HO-HSIEN PAN

FOCUS AND TAIWANESE UNCHECKED TONES

1. INTRODUCTION

Focus, tone, and intonation are all manifested through fundamental frequency (f0) contours and duration in Taiwanese. There is no one-to-one correspondence between the surface acoustical realization and the deeper structure, nor do surface f0 contours and duration directly reflect underlying features. To improve our understanding of surface f0 and duration formation, the contribution of underlying global or local factors to surface f0 and duration patterns must be investigated. The global factors that contribute to f0 modulation can be divided into two categories, i.e. declination and final lowering. The gradual decline of f0 over the course of an utterance is called declination, while the f0 decline at the end of an utterance or phrase is called final lowering (Liberman & Pierrehumbert, 1984; Pierrehumbert & Beckman, 1988; Shih, 1988). Global effects also affect duration. For example the duration of a syllable varies according to a syllable's position relative to a prosodic boundary. Studies have showed that phrase-medial segments are shorter than those in phrase-initial and phrase-final positions (Lindblom & Rapp, 1973). In addition to global effects, f0 and duration are also affected by local factors such as tone and focus (Ho, 1976; Lin, 1988).

The contribution of tone to the duration of a tone-bearing unit has been observed in languages such as Taiwanese. In Taiwanese, the rising tone is longer, and the duration of checked syllables (CVC structures with final voiceless stops) is shorter than the duration of unchecked syllables (CV or CVN structures) (Cheng, 1968, 1973; Lin, 1988). Focus also influences syllable duration. It was found that the duration of narrow focus syllables are longer than broad focus syllables, which in turn are longer than post-focus syllables (Jin 1996; Xu 1999).

Turning to f0, it was observed that local factors such as tone and focus both affect the surface f0 pattern. There are unique intrinsic tonal targets that each Taiwanese lexical tone possesses. These tonal targets determine the f0 height (register), and f0 shape (contour) of tone bearing syllables. For example, a high level tone has an intrinsic high and level f0 contour which coarticulates with surrounding tones (Lin, 1988; Shih, 1988; Gandour et al., 1994; Xu, 1993, 1997).

The contribution of focus on surface f0 patterns was reported in various languages (Pierrehumbert, 1980; Cooper, Eady & Muller, 1985; Eady & Cooper, 1986; Eady, Cooper, Klouda, Mueller & Lotts, 1986; Jin, 1996; Xu, 1999). Jin (1996) found that in Mandarin the f0 range of narrow focus syllables was expanded. In this study he varied the four lexical tones of the first two syllables (or words) in sentences with the following structure, /___ miŋ15 nien15 liau15 yaŋ15/, 'X is

Lee, Gordon, Büring (eds.), Topic and Focus: A Cross-Linguistic Perspective, 197—216.

going to the sanitarium next year.' Each sentence employed four different focus conditions, including broad focus with focus on the entire sentence, and three narrow focus conditions with focus placed either on the first, second, and third word. Results showed that (1) duration of narrow focus syllables was the longest, (2) the f0 range of the narrow focus syllable was expanded and (3) the f0 contours of the final word in broad focus sentences were perceptually indistinguishable from narrow focus final syllable.

Xu (1999) investigated local factors including tone and focus. He varied the lexical values of the first three words in a sentence. Each of the three words carried four Mandarin lexical tones, e.g. level, rising, falling and falling rising tones. For sentence /mao55 mi35 mai51 mao55 mi55/ 'Cat fan sells kitty.' four questions were asked to elicit production with broad focus, or narrow focus on word one, two, or three. For example, when the question 'What is kitty doing?' was asked, the narrow focus was appropriately produced on word three, / mai 51 /, in the target sentence. Results further confirmed that duration increased and f0 range was expanded for narrow focus syllables in Mandarin.

A tone language with its clear specification of local tonal targets on each syllable is suitable for studying the contribution of global and local effects on surface f0 realization and duration. This study followed the line of research on the influence of local effects, i.e. tone and focus, on the surface f0 formation and syllable duration in a tone language, by controlling the intonation of each utterance and its syntactic composition, while varying lexical tone and focus condition (Jin, 1996; Xu, 1999).

Lexical tones in a tone language are contrastive in terms of f0 height, contour, and duration. In Mandarin, there are four lexical tones, namely high level (55), low rising (15), high falling (51), and falling rising tones (315). These four tones are distinguished mainly through f0 shapes. Each Mandarin tone has its own distinctive f0 contour not shared by other tones. However, little is known about a tone language, like Taiwanese, with tones distinguished mainly by not only f0 contour but also f0 height contrasts. There are seven lexical tones in Taiwanese, i.e. high level (55), low rising (24), high falling (51), mid falling (21), mid level (33), high falling checked (51), and mid falling checked tones (21), as shown in Table 1. There are pairs of lexical tones that differ in only tonal height. For example, high falling and mid falling tones differ only in their relative f0 levels, as do high and mid level tones. Compared with Mandarin, Taiwanese has a richer tone inventory. This study contributed to the little data on the realization of focus in a tone language.

Table 1. Taiwanese lexical tones

High level	55	˥	/kun/ ‘army’
Low rising	24	˧˥	/kun/ ‘skirt’
High falling	51	˥˩	/kun/ ‘boiling’
Mid falling	21	˧˩	/kun/ ‘batons’
Mid level	33	˧	/kun/ ‘near’
High falling checked	51	˥˩	/kut/ ‘slippery’
Mid falling checked	21	˧˩	/kut/ ‘plow’

The present study reports on how focus contributes to the realization of f0 and syllable duration of lexical tones in Taiwanese. Words containing different lexical tones were produced in short sentences that controlled for the global effects of intonation and prosodic tonal grouping, while varying the local effects of tonal value and focus pattern. The purpose of this study was to examine the surface realization of f0 and duration of Taiwanese lexical tones under different focus conditions, with attention drawn to following issues: (1) the effect of narrow focus on duration, (2) the effect of a narrow focus syllable’s position in an utterance on its duration, (3) the effect of narrow focus on f0 range and (4) the influence of focus on tone height between high and mid falling tones, and between high and mid level tones.

2. METHOD

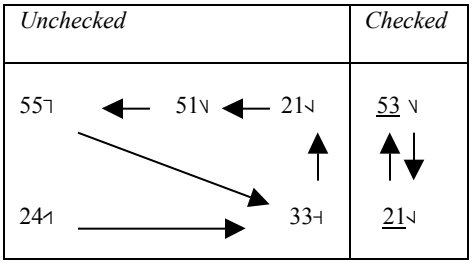
2.1. Corpus

Each Taiwanese syllable has two different lexical tones, i.e. a juncture tone (underlying) tone and a context (sandhi) tone. The surface realization of tonal values depends on a syllable’s position in a tone group. When a syllable is located at the end of a tone group, that is the juncture position and so the juncture (underlying) tone surfaces. Any other syllables that are not last in a tone group carry a context tone. The juncture and context tone values that each syllable possesses are recursive in nature. For example, a syllable that surfaces with either the tones 55 or 24 at the juncture position of a tone group has a context (sandhi) tone value 33 at non-juncture positions. The context tone for a syllable with a juncture tone 33 is tone 21, while the context tone for a syllable with a juncture tone 21 is tone 51. A syllable with a juncture tone 51 would carry a tone 55 in a non-juncture position, as shown in table 2. It should be noted that tone 24 only surfaces at juncture positions, and not in initial or medial positions of a tone group. The domain of the tone group boundary is prosodically determined and closely related to syntactic structures in Taiwanese (Chang, 1968, 1973; Chan, 1987; Lin, 1988).

In the corpus, the sentence type was a statement with SVO structure. The tone group boundaries for these short sentences were located between the first and second words. That is, the first word (first and second syllables) formed a tonal group, while

the second word (third syllable) and third word (fourth and fifth syllables) formed another tone group.

Table 2. Taiwanese tonal sandhi rules



(1) [σ_{cntxt} σ_{jnctr}]tone group [σ_{cntxt} σ_{contxt} σ_{jnctr}] tone group

According to tone sandhi patterns, the second and fifth syllables which are the last syllables in these tone groups carried a juncture tone, while the first, third and fourth syllables carried context tones. Since a low rising tone is not a possible context tone, it was not used in the third and fourth syllables, as shown in Table 3. In the corpus, only sonorants were used as initial consonants to minimize perturbation in vocal fold vibration in order to ensure smooth pitch tracks, as shown in Table 3.

The subject, including the first and second syllables of the sentence, was a surname. The first syllable of the subject was a diminutive morpheme /a- 55/. The second syllable consisted of five juncture tones: high level (55), low rising (24), high falling (51), mid falling (21), and mid level (33). The third syllable consisted of four context tones: high level (55), high falling (51), mid falling (21), and mid level (33). Since a low rising tone was not a possible context tone, only the four tones were used in the third and fourth syllables. The fourth and fifth syllables formed the object. The fourth syllable consisted of the tones 55, 51, 21 and 33. The fifth syllable was the diminutive affix /-a 51/. Since it was not possible to find an object carrying a high falling tone for the fourth and fifth syllables (e.g., 51 51) the lexical item, /a 51 ləŋ 33/ ‘duck egg’, was chosen for the object with a high falling tone in the fourth syllable. Checked syllables were not investigated in this study.

Table 3. Tones and syllables used as corpus. Tones are in underlying form within // and surface forms within [ ], "˜" over the vowel means nasalization.

Tone		***Word 1 (1st and 2nd syllables)***	***Word 2 (3rd syllable)***	***Word 3 (4th and 5th syllables)***
	55	/55 55/ [33 55] [a me]	/51/ [55] [lam] 'hug'	/51 51/ [55 51] [liu a] 'button'
	24	/55 24/ [33 24] [a mõ]		
	51	/55 51/ [33 51] [a mã]	/21/ [51] [liam] 'pinch'	/21 33/ [51 33][a ləŋ] 'duck egg'
	21	/55 21/ [33 21] [a lun]	/33/ [21] [mã] 'scold'	/33 51/ [21 51] [lua a] 'comb'
	33	/55 33/ [33 33] [a liaŋ]	/24/ [33] [law] 'save'	/24 51/ [33 51] [n̂ĩũ a] 'silkworm'

Nine hundred and sixty sentences (5 first word X 4 second word X 4 third word X 4 focus conditions X 3 repetitions) in the corpus were formed by alternating the five words in position 1 to match the four alternating words in position 2 and the four alternating words in position 3. There were four focus conditions. Narrow focus was placed either on the first word (first or second syllables), the second word (third syllable), or the third word (fourth and fifth syllables), while broad focus was placed on the entire sentence. Each sentence was repeated three times. The order in which the 960 sentences were produced was randomized. The sentences were written on a list with no specification of the placement of focus. A question list corresponding to the order of the corpus list was created to elicit focus on the desired part of the sentence, as shown in (2). For example, to elicit broad focus on the sentence 'A-mei holds buttons', the precursor question listed on the question list would be 'What happened?' as shown in (2) d.

(2) a. Who holds buttons? 'A-MEI holds buttons.'

b. What did A-mei do to the buttons? 'A-Mei HOLDS buttons.'

c. What did A-mei hold? 'A-Mei holds BUTTONS.'

d. What happened? 'A-Mei holds buttons.'

2.2. Speaker

Four male native Taiwanese speakers, CYS, LWS, LYK, HYH, participated in the experiment. They were all trilingual speakers of Taiwanese Min, Mandarin, and English. HYH spoke a variety of dialects in which the underlying low rising tone changes into a mid falling surface tone. All speakers were students at National Chiao Tung University at the time of the recordings. They were paid for their participation.

2.3. Instrumentation

Recordings were made in a sound-treated booth in The Department of Foreign Languages and Literatures at National Chiao Tung University in Hsinchu, Taiwan. A TEV TM-728II unidirectional dynamic microphone was placed 40 cm in front of each speaker's mouth and 1 m from the experimenter. A SONY MZS-R4ST Mini Disk recorded acoustical signals in digital quality. The digital acoustical signal was transferred from Mini Disk to PC through an optical fiber at 22kHz to the digital input of Creative Sound Blaster Live sound card, and saved in .wav format. The ESPS *xwaves* program was used to generate fundamental frequency tracks for each sentence.

2.4 Procedure

During the recording a female experimenter and a speaker were present in the sound booth. Short dialogues between the experimenter and speaker were exchanged to ensure that each speaker produced the corpus in a conversational, and not in a citation manner and to ensure that each speaker placed focus in the target position naturally, as opposed to reading the sentence directly from the list. During the recording, speakers read the sentences without indication for the placement of focus from a randomised corpus list. Speakers waited until the experimenter read a precursor question from a question list and then responded by producing the sentence, which he read from the corpus list with focus on the specific part of the sentence. Different questions elicited focus on different parts of the sentence as shown in Table 2. The experimenter judged the utterance according to the desired location of focus at the targeted position. If the experimenter decided that the desired focus condition was not produced, then she would repeat the precursor again, and ask for another production.

2.5 Data Analysis

An Emu labelling program (http://www.shlrc.mq.edu.au/emu/) was used to display fundamental frequency (f0) patterns, spectrograms, and waveforms and to provide a means for labelling relevant tonal and intonational aspects of the utterance using the Taiwanese ToBI annotation conventions, currently under progress. Syllabic boundaries were determined by identifying spectrographic cues, such as the energy difference between nasals and vowels and the formant transitions between consonants and vowels. After identifying and labelling syllable boundaries, labelling

words, phones, tones, and the location of focused elements was completed. Another Emu program (Emuquery) was used to obtain the time at the onset and offset of the second syllable, third, and fourth syllables. The duration of each syllable was calculated by subtracting the time at the syllable onset from the time of the syllable offset.

Next, the fundamental frequency was extracted for each syllable using get_track, and the Emu pitch extraction program. Fundamental frequency values at 5%, 20%, 40%, 60%, 80% and 95% time points in the target syllables were obtained from these pitch tracks. The average f0 and duration for the second, third and fourth syllables carrying the same tone in different focus conditions were compared. One-way ANOVAs (focus position) were used to determine the effect of focus position on peak f0, f0 range expansion, and duration.

3. RESULTS

3.1. Duration

3.1.1. Effect of focus

Table 4 shows the results of 51 one-way ANOVAs (focus position) on the duration of the syllable carrying the same tone at the same position produced by the same speaker.

For CYS, there was a significant difference between the duration of the syllable carrying the same tone at the same position in different focus condition. The mean duration of the narrow focus syllable was the longest among syllables carrying the same tone at the same position in different focus conditions. For speaker HYH, there was a significant difference between the duration of the syllable carrying the same tone at the same position in different focus conditions. This excludes tone 55 in the fourth syllable, tone 51 in the third syllable, and tone 21 in the second syllable. Mean duration showed that the duration of the narrow focus syllable was the longest among syllables carrying the same tone at the same position in different focus conditions. This excludes tone 55 in the fourth syllable, tone 21 in the second syllable, and tone 33 in the fourth syllable. For speaker LWS, there was a significant effect of duration on the syllable carrying the same tone in the same position and with different focus conditions. Mean duration showed that the duration of the narrow focus syllable was the longest among syllables carrying the same tone in the same position. This excludes tones 55, 51 and 33 in the fourth syllable. For speaker LYK the durations for the same syllable in different focus conditions were significantly different. This excludes tone 21 in the fourth syllable. Mean duration showed that besides tones 55 and 21 in the fourth syllable and tone 33 in the second syllable, the duration of narrow focus syllables was the longest among syllables carrying the same tone at the same position under different focus conditions. There was a trend for a narrow focus syllable to be the longest.

3.1.2. Effect of syllable position on duration

Table 4 displays mean duration of syllables in the same position carrying the same lexical tone with different focus conditions across speakers. As shown in Table 4, the duration of narrow focus second syllables was longer than broad focus, pre-narrow focus, or post-narrow focus second syllables. Duration of narrow focus third syllables was also longer than broad focus, pre-narrow-focus, and post-narrow focus third syllables.

Among the narrow focus syllables carrying the same tone in different syllable positions, the duration of the narrow focus third syllables was the longest, compared with the duration of the narrow focus syllables in the second and fourth syllable position. The effect of position on syllable duration was confounded by the vowel quality and the syllable structure (closed vs. open) which were not controlled in the corpus.

Although the duration of narrow focus second and third syllables was longer than the same syllable in other focus conditions, the narrow focus fourth syllable was not the longest, as shown in Table 4. According to table 4, the duration of the narrow focus tones 55 and 33 in the fourth syllable produced by HYH, was not the longest when compared to the same syllable produced in the other focus conditions. This was also the result for syllables with tones 55, 51, and 33 in the fourth syllable produced by LWS, and for syllables produced with tones 55 and 21 in the fourth syllable produced by LYK. The duration of the narrow focus fourth syllable was similar to that of the post-focus fourth syllable, as shown in Table 4. In summary, increased duration for narrow focus syllables was most obvious in second and third syllable position and least noticeable in the fourth syllable position.

3.2 F0

3.2.1. Tonal register (f0 level) contrast

The f0 contours were averaged across speakers to reveal a potential contrast in tonal register between high level vs. mid level tones and between high falling vs. mid falling tones, as shown in Figure 1. A comparison between the f0 range of narrow focus tones 55 and 33 in the syllable onset and the f0 peak revealed that f0 onset of both the tones 55 and 33 was between 140 to 160 Hz. However, the f0 peak was between 170 to 190 Hz for the tone 55 and remained below 160 Hz for the tone 33. The only exception was the 20% point of tone 33 in the second syllable and the 95% point of tone 33 in the fourth syllable, which was slightly above 160 Hz for tone 33. Turning to the tones 51 and 21, we see that the f0 peak of the narrow focus tone 51 was between 180 to 200 Hz, while the f0 peak of the narrow focus tone 21 was between 120 to 140 Hz. As for the lowest point of f0, it was between 150 to 170 Hz for tone 51 and below 140 Hz for tone 21. The f0 level difference between tones 51 vs. 21 and between tones 33 vs. 55 was maintained for narrow focus syllables even after the f0 range was expanded under narrow focus condition.

*Table 4. One-way ANOVA's (4 focuses) on mean duration (ms), ** p < 0.001, p < 0.05, NF: Narrow Focus, bold face: narrow focus syllable*

Tone		***Speaker***	***CYS***			***HYH***		
			Syllable position			*Syllable position*		
			2	*3*	*4*	*2*	*3*	*4*
	55	Broad focus	211.8 **	240.6 **	257.4 **	195.8 **	219.1 *	210.2
		NF on syllable 2	**240.2**	248.4 **	255.9 **	**242.1**	210.7 *	216.8
		NF on syllable 3	199.0 **	**306.2**	280.6 **	202.3 **	**233.8**	224.8
		NF on syllable 4	191.2 **	250.4 **	**322.5**	205.6 **	225.7 *	**221.3**
	24	Broad focus	236.1 *			214.5 **		
		NF on syllable 2	**248.3**			**270.8**		
		NF on syllable 3	226.2 *			228.1 **		
		NF on syllable 4	226.9 *			224.1 **		
	51	Broad focus	213.3 **	234.7 **	199.3 **	205.8 **	193.3	209.8 **
		NF on syllable 2	**230.4**	239.8 **	197.7 **	**243.2**	196.4	198.8 **
		NF on syllable 3	204.9 **	**280.6**	223.3 **	214.8 **	**207.4**	216.0 **
		NF on syllable 4	207.8 **	243.9 **	251.4	216.5 **	206.0	**225.5**
	21	Broad focus	227.3 **	246.7 **	223.3 **	262.4	210.4 **	207.1 *
		NF on syllable 2	**244.9**	257.6 **	227.1 **	**262.2**	217.4 **	190.1 *
		NF on syllable 3	222.7 **	**328.6**	220.2 **	255.9	**255.4**	205.5 *
		NF on syllable 4	211.3 **	257.0 **	**257.4**	261.1	218.6 **	**216.9**
	33	Broad focus	219.4 *	244.7 **	268.7 **	167.6 **		219.9
		NF on syllable 2	**232.2**	248.4 **	273.6 **	**211.4**		223.3
		NF on syllable 3	221.4 *	**310.2**	281.9 **	177.0 **		224.3
		NF on syllable 4	201.7 *	254.3 **	**320.9**	166.9 **		**219.4**
Tone		*Speaker*	*LWS*			*LYK*		
			2	*3*	*4*	*2*	*3*	*4*
	55	Broad focus	265.3 **	233.5 **	227.5 *	225.7 **	233.7 **	276.3 **
		NF on syllable 2	**294.0**	255.2 **	226.1 *	**241.3**	229.9 **	268.7 **
		NF on syllable 3	246.4 **	**320.6**	250.3 *	221.8 **	**263.8**	290.9 **
		NF on syllable 4	252.3 **	273.4 **	**234.0**	207.3 **	245.4 **	**297.7**
	24	Broad focus	255.1 **			242.0 **		
		NF on syllable 2	**296.3**			**280.0**		
		NF on syllable 3	249.3 **			239.5 **		
		NF on syllable 4	250.7 **			218.4 **		
	51	Broad focus	252.0 **	245.8 **	182.7 **	234.4 **	246.4 **	193.4 **
		NF on syllable 2	**295.8**	265.4 **	186.7 **	**258.6**	231.2 **	177.1 **
		NF on syllable 3	244.3 **	**329.5**	219.8 **	228.0 **	**266.0**	199.4 **
		NF on syllable 4	242.1 **	253.0 **	**202.8**	208.6 **	251.9 **	**212.4**
	21	Broad focus	251.3 **	250.8 **	213.2 *	189.3 **	245.1 **	247.6
		NF on syllable 2	**278.0**	271.8 **	218.4 *	**205.2**	230.9 **	239.4
		NF on syllable 3	246.7 **	**342.2**	225.0 *	186.6 **	**295.7**	264.6
		NF on syllable 4	252.5 **	251.2 **	**231.6**	165.6 **	241.1 **	**255.0**
	33	Broad focus	223.7 *	221.6 **	223.0 **	199.3 **	225.0 **	292.6 *
		NF on syllable 2	**251.8**	251.9 **	214.8 **	**213.2**	213.8 **	274.8 *
		NF on syllable 3	232.3 *	**309.7**	259.8 **	215.0 **	**255.1**	296.9 *
		NF on syllable 4	242.9 *	231.8 **	**237.3**	185.7 **	228.8 **	**302.7**

3.2.2. Tonal shapes

Observation of f0 movement within the vowel nuclei revealed both assimilatory and anticipatory tonal coarticulation in Taiwanese (Peng, 1997). The corpus of the present study was composed of sonorants and vowels, therefore f0 movements during consonants surrounding the vowel nuclei were also included. Since surrounding lexical tones influenced f0 movement of different lexical tones, the averaged tonal contexts for each syllable should be discussed first.

Lexical tones in the second syllable were preceded by tone 33 with mid offset at the first syllable and followed by tones 55, 51, 21, and 33 at the third syllable with an averaged onset realized at a slightly above mid average. For the third syllable, it was preceded by tones 55, 24, 51, 21, and 33 at the second syllable and produced with a slightly below mid average f0 onset. The third syllable was followed by tones 55, 51, 21, and 33 and produced with a slightly above mid average f0 offset. The fourth syllable was preceded by tones 55, 51, 21, and 33 and realized at a mid average onset. The fourth syllable was followed by suffixes, /a 51/, in seventy five percent of the tokens and followed by the morpheme, /ləŋ 33/ 'egg', in twenty five percent of the tokens. On the average the offset of fourth syllable was realized at an upper mid to high average.

Due to preservatory tonal coarticulation, tone 55 at the second, third, and fourth syllables started around the mid tonal range following the averaged mid offset of the first, second and third syllables. The f0 contours of tone 55 at second and third syllables then gradually rose to a higher offset target at 80% into the syllables then slightly declined to coarticulate anticipatorily with the following mid onset of third and fourth syllable. The f0 contours of tone 55 at the fourth syllable did not decline at the end of the syllable, since they were followed by an upper mid to high onset at the fifth syllable. Both preservatory and anticipatory tonal coarticulation was observed on tone 55. The gradual decrease of the high offset of tone 55 from the second, to third and fourth syllables was a sign of global declination.

The onset of tone 24 at the second syllable started from the mid offset of preceding syllable then moved downward to the low onset target of rising tone 24. The low onset target of tone 24 was reached around the 60% time point into the syllable and then the f0 pattern began to take on the rising contour of tone 24. Preservatory tonal coarticulation can be observed at the beginning of tone 24.

The onset of tone 51 at the second, third and fourth syllable began around the mid tonal range then began to rise toward the high onset target. The high target was reached at the 60% time point in the second syllable and the 40% time point in the third and fourth syllables. After this, the f0 pattern began to move downward toward the low offset target of falling tone 51. Effects of declination can be observed by comparing the f0 height of high onset targets that gradually decreased from the second to the third and to the fourth syllable. Preservatory tonal coarticulation was observed at the beginning of tone 51.

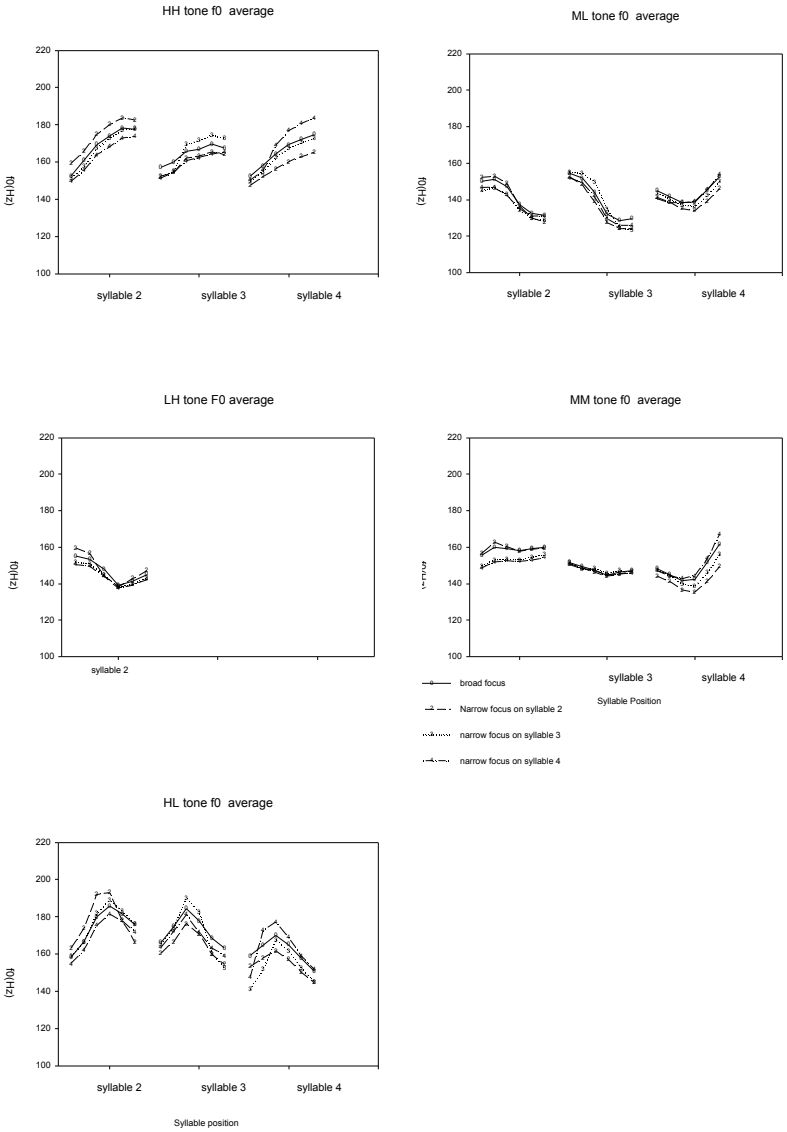


Figure 1. F0 of five tones in the second, third and fourth syllable position receiving four different focus conditions

The onset of tone 21 began around the mid tonal range for the second and third syllables. The onset of tone 21 in the fourth syllable was much lower due to global declination and the lower averaged offset of the third syllable. F0 moved downward

toward the target and then began to rise at the 95% for the third syllable and the 60% time point for the fourth syllable. Effects of declination were observed on the f0 height of the low offset target between the second and third syllables. The rising contour of tone 21 at the fourth syllable was due to anticipatory tonal coarticulation with the high to mid onset of following fifth syllable.

The onset of tone 33 gradually declined from the second, third to the fourth syllable. The rising f0 of tone 33 at the fourth syllable was due to anticipatory tonal coarticulation with averaged upper mid to high onset of the following fifth syllable. Both anticipatory and preservatory tonal coarticulation was observed here.

3.2.3. Effect of focus on f0 range

Fifty-one one-way ANOVAs (focus position) were used to analyse individual speakers' f0 range of syllables carrying the same tone in the same sentence position. F0 range was the difference between the highest and lowest f0 values for a given syllable. Results are shown in table 5. There was missing data for the narrow focus tone 55 in the second syllable, since HYH produced this syllable with tone 33. Results indicated that a significant effect of focus on f0 range was consistently observed on tones 24 and 51, but not on level tones (55, 33) or the low falling tone (21). The exceptions were tone 55 in the second and fourth syllable, tone 21 in the third syllables, and tone 33 in the third and fourth syllables produced by CYS; tone 55 in the second syllable produced by HYH; tone 55 in the third syllable and tone 33 in the second syllable produced by LWS; tone 55 in the second syllable, and tones 21 and 33 in the third syllable produced by LYK.

The mean f0 range of syllables carrying the same tone in the same position and produced by same speaker, but under different focus conditions revealed that the f0 range of narrow focus syllables was the greatest, as shown in Table 5. However, there were some exceptions. These include the f0 range of tone 24 in the second syllable and tone 33 in the fourth syllable produced by CYS; tones 55 and 33 in the second syllable, tone 21 in the third syllable, and tone 33 in the fourth syllable produced by HYH; tones 24 and 33 in the second syllable produced by LWS; tones 24 and 33 in the second syllable, tone 33 in the third syllable, and tones 21 and 33 in the fourth syllables produced by LYK.

3.2.4. Effect of focus on mean f0

In addition to differences in f0 range, a significant effect of focus was observed in the mean f0 value of syllables carrying the same tone in the same position but with different focus conditions. For syllables that did not have a significant effect of focus on f0 range, a significant effect of focus on mean f0 height was usually observed, as shown in (6). This is illustrated in production of tone 55 in the second and fourth syllables, and tones 21 and 33 in the third syllable produced by CYS; productions of tone 55 in the second syllable produced by HYH; productions of tone 55 in the second syllable, and tones 21 and 33 in the third syllable produced by LYK; and in productions of tone 55 in the third syllable, and tone 33 in the second syllable produced by LWS.

Table 7 summarizes the significant effect of focus on duration, f0 range and mean f0 on each syllable. Duration was more consistent than f0 range and mean f0 in distinguishing focus conditions produced by CYS, LWS, and LYK, but not HYH. A significant effect of focus was found on either f0 range or mean f0, and sometimes both f0 range and mean f0 of most syllables. The exceptions occurred mainly on tones 33 and 21 in either the third or fourth syllable.

*Table 5. One-way ANOVAs (4 focus conditions) on f0 range (Hz), ** p < 0.001, * p < 0.05, BF: Broad focus, NF: Narrow focus, bold face: narrow focus syllable*

		Speaker	***CYS***			***HYH***		
			Syllable position			*Syllable position*		
			2	*3*	*4*	*2*	*3*	*4*
Tone	55	Broad focus	10.95	11.11*	10.89	49.08	22.25**	22.81**
		NF on syllable 2	**13.08**	12.31*	11.08	**35.56**	25.05**	22.42**
		NF on syllable 3	12.14	**15.15**	11.56	37.71	**40.71**	24.29**
		NF on syllable 4	11.52	12.47*	**12.56**	33.82	25.50**	**41.05**
	24	Broad focus	7.22 **			13.97 **		
		NF on syllable 2	**13.11**					
		NF on syllable 3	16.90 **			36.89 **		
		NF on syllable 4	10.62 **			14.34 **		
	51	Broad focus	20.49 **	23.19 **	17.56 **	37.52**	34.04 **	40.37 *
		NF on syllable 2	**26.88**	24.71 **	21.11 **	**56.04**	42.61 **	37.65 *
		NF on syllable 3	22.49 **	**34.17**	26.05 **	38.23 **	**49.38**	45.86 *
		NF on syllable 4	20.11 **	29.04 **	**29.44**	37.18 **	33.59 **	**52.81**
	21	Broad focus	18.35 *	19.72	14.73 *	30.06 **	34.85 *	36.24 **
		NF on syllable 2	**21.12**	22.17	16.57 *	**40.11**	47.18 *	28.21 **
		NF on syllable 3	19.43 *	**24.90**	15.20 *	25.02 **	**38.80**	36.01 **
		NF on syllable 4	17.54 *	22.98	**13.28**	26.74 **	32.33 *	**42.04**
	33	Broad focus	7.22 **	13.11	16.90	13.97 *		36.89 *
		NF on syllable 2	**10.62**	13.30	17.29	**14.34**		33.48 *
		NF on syllable 3	6.63 **	**15.58**	19.27	15.05 *		42.00 *
		NF on syllable 4	6.39 **	13.06	**17.65**	10.69 *		**41.56**
		Speaker	***LWS***			***LYK***		
			2	*3*	*4*	***2***	***3***	***4***
Tone	55	Broad focus	27.91 **	19.47	24.21 **	29.537	25.63*	38.09 **
		NF on syllable 2	**27.68**	19.56	21.68 **	**30.80**	27.60*	25.85 **
		NF on syllable 3	33.72 **	**25.16**	29.80 **	34.39	**37.44**	36.50 **
		NF on syllable 4	30.69 **	23.19	**41.93**	30.13	26.25*	**47.08**
	24	Broad focus	9.31 **			12.17 **		
		NF on syllable 2	**14.86**			**18.05**		
		NF on syllable 3	26.38 **			30.96 **		
		NF on syllable 4	7.97 **			10.52 **		
	51	Broad focus	29.25 **	26.36 **	18.73 **	29.25 **	26.36 **	18.73 **
		NF on syllable 2	**35.13**	24.24 **	16.41 **	**35.13**	24.24 **	16.41 **
		NF on syllable 3	34.33 **	**45.66**	21.25 **	34.33 **	**45.66**	20.91 **
		NF on syllable 4	29.86 **	28.36 **	**27.69**	29.86 **	28.36 **	**27.69**
	21	Broad focus	22.59 **	25.81 **	17.33 *	23.85 **	39.20	25.88
		NF on syllable 2	**27.23**	25.51 **	17.64 *	**31.00**	37.38	24.17
		NF on syllable 3	20.08 **	**38.62**	22.10 *	23.62 **	**41.77**	29.53
		NF on syllable 4	17.36 **	24.60 **	**23.76**	16.96 **	37.76	**26.30**
	33	Broad focus	9.31	14.86 *	26.38 **	12.17 *	18.05	30.96
		NF on syllable 2	**7.97**	13.71 *	19.10 **	**10.52**	19.22	25.80
		NF on syllable 3	8.63	**18.44**	29.66 **	11.55 *	**16.67**	30.52
		NF on syllable 4	9.89	15.07 *	**33.98**	13.50 *	15.63	**29.86**

*Table 6. One-way ANOVA's (4 focus) on mean f0 (Hz), ** p < 0.001, * p < 0.05, BF: Broad focus, NF: Narrow focus, bold face: narrow focus syllable*

		Speaker	***CYS***			***HYH***		
			Syllable position			*Syllable position*		
			2	*3*	*4*	*2*	*3*	*4*
Tone	*55*	BF	145.0 **	139.2	133.9 **	184.7 *	176.7 *	177.5 **
		NF on syllable 2	**133.9**	141.2	134.8 **	**177.5**	169.6 *	159.2 **
		NF on syllable 3	150.5 **	**141.9**	137.1**	176.0 *	**176.5**	171.1 **
		NF on syllable 4	147.4 **	140.7	**138.5**	171.4 *	166.5 *	**178.0**
	24	Broad focus	137.3 **			171.6 **		
		NF on syllable 2	**131.3**			151.8 **		
		NF on syllable 3	129.7 **			178.6 **		
		NF on syllable 4	142.8 **					
	51	Broad focus	151.3 **	144.0	134.0 **	187.4 **	179.9 **	163.2 **
		NF on syllable 2	**157.8**	145.7	136.2 **	**189.0**	169.1 **	145.4 **
		NF on syllable 3	155.5 **	**146.5**	135.8 **	174.4 **	**177.7**	153.8 **
		NF on syllable 4	155.1 **	147.1	**139.1**	172.6 **	165.7 **	**173.7**
	21	Broad focus	127.1	123.9 *	125.6 *	138.6 **	144.0 *	147.8 **
		NF on syllable 2	**127.7**	124.6 *	127.5 *	**144.2**	136.1 *	132.0 **
		NF on syllable 3	127.7	**127.7**	127.9 *	130.8 **	**143.3**	141.3 **
		NF on syllable 4	128.1	127.6 *	**129.4**	135.4 **	136.6 *	**142.3**
	33	Broad focus	137.3 **	131.3 **	129.7	171.6 **		151.8 **
		NF on syllable 2	**142.8**	132.7 **	129.1	**178.6**		138.4 **
		NF on syllable 3	139.6 **	**126.1**	130.3	152.6 **		145.2 **
		NF on syllable 4	139.1 **	126.0 **	**131.8**	153.5 **		**152.7**
		Speaker	***LWS***			***LYK***		
			2	*3*	*4*	*2*	*3*	*4*
Tone	*55*	Broad focus	180.3	178.0 **	180.7 **	170.9 *	168.1 *	170.9 *
		NF on syllable 2	**180.7**	173.2 **	173.9 **	**170.9**	161.7 *	162.5 *
		NF on syllable 3	180.7	**184.1**	176.5 **	166.4 *	**167.0**	169.3 *
		NF on syllable 4	176.9	178.6 **	**188.8**	164.6 *	158.7 *	**174.0**
	24	Broad focus	170.1 **			157.6 **		
		NF on syllable 2	**164.9**			**144.2**		
		NF on syllable 3	171.0 **			141.7 **		
		NF on syllable 4	166.5 **			155.9 **		
	51	Broad focus	180.7 *	182.1 **	176.3 **	180.7 *	182.1 **	176.3 **
		NF on syllable 2	**182.6**	171.8 **	167.5 **	**182.6**	171.8 **	167.5 **
		NF on syllable 3	184.7 *	**179.1**	170.7 **	184.7 *	**179.1**	170.7 **
		NF on syllable 4	181.5 *	179.7 **	**178.6**	181.5 *	179.7 **	**178.6**
	21	Broad focus	162.1 *	154.2	162.7	136.6 **	138.1	138.7
		NF on syllable 2	**159.4**	150.0	160.1	**137.7**	133.9	133.1
		NF on syllable 3	160.4 *	**154.2**	159.4	133.3 **	**138.9**	137.2
		NF on syllable 4	159.0 *	152.7	**161.6**	134.7 **	136.3	**137.2**
	33	Broad focus	170.1 **	164.9 *	171.0 **	157.6 **	144.2	157.6 **
		NF on syllable 2	**166.5**	161.8 *	161.4 **	**155.9**	144.0	155.9 **
		NF on syllable 3	166.4 **	**164.4**	165.0 **	151.9 **	**142.1**	151.9 **
		NF on syllable 4	164.3 **	162.2 *	**170.8**	150.6 **	143.9	**150.6**

Table 7. Summary of significant effect of focus on duration (D), f0 range (R), and mean f0 (M)

	CYS			***HYH***			***LWS***			***LYK***		
	2	*3*	*4*	*2*	*3*	*4*	*2*	*3*	*4*	*2*	*3*	*4*
55	DM	DR	DM	DM	DRM	RM	DR	DM	DRM	DM	DRM	DRM
24	DRM			DRM			DRM			DRM		
51	DRM	DR	DRM	DRM	RM	DRM	DRM	DRM	DRM	DRM	DRM	DRM
21	DR	DM	DRM	RM	DRM	DRM	DRM	DR	DR	DRM	D	D
33	DRM	DM	D	DRM	D	RM	DM	DRM	DRM	DRM	D	DM

3.2.5. Mandarin vs. Taiwanese

Jin (1996) found that perceptually it is difficult to distinguish between broad focus sentences and sentences with narrow focus on the last word. However, Xu (1999) found that the duration of the same syllable under broad focus and narrow focus was significantly different at all five syllable positions. The f0 range differences between the same word but under either broad or narrow focus conditions was significantly different from each other in Mandarin. The discrepancy between production and perceptual data in Mandarin focus studies was not investigated.

To examine the production distinctiveness between broad focus, narrow focus, and post-focus final words in Taiwanese, a post-hoc Duncan test was used to analyse the duration and f0 range of the penultimate syllables of the final words carrying the same tone, but under different focus conditions, as shown in Table 8. Results of Post-hoc Duncan tests shown in Table 8 indicated that the duration difference between narrow and broad focus penultimate syllables was significant regardless of the following syllables, e.g. tone 55 produced by HYH and LWS, tone 21 produced by HYH and LYK, tone 33 produced by HYH and LYK. As for the f0 range, it was found that the f0 range of narrow and broad focus penultimate syllables was distinctive, besides tone 55 produced by CYS and LYK, tone 21 produced by CYS and LYK, and tone 33 produced by HYH and LYK. In summary, both the duration and f0 range of broad focus and narrow focus penultimate syllables in the final word were significantly different when the penultimate syllable carried tone 51, but not when they carried a level tone (55, 33) or low falling tone (21). Speaker-wise, either the duration or the f0 range was significantly different between narrow focus and broad focus fourth syllables produced by CYS and LWS. Narrow focused and broad focused penultimate syllables carrying tone 33 produced by HYH and LYK, or carrying tone 21 produced by LYK were not significantly different from each other in terms of either duration or f0 range.

In Mandarin narrow focused final words and final words in broad focus sentences were perceptually indistinguishable, but acoustically distinguishable.

According to the Taiwanese acoustical data observed here, narrow focus final words was distinguishable from final words in broad focus sentences produced by CYS and LWS, but not for LYK and HYH. The discrepancy between production and perceptual data in Mandarin can be further explored by comparing the results of future production and perceptual studies in Taiwanese.

Table 8. Post-hoc Duncan tests on the mean duration and f0 range of the penultimate (fourth) syllable. Means of the fourth syllable in different focus conditions produced by the same speaker were significantly different from each other when followed by different alphabets. Means followed by the same alphabets were not significantly different from each other. $p < 0.05$.

DURATION		*CYS*	*HYH*	*LWS*	*LYK*
55	Narrow Focus	322.5 a	221.3 A	234.0 B	297.7 A
	Post- Focus	280.6 B	224.8 A	250.3 A	290.9 AB
	Broad Focus	257.4 C	210.2 A	227.5 B	276.3 B
51	Narrow Focus	251.4 a	225.5 A	202.8 B	212.4 A
	POST- Focus	223.3 B	216.0 AB	219.8 A	199.4 B
	Broad Focus	199.3 C	209.8 B	182.7 C	193.4 B
21	Narrow Focus	257.4 A	216.9 A	231.6 A	255.0 A
	Post- Focus	220.2 B	205.5 A	225.0 AB	264.6 A
	Broad Focus	223.3 B	207.1 A	213.2 B	247.6 A
33	Narrow Focus	320.9 A	219.4 A	237.3 B	302.7 A
	Post- Focus	281.9 B	224.3 A	259.8 A	296.9 A
	Broad Focus	268.7 B	219.9 A	222.9 C	292.6 A
F0 RANGE		*CYS*	*HYH*	*LWS*	*LYK*
55	Narrow Focus	12.6 A	41.0 A	41.9 A	47.1 A
	Post-Focus	11.6 A	24.3 B	29.8 B	36.5 B
	Broad Focus	10.9 A	22.8 B	24.2 B	38.1 AB
51	Narrow Focus	29.4 A	52.8 A	27.7 A	27.7 A
	Post-Focus	26.0 B	45.9 AB	21.2 B	20.9 B
	Broad Focus	17.6 d	40.4 B	18.7 B	18.7 B
21	Narrow Focus	13.3 B	42.0 A	23.8 A	26.3 A
	Post-Focus	15.2 B	36.0 B	22.1 A	29.5 A
	Broad Focus	14.7 B	36.2 B	17.3 B	25.9 A
33	Narrow Focus	17.7 A	41.6 A	34.0 A	29.7 A
	Post-Focus	19.3 A	42.0 A	29.7 B	30.5 A
	Broad Focus	16.9 B	36.9 A	26.4 B	31.0 A

4. DISCUSSION

The f0 and duration data produced by Taiwanese speakers in the present study revealed five major results. First, the duration of narrow focus syllables was longer than syllables under other focus conditions. Second, the degree of lengthening due to narrow focus was affected by a syllable's position in a sentence. Third, the f0 range of the narrow focus syllable was expanded. Fourth, the tonal register (f0 level) contrasts between narrow focus high falling vs. mid falling tones, and between narrow focus high level vs. mid level tones was maintained even when f0 range was

expanded. Fifth, duration was a more consistent cue than either f0 range or mean f0 values in signalling focus condition in Taiwanese. F0 range and mean f0 value complement each other in distinguishing focus conditions.

In addition to the effect of focus, tonal coarticulation also influenced the f0 contour in Taiwanese. In Taiwanese the f0 offset target of a dynamic tone occurred after the offset boundary of a tone bearing unit, while the f0 offset target of a level tone occurred before the syllable boundary (Pan, 2002). By using only sonorants at either the beginning or end of a syllable, both anticipatory and preservatory tonal coarticulation was observed in this study. Preservatory tonal coarticulation was observed in tones 55, 24, and 51, while anticipatory tonal coarticulation was found in tones 55, 21, and 33. It was proposed that the preservatory tonal coarticulation took place during the initial consonant of the syllable, as found in Mandarin (Xu, 1999). To support the claim that preservatory tonal coarticulation occurred during the initial consonant of the syllable in Taiwanese, further studies with various syllable structures are necessary.

Among narrow focus second, third, and fourth syllables, the duration of narrow focus third syllable was the longest, while the duration of the fourth syllable was the shortest. In Mandarin the duration of the narrow focus third syllable was also the longest, however the shortest syllable was the second syllable (Xu, 1999). The effect of focus lengthening was the strongest on the third syllable in both Mandarin and Taiwanese. According to global final lengthening rules, the duration of the narrow focus fourth syllable should be longer than the duration of the narrow focus third syllable, however local focus lengthening interacts with final lengthening here to determine the surface syllable duration. Focus lengthening exerts a strong effect on the third syllable but not on the fourth syllable. Narrow focused fourth syllables appeared to be shorter than narrow focused third syllables in both Taiwanese and Mandarin data. Further investigations with more variable sentence structure are needed to explore possible factors such as syllable position, part of speech, and syntactic or prosodic structures that contribute to the longer duration of narrow focus third syllable.

In Mandarin with four distinctive f0 contours for each lexical tone, f0 range expansion was used as the major cue for signaling narrow focus. In Taiwanese, duration lengthening is a more consistent cue for narrow focus. The fact that there are two tonal pairs in Taiwanese contrasted mainly by f0 height and not by f0 contour may contribute to the limited manipulation of f0 range in different focus conditions. To further explore this potential cause, studies on other tonal languages with tonal pairs contrasting mainly by f0 height are needed.

The study here concentrated only on the effect of focus on Taiwanese unchecked tones. Taiwanese checked tones are known for their shorter syllable duration and glottalized voiced quality in contrast with unchecked tones. To fully understand the influence of focus on duration contrasts between checked and unchecked syllables in Taiwanese and the influence of focus on voice quality in Taiwanese, further study are necessary. The interaction between focus conditions, final and initial lengthening in different prosodic domains, and tonal coarticulation should also be investigated to fully understand the interaction of prosodic effects on surface duration and f0 contour in tonal languages.

Department of Foreign Languages and Literatures, National Chiao Tung University, Hsinchu, TAIWAN.

5. NOTES

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