realization of prominent syllables. Section 3 describes the methodology used in this study, and section 4 reviews its results. Section 5 discusses the acoustic realization of Saisiyat pitch accents, and the ways in which the current data provide support for classification of Saisiyat as a pitch accent language.

4. For a comprehensive list of the languages included in each category, see Zorc (1993).
5. Saisiyat is divided into northern and southern dialects. Northern Saisiyat, generally called the Taai dialect, is spoken in Hsinchu County. Southern Saisiyat, generally spoken in Miaoli County, is called the Tungho dialect (Yeh 2000).
6. Wolff (1993) concluded that stress in Proto-Austronesian falls on the penult of the root if it is long (or accented) and on the final syllable of the root if the penult is short (or unaccented). In other words, there are two kinds of roots: those with a stressed penult and those with a stressed final syllable. If there is suffixation, the accent remains on the penult of the suffixed form if the penult of the root is accented, and on the final syllable of the suffixed form if the final syllable of the root is accented. Wolff's conclusions were based on detailed work with Philippine and Formosan Austronesian languages. He concluded that (1) stress patterns tend to remain unchanged in nouns and unaffixed forms that are not stative adjectives, and (2), while the stress patterns of actor focus verbs tend to reflect the underlying stress pattern of their verbal roots in Philippine aboriginal languages, no such tendency was found in the Austronesian languages of Taiwan.

2. DEFINITIONS OF THE PARAMETERS UNDER INVESTIGATION, ACCENT TYPES AND CODA TYPES

2.1 DEFINITIONS OF PITCH ACCENT. The term "pitch accent" was first proposed by Bolinger (1958), who defined it as an actual prominence in an utterance and a major cue to the perception of stress. His definition seemed to be based on Indo-European language data in the sense that it links "pitch accent" to stress. Beckman (1986) argued that melodic accent (pitch accent) and dynamic accent (stress accent) are actually two distinct accent types. According to her classification system, in pitch accent languages such as Japanese, pitch change is the only acoustic cue to accent. In stress accent languages such as English, however, stressed syllables are differentiated using not only pitch height, but also duration, intensity, and vowel quality.[7] Fox (2000) defined "accent" as a phonological unit that is manifested using stress features in stress-accent languages and nonstress features in pitch accent languages. The former is dynamic and is realized as a composite of pitch, duration, and intensity. The latter is melodic and is realized by means of pitch features only. Cruttenden (1997) views pitch accent as being equivalent to "accent," which he defines as prominence that is created by use of pitch. Pitch accent languages such as Japanese and Swedish license no more than one accent per word; these accents are realized using only pitch, and their properties are not affected by intonation.

Remijsen (2003) divides lexical-level prosodic properties into three types: lexical tones, lexical stress, and lexical pitch accent. The function of lexical tone is to distinguish words from one another, and it does so by means of differences in fundamental frequency (Fo) pattern. Lexical pitch accent and lexical stress are both categorized as varieties of lexical accent. They differ in the sense that lexical pitch accent consists of a single, specific Fo pattern, whereas lexical stress is realized using Fo, duration, and intensity.

2.2 DEFINITIONS OF PARAMETERS. The parameters to be measured are:

Fo height (Hz): at onset, offset, peak, and valley
Pitch range (Hz): $Fo_{peak} – Fo_{valley}$
Duration (ms): $t_{offset} – t_{onset}$
Fo slope: $(Fo_{peak} – Fo_{valley})/(t_{peak} – t_{valley})$
Fo peak alignment (%): $(t_{peak} - t_{onset})/(t_{offset} – t_{onset}) * 100$
Intensity peak (dB)

Fo height will be measured at four locations in the rhyme of each syllable: onset, offset, peak, and valley. Pitch range will be measured as the difference in Fo values between the peak and valley ($Fo_{peak} – Fo_{valley}$). Duration will be measured as the time difference between the rhyme onset and offset points ($t_{offset} – t_{onset}$). Fo slope will be measured as the rate of movement from the Fo peak to the valley, which is calculated as Fo peak-valley difference divided by duration. If an Fo slope value is positive, the pitch contour can be described as rising; if that value is negative, the pitch contour is falling. Fo peak alignment will be measured as the temporal position in which the pitch peak is located within a syllable rhyme. This will be calculated using the formula, $(t_{peak} – t_{onset}) / (t_{offset}– t_{onset}) * 100$,

7. Similar claims were also proposed by some recent studies (e.g., Campbell 1993), which provided evidence that duration or intensity may serve as a reliable indicator of stress even in the absence of pitch features.

which divides syllable duration by the duration from onset to peak. Finally, intensity peak will be measured as the highest dB value within a rhyme.

2.3 ACCENT TYPES. Previous research on the acoustic properties of accent has generally concluded that F0 is the most salient, and often the only cue in the realization of accent (Muyskens 1931, Parmenter and Blanc 1933, Beckman 1986). Some studies have claimed that duration is another important parameter in determining pitch accent location (Schramm 1937 and Jassem 1959). Intensity is generally considered to be the least important cue (Fry 1958 and Bolinger 1958).[8]

Research on the acoustic realization of accent has often investigated F0 alignment. Bruce (1977) found that the temporal anchoring of pitch movements to the segmental string could distinguish accented from unaccented syllables in Swedish. The two accent types in Swedish, Accent 1 (acute) and Accent 2 (grave) are distinguished by F0 peak alignment. In citation form, Accent 1 has a single peak, while Accent 2 has two. Bruce, however, claimed that the distinction between these two accents actually lies in their alignment of pitch peak with respect to the stressed vowel. The pitch peak in Accent 1 precedes the onset of the stressed vowel; if there is no unstressed syllable preceding the stressed vowel, an Accent 1 peak will not be realized in the F0 contour. The sharply falling contour of an Accent 2 peak, in contrast, coincides with the stressed vowel; thus, they always surface in the F0 contour. F0 valley alignment has also been investigated. Prieto, van Santen, and Hirschberg (1995) found that in Mexican Spanish, F0 valley is very consistently aligned in a position occurring before the onset of accented syllables. Their conclusion was similar to Bruce (1977), namely that: "reaching a certain pitch level at a particular point in time is the important thing, not the movement (rise or fall) itself" (Bruce 1977:132). The phenomenon of F0 peak delay— the postponement in various prosodic conditions of an F0 peak from an accented syllable into the unaccented syllable directly following it—has also been observed (Silverman and Pierrehumbert 1990).

2.4 CODA TYPES. The F0 realization of tone, accent, or intonation is intrinsically influenced by segmental content. Prevocalic consonants create the most substantial F0 perturbation in the nuclear vowel. For example, if a prevocalic consonant is voiced, F0 of the following vowel will be lowered; if it is voiceless, F0 of the following vowel will be raised. This kind of consonantal influence on pitch has been widely attested in Southeast Asian tone languages, including Austronesian languages (Blood 1964, cited in Haudricourt 1972). The voicing of postvocalic consonants has the same effect on nuclear vowels, but on a smaller scale (Mohr 1968). However, the postvocalic laryngeals *ʔ* and *h* have been claimed to bring about the opposite effects. The glottal stop *ʔ* tends to contribute to F0 rise in preceding vowels (e.g., Haudricourt 1954), while the glottal fricative *h* tends to contribute to an F0 fall (e.g., Matisoff 1973). With the exception of those two consonants, postvocalic nonglottal consonants and intrinsic vowel height have rarely been claimed to influence realization of F0 in rising and falling tones (Hombert 1978; Hombert, Ohala, and Ewan 1979, cited in Fox 2000). Subsequently, House (1989) found that voiced rhymes either following voiceless consonants or containing intrinsically short vowels may undergo steeper, more compressed pitch movements than long vowels followed by sonorant consonants, especially nasals.

8. Many scholars claim that duration is more important in marking prominence than intensity, while others claim that intensity is more salient than duration (Liberman 1960, van der Mark 2002).

3. METHOD

3.1 PARTICIPANTS. Two male native speakers of approximately sixty years of age participated in this experiment. One was a speaker of the southern Saisiyat (later referred to as Speaker 1) and the other was a speaker of northern Saisiyat (later referred to as Speaker 2).[9] Both are well educated and have spoken Saisiyat for decades. They also use Mandarin on a daily basis to communicate with Mandarin-speaking people.

3.2 EXPERIMENTAL MATERIALS

3.2.1 The Saisiyat phonemic inventory and lexicon. We preface this section with a brief introduction of the phonology and word-level prosody of Saisiyat. Phonologically speaking, Saisiyat[10] has a phonemic inventory of six vowels (*i, oe, ae, o, a,* and schwa) and seventeen consonants (*p, b, t, k, ', m, n, ng, s, z, S, h, l, L, r, w, j*).[11] Word-level prosody in Saisiyat is the combined product of its syllabic structure and accent assignment. Its most frequently occurring syllable structures are CV and CVC.

As for the distribution of mono- and polysyllabic words in Saisiyat, our investigation found 2-syllable words to be predominant, comprising 45.42 percent of the lexicon. 3-syllable words comprise 28.32 percent, and 4-syllable words comprise 16.24 percent. These three types account for 90 percent of the lexical items in Saisiyat.[12] As for syllable coda consonants, final accented syllables tend to include a coda consonant more often than unaccented syllables do. Our survey of the Saisiyat lexicon found that about 85.3 percent of accented syllables end with coda consonants, compared with the 21.8 percent that occur in unaccented syllables.

3.2.2 Materials. Experimental materials for this study consisted of a wordlist that was controlled for two variables: number of syllables per lexical item (2, 3, 4, and 5 syllables) and coda type (no coda, nasal coda, and stop coda). To control for possible effects of adjacent syllable type, the syllable preceding each accented syllable was a CV syllable, while the target accented syllable was either CV or CVC. /a/ or /i/ was chosen as the vowel for the accented syllables, because these two vowels occur most frequently in Saisiyat, and they allow for relatively stable and consistent pitch and formant value extraction. We also chose /a/ or /i / to be the vowel in unaccented syllables as much as possible.

9. Because Saisiyat is an endangered language, informants who are both proficient enough to participate in the experiment and fluent enough in Mandarin Chinese to comprehend the instructions are difficult to find. Speaker 1 is Paway a tahis and Speaker 2 is Oebay a oemaw. The ordering of these two speakers is based on the time sequence in which we recorded our data.

10. Saisiyat is morphologically similar to other Austronesian languages of Taiwan in that it uses a wide inventory of affixes to mark focus, as well a wide variety of case markers to specify semantic roles. However, it differs from other Formosan languages in that it has an SVO word order, whereas most others exhibit a VOS word order.

11. For orthographic convenience, IPA transcription of the mid rounded front vowel and the low front vowel in Saisiyat have been written as *oe* and *ae;* the voiced bilabial fricative has been written as *b* and the velar nasal as *ng*. In addition, *S* represents a voiceless alveopalatal fricative and ' represents the glottal stop. Note that the lateral flap *L* was reported to be extinct in some dialects, retained by only a few speakers (Yeh 2000). For this reason, *L* is not included in this study.

12. The survey was based on the 579 Saisiyat words appearing in Yeh (2000) and calculated by Lin Zhe-min, a linguistics graduate student at National Taiwan University. The remaining 10 percent of lexical items in this survey included 1-syllable (3.45%), 5-syllable (5.36%), 6-syllable (1.04%), and 7-syllable (0.17%).

Coda types included: no coda, the nasal /n/, and a glottal stop /'/. The latter two were chosen to represent sonorants and obstruents, respectively. Sonorants were chosen as preferred onset consonants for two reasons: pitch can be more easily extracted from sonorant segments, and sonorants tend not to cause as much pitch perturbation of the nuclear vowel as obstruents do. The wordlist is shown in table 1.

The total number of experimental items should have been thirty-six (4 syllable types × 3 coda types × 3 items). However, no 5-syllable words containing a glottal stop coda could be found, so the only item in that condition is the word *m-in-aywawa:ak,* which has a /k/ coda. We are not entirely certain of whether the absence of 5-syllable stop-coda items is the result of a gap in the lexicon or our own failure to locate such items. Consequently, there are thirty-four, rather than thirty-six items in the wordlist.

3.3 RECORDING. Recording was conducted in the phonetics laboratory of National Taiwan University Linguistics Institute, using the Kay Elemetrics Computerized Speech Lab (CSL) 4400 at a 22050-Hz sampling rate. The items in the wordlist were randomized, and the speakers were directed to read each word five times at a natural speed with about 0.5-second intervals between repetitions. Each recording session lasted about one hour. All recordings were made using a condenser microphone positioned approximately 10 cm away from the speaker's mouth.

TABLE 1. WORDLIST OF 34 LEXICAL ITEMS

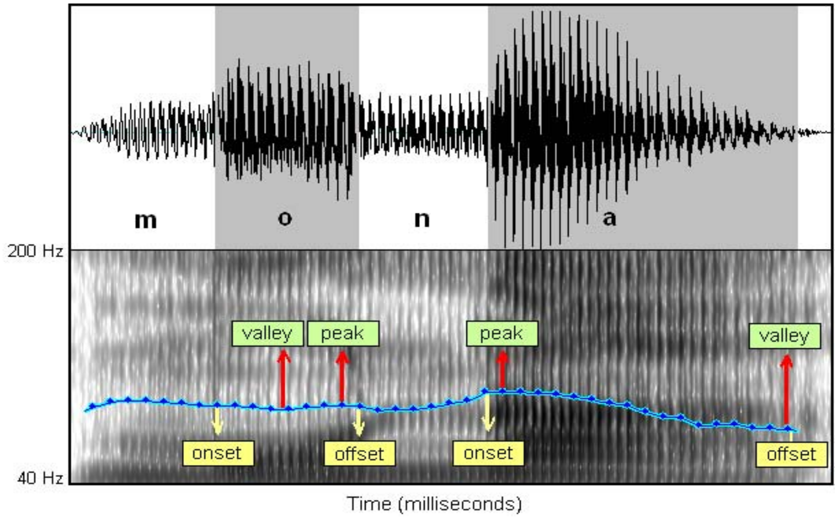
		NO CODA OR NASAL CODA	STOP CODA
2-SYLLABLE			
	CVCV	**mona** 'snail' **rawa** 'flying squirrel' **hini** 'here'	—
	CVCVC	**haewan** 'night' **mawan** 'brother-in-law' **nahaen** 'a while'	**bala'** 'stone' **kala'** 'basket' **rima'** 'go-AF'†
3-SYLLABLE			
	CVCVCV	**hahila** 'day' **h-om-ila** '(sun) shine-AF-PFV' **h-in-ila** '(sun) shine-PFV'	—
	CVCVCVC	**lolongan** 'brook' **waliSan** 'porcupine' **hanuwan** 'horse'	**tatini'** 'the elder' **hahoela'** 'to snow' **h-om-iwa'** 'to kill-AF'
4-SYLLABLE			
	CVCVCVCV	**t-om-okani** 'to put in-AF' **h-om-in-ila** '(sun) shine-AF-PFV' **si-pa-hila** 'RF-Causative-(sun)shine'	—
	CVCVCVCVC	**ka'ina'an** 'mother' **'in-oral-an** 'to rain-PFV-LF' **kalangoy-an** 'a pool'	**'-ina-rima'** 'Aspect-go' **pa-'alowa'** 'Causative-to warn' **minatini'** 'senior siblings'
5-SYLLABLE			
	CVCVCVCV	**p-om-asa'ani** 'to wear glasses-AF' **naremeS-ani** 'to endure' **patomok-ani** 'to take over'	—
	CVCVCVCVC	**kapatawawan** 'factory' **kapapama'an** 'car' **'inalingo'an** 'photo'	**m-in-aywawa:ak** 'to lie and sleep-AF-PFV'

† AF, RF, and LF represent agent-focus, referential-focus, and locative-focus, respectively. PFV is the abbreviation for PERFECTIVE.

3.4 MEASUREMENT. The data were analyzed using the software *Praat* and digitized at a 22050-Hz sampling rate. Onset consonants were excluded from measurement to minimize the effects of microprosodic variation. Coda consonants, in contrast, were included in the measurement of accented syllables, because pitch differences caused by coda type were operationalized in this experiment. Each syllable was measured with respect to the parameters mentioned in section 2: F0 height, pitch range, slope, and peak alignment, plus duration and intensity peak. Figure 1 provides an example of the estimation process. The onsets *m* and *n* were excluded and the rhymes *o* and *a* were preserved using visual examination of the waveform and formant history.[13] Four points were identified within each rhyme: onset, offset, peak, and valley, as indicated in figure 1 by arrows. F0 (in Hz) and time (in ms) values were determined for these four points, as well as the value of the intensity peak (in dB) within the rhyme. Often, two points occurred very close to one another in time. For example, offset and valley occurred almost simultaneously in the accented syllable *-na,* as shown in figure 1.

4. RESULTS. For each of the above-mentioned parameters, preaccented syllables (abbreviated as pre-Acc) were compared with accented (abbreviated as Acc) syllables across 2-, 3-, 4-, and 5-syllable word conditions, and accented syllables were compared across three different coda types: open, nasal, and stop. A data overview will be given in 4.1, followed by a detailed discussion of each separate parameter.

FIGURE 1. THE ITEM *mona* 'SNAIL' REPRESENTED AS A WAVEFORM (TOP), SPECTROGRAM (BOTTOM) AND PITCH (DOTTED LINE) †



† Arrows indicate the points measured.

13. The formant history and intensity curve are not shown in figure 1 for a clearer picture of pitch realization (the dotted line).

4.1 OVERALL F_0 CONTOUR

4.1.1 Accented vs. preaccented syllables. Figure 2 illustrates the overall pitch contour produced in each of the three coda-type conditions by the two speakers. The three curves in each plot represent no-coda, nasal-coda, and stop-coda conditions, respectively. It can be seen in figure 2 that a falling contour is the prevalent pattern for accented syllables. However, three exceptions were observed in the productions of Speaker 2. For stop-coda items occurring in the two-syllable, four-syllable, and five-syllable conditions, Speaker 2 produced accents with a rising pitch contour. Preaccented syllables, in contrast, exhibit no clear patterns in pitch movement direction.

Table 2a provides mean F0 values for the four pitch measurement points (onset, offset, peak, and valley) for each condition.[14] Table 2a illustrates two findings: first, onset and offset F0 values are similar to peak and valley values, respectively (with the exception of pre-Acc2 and pre-Acc4 in the 5-syllable condition). Thus, pitch contour is gradually falling throughout the rhyme in both accented and unaccented syllables. Second, the highest F0 peak and the lowest valley always occur within the accented syllable of a word.

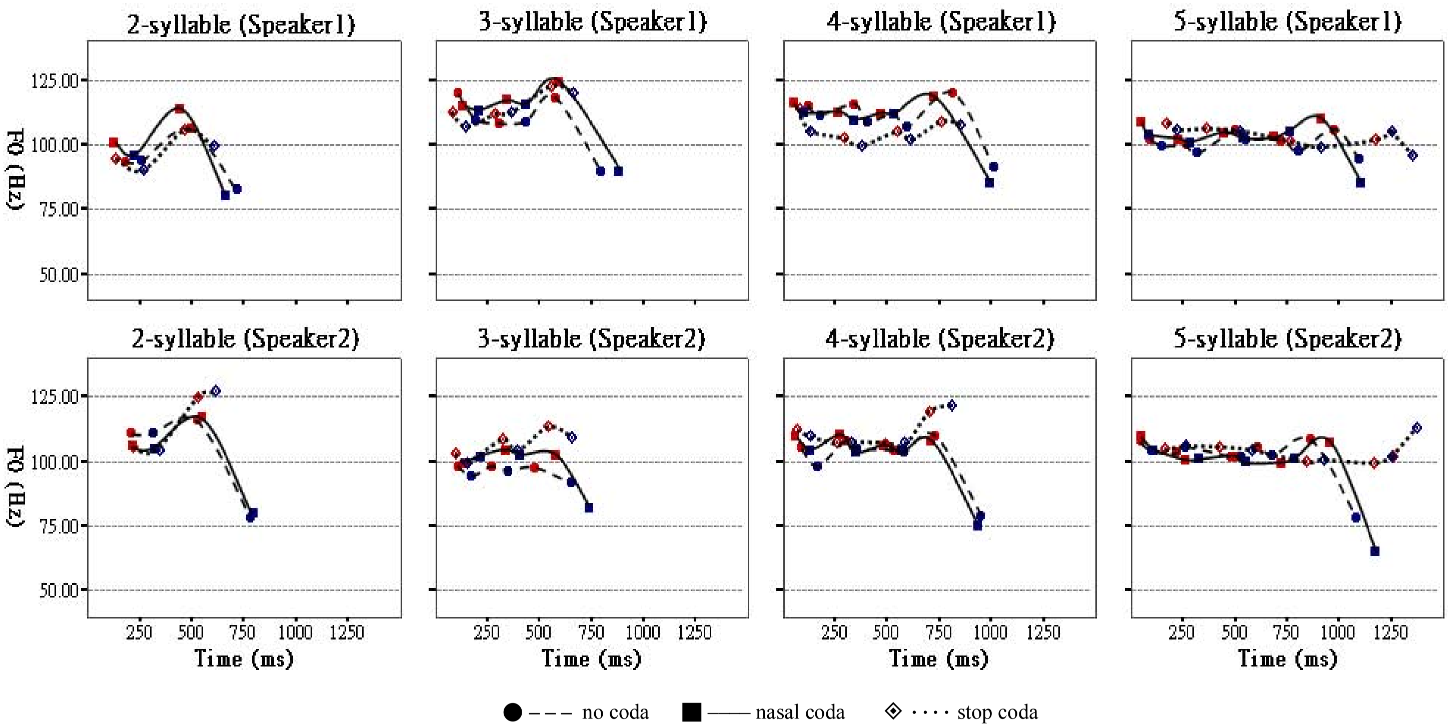
Table 2b shows ANOVA results comparing four pitch values in both preaccented and accented syllables for 2–5 syllable items. In each condition, F0 is the dependent variable, and the four measurement points (onset, offset, peak, and valley) are the independent variables. Significance here and in all subsequent tests was selected to be .01.

Tables 2a and 2b demonstrate that for preaccented syllables, F0 values of the four points (onset, offset, peak, and valley) were generally not significantly different. Pre-Acc1 of 4-syllable words was the sole exception ($F(3,64)=4.881$, $p < .01$). As for accented syllables, a Bonferroni post hoc test showed that F0 values were significantly higher at the onset and peak points than at the offset or valley points regardless of syllabicity. The results confirm figure 2's observation that most pitch contours in accented syllables exhibit falling contours.

4.1.2 Accented syllables in different coda types. Figure 2 and table 2a demonstrate that the highest F0 peaks and the lowest valleys were usually realized within accented syllables. However, the lowest F0 valley seldom occurred within accented syllables with a stop coda. Table 2c shows ANOVA results of the four measurement points within accented syllables compared across coda type. As in table 2b, the dependent variable is F0 value and the independent variables are the four measurement points. Table 2c shows that accented syllables with no coda or a nasal coda had significantly higher F0 values at the onset or peak points than at the offset or valley points (determined by a Bonferroni post hoc test). F0 values in accented syllables with a stop coda, in contrast, were not significantly different among the four points (onset, offset, peak, and valley).

14. Detailed statistics for the pitch values across coda types are provided in appendix 1a–1d.

FIGURE 2. AN OVERVIEW OF THE PITCH COUTOURS OF SPEAKER 1 AND SPEAKER 2



† Note that the curves in each plot represent interpolated, rather than actual pitch contours. The figures were plotted using an SPSS scatter plot.

TABLE 2A. MEAN F0 VALUES AND STANDARD DEVIATIONS OF FOUR MEASURED POINTS IN PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS SYLLABICITY CONDITIONS

SYLLABICITY	ACCENT †	Fo: Mean (SD)							
		ONSET		OFFSET		PEAK		VALLEY	
2-syllable	pre-Acc1	101.73	(7.82)	99.92	(8.50)	102.96	(7.55)	98.23	(7.89)
	Acc	113.83	(8.21)	91.16	(18.45)	115.03	(10.14)	90.06	(17.59)
3-syllable	pre-Acc1	107.71	(9.48)	103.92	(7.62)	108.60	(9.19)	102.95	(7.82)
	pre-Acc 2	107.91	(6.79)	106.49	(7.66)	108.84	(7.11)	105.41	(6.91)
	Acc	113.05	(10.57)	97.02	(15.63)	114.23	(10.52)	93.14	(13.39)
4-syllable	pre-Acc 1	112.32	(5.72)	107.16	(5.94)	112.39	(5.69)	106.77	(5.91)
	pre-Acc 2	109.34	(6.54)	105.42	(6.27)	109.96	(5.87)	104.64	(6.20)
	pre-Acc 3	107.64	(6.28)	105.89	(6.34)	107.89	(6.34)	104.96	(5.71)
	Acc	114.23	(6.55)	94.06	(17.32)	115.59	(6.97)	92.50	(15.95)
5-syllable	pre-Acc 1	106.76	(6.54)	103.14	(6.63)	107.06	(6.50)	102.71	(7.07)
	pre-Acc 2	101.78	(3.51)	101.00	(3.73)	102.49	(3.50)	99.55	(3.00)
	pre-Acc 3	102.98	(4.61)	101.10	(4.22)	103.47	(4.32)	100.70	(4.30)
	pre-Acc 4	101.49	(3.92)	101.52	(4.97)	103.25	(4.09)	99.53	(4.25)
	Acc	106.94	(3.70)	85.00	(15.00)	107.95	(3.54)	83.51	(13.16)

† Acc = accented syllable, pre-Acc1 = the first unaccented syllable, pre-Acc2 = the second unaccented syllable, etc.

TABLE 2B. ANOVA: COMPARISON OF F0 OF FOUR MEASURED POINTS IN VARIOUS SYLLABICITY AND ACCENT-TYPE CONDITIONS

SYLLABICITY	ACCENT	DEGREES OF FREEDOM	F	*p*
2-syllable	pre-Acc1	3, 68	1.225	.307
	Acc	3, 68	16.641	< .01
3-syllable	pre-Acc1	3, 68	1.896	.139
	pre-Acc2	3, 68	.817	.489
	Acc	3, 68	13.101	< .01
4-syllable	pre-Acc1	3, 64	4.881	< .01
	pre-Acc2	3, 64	3.201	.029
	pre-Acc3	3, 64	.935	.429
	Acc	3, 64	16.492	< .01
5-syllable	pre-Acc1	3, 44	1.430	.247
	pre-Acc2	3, 44	1.609	.201
	pre-Acc3	3, 44	1.177	.329
	pre-Acc4	3, 44	1.479	.233
	Acc	3, 44	20.338	< .01

TABLE 2C. ANOVA: COMPARISON OF F0 OF FOUR MEASURED POINTS OF ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	CODA TYPES	DEGREES OF FREEDOM	F	*p*
2-syllable	no coda	3, 20	62.655	< .001
	nasal	3, 20	61.082	< .001
	stop	3, 20	.318	.813
3-syllable	no coda	3, 20	8.235	< .01
	nasal	3, 20	19.610	< .01
	stop	3, 20	1.956	.153
4-syllable	no coda	3, 16	30.278	< .01
	nasal	3, 20	46.639	< .01
	stop	3, 20	.650	.592
5-syllable	no coda	3, 12	10.438	< .01
	nasal	3, 20	29.583	< .01
	stop	3, 4	.806	.553

4.2 PITCH RANGE

4.2.1 Comparison of accented and preaccented syllables. Figure 3 displays pitch range (in Hz) for each speaker across syllabicity and coda type. It shows that most accented syllables exhibit larger pitch ranges than preaccented syllables, with the exception of Speaker 1's 4-syllable words in the stop-coda condition. Generally, pitch ranges are more compressed in stop-coda accented syllables (6 to 16 Hz) than they are in nasal-coda (21 to 43 Hz) or no-coda (12 to 38 Hz) accented syllables.

In table 3a, pitch range values were compared between accented and preaccented rhymes. Pitch range (in Hz) is the dependent variable, and Accent (Acc vs. pre-Acc) is the independent variable. According to the ANOVA results in table 3a, pitch range values were significantly different between accented and preaccented syllables except in the stop-coda 2-syllable and 4-syllable conditions. A Bonferroni post hoc test showed that pitch range in accented syllables was wider than in preaccented syllables, and that pitch range differences contributed significantly to the overall difference between accented and preaccented syllables.

4.2.2 Accented syllables across coda types. Table 3b compares pitch range within the accented syllables across different coda types. Pitch range is demonstrated to be the largest in the nasal-coda condition and the smallest in the stop-coda condition. In addition, pitch range decreased as the number of syllables increased (from 31.86 Hz to 17.35 Hz) for words in the no-coda condition. However, pitch range in words with a nasal or a stop coda did not exhibit as much within-group variation as those in the no-coda condition did.

TABLE 3A. ANOVA: COMPARISON OF PITCH RANGES BETWEEN PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	CODA TYPE	DEGREES OF FREEDOM	F	*p*
2-syllable	no coda	1, 10	60.033	< .01
	nasal	1, 10	42.663	< .01
	stop	1, 10	6.774	.026
3-syllable	no coda	2, 15	10.150	< .01
	nasal	2, 15	34.103	< .01
	stop	2, 15	9.390	< .01
4-syllable	no coda	3, 16	46.823	< .01
	nasal	3, 20	64.299	< .01
	stop	3, 20	1.055	.390
5-syllable	no coda	4, 15	8.206	< .01
	nasal	4, 25	41.632	< .01
	stop	4, 5	12.728	< .01

TABLE 3B. MEANS AND STANDARD DEVIATIONS OF PITCH RANGES OF ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	PITCH RANGE (IN HZ.) BY CODA TYPES					
	NO CODA		NASAL		STOP	
2-syllable	31.86	(8.18)	35.62	(11.14)	7.42	(3.03)
3-syllable	21.40	(11.75)	30.31	(10.40)	11.54	(5.36)
4-syllable	29.88	(4.62	34.21	(7.10)	6.34	(2.58)
5-syllable	17.35	(8.72)	33.78	(10.72)	10.58	(0.66)

FIGURE 3. PITCH RANGES FOR SPEAKERS 1 AND 2
IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

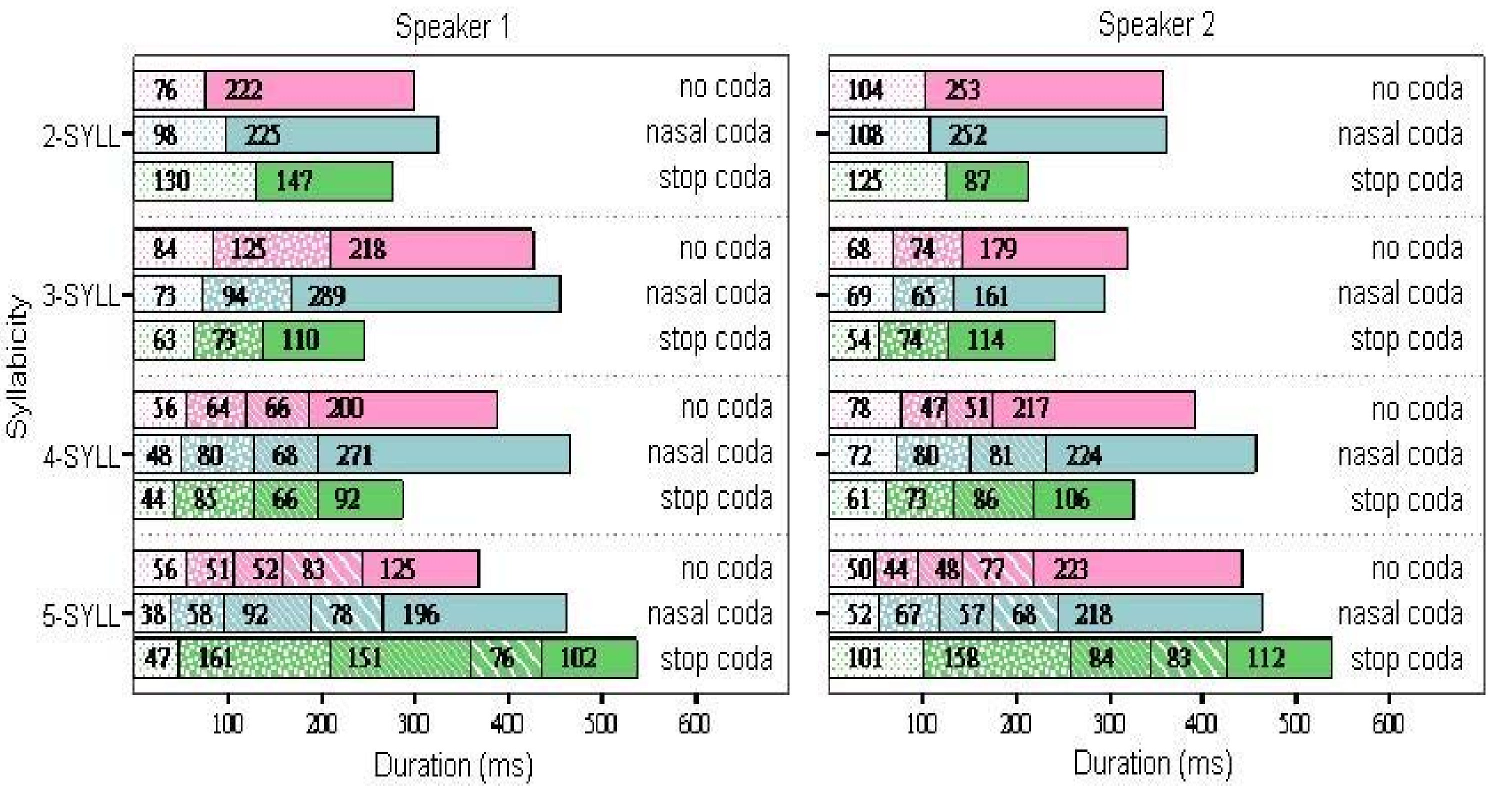
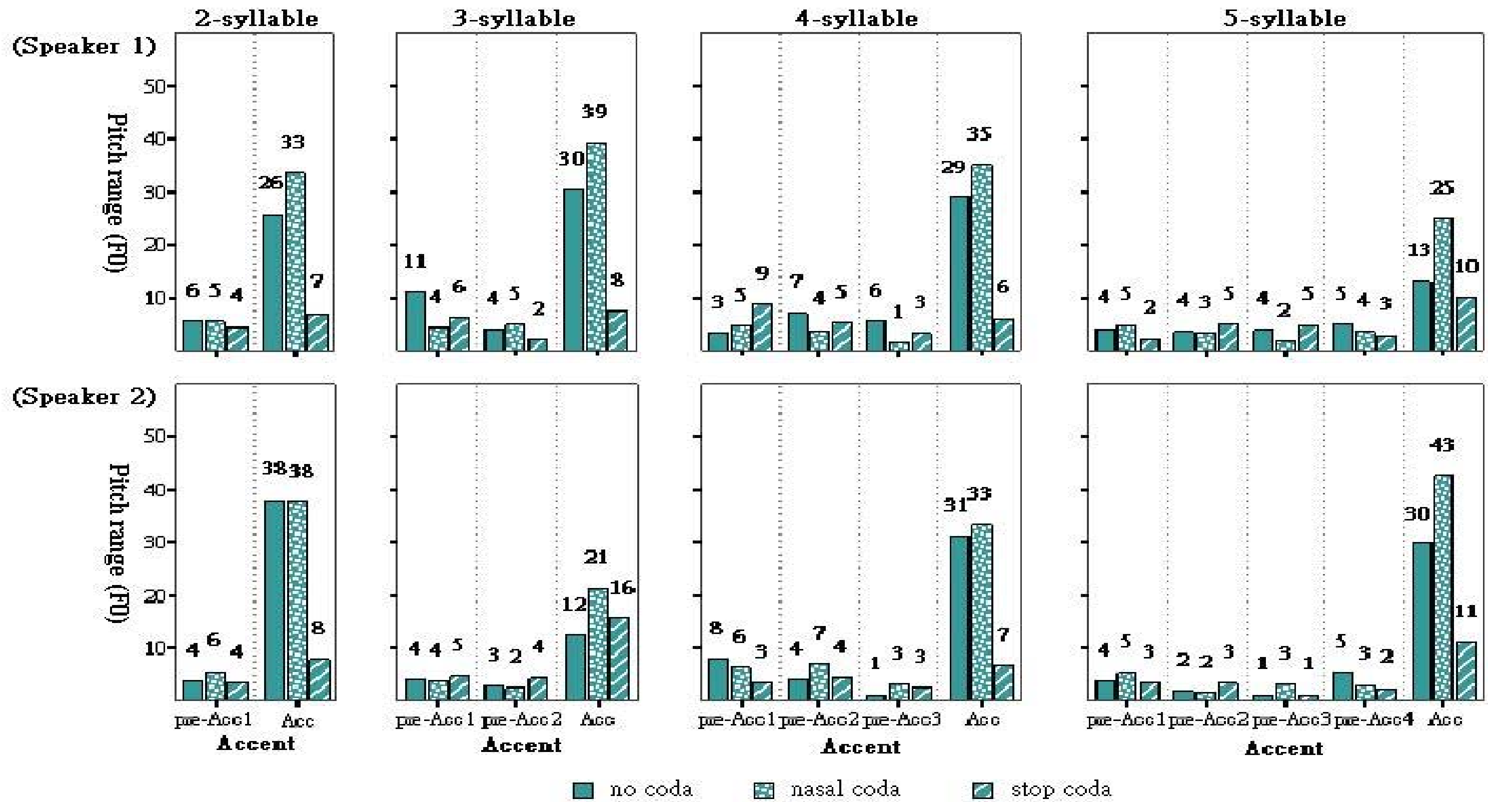


FIGURE 4. DURATIONS OF PREACCENTED AND ACCENTED SYLLABLES DISPLAYED BY SPEAKERS, SYLLABICITY, AND CODA TYPE CONDITIONS



4.3 DURATION

4.3.1 Comparison of accented and preaccented syllables. Durations of preaccented and accented syllable rhymes are shown in figure 4. In most instances, the accented rhymes were much longer than the preaccented ones. In the stop-coda condition, however, the accented rhyme was not necessarily longer but rather approximate in length to the preaccented syllables. In the 5-syllable condition, the second preaccented syllable was actually longer than the accented syllable, which could be the result of its intrinsically longer diphthong vowel /ay/ (*min**ay**wawa:ak*).

The results presented in table 4a represent a statistical analysis of the data in figure 4. This analysis compared the durations of preaccented and accented rhymes; the dependent variable is duration (in ms), and the independent variable is accent (Acc vs. pre-Acc).These results demonstrate that rhyme durations were significantly different between accented and preaccented syllables in both no-coda and nasal-coda conditions. As shown in table 4a, the durations of accented and preaccented rhymes in the stop-coda condition did not significantly differ from one another. A Bonferroni post hoc test also showed that accented rhymes were longer than preaccented rhymes in both no-coda and nasal-coda conditions, and that preaccented rhymes did not significantly differ in length across coda and syllabicity conditions.

4.3.2 Accented syllables compared across coda types. Table 4b presents the results of an ANOVA comparing the durations of accented syllables (the dependent variable) across three coda types (the independent variable). Results demonstrate significant differences among the three coda types. A Bonferroni post-hoc test showed that accented rhymes in the no-coda and nasal-coda conditions were longer than accented rhymes in the stop-coda condition.

TABLE 4A. ANOVA: COMPARISON OF DURATIONS BETWEEN PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	CODA TYPES	DEGREES OF FREEDOM	F	*p*
2-syllable	no coda	1, 10	25.331	< .01
	nasal	1, 10	59.734	< .01
	stop	1, 10	.127	.729
3-syllable	no coda	2, 15	12.373	< .01
	nasal	2, 15	18.881	< .01
	stop	2, 15	12.972	< .01
4-syllable	no coda	3, 16	54.486	< .01
	nasal	3, 20	64.180	< .01
	stop	3, 20	4.290	.017
5-syllable	no coda	4, 15	9.888	< .01
	nasal	4, 25	35.748	< .01
	stop	4, 5	3.114	.122

TABLE 4B. ANOVA: COMPARISON OF THE DURATIONS OF ACCENTED SYLLABLES AMONG THREE CODA TYPES IN VARIOUS SYLLABICITY CONDITIONS

SYLLABICITY	DEGREES OF FREEDOM	F	*p*
2-syllable	2, 15	13.485	< .01
3-syllable	2, 15	5.510	< .05
4-syllable	2, 14	31.347	< .01
5-syllable	2, 9	5.472	< .05

4.4 SLOPE

4.4.1 Comparison of accented and preaccented syllables. Slope measurement examined the rate of movement from the Fo peak to the Fo valley. Table 5a illustrates the individual differences found between the two speakers. Most of the Fo slopes produced by Speaker 1 have negative values, which represent falling contours. Only three exceptions occur, in which the values of slopes (0.02 to 0.08) exhibit slightly rising contours. Moreover, items in the no-coda and nasal-coda conditions have steeper falling contours (–0.16 to –0.11) on accented syllables than those in the stop-coda condition do (0.08 to –0.16). Speaker 2, in contrast, exhibits no clear tendency to produce steeper falling contours on no-coda and nasal-coda accented syllables than he does on stop-coda syllables.

ANOVA results for the comparison of the slopes of accented and preaccented rhymes are given in table 5b. As in 5a, slope is the dependent variable and accent (Acc v. pre-Acc) is the independent variable. Surprisingly, differences between the slopes of accented and preaccented rhymes were not significant. In the nasal-coda condition, however, accented rhymes exhibited significantly steeper slopes than preaccented rhymes, for all items except those in the 4-syllable group.

4.4.2 Comparison of accented syllables across coda types. Tables 5a and 5b show that in the nasal-coda condition, slopes of accented rhymes are steeper than those of preaccented rhymes. This section examines the effect of coda type on the Fo slope of accented rhymes. ANOVA results comparing the slopes of accented rhymes (the dependent variable) across three coda types (the independent variable) are given in Table 5c. Slopes of accented rhymes were not significantly different across coda types, except in the 2-syllable condition. Thus, it appears that coda type does not affect the slope of accented rhymes.

4.5 F0 PEAK ALIGNMENT. Our investigation of Fo peak alignment measured the temporal position in which the pitch peak is located within any given lexical item. Table 6 shows the locations of Fo peak alignment in accented and preaccented syllables.

TABLE 5A. SLOPES OF PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS CODA-TYPE AND SYLLABICITY CONDITIONS

		Speaker 1				Speaker 2			
CODA	ACCENT	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.
NO CODA	pre-Acc1	–0.07	–0.14	–0.09	–0.03	–0.01	–0.05	–0.14	–0.08
	pre-Acc2	—	–0.02	–0.11	–0.05	—	–0.01	–0.06	0.05
	pre-Acc3	—	—	–0.12	–0.10	—	—	–0.03	0.05
	pre-Acc4	—	—	—	–0.08	—	—	—	–0.11
	Acc	–0.14	–0.15	–0.15	–0.11	–0.17	0	–0.15	–0.13
NASAL	pre-Acc1	–0.07	–0.01	–0.07	–0.07	0.03	0.03	–0.10	–0.10
	pre-Acc2	—	–0.01	–0.07	–0.04	—	–0.05	–0.13	0.02
	pre-Acc3	—	—	–0.02	–0.03	—	—	–0.06	–0.04
	pre-Acc4	—	—	—	0.04	—	—	—	0.04
	Acc	–0.15	–0.16	–0.13	–0.14	–0.16	–0.15	–0.17	–0.19
STOP	pre-Acc1	–0.04	–0.11	–0.26	–0.05	–0.04	–0.12	–0.10	0.05
	pre-Acc2	—	0.02	–0.08	–0.08	—	–0.07	0	–0.07
	pre-Acc3	—	—	–0.08	–0.04	—	—	–0.01	0.02
	pre-Acc4	—	—	—	–0.04	—	—	—	0.04
	Acc	–0.05	0.08	–0.09	–0.16	0.13	–0.14	–0.11	0.10

Two observations about pitch peak alignment can be drawn from these data. First, no discernable pattern of pitch peak alignment appeared to occur in preaccented rhymes. Accented rhymes, in contrast, exhibited the following patterns: in no-coda and nasal-coda conditions, the F0 peak regularly occurred in the first one-third of the accented syllable rhyme. In the stop-coda condition, however, the F0 peak usually occurred in the later half of the rhyme, which we classify as "peak delay." In addition, individual differences were observed between speakers. Speaker 2 produced a larger degree of peak delay than Speaker 1 did. Moreover, Speaker 1 exhibited no peak delay at all in the 2-syllable accented condition.

TABLE 5B. ANOVA: COMPARISON OF SLOPES BETWEEN PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	CODA TYPES	DEGREES OF FREEDOM	F	*p*
2-syllable	no coda	1, 10	7.174	.023
	nasal	1, 10	10.270	< .01
	stop	1, 10	2.437	.150
3-syllable	no coda	2, 15	1.672	.221
	nasal	2, 15	8.170	< .01
	stop	2, 15	.809	.464
4-syllable	no coda	3, 16	1.002	.418
	nasal	3, 20	2.565	.083
	stop	3, 20	1.154	.352
5-syllable	no coda	4, 15	.861	.510
	nasal	4, 25	11.038	< .01
	stop	4, 5	.447	.772

TABLE 5C. ANOVA: COMPARISON OF THE SLOPES OF ACCENTED SYLLABLES AMONG THREE CODA TYPES IN VARIOUS SYLLABICITY CONDITIONS

SYLLABICITY	DEGREES OF FREEDOM	F	*p*
2-syllable	2, 15	12.037	< .01
3-syllable	2, 15	1.019	.385
4-syllable	2, 14	.593	.566
5-syllable	2, 9	2.886	.108

TABLE 6. PITCH PEAK ALIGNMENT OF PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS CODA-TYPE AND SYLLABICITY CONDITIONS

	(%)	SPEAKER 1				SPEAKER 2			
CODA	ACCENT	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.
NO CODA	pre-Acc1	21.75	4.08	20.00	33.33	66.67	26.09	0	0
	pre-Acc2	—	47.31	0	33.33	—	23.39	50.00	100
	pre-Acc3	—	—	0	22.22	—	—	5.36	45.83
	pre-Acc4	—	—	—	8.00	—	—	—	7.79
	Acc	0	0	0	0	1.77	33.33	1.10	0
NASAL	pre-Acc1	8.64	13.08	33.33	0	41.89	58.56	0	8.18
	pre-Acc2	—	64.57	13.54	33.33	—	0	0	67.29
	pre-Acc3	—	—	42.08	0	—	—	5.47	33.33
	pre-Acc4	—	—	—	66.67	—	—	—	66.67
	Acc	0	0	0	0	0	0	3.01	0
STOP	pre-Acc1	5.56	2.47	0	0	33.33	0	0	63.37
	pre-Acc2	—	72.10	52.73	0	—	0	33.33	0
	pre-Acc3	—	—	0	27.15	—	—	55.30	85.71
	pre-Acc4	—	—	—	100	—	—	—	62.65
	Acc	0	61.99	55.36	39.26	88.21	52.26	71.70	100

4.6 INTENSITY PEAK

4.6.1 Comparison of accented and preaccented syllables. Intensity peak was measured as the highest dB value occurring in each syllable rhyme. Intensity peaks of preaccented and accented rhymes across syllabicity and coda-type conditions are given in table 7a. Accented syllables exhibit the highest intensity peak in the 2-, 3- and 4-syllable conditions, with the exception of Speaker 2's 2- and 4-syllable nasal-coda condition productions. For both speakers, the intensity peak in the accented syllables of five-syllable items does not exceed that of preaccented syllables.

Results of an ANOVA comparing intensity peak across accented and preaccented syllables appear in table 7b. Intensity peak (dB) is the dependent variable, and Accent (Acc vs. pre-Acc) is the independent variable. As seen in table 7b, no significant difference was found in intensity peak height between preaccented and accented syllables, irrespective of syllabicity and coda type.

TABLE 7A. INTENSITY PEAKS OF PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS CODA-TYPE AND SYLLABICITY CONDITIONS

dB: Mean (SD)		SPEAKER 1				SPEAKER 2			
CODA	ACCENT	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.	2-SYLL.	3-SYLL.	4-SYLL.	5-SYLL.
NO CODA	pre-Acc1	72 (2.4)	55 (2.4)	57 (3.2)	55 (2.9)	59 (4.5)	53 (2.5)	56 (2.9)	57* †
	pre-Acc2	—	56 (2.0)	59 (1.1)	52 (1.8)	—	52 (2.2)	57 (0.2)	59*
	pre-Acc3	—	—	56 (7.1)	55 (2.5)	—	—	59 (1.3)	56*
	pre-Acc4	—	—	—	53 (0.6)	—	—	—	57*
	Acc	75 (3.6)	59 (1.8)	59 (1.7)	54 (1.5)	61 (3.1)	57 (1.4)	59 (2.4)	55*
NASAL	pre-Acc1	68 (2.4)	59 (2.0)	57 (2.0)	56 (2.7)	60 (2.8)	56 (1.4)	60 (0.5)	57 (2.8)
	pre-Acc2	—	60 (1.9)	56 (0.9)	56 (1.2)	—	53 (3.1)	57 (1.0)	58 (1.0)
	pre-Acc3	—	—		57 (1.4)	—	—	58 (2.3)	57 (2.9)
	pre-Acc4	—	—	—	56 (1.6)	—	—	—	56 (3.0)
	Acc	74 (2.7)	63 (1.7)	59 (1.9)	55 (0.2)	60 (0.7)	56 (3.3)	58 (1.5)	57 (0.8)
STOP	pre-Acc1	71 (1.7)	57 (3.5)	55 (2.4)	57*	60 (1.8)	56 (3.7)	59 (2.6)	57*
	pre-Acc2	—	57 (1.3)	54 (0.9)	56*	—	57 (2.0)	58 (1.9)	57*
	pre-Acc3	—	—	56 (2.7)	57*	—	—	56 (1.9)	58*
	pre-Acc4	—	—	—	54*	—	—	—	60*
	Acc	74 (2.5)	62 (1.8)	58 (3.3)	54*	62 (0.8)	60 (2.2)	59 (0.7)	59*

† Asterisks indicate inability to calculate standard deviation because only one item could be found in the lexicon (5-syllable, stop-coda), or because of missing data in the test condition paradigm (Speaker 2, 5-syllable, no coda).

TABLE 7B. ANOVA: COMPARISON OF INTENSITY PEAKS BETWEEN PREACCENTED AND ACCENTED SYLLABLES IN VARIOUS SYLLABICITY AND CODA-TYPE CONDITIONS

SYLLABICITY	CODA TYPES	DEGREES OF FREEDOM	F	*p*
2-syllable	no coda	1, 10	.201	.663
	nasal	1, 10	.759	.404
	stop	1, 10	.437	.524
3-syllable	no coda	2, 15	5.125	.02
	nasal	2, 15	.791	.471
	stop	2, 15	5.805	.014
4-syllable	no coda	3, 16	.686	.573
	nasal	3, 20	1.794	.181
	stop	3, 20	1.553	.232
5-syllable	no coda	4, 15	.340	.846
	nasal	4, 25	.387	.816
	stop	4, 5	.066	.989

4.6.2 Comparison of accented syllables across coda types. Next, we compare intensity peaks in accented rhymes (the dependent variable) across different coda types (the independent variable), the results of which appear in table 7c. There is no significant difference among the intensity peaks of accented syllables across the three coda types. Thus, the factor of coda type did not appear to cause variation in the intensity peak height of accented syllables.

4.7 INTERIM SUMMARY. The checklist in table 8 summarizes the results presented above. A check mark indicates that variation in a particular parameter contributes to the contrast between preaccented and accented syllables, while the absence of a check mark means that no significant difference in that parameter value was observed between preaccented and accented syllables.

Our results suggest that pitch range is the most important parameter used to contrast accented and preaccented syllables. That is to say, accented syllables differ most substantially from preaccented syllables in terms of pitch range. In both no-coda and nasal-coda conditions, duration and F0 height are also important in distinguishing accented syllables, which were found to have a significantly longer duration and greater F0 variation among the four points than the preaccented syllables did. Furthermore, F0 peak alignment, F0 slope, and intensity seem to have less of an effect.

As for coda type, the stop-coda items differed from the other two coda types in many respects: they exhibit peak delay on accented syllables, and they have less pronounced F0 variation, shorter duration, and shallower F0 slopes. No-coda and nasal-coda items differ from one another only with respect to F0 slope; accented syllables usually have significantly steeper slopes in the nasal-coda condition than they do in the no-coda condition.

TABLE 7C. ANOVA: COMPARISON OF THE INTENSITY PEAKS OF ACCENTED SYLLABLES AMONG THREE CODA TYPES IN VARIOUS SYLLABICITY CONDITIONS

SYLLABICITY	DEGREES OF FREEDOM	F	*p*
2-syllable	2, 15	.028	.973
3-syllable	2, 15	1.510	.253
4-syllable	2, 14	.118	.889
5-syllable	2, 9	2.299	.156

TABLE 8. INTERIM SUMMARY

PARAMETERS	2-SYLLABLE			3-SYLLABLE			4-SYLLABLE			5-SYLLABLE		
	NO CODA	NASAL	STOP	NO CODA	NASAL	STOP	NO CODA	NASAL	STOP	NO CODA	NASAL	STOP
F0 HEIGHT	√	√		√	√		√	√		√	√	
PITCH RANGE	√	√		√	√	√	√	√		√	√	√
DURATION	√	√		√	√	√	√	√		√	√	
SLOPE		√			√						√	
F0 PEAK ALIGNMENT			peak delay			peak delay			peak delay			peak delay
INTENSITY PEAK												

5. DISCUSSION AND CONCLUSION. The results presented in this paper demonstrate that in Saisiyat, accented and preaccented syllables are primarily contrasted using two parameters: Fo height and pitch range. Changes in these two parameters create prominence on accented syllables. Accented rhymes always exhibit the highest Fo peaks and lowest Fo valleys; significant Fo peak/valley differences and onset/offset differences have been shown between accented and preaccented syllables.

The pitch range of an accented syllable is also significantly larger than that of a preaccented syllable. Pitch range, peak/valley, and onset/offset parameters are similar in that they are all related to pitch height; however, the use of one parameter does not guarantee the presence of another. For example, in the stop-coda condition, even though there is no significant difference between Fo peak and valley between accented and preaccented syllables, the pitch range of accented syllables is still much larger than those of preaccented syllables. Overall, pitch range seems to be the most important parameter used to distinguish accented from preaccented syllables.[15]

Intensity does not appear to play an important role in realizing syllable prominence. As for duration, even though most accented rhymes have longer durations than preaccented ones do, these may be the result of final lengthening, because in Saisiyat, accent falls on the final syllable. To remove the final lengthening confound, languages whose accent falls on the penultimate syllable should be investigated to test whether duration is used to realize prominence. However, Chiang's (1997) research on Seediq,[16] a language in which accent falls on the penultimate syllable, showed that accented syllables are not longer in duration than unaccented final syllables. This phenomenon might indirectly suggest that final lengthening contributes to longer durations of the final-syllable accented rhymes in Saisiyat, and that duration might not be as reliable a cue of accent as pitch, from a cross-linguistic perspective.

Fo slope is another parameter that does not appear to contribute to distinguishing accented from preaccented syllables. This confirms the predictions made by Carroll and associates (Carroll and Chang 1970; Harshman 1970, 1972; Carroll and Wish 1974a, 1974b) in their model of Multidimensional Scaling Analysis of tone perception. This model proposed that the world's languages are perceived in terms of very similar dimensions, but differ enormously with respect to the relative importance of those dimensions.

15. One might argue that the final syllable can exhibit some properties that are independently associated with accent or stress, the potential confounds being terminal pitch falls (final lowering) and final lengthening in neutral declarative intonation contours. (We would like to thank a very helpful anonymous reviewer for pointing this out.) With respect to final lowering, it might cause the pitch range to enlarge at the final syllable, which happens to be the accented syllable. To disentangle the use of pitch to convey final lowering from the use of pitch to indicate accent, it might be necessary to see whether the peak in accented syllable is statistically higher than that in unaccented syllable. The ANOVA test in our study shows that the peak in the accented syllable is significantly higher than that in the unaccented syllable in 2-syllable and 4-syllalbe conditions at the $p <$ .01 level ($F[1, 34] = 4.048$ and $F[3, 64] = 4.795$, respectively). Furthermore, the peak in the accented syllable is significantly higher than that in the unaccented syllable in the 5-syllable condition at the $p < .05$ level ($F[4, 55] = 3.591$). With respect to the 3-syllable condition, there is no significant difference between the accented and unaccented syllables ($F[2, 51] = 2.223$), although the mean of the former is higher than the latter (mean=114.23 [SD = 10.52] Hz for accented syllables, 108.60 [SD = 9.19] Hz for pre-Acc1 syllables, and 108.84 [SD = 7.11] Hz for pre-Acc2 syllables). Overall, the accented syllable exhibits a higher peak than the unaccented one does.

16. Seediq is another Austronesian language of Taiwan.

The five dimensions are: (1) average pitch, (2) direction, (3) length, (4) extreme endpoint, and (5) slope. Among these, they claim that slope is the least important as a perceptual cue in both tonal and nontonal languages (English, Yoruba, and Thai). In summary, extreme F0 values and pitch range appear to be the most important features used to distinguish accented syllables in Saisiyat.

These results provide evidence that Saisiyat should be classified as a pitch accent language with respect to its realization of lexical-level accent, because realization of accent within words is accomplished using F0 parameters only. Duration is used only inconsistently for accent realization, and intensity does not appear to be used at all. These results are consistent with previous studies suggesting that pitch is the primary parameter used to realize accent (Muyskens 1931, Parmenter and Blanc 1933, Beckman 1986, Cruttenden 1997, Fox 2000, Remijsen 2003), and that intensity and duration play much less important roles (Schramm 1937, Jassem 1959, Bolinger 1958, Fry 1958). Among the three typological categories proposed by Remijsen (2003), namely lexical tone, lexical stress, and lexical pitch accent, we claim that the accents in Saisiyat are consistent with the category "lexical pitch accent," because their realization consists of a single, specific F0-pattern, with no apparent contribution from other acoustic parameters.

It should be noted that variations in F0 peak alignment do occur across coda types. Stop-coda accented rhymes exhibit two distinguishing characteristics: F0 peak delay and truncation of their falling contours. In stop-coda syllables, F0 peaks occur in the latter half of the accented rhyme, whereas F0 peaks occur within the first third of the syllable in the no-coda syllable and nasal-coda conditions. Section 4.4 has presented evidence that stop-coda accented rhymes generally exhibit a shorter falling contour than those occurring in no-coda and nasal-coda accented syllables. We attribute this to the fact that their F0 peak occurs later in the syllable, and that their overall duration is much shorter than those of no-coda and nasal-coda syllables. The falling contour is truncated because the duration of a stop-coda syllable's rhyme is insufficient for pitch to fall as far as it does in no-coda or nasal-coda accented rhymes. Note that the term "peak delay" is used here in a sense that differs somewhat from previous studies (Silverman and Pierrehumbert 1990, Xu 2001) in which it is defined as postponement of an F0 peak from an accented syllable into the unaccented syllable directly following it in various prosodic conditions. The peak delay that we describe is a temporal difference in F0 alignment within the accented syllable that is caused by segmental differences in coda type. We use it to more precisely differentiate the pitch contours occurring in stop-coda syllables from those occurring in nasal-coda and no-coda syllables. The peak delay in Saisiyat stop-coda syllables, however, is not used to contrast accent type, as it does in Swedish (Bruce 1977). Our study has found no evidence to suggest that Saisiyat has more than one pitch accent type.

The acoustic data presented here demonstrate that pitch accents in Saisiyat are realized in F0 height and range, but not F0 slope or peak alignment. Specifically, lexical pitch accents in Saisiyat are made prominent through expansion of pitch contrasts. Due to the paucity of acoustic studies on Austronesian languages, little is known about their prosodic typology. This is the first study to contribute acoustic data for the prosodic analysis of Saisiyat, and it provides evidence for the typological classification of

Saisiyat as a pitch accent language. Future research is needed to investigate whether other Austronesian languages of Taiwan exhibit similar prosodic patterns.

APPENDICES

APPENDIX 1. MEAN F0 VALUES AND STANDARD DEVIATIONS OF FOUR MEASURED POINTS IN PREACCENTED AND ACCENTED SYLLABLES IN THE 2-SYLLABLE CONDITION ACROSS THREE CODA TYPES

2-SYLLABLE		Fo: Mean (SD)							
CODA	ACCENT	ONSET		OFFSET		PEAK		VALLEY	
NO CODA	pre-Acc1	102.16	(9.95)	102.34	(10.26)	103.76	(9.02)	99.03	(9.99)
	Acc	111.19	(6.53)	80.58	(4.72)	111.20	(6.54)	79.34	(4.12)
NASAL	pre-Acc 1	103.17	(7.88)	100.24	(7.91)	104.77	(7.44)	99.29	(7.37)
	Acc	115.11	(7.74)	79.87	(4.97)	115.11	(7.74)	79.49	(4.46)
STOP	pre-Acc 1	99.88	(6.33)	97.17	(7.83)	100.36	(6.66)	96.37	(7.17)
	Acc	115.18	(10.69)	113.04	(15.76)	118.77	(14.58)	111.35	(14.11)

APPENDIX 2. MEAN F0 VALUES AND STANDARD DEVIATIONS OF FOUR MEASURED POINTS IN PREACCENTED AND ACCENTED SYLLABLES IN THE 3-SYLLABLE CONDITION ACROSS THREE CODA TYPES

3-SYLLABLE		Fo: Mean (SD)							
CODA	ACCENT	ONSET		OFFSET		PEAK		VALLEY	
NO CODA	pre-Acc 1	108.63	(12.91)	101.75	(8.87)	108.90	(12.68)	101.46	(8.92)
	pre-Acc 2	102.99	(6.49)	102.21	(7.16)	104.26	(6.68)	100.82	(6.26)
	Acc	107.84	(11.42)	90.77	(9.08)	108.88	(10.57)	87.48	(6.38)
NASAL	pre-Acc1	106.77	(8.86)	107.20	(6.72)	109.20	(8.16)	105.15	(7.84)
	pre-Acc2	110.71	(9.06)	108.85	(9.06)	111.51	(8.67)	107.87	(7.90)
	Acc	113.32	(12.43)	85.63	(5.47)	113.32	(12.43)	83.00	(2.38)
STOP	pre-Acc1	107.71	(7.62)	102.82	(7.33)	107.71	(7.62)	102.23	(7.59)
	pre-Acc2	110.02	(2.80)	108.41	(5.77)	110.77	(3.74)	107.53	(4.79)
	Acc	118.00	(5.73)	114.65	(11.97)	120.48	(5.26)	108.94	(10.10)

APPENDIX 3. MEAN F0 VALUES AND STANDARD DEVIATIONS OF FOUR MEASURED POINTS IN PREACCENTED AND ACCENTED SYLLABLES IN THE 4-SYLLABLE CONDITION ACROSS THREE CODA TYPES

4-SYLLABLE		Fo: Mean (SD)							
CODA	ACCENT	ONSET		OFFSET		PEAK		VALLEY	
NO CODA	pre-Acc1	111.07	(5.79)	105.88	(7.82)	111.08	(5.79)	105.83	(7.900
	pre-Acc2	112.26	(4.70)	106.81	(6.36)	112.45	(4.58)	106.59	(6.22)
	pre-Acc3	108.46	(10.37)	105.34	(7.53)	108.52	(10.38)	104.73	(8.36)
	Acc	115.84	(5.93)	86.36	(7.86)	115.84	(5.92)	85.96	(7.87)
NASAL	pre-Acc1	112.88	(5.68)	108.31	(5.59)	113.08	(5.56)	107.65	(5.99)
	pre-Acc2	111.51	(5.69)	106.45	(5.69)	111.63	(7.63)	106.25	(5.54)
	pre-Acc3	108.87	(5.16)	107.82	(5.94)	109.21	(5.31)	106.91	(5.64)
	Acc	113.23	(7.87)	80.24	(6.23)	113.42	(7.82)	79.21	(5.64)
STOP	pre-Acc1	112.81	(6.58)	107.09	(5.42)	112.81	(6.58)	106.67	(4.93)
	pre-Acc2	104.76	(4.58)	103.23	(7.22)	106.21	(2.95)	101.40	(6.45)
	pre-Acc3	105.73	(2.62)	104.42	(3.71)	106.06	(2.75)	103.21	(2.91)
	Acc	113.90	(6.60)	114.30	(9.58)	117.56	(7.49)	111.22	(7.61)

APPENDIX 4. MEAN F0 VALUES AND STANDARD DEVIATIONS FOR TARGETS IN PREACCENTED AND ACCENTED SYLLABLES IN THE 5-SYLLABLE CONDITION ACROSS THREE CODA TYPES

5-syllable		Fo: Mean (SD)							
CODA	ACCENT	ONSET		OFFSET		PEAK		VALLEY	
NO CODA	pre-Acc1	103.26	(8.75)	100.33	(6.89)	103.30	(8.67)	99.25	(7.85)
	pre-Acc2	100.75	(2.66)	99.14	(4.14)	101.35	(2.88)	98.22	(3.45)
	pre-Acc3	104.38	(6.21)	101.85	(6.27)	104.72	(6.07)	101.55	(6.09)
	pre-Acc4	102.47	(3.59)	98.78	(5.02)	103.19	(4.42)	98.27	(5.21)
	Acc	106.28	(2.84)	90.28	(8.04)	106.28	(2.84)	88.93	(7.86)
NASAL	pre-Acc1	109.18	(5.52)	104.13	(7.62)	109.18	(5.52)	104.13	(7.62)
	pre-Acc2	101.11	(3.83)	101.03	(3.50)	102.13	(4.02)	99.69	(3.03)
	pre-Acc3	102.85	(4.39)	101.07	(3.75)	103.07	(4.00)	100.61	(4.11)
	pre-Acc4	101.17	(4.90)	102.84	(5.39)	103.34	(4.89)	100.05	(4.53)
	Acc	108.64	(3.83)	75.10	(11.87)	108.64	(3.83)	74.87	(11.67)
STOP	pre-Acc1	106.49	(2.21)	105.78	(0.06)	108.23	(0.25)	105.37	(0.64)
	pre-Acc2	105.88	(0.64)	104.63	(0.47)	105.88	(0.64)	101.79	(0.40)
	pre-Acc3	100.55	(1.15)	99.70	(1.11)	102.15	(2.11)	99.24	(0.47)
	pre-Acc4	100.52	(2.04)	103.04	(2.46)	103.10	(2.38)	100.52	(2.04)
	Acc	103.16	(2.30)	104.15	(11.93)	109.21	(4.77)	98.62	(4.11)

REFERENCES

Beckman, Mary E. 1986. *Stress and non-stress accent.* Netherlands Phonetic Archives 7. Dordrecht: Foris.

Blood, David L. 1964. Applying the criteria of patterning in Cham phonology. Van-hóa Nguyêt-san 13:515–20.

Bolinger, Dwight L. 1958. A theory of pitch accent in English. *Word* 14:109–49.

Bruce, Gösta. 1977. *Swedish word accents in sentence perspective.* Lund: Gleerup.

Campbell, Nick. 1993. Automatic detection of prosodic boundaries in speech. *Speech Communication* 13:343–54.

Carroll, J. Douglas, and Jie-Jie Chang. 1970. Analysis of individual differences in multidimensional scaling via an n-way generalization of “Eckart-Young” decomposition. *Psychometrika*, 35(3): 283–319.

Carroll, J. Douglas, and Myron Wish. 1974a. Multidimensional perceptual models and measurement methods. In *Handbook of perception: Psychophysical judgment and measurement,* vol. 2, ed. by E. C. Carterette and M. P. Friedman, 391–447. New York: Academic Press.

———. 1974b. Models and methods for three-way multidimensional scaling. In *Contemporary developments in mathematical psychology,* vol. 2, ed. by D. H. Krantz, R. O. Atkinson, R. D. Luce, and P. Suppes, 57–105. New York: W. H. Freeman.

Chiang, Wen-yu. 1997. An acoustic study of Atayal and Seediq accents. Ms.

Cruttenden, Alan. 1997. *Intonation.* (2d ed.) New York: Cambridge University Press.

Fox, Anthony. 2000. *Prosodic features and prosodic structure: The phonology of suprasegmentals.* New York: Oxford University Press.

Fry, Dennis B. 1958. Experiments in the perception of stress. *Language and Speech* 1:126–52.

Gandour, Jackson T. 1978. The perception of tone. In *Tone: A linguistic survey,* ed. by V. A. Fromkin, 41–76. New York: Academic Press.

Harshman, Richard A. 1970. Foundations of the PARAFAC procedure: Models and condition for an "explanatory" multidimensional factor analysis. *UCLA Working Papers in Phonetics* 16.

———. 1972. Determination and proof of minimum uniqueness conditions for PARAFAC 1. *UCLA Working Papers in Phonetics* 22:111–17.

Haudricourt, André Georges. 1954. *Les origines asiatiques des langues malayo-polynesiennes*. JSO 10:180–83.

———. 1972. Research in historical phonetics. *La Pensee* 163:34–38.

Hombert, Jean-Marie. 1978. Consonantal types, vowel quality, and tone. In *Tone: A linguistic survey,* ed. by V. A. Fromkin, 71–111. New York: Academic Press.

Hombert, Jean-Marie, John J. Ohala, and William G. Ewan. 1979. Phonetic explanations for the development of tones. *Language* 55:37–58.

House, J. Daniel. 1989. Syllable structure constraints on Fo timing. Poster presentation, *Second Conference of Laboratory Phonology*, Edinburgh.

Jassem, Wiktor. 1959. The phonology of Polish stress. *Word* 15:252–69.

Ladd, D. Robert. 1996. *Intonational phonology.* Cambridge: Cambridge University Press.

Liberman, Philip. 1960. Some acoustic correlates of words stress in American English. *Journal of the Acoustical Society of America* 35: 344–53.

Matisoff, James A. 1973. Tonogenesis in Southeast Asia. In *Consonant types and tone.* Southern California Occastional Papers in Linguistics, ed. by L. M. Hyman, 71–96.

Mohr, Boudewijn. 1968. Intrinsic fundamental frequency variation, II. *Monthly Internal Memorandum, Phonology Laboratory.* Univ. of California, Berkeley, June 23–30.

Muyskens, John H. 1931. An analysis of accent in English from kymograph records. *Vox* 17(2): 55–65.

Parmenter, Clarence E., and A. V. Blanc. 1933. An experimental study of accent in English and French. *Publications of the Modern Language Association of America (PMLA)* 48:598–607.

Prieto, Pilar, Jan van Santen, and Julia Hirschberg. 1995. Tonal alignment patterns in Spanish. *Journal of Phonetics* 23: 429–51.

Remijsen, Bert. 2003. New perspectives in word-prosodic typology. http://www.iias.nl/iiasn/32/RR_new_perspectives_in_word_prosodic_typology.pdf

Schramm, Wilbur L. 1937. The acoustical nature of accent in American speech. *American Speech* 12:49–56.

Silverman, Kim E. A., and Janet B. Pierrehumbert. 1990. The timing of prenuclear high accents in English. In *Papers in Laboratory Phonology I. Between the grammar and physics of speech,* ed. by John Kingston and Mary E. Beckman, 72–106. Cambridge: Cambridge University Press.

van der Mark, Sheena. 2002. The acoustic correlates of Blackfoot prominence. *Calgary Working Papers in Linguistics* 24: 169–216.

Wolff, John U. 1993. Proto-Austronesian stress. In *Tonality in Austronesian languages*, ed. by Jerold A. Edmondson and Kenneth J. Gregerson, 1–15. Honolulu: University of Hawai'i Press.

Xu, Yi. 2001. Fo peak delay in Mandarin. *Phonetica* 58:26–52.

Yeh, Mei-li. 2000. *Saisiyat reference grammar.* Taipei: Yuan-Liu.

Zorc, R. David. 1993. Overview of Austronesian and Philippine accent patterns. In *Tonality in Austronesian languages,* ed. by Jerold A. Edmondson and Kenneth J. Gregerson, 17–24. Honolulu: University of Hawai'i Press.

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