INITIAL F_0-CONTOURS IN SHANGHAI CV-SYLLABLES - AN INTERACTIVE FUNCTION OF TONE, VOWEL HEIGHT, AND PLACE AND MANNER OF STOP ARTICULATION

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ABSTRACT

F_0 perturbations after voiceless and voiceless aspirated stops are analyzed in Shanghai, a tone language. It turned out that F_0 is always higher after voiceless than after aspirated stops, and this difference disappears after 15 to 30 ms. The place of articulation of the stops does not contribute significantly to the F_0 difference, whereas the vowel does.

INTRODUCTION

For languages such as German and English it is well known that voiced stops cause an initial lowering of F_0 in CV-syllables and voiceless stops a relative raising. Umeda [6] and Lea [3] found that this effect remains evident during the first 75 to 100 ms of the vowel, whereas Hombert et al [1] showed that in a tone-language this effect disappeared after 40 to 60 ms. This raises the question whether this specific glottal behavior is language dependent or not. Most studies on F_0 perturbations after stops focused on the difference between voiced and voiceless aspirated stops rather than on the difference between the two voiceless categories (aspirated and unaspirated). On the other hand, those studies which examined that difference provided rather diverse results as in some of the languages voiceless aspirated stops caused higher F_0 values than the voiceless ones (Korean [2]), whereas other authors report the reverse (English [4]). A higher F_0 after aspirated stops was reported too for Cantonese by Zee [7], who measured the F_0 perturbations after [p] and [ph], respectively. The rather conflicting results cannot be explained easily as the studies differ in (i) number of speakers employed, (ii) material included (in most studies only a subset of either the stops or stop-vowel combinations is analyzed), and especially (iii) in method. With our present study we wanted to help contribute to a solution of the problem by employing further material from a tone language. Thus, the aim of our study is threefold: (i) to examine the F_0 perturbations caused by two voiceless stops in a tone-language, (ii) to measure the duration of these perturbations, and (iii) to analyze whether the F_0 perturbations interact either with tone, the stop's place of articulation, or the vowel.

MATERIAL AND INFORMANT

We constructed a list of words containing voiceless unaspirated (henceforth VL) and voiceless aspirated (henceforth ASP) stops in three places of articulation (labial, alveolar, and velar) followed by one of the vowels /a e i o u/ in word initial position and combined with one of the four tones high level (Tone 1), rising (Tone 2), mid level or dipping (Tone 3), and falling (Tone 4). As ASP stops do not occur with Tone 2, the difference between the stop's manner of articulation could be measured for Tone 1, Tone 3, and Tone 4 only. It should be mentioned here, that our analysis does not support the hypothesis of Zee-Maddieson [8] that Tone 2 is associated with voiced stops, as in the speech of our informant Tone 2 occurred (with few exceptions) only after VL, i.e., short lag stops. Not all possible combinations between stop, vowel, and tone occur in our material, as shown in Table 1.

TABLE 1: CV combinations as a function of manner of articulation and tone

		Tone 1 high level					Tone 2 rising					Tone 3 mid level					Tone 4 falling				
		a	e	o	i	u	a	e	o	i	u	a	e	o	i	u	a	e	o	i	u
VL	lab	x	-	x	x	-	x	x	x	x	x	-	x	x	x	x	x	x	x	x	x
	alv	x	-	x	x	-	x	x	x	x	x	-	x	-	-	x	-	x	x	x	x
	vel	x	-	-	-	x	x	x	x	-	-	-	x	x	-	x	-	x	-	-	x
ASL	lab	x	-	x	x	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x
	alv	x	-	x	x	-	-	-	-	-	-	x	x	x	x	x	x	x	x	x	x
	vel	x	-	x	-	-	-	-	-	-	-	x	x	x	-	x	x	x	x	-	x

Every word, containing one of the CV combinations, was written ten times on separate cards. The words were read by one informant (male, 34 years old), native speaker of Shanghai, but with imperfect knowledge of Mandarin. The recordings were made in our Institute on a Telefunken M15 tape recorder using a Neumann U87 studio microphone. The microphone was placed in front of the speaker at a distance of about 50 cm, who was seated comfortably in a chair. He was asked to read the words at a comfortable loudness and tempo. He was given the cards in randomized order and he had to read the words in the following way: after reading the first word (on the first card), he had to turn the card and put it aside before continuing with the next word. This procedure caused the speaker to read slowly and breathe after every word. We employed this method in order to avoid any kind of "list effects". The recordings were made in one session, interrupted by a pause of about 15 mins.

PROCEDURE

A preliminary analysis of the fundamental frequency was run with the Frokjer-Jensen F_0-Meter in order to check the realisation of the tones and to eliminate any mistake made by the speaker. The material was then digitized on a PDP11/50 with a sample rate of 20 kHz and filtered with a cut off frequency of 8 kHz. The first 15 pitch periods of the vowels in long syllables and the first ten periods in short syllables of Tone 1 were delimited manually with the help of a segmentation routine and stored for analysis (for detail cf. [5]). The F_0 was calculated separately for all CV conditions in all tones, averaged over all repetitions. Separate multivariate analyses of variance were applied for each tone condition.

RESULTS

The results of the statistical analysis are given in Table 2.

TABLE 2: Statistical results from the analysis of variance for Tone 1, Tone 2, Tone 3, and Tone 4, as well as the manners of articulation, places of articulation, and vowels included in the analyses. M=manner of articulation, P=place of articulation, V=vowel

	Tone 1	Tone 2	Tone 3	Tone 4
Manner	VL, ASP	VL	VL, ASP	VL, ASP
Place	l, a	l, a, v	l, al, v	l, a, v
Vowel	a, o, i	a,e,o,i,u	e, u	e, o ,u
Interactions				
M-P-V	p <.01	---	n.s.	n.s.
P-V	n.s.	n.s.	p <.05	n.s.
M-V	p <.01	---	p <.05	p <.001
M-P	n.s.	---	n.s.	p <.05
Main factors				
Manner	p <.001	---	p <.001	p <.001
Place	n.s.	n.s.	n.s.	p <.05
Vowel	p <.001	p <.001	p <.001	p <.01

Manner of articulation. The main effect of the stop's manner of articulation (cf. Fig. 1) is significant in all tone conditions (but cf. the interactions between manner of articulation and vowel). The F_0 onset is always higher after VL than after ASP stops. This effect disappears in Tone 1 after the third pitch period (P3), in Tone 3 after P6, and in Tone 4 after P5, respectively. This is equivalent to either 15, 30, or 25 ms.

Place of articulation. The effect of the stop's place of articulation is significant only in Tone 4 ($p < .05$), where the velar stop causes significantly higher F_0 values than the labial or alveolar stops. As there is an interaction between the manner and place of articulation, as plotted in Fig. 2, the main effect of the place cannot be interpreted by itself. It is apparent that the interaction is due to the velar VL stop /k/, which causes significantly higher F_0 values than the other stops /p/ and /t/, respectively.

Vowel. The main effect of the vowel is significant throughout. The difference between the vowels is usually greater after VL than after ASP stops and the results reflect the well known phenomenon of intrinsic pitch, where high vowels cause higher F_0 values than mid or low ones. As there is no interaction between the vowels and places of articulation, the results for Tone 2 and the VL stops are displayed in Fig. 3. In all vowel conditions F_0 falls from P1 to P2 and rises towards the end of the contour. The F_0 differences between the vowels are nearly the same at P2 as well as at P15. Tone 3 shows an interaction between place of articulation and the vowel (cf. Fig. 4), which obviously is due to a different behavior of the velar stop. Whereas the F_0 onset in /e/ is low after the labial and alveolar stop, it is higher after /k/, followed by a short fall instead of a rise. The differences are even greater for /u/, where the F_0 after /k/ is significantly higher than after the other stops.

Interaction between manner of articulation and vowel. In all tone conditions a significant interaction between the stops manner of articulation and the vowel can be observed. The results are plotted separately for the tones. Fig. 5 shows the results for Tone 1. The F_0 differences between the vowels are small after the ASP stops, greater after the VL ones; /i/ after the VL stops differs significantly from all other vowels. Fig. 6 displays the results for Tone 3. F_0 after the ASP stops is rising in /e/, level in /u/, whereas both vowels have a falling pattern after the VL stops; /u/ differs significantly from all other vowels. Tone 4 (cf. Fig 7.) shows a somewhat different pattern. This time, the interaction is caused by the ASP stops rather than the VL ones as the F_0 after the VL stops is nearly the same for all vowels: the onset is high, followed by a F_0 fall. After ASP stops the F_0 onset is extremely low in /e/, which shows a rising-falling pattern, whereas the onset is high in /o/, followed by a quasi-linear F_0 fall towards the end of the contour. /u/ on the other hand, is associated with a high F_0 onset and a falling-rising pattern. To summarize these results it can be stated that (i) the interaction between manner and vowel is caused by a specific behavior of /i/ (Tone 1) and /u/ (Tone 3) after VL stops, and (ii) the different behavior of the ASP stops in Tone 4.

There is one higher level interaction

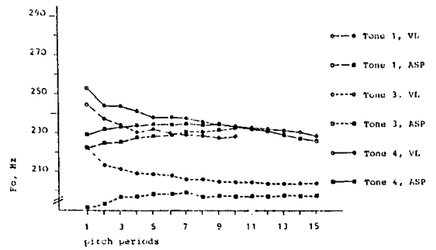

Fig. 1: Fo values in Hz for the manners of articulation as a function of pitch period and tone

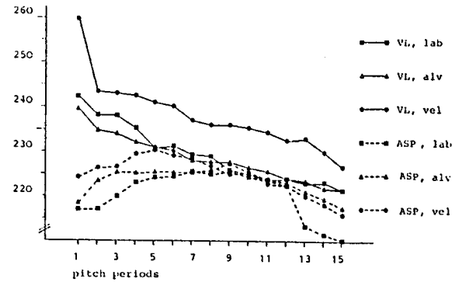

Fig. 2: Fo values in Hz for Tone 4 as a function of pitch period, manner and place of articulation

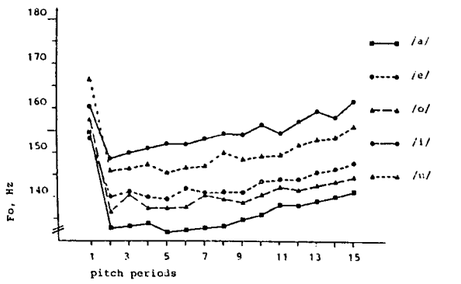

Fig. 3: Fo values in Hz for Tone 2 as a function of pitch period and vowel

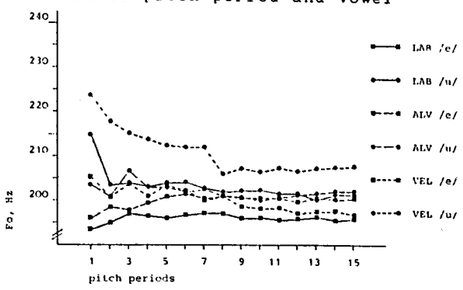

Fig. 4: Fo values in Hz for Tone 3 as a function of pitch period, place of articulation, and vowel

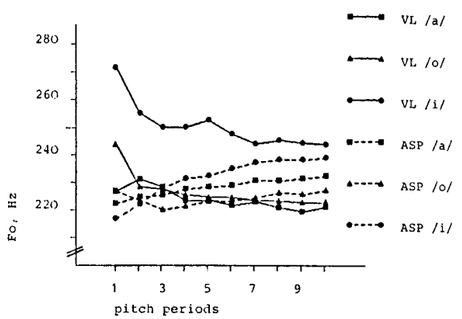

Fig. 5: Fo values in Hz for Tone 1 as a function of pitch period, manner of articulation, and vowel

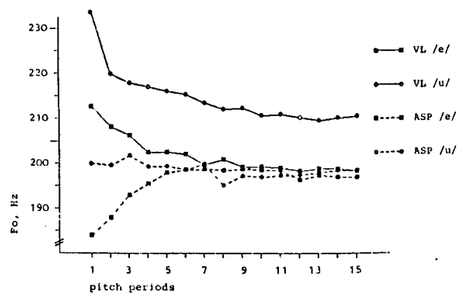

Fig. 6: Fo values in Hz for Tone 3 as a function of pitch period, manner of articulation, and vowel

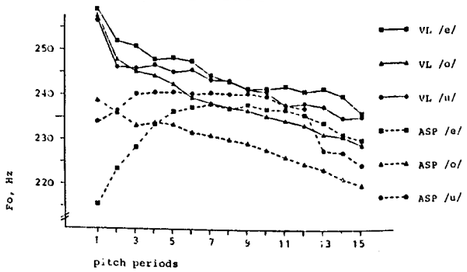

Fig. 7: Fo values in Hz for Tone 4 as a function of pitch period, manner of articulation, and vowel

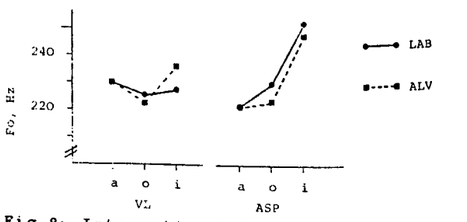

Fig. 8: Interaction between manner of articulation, place of articulation, and vowel in Tone 1. Fo values in Hz

between manner of articulation, place of articulation, and vowel in Tone 1, i.e. none of the factors examined contribute independently to the F_o perturbations. The interaction (based on the mean F_o values) is shown in Fig. 8. It is obvious that F_o is higher after /p/ than after /t/; /a/ is associated with the lowest, /o/ with mid, and /i/ with the highest F_o. After /ph/ F_o is highest in /a/, lower in /i/, and lowest in /o/, whereas after /th/ /i/ shows the highest F_o, /a/ mid, and /o/ lowest values. The differences for /a/ and /o/ are small, those for /i/ greater.

In order to have results comparable to those of Zee [7], who used the Cepstrum method to gain F_o values and measured F_o over the initial 78.0 ms of the vowels, we (i) give averaged F_o values in Table 3 for Tone 1, Tone 3, and Tone 4, as well as the corresponding ms and (ii) analyzed the F_o contour in /pey/ vs /phey/ in Tone 1, the results of which are displayed in Fig. 9.

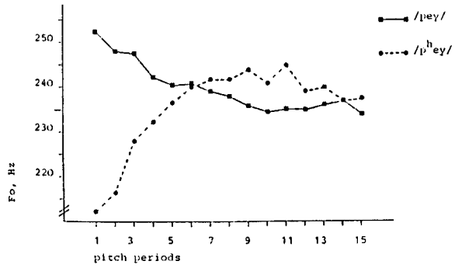

Fig. 9: Fo values in Hz as a function of pitch period and manner of articulation

It is clear from the averaged data that in our material the F_o after VL stops exceeds those after ASP stops. On the other hand, the F_o onset is high in /pey/ and falls towards the end of the contour, whereas it is low after /phey/ and rises till P6 where it exceeds the value of /pey/. The mean F_o value for /pey/ averaged over about 65 ms (this corresponds to 15 pitch periods) is 239.4 Hz, that for /phey/ 235.6 ms.

DISCUSSION

To answer the question we have asked in the introduction it can be stated that there is a remarkable difference in F_o after VL and ASP stops: F_o is always higher after the VL than the ASP stops. This difference disappears after 15 to 30 ms. Our results thus are in agreement with those of Hombert et al [1] for Yoruba, as well as with those studies which reported higher F_o values after VL stops [4], but disagree with the findings of Zee [7] for Cantonese. In the speech of our informant, the stops' places of articulation do not contribute significantly to the F_o pattern. It is worth mentioning that the phenomenon of intrinsic pitch could be verified in a tone language, too. But the influence of the vowel is not independent of the stop's manner of articulation. The intrinsic pitch effect is greater after VL than after ASP stops and seems to interact with the tone too: the differences between the vowels are greater in Tone 2 than in Tone 1 or Tone 4. This factor cannot be discussed in detail here but will be dealt with in another paper. On the other hand, the interaction between the VL stop and high vowels seems to reflect a stronger coupling between the supra- and subglottal cavities after VL than after ASP stops.

TABLE 3: Mean F_o values in Hz for the VL and ASP stops in Tone 1, Tone 3, and Tone 4, as well as the duration of the vowel portion in ms.

	Tone 1		Tone 3		Tone 4	
	F_o	duration	F_o	duration	F_o	duration
VL	232.3	43.0	209.5	47.7	240.1	41.7
ASP	228.5	43.8	196.8	50.8	233.2	42.9

REFERENCES

[1] Hombert, J.-M. - Ohala, J.J. - Ewan, W.G.: Phonetic explanations for the development of tones. Language 55: 37-58 (1979)

[2] Kagaya, R.: A fiberoptic and acoustic study of the Korean stops, affricates and fricatives. Journal of Phonetics 2: 161-180 (1974)

[3] Lea, W.A.: Segmental and suprasegmental influences on fundamental frequency contours; in Hyman, L. Consonant types and tones, pp. 17-70 (Linguistic Program, University of Southern California, Los Angeles 1973)

[4] Ohde, R.: Fundamental frequency as an acoustic correlate of stop consonant voicing. J. acoust. Soc. Am. 75: 224-230 (1984)

[5] Schiefer, L.: F_o in the production and perception of breathy stops: evidence from Hindi. Phonetica 43: 43-69 (1986)

[6] Umeda, N.: Influence of segmental factors on fundamental frequency in fluent speech. J. acoust. Soc. Am. 70: 350-355 (1981)

[7] Zee, E.: The effect of aspiration on the F_o of the following vowel in Cantonese. UCLA Working Papers in Phonetics 49: 90-97 (1980)

[8] Zee, E. - Maddieson, I.: Tones and tone sandhi in Shanghai: Phonetic evidence and phonological analysis. University of California Working Papers in Phonetics 45: 93-129 (1979)