Speech Prosody 2004
Nara, Japan
March 23-26, 2004

The Prosody of the Compound Words in Standard Chinese

Eric Zee

Phonetics Lab, Department of Chinese, Translation and Linguistics
City University of Hong Kong
eric.zee@cityu.edu.hk

10.21437/SpeechProsody.2004-32

Abstract

The bisyllabic, trisyllabic, and quadrisyllabic compounds in Standard Chinese (the Beijing variety) were analyzed for their prosodic characteristics, including temporal structure, F_0 contours, and intensity curves. Results show that (1) the durations of the syllable-initial fricatives [f s ʂ ɕ x], the voice onset time of the aspirated stops [pʰ tʰ kʰ] and aspirated affricates [tsʰ tʂʰ tɕʰ] of the component syllables, and the durations of the rimes of the component syllables all vary according to the position of the syllables in the compounds; (2) the unaspirated stops and affricates as well as the closure durations are not affected by the positions of the component syllables of the compounds; (3) the F_0 contours are subject to the F_0 declination effect, and the same citation tones on the component syllables of a compound are downstepped; (4) the shapes of the citation tones [35 214] often change, not however [55] and [51]; and (5) with a few exceptional cases, the intensity curves for the rimes co-vary with the F_0 contours.

1. Introduction

This paper analyzes the prosodic characteristics of the bisyllabic, trisyllabic, and quadrisyllabic compound words in the Beijing variety of Standard Chinese (SC, henceforth). A total of 32 bisyllables (2 different bisyllabic compounds for each of the 16 tonal permutations (4 citation tones x 4 citation tones)), 128 trisyllables (2 different trisyllabic compounds for each of the 64 tonal permutations (4 x 4 x 4)), and 256 quadrisyllabic compounds (1 quadrisyllabic compound for each of the 256 tonal permutations (4 x 4 x 4 x 4)). The four citation tones in SC are [55 35 214 51].

2. Method

Randomised lists of 416 test compound words were prepared. Two 26 year old female native speakers (Speaker 1: FXJ and Speaker 2: HQA) of SC provided the speech data. They were born and grew up in Beijing and recently left the city to study as graduate students in Hong Kong. They were instructed to read the word lists at a normal rate of speech. The recordings were performed in a sound-proof booth (IAC). The recorded speech data on minidisks were analyzed for temporal, F_0, and intensity data, using Kay's CSL4400 speech analysis software. The F_0 contours and intensity curves were obtained for all the component syllables of the compound words, using the pitch synchronous method. The durations of the syllable-initial fricatives, the voice onset time (VOT) and closure durations of the syllable-initial stops and affricates, and the durations of the rimes of the component syllables of the compounds were measured from the speech waveforms with the aid of the wideband spectrograms of the test compounds.

3. Results

3.1. Temporal structure

The following temporal data were obtained: (1) the durations of the syllable-initial fricatives [f s ʂ ɕ x], (2) the voice onset time of the syllable-initial stops [p t k pʰ tʰ kʰ] and affricates [ts tsʰ tʂ tʂʰ tɕ tɕʰ], (3) the closure durations of the stops and affricates of the non-compound-initial component syllables, and (4) the durations of the rimes of the component syllables. No measurements were made of the component elements of the syllables, such as (i) the durations of the target vowels and V-to-V transitions of the diphthongs and (ii) the durations of the vowels, V-to-N transitions, and nasal endings of the CVN syllables.

3.1.1. *Rime duration*

Table 1 and Table 2 show the mean rime durations (in ms) for the component syllables of the bisyllabic, trisyllabic and quadrisyllabic compounds for Speaker 1 and Speaker 2, respectively. It should be noted that only the rime durations for the compounds consisting of a compound-final syllable associated with a non-falling F_0 contour, i.e., level or rising, were included in the calculation. This is because a falling F_0 contour is much shorter than any other F_0 contours.

Table 1. *The mean rime durations (in ms) for the component syllables of the bisyllabic (n = 19), trisyllabic (n = 65) and quadrisyllabic (n = 131) compounds containing a compound-final syllable associated with a level or rising F_0 contour (Speaker 1).*

Compounds	1st rime	2nd rime	3rd rime	4th rime
bisyllabic	139.44 s.d. = 27.68	198.26 s.d. = 37.62		
trisyllabic	125.50 s.d. = 27.78	139.48 s.d. = 21.98	196.36 s.d. = 32.63	
quadri-syllabic	134.78 s.d. = 25.33	138.98 s.d. = 29.53	130.32 s.d. = 29.37	201.16 s.d. = 32.42

Table 2. *The mean rime durations (in ms) of the component syllables of the bisyllabic (n = 19), trisyllabic (n = 68) and quadrisyllabic (n = 124) compounds containing a compound-final rime with a level or rising F_0 contour (Speaker 2).*

Compounds	1st rime	2nd rime	3rd rime	4th rime
bisyllabic	169.78 s.d. = 24.71	240.76 s.d. = 40.20		
trisyllabic	130.26 s.d. = 30.97	156.43 s.d. = 28.26	206.45 s.d. = 24.88	
quadri-syllabic	128.55 s.d. = 22.67	135.96 s.d. = 27.75	131.14 s.d. = 27.73	200.32 s.d. = 34.09

The temporal data in the tables show that (i) for the bisyllabic, trisyllabic, and quadrisyllabic compounds the mean rime duration is longer for the compound-final syllable than the preceding component syllable(s), and the results of the grouped data *t-tests* show that in all the cases the differences are significant ($p < 0.001$); (ii) for the trisyllabic compounds, the mean rime duration for the compound-initial syllable is shorter than the mean duration of the 2nd rime, and the difference is significant ($p < 0.001$); and (iii) the differences in duration among the first three rimes of the quadrisyllabic compounds are small and non-significant, although there is a tendency for the 2nd rime to be longer than the 1st and 3rd rimes. (i), (ii), and (iii) are true for both speakers.

The ratios of the mean rime durations of the compound-final syllable and non-compound-final syllable for the bisyllabic, trisyllabic, and quadrisyllabic compounds are shown in Table 3 (Speaker 1) and Table 4 (Speaker 2). A comparison of the two tables shows that the similarity between the two sets of the corresponding ratios for the two speakers is striking. This indicates that there are invariant temporal patterns for the rimes of the component syllables of a bisyllabic, trisyllabic, or quadrisyllabic compound in SC.

Table 3. *The ratios of the mean rime durations (in ms) for the non-compound-final syllable and compound-final syllable for the bisyllabic and polysyllabic compounds (Speaker 1).*

bisyllables	1st rime/2nd rime 139.44 : 198.26 = *0.71*		
trisyllables	1st rime/3rd rime 125.50 : 196.36 = *0.64*	2nd rime/3rd rime 139.48 : 196.36 = *0.71*	
quadri-syllables	1st rime/4th rime 134.78 : 201.16 = *0.64*	2nd rime/4th rime 138.98 : 201.16 = *0.68*	3rd rime/4th rime 130.32: 201.16 = *0.65*

Table 4. *The ratios of the mean rime durations (in ms) for the non-compound-final syllable and compound-final syllable for the bisyllabic and polysyllabic compounds (Speaker 2).*

bisyllables	1st rime/2nd rime 169.78 : 240.76 = *0.70*		
trisyllables	1st rime/3rd rime 130.26 : 206.45 = *0.63*	2nd rime/3rd rime 156.43 : 206.45 = *0.75*	
quadri-syllables	1st rime/4th rime 128.55 : 200.32 = *0.64*	2nd rime/4th rime 135.96: 200.32 = *0.68*	3rd rime/4th rime 131.14: 200.32 = *0.65*

Table 5. *The mean rime durations (in ms) for the component syllables of the bisyllabic (n = 12), trisyllabic (n = 62) and quadri-syllabic (n = 133) compounds consisting of a compound-final syllable associated with a falling F_0 contour (Speaker 1).*

Compounds	1st rime	2nd rime	3rd rime	4th rime
bisyllabic	146.60 s.d. = 31.99	139.90 s.d. = 15.83		
trisyllabic	131.51 s.d. = 23.08	143.91 s.d. = 21.98	154.25 s.d. = 24.43	
quadri-syllabic	134.68 s.d. = 27.35	138.44 s.d. = 26.38	133.46 s.d. = 33.97	152.38 s.d. = 28.50

Table 6. *The mean rime durations (in ms) for the component syllables of the bisyllabic (n = 11), trisyllabic (n = 66) and quadri-syllabic (n = 131) compounds consisting of a compound-final syllable associated with a falling F_0 contour (Speaker 2).*

Compounds	1st rime	2nd rime	3rd rime	4th rime
bisyllabic	179.03 s.d. = 29.60	157.26 s.d. = 38.17		
trisyllabic	136.58 s.d. = 23.67	156.66 s.d. = 25.91	141.35 s.d. = 20.74	
quadri-syllabic	129.58 s.d. = 24.47	139.74 s.d. = 26.68	133.16 s.d. = 31.74	131.67 s.d. = 27.30

Table 5 and Table 6 show the mean rime durations for the component syllables of the bisyllabic, trisyllabic and quadrisyllabic compounds consisting of a compound-final syllable associated with a falling F_0 contour for Speaker 1 and Speaker 2, respectively. As can be seen from the tables, for Speaker 1 the temporal pattern in Table 5 are similar to that in Table 1, except that the mean rime durations for the compound-final syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds in Table 5 are much shorter. This is also true for Speaker 2 (*compare* Table 2 and Table 6). Thus, (i) for the trisyllabic compounds, the mean rime duration for the compound-initial syllable is shorter than the mean duration of the 2nd rime, and the difference is significant ($p < 0.001$), and (ii) the differences in duration among the first three rimes of the quadrisyllabic compounds are small and non-significant, although there is a tendency for the 2nd rime to be longer than the 1st and 3rd rimes. (i) and (ii) are true for both speakers. For Speaker 1, the 3rd rime of the trisyllabic compound and the 4th rime of the quadrisyllabic compound are longer than the rimes of the preceding component syllables. However, for Speaker 2, this is not so, as the compound-final rime of the trisyllabic and quadrisyllabic compounds may be longer or shorter than the rimes of the preceding component syllables. Thus, between the two speakers there is no common temporal pattern for the compound-final rime of the trisyllabic and quadrisyllabic compounds consisting of a compound-final syllable associated with a falling F_0 contour.

3.1.2. Duration of the syllable-initial fricatives [s ʂ ɕ f x]

Table 7 shows the mean durations (in ms) of the syllable-initial fricatives of all types [s ʂ ɕ f x] of the bisyllabic, trisyllabic, and quadrisyllabic compounds for Speaker 1. The difference in mean duration between the fricatives of the 1st and 2nd syllables of the bisyllabic compounds is non-significant ($p < 0.5$), though there is a tendency for the fricatives of the 1st syllable to be longer. For both the trisyllabic and quadrisyllabic compounds, (i) the mean duration of the fricatives is longer for the compound-initial (or the 1st) syllable than for the other syllables, and in all the cases the differences are significant ($p < 0.001$); (ii) the mean duration of the fricatives is longer for the compound-final syllable than for the syllable(s) in medial position(s), and in all the cases the differences are significant ($p < 0.001$); and (iii) the mean duration of the fricatives is longer for the 3rd syllable of the quadrisyllabic compounds than the 2nd syllable, and again the difference is significant ($p < 0.001$).

Table 7. *The mean durations (in ms) of the syllable-initial fricatives [s ʂ ɕ f x] of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 1).*

[s ʂ ɕ f x]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	103.49 s.d. = 27.78 *n* = 6	96.62 s.d. = 19.35 *n* = 8		
trisyllables	100.20 s.d. = 20.20 *n* = 46	65.73 s.d. = 20.09 *n* = 52	87.97 s.d. = 20.36 *n* = 50	
quadri-syllables	105.99 s.d. = 21.12 *n* = 76	69.67 s.d. = 20.33 *n* = 51	85.96 s.d. = 25.12 *n* = 82	93.90 s.d. = 22.61 *n* = 84

Table 8. *The mean durations (in ms) of the syllable-initial fricatives [s ʂ ɕ f x] of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 2).*

[s ʂ ɕ f x]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	122.08 s.d. = 19.17 *n* = 6	130.83 s.d. = 21.61 *n* = 5		
trisyllables	88.63 s.d. = 20.50 *n* = 45	77.65 s.d. = 16.15 *n* = 55	109.51 s.d. = 23.00 *n* = 50	
quadri-syllables	85.85 s.d. = 23.61 *n* = 74	82.73 s.d. = 13.78 *n* = 75	94.54 s.d. = 18.85 *n* = 78	113.13 s.d. = 19.62 *n* = 80

Table 8 shows the mean durations (in ms) of the syllable-initial fricatives [s ʂ ɕ f x] of the bisyllabic, trisyllabic, and quadrisyllabic compounds for Speaker 2. The difference in mean duration between the fricatives of the 1st and 2nd syllables of the bisyllabic compound is non-significant ($p < 0.5$), though there is a tendency for the fricatives of the 2nd syllable to be longer. For both the trisyllabic and quadrisyllabic compounds, (i) the mean duration of the fricatives is longer for the compound-final syllable than any other component syllables, and in all the cases the differences are significant ($p < 0.001$), and (ii) the mean duration of the fricatives is longer for the compound-final syllable than for the syllable(s) in the medial position(s), and in all the cases the differences are significant ($p < 0.001$). For the quadrisyllabic compounds, (i) the mean duration of the fricatives is longer for the 3rd syllable of the compounds than the 2nd syllable, and the difference is significant ($p < 0.001$), and (ii) the difference in mean duration of the fricatives between the 1st and 2nd syllables is non-significant.

The main difference between Speaker 1 and Speaker 2 is that for Speaker 1 the fricatives of the compound-initial syllable have a longer duration than any other component syllables, however, for Speaker 2 the fricatives of the compound-final syllable have the longest mean duration.

3.1.3. *VOT of the syllable-initial aspirated stops [p^h t^h k^h]*

The mean VOT (in ms) of the syllable-initial aspirated stops of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds are given in Table 9 and Table 10 for Speaker 1 and Speaker 2, respectively.

Table 9. *The mean VOT (in ms) of the syllable-initial aspirated stops [p^h t^h k^h] of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 1).*

[p^h t^h k^h]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	74.54 16.95, $n = 6$	47.59 15.92, $n = 6$		
trisyllables	69.76 14.46, $n = 15$	41.72 17.70, $n = 18$	60.43 18.13, $n = 14$	
quadri-syllables	69.39 12.53, $n = 35$	46.81 20.55, $n = 47$	52.66 17.55, $n = 20$	55.73 19.40, $n = 27$

Table 10. *The mean VOT (in ms) of the syllable-initial aspirated stops [p^h t^h k^h] of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 2).*

[p^h t^h k^h]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	75.76 15.26, $n = 6$	71.78 13.78, $n = 6$		
trisyllables	69.99 11.72, $n = 15$	50.99 15.59, $n = 18$	71.02 14.24, $n = 14$	
quadri-syllables	63.74 11.54, $n = 36$	50.48 14.45, $n = 44$	61.19 13.87, $n = 22$	65.09 14.83, $n = 26$

For both speakers, in the case of the bisyllabic compounds the mean VOT is longer for the aspirated stops of the 1st syllable than the aspirated stops of the 2nd syllable, but the difference is significant only for Speaker 1 ($p < 0.01$). As for the trisyllabic compounds, the mean VOT of the aspirated stops of the 2nd syllable is shorter than those of the 1st and 3rd syllables, and the differences are significant for both speakers (for Speaker 1, the difference between the 1st and 2nd syllables: $p < 0.001$, between the 2nd and 3rd syllables: $p < 0.01$; for Speaker 2, between 1st and 2nd syllables and between 2nd and 3rd syllables: $p < 0.001$). And, for both speakers, the difference in mean VOT between the 1st and 3rd syllables is non-significant.

As for the quadrisyllabic compounds, similar to the trisyllabic compounds, the aspirated stops of the 2nd syllable also have the shortest mean VOT. The difference between the 1st and 2nd syllables is significant ($p < 0.001$) for both speakers, however, the differences between the 2nd and 3rd syllables and between 2nd and 4th syllables are significant ($p < 0.005$ and $p < 0.001$) for Speaker 2 only. The mean VOT of the aspirated stops of the 3rd syllable is also shorter than those of the 1st and 4th syllables, however, the difference is significant ($p < 0.001$) for Speaker 2 only.

3.1.4. *VOT of the syllable-initial aspirated affricates [ts^h tʂ^h tɕ^h]*

Table 11 and Table 12 show the mean VOT (in ms) of the syllable-initial aspirated affricates [ts^h tʂ^h tɕ^h] of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds for Speaker 1 and Speaker 2, respectively. The temporal patterns are similar between the two speakers. For the bisyllabic compounds, the difference in mean VOT of the aspirated affricates between the 1st and 2nd syllables is non-significant for both speakers. As for the trisyllabic compounds, the mean VOT of the aspirated affricates of the 2nd syllable is shorter than those of the 1st and 3rd syllables, and the differences are significant for both speakers (for Speaker 1, the differences between the 1st and 2nd syllables and between the 2nd and 3rd syllables: $p < 0.001$; for Speaker 2, the differences between 1st and 2nd syllables: $p < 0.005$, between 2nd and 3rd syllables: $p < 0.001$). And, for both speakers, the difference in mean VOT between the 1st and 3rd syllables is non-significant.

Table 11. *The mean VOT (in ms) of the syllable-initial aspirated affricates [ts^h tʂ^h tɕ^h] of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 1).*

[ts^h tʂ^h tɕ^h]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	81.90 18.14, $n = 4$	94.98 24.45, $n = 5$		
trisyllables	92.32 16.11, $n = 7$	55.79 12.69, $n = 9$	89.36 21.17, $n = 23$	
quadri-syllables	91.29 21.02, $n = 28$	69.23 24.11, $n = 32$	97.77 22.96, $n = 30$	92.96 26.68 $n = 34$

Table 12. *The mean VOT (in ms) of the syllable-initial aspirated affricates [ts^h tʂ^h tɕ^h] of the component syllables of the bisyllabic, trisyllabic, and quadrisyllabic compounds (Speaker 2).*

[ts^h tʂ^h tɕ^h]	1st syllable	2nd syllable	3rd syllable	4th syllable
bisyllables	116.91 24.75, $n = 4$	114.35 20.50, $n = 6$		
trisyllables	93.21 12.55, $n = 7$	67.81 15.93, $n = 11$	112.14 24.87, $n = 24$	
quadri-syllables	92.33 17.90, $n = 25$	75.33 20.40, $n = 33$	100.52 18.87, $n = 29$	106.28 24.49, $n = 29$

As for the quadrisyllabic compounds, similar to the trisyllabic compounds, the aspirated affricates of the 2nd syllable also have the shortest mean VOT. The difference between the 2nd syllable and the 1st, 3rd, or 4th syllable is significant ($p < 0.001$) for both speakers. The differences in mean VOT between the 1st and 3rd syllables and between the 3rd and 4th syllables are non-significant. As for the difference in mean VOT between the 1st and 4th syllables, it is significant ($p < 0.05$) for Speaker 2 only.

3.1.5. *VOT of the syllable-initial unaspirated stops [p t k] and unaspirated affricates [ts tʂ tɕ] and closure duration*

The mean VOT (in ms) of the syllable-initial unaspirated stops [p t k] and unaspirated affricates [ts tʂ tɕ] of the syllables are unaffected by the position in which a syllable occurs in a compound. The differences in mean VOT of the unaspirated stops or affricates between any two component syllables are in most cases non-significant. The mean VOT of the syllable-initial unaspirated stops [p t k] for the quadrisyllabic compounds for Speaker 1 are 13.02 (s.d. = 6.01, $n = 64$), 12.56 (s.d. = 7.17, $n = 44$), 13.58 (s.d. = 6.31, $n = 62$), and 14.88 (s.d. = 8.51, $n = 40$) for the 1st, 2nd, 3rd, and 4th syllables, respectively. The large standard deviations are due to the large differences in VOT between [k] and [p t]. For Speaker 2, the mean VOT of the syllable-initial unaspirated stops [p t k] for the quadrisyllabic compounds are 16.05 (s.d. = 5.92, $n = 59$), 16.36 (s.d. = 5.24, $n = 44$), 17.69 (s.d. = 6.61, $n = 55$), and 18.47 (s.d. = 7.20, $n = 40$). As for the mean VOT of the syllable-initial unaspirated affricates [ts tʂ tɕ] for the quadrisyllabic compounds for Speaker 1, they are 49.81 (s.d. = 17.40, $n = 42$), 49.01 (s.d. = 13.71, $n = 47$), 51.04 (s.d. = 15.10, $n = 64$), and 50.51 (s.d. = 17.32, $n = 57$) for the 1st, 2nd, 3rd and 4th syllables, respectively. For Speaker 2, the mean VOT of the syllable-initial unaspirated affricates for the quadrisyllabic compounds are 49.05 (s.d. = 15.08, $n = 40$), 45.74 (s.d. = 15.04, $n = 46$), 50.96 (s.d. = 18.93, $n = 60$), and 51.10 (s.d. = 13.76, $n = 53$).

Due to space limit, the closure durations for the stops and affricates, aspirated and unaspirated, are not presented here, though briefly, they are also unaffected by the position in which a syllable occurs in a compound.

3.2. F_0 contours and intensity curves

The F_0 contours of the citation tones on all the test bisyllabic, trisyllabic, and quadrisyllabic compounds were analyzed for both speakers. Also analyzed were the intensity curves of the component syllables of the compounds. Due to space limit, only those for the compounds consisting of the syllables with the same citation tone from Speaker 1 are presented in Figure 1. Some generalizations are made about the F_0 shape and level of the citation tones that occurs on the component syllables of the compounds, based on the F_0 contours shown in Figure 1 and those which are not.

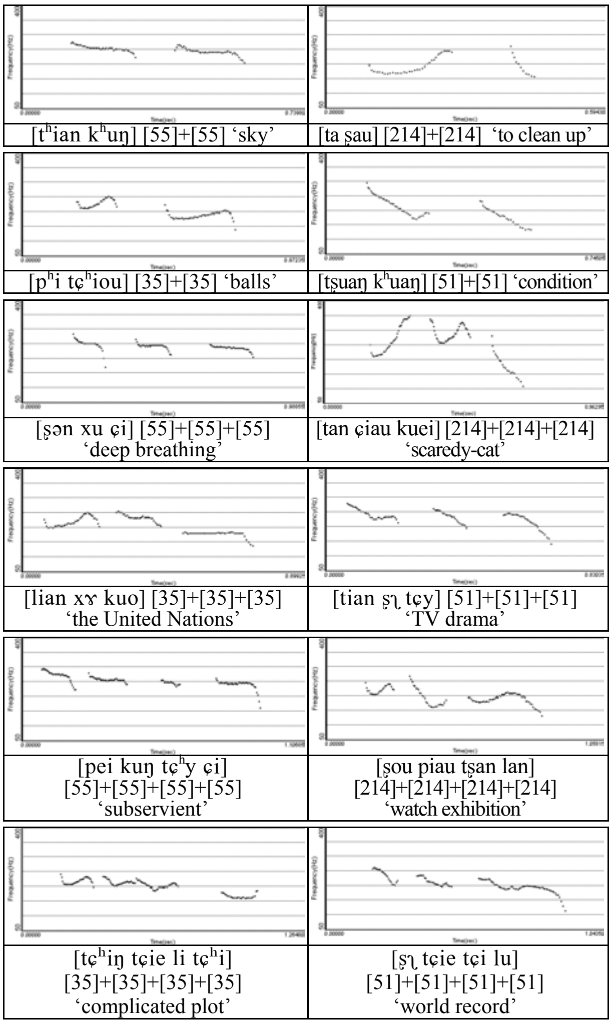

Figure 1. *F_0 contours of the same citation tone [55 35 214] or [51] on the component syllables of the test bisyllabic, tri-syllabic, and quadrisyllabic compounds (Speaker 1).*

In general, the F_0 contours of the identical citation tones on the component syllables of the compounds are down-stepped as shown in Figure 1 and in some cases the F_0 contour is re-shaped. For instance, a [55] tone on any component syllables remains level or it may fall slightly; a [35] tone on the component syllables remains rising, except when the syllable occurs in the compound-final position, it may become falling or level; a [214] tone when preceding another [214] becomes rising; a [214] tone falls in the compound-final position and when preceded by another [214] in the non-compound-final position; as for [51], it falls wherever it occurs. The F_0 range of a falling or rising F_0 contour may change, depending on the duration of the rime.

Figure 2 shows the F_0 contours and intensity curves for the six test bisyllabic, trisyllabic and quadrisyllabic compounds. The left column of the figure shows the co-varying F_0 contours and intensity curves for the bisyllabic (a) 'railway', trisyllabic (c) 'water ink paint', and quadrisyllabic compounds (e) 'people of all sorts'. In the large majority of cases, the two parameters co-vary. There are however sporadic cases in which the two parameters do not co-vary so well, as shown in the F_0 contours and intensity curves for the compounds, 'fruit candy' (b), 'locomotive' (d), and 'not well-informed' (f) in the right column.

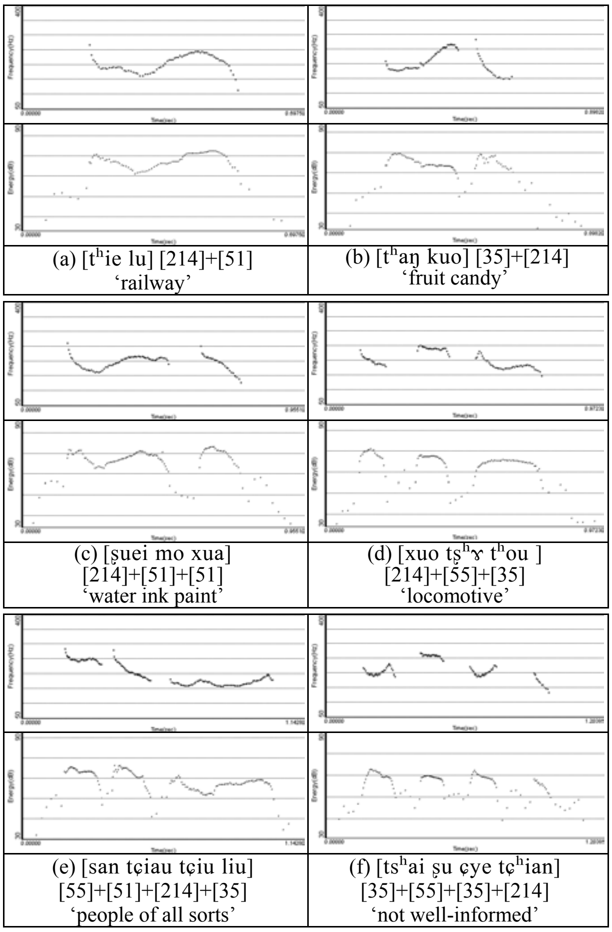

Figure 2. *F_0 contour (upper) and corresponding intensity curve (lower) for the component syllables of two bisyllabic, two trisyllabic, and two quadrisyllabic compounds, with one of the two showing close co-variation of the F_0 contour and intensity curve, and the other showing the discrepancy between the two (Speaker 1).*

4. Conclusion

It appears from the temporal data obtained in this study that the durations of initial fricatives, rime durations, and VOT of the syllable-initial aspirated stops and affricates are conditioned by the positions of the component syllables in the compounds. There are temporal patterns for the rimes and longer consonants, namely fricatives, aspirated stops, aspirated affricates, but not the shorter ones, namely unaspirated stops, unaspirated affricates, and closures. The patterns of the rime duration for the two speakers are strikingly similar, however, the patterns of the durations of the longer consonants vary for the two speakers. The F_0 contours of the citation tones on the component syllables of the compounds may change due to the positions of the syllables in the compounds or the tone sandhi rules in the language. In the large majority of cases, the intensity curves co-vary with the F_0 contours. The differences between the two speakers in F_0 contours and in F_0 contour and intensity curve co-variation are minimal.

[The research was supported by a Strategic Research Grant (7000901) from the City University of Hong Kong.]