VOICELESS STOPS AND F_0 IN KAMMU

Jan-Olof Svantesson
Institute of East Asian Languages, Lund University

It is a well-documented fact that voiceless stops increase fundamental frequency in the first part of a following vowel, while voiced stops do not have this effect. This has been shown for several languages, including the tone languages Thai and Yoruba. It was found in these investigations that the F_0 perturbation due to a voiceless stop lasts for a relatively long time period, more than 100 ms in non-tonal languages such as English and Swedish, but only for 30-40 ms in the tone languages that have been investigated. See Hombert 1978 and Silverman 1987 for a general discussion and a survey of the literature.

In Kammu, an Austroasiatic language spoken in northern Laos, two tones (high level, denoted ´ and low level, `) have developed in connection with the merger of voiced and voiceless initial stops, *voiceless stops (or other consonants) giving rise to high and *voiced stops to low tone, as in the example: **kaa* > *káa* 'seal'; **gaa* > *kàa* 'to climb'. The original state with an opposition between voiced and voiceless stops is preserved in some Kammu dialects (see Svantesson 1983 for details).

Experimental procedure

In order to find out if the voiceless stops of Kammu have a raising effect on F_0, recordings of 24 Kammu words consisting of open syllables were investigated. These words were obtained by combining each of the four voiceless unaspirated stops in Kammu (*p, t, c* and *k*) with the three (out of ten) long vowels *aa, ii* and *uu,* and the two tones. There are also aspirated stops (p^h, t^h, c^h, k^h) and implosives (*ɓ, ɗ*), which can be followed only by high tone; they have not been investigated here.

A list consisting of these 24 words inserted into a sentence frame *Ò lʌ̀ʌ ___ pàar pàt.* 'I said ___ twice.' was read six times (each time in a different, random order) by a male Kammu speaker, Kàm Ràw, living in Sweden. The recording was made in the sound studio at the Department of Linguistics, Lund University. The recording was digitized at the sampling rate 20 KHz, and the length of the six first periods of the vowel, as well as the duration of the occlusion and aspiration phases of the stops were measured directly from computer oscillograms, using an interactive wave form editor developed by Lars Eriksson. The vowel period durations were converted into frequencies. The main results are shown in Table 1 and Figure 1.

F_0 raising

The F_0 raising effect of voiceless stops is present in Kammu, and its magnitude (the average is 17.7 Hz in low-tone and 25.8 Hz in high-tone words) is comparable to what has been found for other languages. On the other hand, its duration is small, comprising mainly the first period of the vowel (i.e. 6-9 ms), whose F_0 is in all cases except for *káa* and *kíi* significantly higher than that of the second period. In most cases the second period has higher F_0 than the third, but the difference is usually not significant, and F_0 does not change significantly in

periods 3-6. In Table 1, the average F_0 of periods 3-6 is given, representing a stable pitch value for the beginning of the syllable. At the end of the syllable, fundamental frequency usually falls slightly, but the distance between the two tones remains fairly constant.

As seen in Figure 1, the raising effect is, in all cases except for *caa*, smaller for the low than for the high tone. Because of the rather large F_0 variation in the first period (see Table 1), this difference is significant only for *paa* ($p<1\%$), *taa* ($p<5\%$) and *kuu* ($p<5\%$). According to Silverman 1987:4.10, F_0 raising does not increase with increasing F_0.

Stop duration

Since the voiced stops have been devoiced fairly recently in Kammu, one possible cause of the different size of F_0 raising for high and low tone may be a remaining lenis/fortis difference in the stops, although oscillograms show that the *voiced stops have become completely devoiced. In order to investigate this, the duration of the stops was measured. As is usually the case, the 'unaspirated' stops have a short aspiration phase, longer (averaging 26.6 ms) for *k* than for *t* (12.3 ms), and still shorter (and difficult to measure) for *p*. Although analysed as a stop, *c* has a short (37.1 ms) fricative/aspiration phase.

There is no systematic difference in the total stop duration between words with high tone and those with low tone. Before the vowels *aa* and *ii*, the total consonant duration is greater in high-tone than in low-tone words, but before *uu* it is shorter. (The mean differences were 10.6, 10.0 and -1.6 Hz) This difference is significant only for *paa, pii, tii* ($p<5\%$) and *kaa* ($p<0.1\%$), however.

Intrinsic pitch

My data also show that the effect of vowel intrinsic pitch is smaller for the low than for the high tone. The mean F_0 for periods 3-6 is on the average 20.5 and 19.4 Hz higher for *uu* and *ii* , respectively, than for *aa* in the high tone, but only 11.4 and 11.5 Hz higher than *aa* in the low tone. Although the intrinsic pitch effect increases with increasing F_0 (Silverman 1987:4.4), the difference found here is much larger than the expected proportional increase.

Conclusion

The F_0 raising effect of a voiceless stop has a short duration in Kammu, affecting only one or two periods of the vowel. Raising is smaller for the low than for the high tone, and this can probably not be attributed to any remaining difference in the stop itself. These facts, as well as the fact that the intrinsic pitch effect is smaller for the low than for the high tone, suggest that Kammu speakers control these features in order to avoid the fundamental frequency of the low tone becoming so high that discrimination of the two tones is endangered.

This active control contradicts the theory that F_0 raising after voiceless stops and intrinsic pitch are due to purely aerodynamic factors. The simultaneous suppression of these two effects in the low tone may suggest a common control mechanism for them, probably involving the crico-thyroid muscle, whose activity has been shown to be correlated with intrinsic pitch by Dyhr 1988 and with F_0 raising after voiceless stops by Baer et al. forthc.

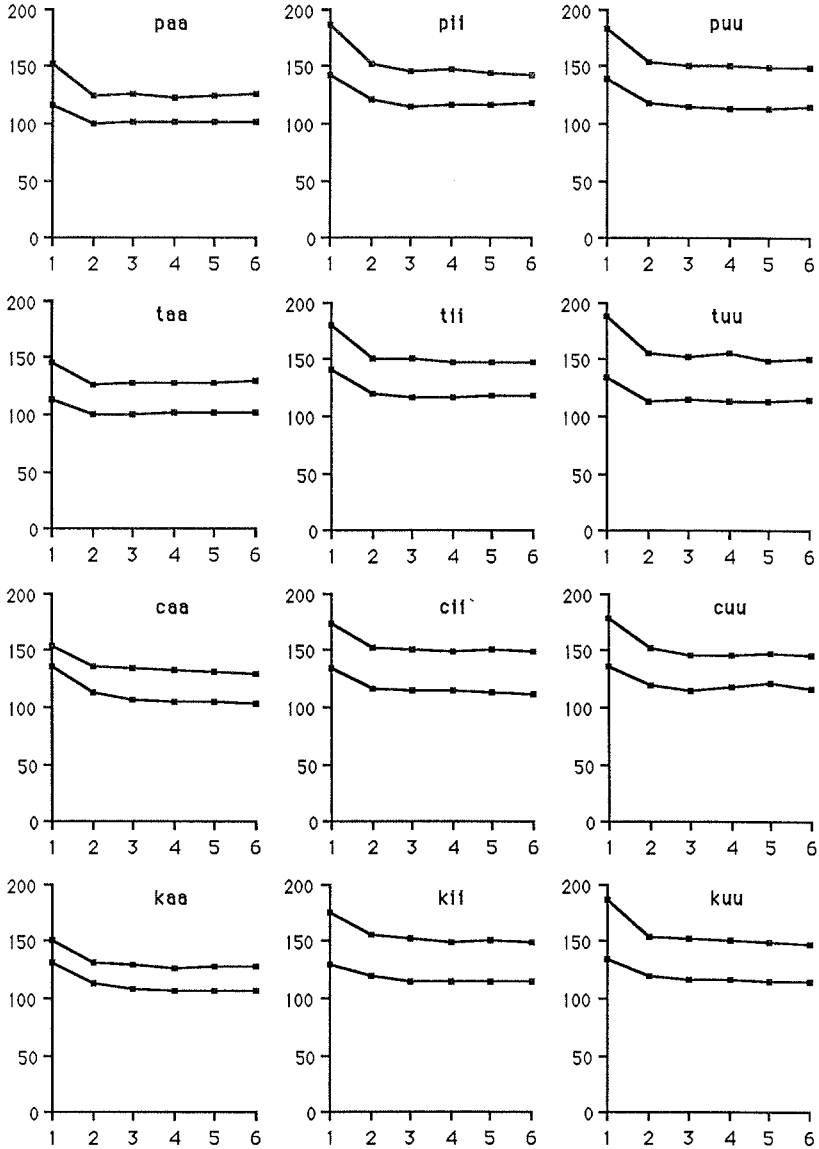

Figure 1. Fundamental frequency in the first six periods (Hz). Each point represents the average of six values.

Table 1. Mean values and standard deviations for the total duration of the stops, the duration of their aspiration or fricative phase, and for F_0 in the first two periods as well as the average F_0 in periods 3-6 (n=6 in all cases).

	Total duration (ms)		Asp./fric. (ms)		Period 1 (Hz)		Period 2 (Hz)		Period 3-6 (Hz)	
	x̄	s	x̄	s	x̄	s	x̄	s	x̄	s
pàa	122.5	6.57	-	-	116.6	5.01	100.5	3.65	102.1	2.66
páa	132.8	5.25	-	-	153.1	11.28	124.3	3.78	125.1	2.69
pìi	136.3	6.64	-	-	143.4	12.67	120.8	5.25	116.4	4.30
píi	147.6	8.96	-	-	186.1	8.58	151.7	8.70	145.0	3.48
pùu	142.8	3.80	-	-	140.1	3.47	118.0	3.50	113.8	3.37
púu	140.2	8.58	-	-	183.0	24.35	153.7	4.19	149.9	3.35
tàa	125.9	6.10	10.3	0.69	112.6	9.02	100.1	4.23	101.1	3.73
táa	129.3	4.43	8.9	0.68	146.1	4.72	126.9	3.80	128.6	3.28
tìi	130.9	5.83	17.0	1.90	140.2	9.18	120.4	4.63	117.2	2.39
tíi	140.6	4.92	13.3	2.51	179.5	24.77	150.7	5.47	148.1	4.23
tùu	145.7	4.49	13.0	1.72	133.8	8.77	113.7	4.09	114.4	4.65
túu	144.5	8.93	11.3	1.90	189.0	13.75	156.6	4.34	151.9	1.02
càa	118.0	6.90	27.1	3.41	135.7	10.80	112.7	5.15	105.1	4.89
cáa	123.7	5.55	28.2	1.41	153.5	19.27	135.6	5.81	134.7	5.48
cìi	137.4	10.65	56.4	7.29	133.8	17.91	116.1	5.91	113.6	3.33
cíi	144.4	15.35	39.7	5.85	173.4	14.27	152.0	9.19	150.0	8.35
cùu	145.9	11.07	38.8	6.84	135.5	14.33	119.3	5.84	117.5	2.57
cúu	145.1	8.13	32.4	6.04	179.1	23.92	152.4	4.33	146.4	4.61
kàa	105.1	7.32	24.2	4.55	131.1	19.59	112.7	6.25	107.0	1.34
káa	127.8	7.94	21.1	3.52	150.9	26.39	130.6	6.42	127.7	3.62
kìi	130.7	8.61	32.0	4.49	129.3	9.53	119.6	8.21	114.5	2.74
kíi	142.5	15.79	24.7	4.84	174.6	20.44	156.2	10.33	150.3	9.35
kùu	135.3	7.61	32.5	5.52	134.7	17.10	120.4	5.35	115.4	2.61
kúu	133.5	8.72	24.8	4.54	187.2	16.38	154.7	3.68	149.8	3.76

References

Baer, Thomas, Anders Löfqvist, Nancy S. McGarr and Robin Seider Story. forthc. 'The crico-thyroid muscle in voicing control'. ms.

Dyhr, Niels. 1988. *Intrinsik tonehøjde og aktiviteten i musculus cricothyroideus.* Specialeopgave i fonetik, Københavns universitet.

Hombert, Jean-Marie 1978. 'Consonant types, vowel quality, and tone'. *Tone: a linguistic survey,* ed. Victoria Fromkin, 77-111. New York: Academic Press.

Silverman, Kim. 1987. *The structure and processing of fundamental frequency contours.* Ph.D. thesis, University of Cambridge.

Svantesson, Jan-Olof. 1983. *Kammu phonology and morphology.* Lund: Gleerup.