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AN INSTRUMENTAL ANALYSIS OF SHARCHHOP OBSTRUENTS

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1.0. INTRODUCTION*

A great many of the world's languages have never received serious phonetic study. This report concerns itself with one language, colloquially known as Sharchhop, on which no instrumental phonetic investigation has been conducted in the past. Sharchhop-kha, as it is also known, is spoken by about 140,000 citizens of Bhutan (Andvik 1993), a small nation in the Himalayas north of India. Its main variety is called Tshangla, a term which also refers to the central ethnic group of Sharchhop speakers. Tshangla is considered by some sources (e.g., "Bodish Languages" 1991-92) to be a distinct language rather than a dialect of Sharchhop. Either way, both are members of the Tshangla group as classified by Shafer (1955). The Tshangla group is a major division of the Bodish languages, all of which are grouped with the East Himalayan languages to form the Bodic sub-branch within the Himalayish branch of the Tibeto-Burman family.

2.0. PHONOLOGY

2.1. Consonants

fortis	p	t	ts	tʃ	ʈ		k	
lenis	b	d	dz	ʒ	ɖ		g	
aspirated	p^h	t^h	ts^h	$tʃ^h$	$ʈ^h$		k^h	
fricatives		s		ʃ				h
		z		ʒ				
nasals	m	n				ɲ	ŋ	
liquids		l			r			
glides	w					j		

Table 1. Consonants of Sharchhop

* Language material for this paper was gathered under a STEP grant to the University of Calgary, during the summer of 1994, under the direction of M. Dobrovolsky.

Sharchhop has a rich system of obstruents, with plosives in four places of articulation for each of three manners of articulation, and two different affricates exhibiting the three manners. The plosive manners will be called *fortis*, *lenis*, and *aspirated*. This terminology is used because varying degrees of tension seem to be involved in the production of fortis and lenis stops, while Voice Onset Time is not a reliable indicator of stop manner beyond distinguishing the aspirated stops from the other two series. Plosives can be bilabial, dental, retroflex, or velar. The dental stops may be better described by resurrecting the older term *gingival*, as they seem to be produced with the tongue tip against the base of the gums. The retroflex plosives are in free variation with corresponding retroflex clusters [ʈɹ, ʈ^{h}ɹ, ɖɹ].

The fricatives are also distinguished along a fortis/lenis dimension; voicing is unimportant in the [s/z, ʃ/ʒ] oppositions provided the articulation is lax. The phoneme /r/ is a retroflex trill, which is pronounced as a flap intervocalically. All consonants are possible as initials, and most were found to occur intervocalically. In final position, however, the only obstruents that occur are the fortis [p, k]. This restricted array of final consonants is a common feature of Sino-Tibetan languages.

2.2. Vowels

Tshangla has essentially five full vowel phonemes (Andvik 1993):

i		u
ɪ		
		o
	a	

The high front vowels are quite similar in quality; the back vowel /o/ is often pronounced as [ɔ], while the front vowel /ɪ/ is a lax vowel whose quality may range down to [ɛ]. There is one diphthong, /aj/.

3.0. ACOUSTIC STUDY OF FORTIS AND LENIS OBSTRUENTS

It was mentioned above that the two obstruent classes called here fortis and lenis do not have VOT (in plosives) or voicing (in fricatives) as a reliable distinguishing feature. This is not to say that the lenis segments are never phonetically voiced; one of our informants voiced these segments quite consistently, while the other showed voicing only sporadically. One feature that does distinguish these two obstruent classes is the voice quality of the following vowel. In general, lenis obstruents are followed by vowels with lax or slack voicing (not to be confused with lax vowels), while fortis obstruents are linked to a tenser voice quality. We speculate that these voice qualities, or *registers*, are produced largely by variation in tension of the glottal source. Laver (1980:145-46) writes: "The two muscular parameters that are most exploited in the laryngeal contributions to tense voice and lax voice are adductive tension and medial compression.[1] In tense voice, the values of both parameters are boosted." In lax voice, on the other hand, "the values of the laryngeal parameters of adductive tension and medial compression are lower than in the neutral state of modal voice." Lax voice is frequently accompanied by varying degrees of breathiness.

This report presents preliminary results of a small utterance corpus elicited from two Sharchhop speakers. The data will be examined for evidence that the voice quality of vowels is in fact affected by the fortis or lenis nature of a preceding obstruent. The effect of obstruents on the voice quality of following vowels has been observed in previous studies of other languages (e.g., Fulop 1994 on Zürich German and Korean; Hardcastle 1973 on Korean).

3.1. *Procedures*

Two Sharchhop speakers were recorded; only one of these spoke the Tshangla dialect. There are, however, very few substantive lexical, semantic, or phonological differences between the two speakers' dialects with the exception that the non-Tsangla speaker's vowel inventory included infrequent examples of the front rounded vowels [y] and [ø]. The speakers were recorded on a Panasonic Digital Audio Tape machine with a Shure 57 dynamic cardioid microphone and a Peavey 16 channel mixing board. They were asked to give three repetitions of each word in the corpus. The items of interest were subsequently digitized at 8 bit quantization using Soundscope from GW Instruments on a Macintosh Quadra 660AV. Tokens demonstrating the fricatives in word-initial position were also digitized at 16 bit quantization using Computer Speech Lab from Kay Elemetrics. The entire corpus used in this study is reproduced in the appendix.

3.2. *Methods*

There are several ways to measure the relative voice quality of vowels. One successful method was employed by Maddieson and Ladefoged (1985:437). In this procedure, the difference in amplitude between the fundamental frequency and the second harmonic is measured:

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1 These terms refer to tension at the meeting point of the arytenoid cartilages and the pressing together of the ligamental glottis, respectively.

> It has been shown by various authors that in a breathy voice there is comparatively more energy in the fundamental and less in the higher harmonics, whereas in a vowel pronounced with a more constricted glottis the reverse is true (Ladefoged 1981, Bickley 1982, Ladefoged 1983, Kirk et al. 1984). Moreover, variation in this parameter, measured by the relative amplitudes of the fundamental and either the second harmonic or the first formant, correlates very closely with listeners' judgments on degrees of breathiness (Ladefoged and Antoñanzas-Barroso 1985), and reflect differences in "spectral tilt" generated in models of the voice source by varying the rate of vocal cord closure in the glottal pulse (Fant 1983).

We have chosen to measure the harmonic amplitudes, as they are more consistent than the formant amplitudes.

Speakers vary in which harmonic amplitude best reflects their voice quality (Peter Ladefoged, pers. comm.), so both the second and third harmonics will be employed in the measure here. Let us call the fundamental frequency's amplitude A_1, and the amplitudes of the second and third harmonics A_2 and A_3. Then the difference $A_n - A_1$ (n = 2 or 3, depending on the speaker) will be a measure of the glottal tension. We thus expect $A_n - A_1$ to be larger the more tense is the voice quality, and smaller (or negative) the more lax is the voice quality, for one of A_2 or A_3.

The corpus of data to be measured consists of one word illustrating each obstruent in initial position. In each case the obstruent is followed by the vowel [a], except for the [ʃ / ʒ] examples, which are followed by the vowel [u]. There are three tokens of each word for each speaker. Initial VOTs and intervocal closure durations were measured (for the plosives and affricates), as well as intervocal fricative durations. The intervocalic measurements were performed on an additional corpus exemplifying obstruents in this position.

The primary results obtained, however, are from measurements of the fundamental frequency and harmonic amplitudes of the vowels following initial fortis and lenis obstruents (the aspirated plosives and affricates are not included in this part of the study). To accomplish this, a narrow band FFT was generated using a 512 point Hamming window beginning at some point in the initial portion of the vowel, usually 20–40 ms following the start of the vowel. This position for the power spectrum was chosen because it best reflects the influence of the preceding obstruent on the voice quality; further into the vowel, its own inherent voice quality may take over, possibly obscuring any influence of the preceding obstruent. From this spectrum, the frequencies and amplitudes of the fundamental and first two harmonics were measured. The difference between the harmonic amplitudes and the F_0 amplitude (A_1) were subsequently calculated. We would expect, given our earlier discussion, that vowels following fortis stops will show consistently greater glottal tension than vowels following lenis stops.

The word pairs measured are given in Appendix A; the fortis and lenis initials each had a total of six tokens. The pairs are not minimal; we contend that the only other factors which may affect voice quality are syllable stress and vowel quality. These factors have been kept constant within the pairs, and largely across the entire data set.

3.3. Results

3.3.1. VOT and duration

Table 2 illustrates that VOT is not a robust cue to the fortis and lenis plosives. Speaker 2 uses voicing fairly reliably in the lenis plosives, but Speaker 1 (Tshangla) does not. For his plosives, both fortis and lenis are more or less "plain" on this parameter.

	fortis	*lenis*	*aspirated*
labial	9	5	70
Speaker 1			
Speaker 2	8	–49	47
dental	6	–53	64
Speaker 1			
Speaker 2	5	–59	43
alveolar	55	108	99
Speaker 1			
Speaker 2	35	66	74
palatoalveolar	50	64	111
Speaker 1			
Speaker 2	44	–77	92
retroflex	27	31	62
Speaker 1			
Speaker 2	16	–73	57
velar	26	27	91
Speaker 1			
Speaker 2	14	–69	51

Table 2. Mean word initial plosive/affricate VOT (ms)

Kohler (1979) demonstrates that fortis stops typically have longer closure intervals than lenis stops in New High German. Preliminary measurements were performed that reveal a similar correlation in Sharchhop. Table 3 shows that the closure duration shows the expected dependence on fortis or lenis articulation.[2] For both speakers, fortis stops show a longer closure than lenis stops.

	fortis	*lenis*
labial	112	80
Speaker 1		
Speaker 2	93	35
alveolar	119	70
Speaker 1		
Speaker 2	88	40
palatoalveolar	81	35
Speaker 1		
Speaker 2	65	27
retroflex	96	35
Speaker 1		
Speaker 2	97	21
velar	108	63
Speaker 1		
Speaker 2	71	50

Table 3. Mean plosive/affricate intervocalic closure duration (ms)

	fortis	*lenis*
alveolar	113	87
Speaker 1		
Speaker 2	99	74
palatoalveolar	124	88
Speaker 1		
Speaker 2	98	78

Table 4. Mean intervocalic fricative duration (ms)

It is well known that voiceless fricatives are typically longer than their voiced counterparts, in English and other languages. In Sharchhop, lenis fricatives are not always voiced; this is also true of other languages. Table 4 shows that the fortis fricatives of Sharchhop are longer than their lenis counterparts, for both speakers. No statistical tests of significance were

2 The affricate [dz] was not found to occur intervocally, so this fortis/lenis opposition could not be measured on this parameter.

performed on the results so far presented, as they are only meant to illustrate the overall nature of the fortis/lenis contrast in Sharchhop. The central point of this report is the investigation of voice quality dependence on initial consonant manner.

3.3.2. Voice quality

The voice quality measurements described earlier are presented in Tables 5 and 6. These results indicate that the relative amplitude of the second harmonic is generally greater for vowels following fortis obstruents than for those following lenis obstruents. This is true of both speakers for plosives, affricates, and fricatives. Overall, the relative A_2 values are 4 dB higher following fortis obstruents for Speaker 1, and 6 dB higher for Speaker 2.

The only exception to this generalization is the [s/z] contrast for Speaker 2, whose relative H_2 amplitudes show no difference. It should also be noted that the effect is often quite small (sometimes only 1 or 2 dB) for Speaker 1; in these instances, however, a noticably larger effect is observed in the relative H_3 amplitude. Statistical analysis reveals, however, that it is the H_2 effect that is consistent for both speakers, however small it might be for Speaker 1.

Statistical analysis

A one-way analysis of variance (ANOVA) was computed using SYSTAT 5.0 on a Macintosh II, to determine whether the values $A_2 - A_1$ in fact depend on the initial obstruent at all, and are not just randomly distributed. To perform this, the data were grouped by initial obstruent (i.e. by word, except for the segments [s] and [z], which are each exemplified by two words in the corpus), and the ANOVA was calculated over the $A_2 - A_1$ values. Recall that there are three tokens of each word for each speaker.[3] Results are as follows:

Speaker 1[4]	$p < 0.0009$
Speaker 2	$p < 0.0009$

So, there is a smaller than 0.1 percent probability that the difference can be attributed to chance.

The ANOVA shows that the relative amplitude of the second harmonic is significantly correlated with the fortis or lenis nature of the initial obstruent.

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3 Because of the small sample size for each group, SYSTAT calculates Box's small sample F approximation, and reports this as the F statistic.

4 A few groups showed zero variance in this value for Speaker 1; these data were removed to facilitate ANOVA computation.

	$A_2 - A_1$	$A_3 - A_1$
[p]	0	−1
[b]	−1	−6
[t]	1	−2
[d]	−1	−4
[ts]	2	−1
[dz]	−1	−5
[tʃ]	0	−1
[dʒ]	−1	−5
[ʈ]	1	5
[ɖ]	−4	−2
[k]	0	−2
[g]	−2	−1
[s]	2	−3
[z]	−5	−3
[ʃ]	4	−17
[ʒ]	−9	−17

Table 5. Mean relative harmonic amplitudes (dB) for speaker 1

	$A_2 - A_1$	$A_3 - A_1$
[p]	−10	−12
[b]	−17	−13
[t]	−3	−10
[d]	−6	−11
[ts]	−2	−7
[dz]	−10	−11
[tʃ]	−6	−11
[dʒ]	−9	−10
[ʈ]	−6	−12
[ɖ]	−13	−13
[k]	−1	−8
[g]	−7	−6
[s]	−7	−15
[z]	−7	−12
[ʃ]	−3	−16
[ʒ]	−18	−24

Table 6. Mean relative harmonic amplitudes (dB) for speaker 2

3.4. Discussion

The results demonstrate that the voice quality of Sharchhop vowels is influenced by the nature of preceding obstruents. Specifically, a more tense voice quality generally results from an initial fortis obstruent. This is not an unexpected correlation, and has been demonstrated to occur in other languages (especially Korean). Regarding perception, Kohler and van Dommelen (1987) demonstrated that voice quality in the neighborhood of a plosive is a sufficient perceptual cue to fortis or lenis manner, even when no other cues are present.

As far as we can tell, Sharchhop does not have contrasting vowel registers that are phonologically significant or directly salient *as such* to native speakers. This concurs with the judgements of Andvik (1993). This does not mean that native speakers can't hear the differences; rather, when they hear a voice quality difference, they associate it with preceding (and possibly following) obstruents. Although the vowel quality is linked to obstruent manner, it is the obstruent features that are important for the opposition.

4.0. CONCLUDING REMARKS

The topics touched on above are too extensive to discuss at length in a report of this nature. Suffice it to say that voice quality dependence on fortis/lenis obstruents is not unique to Sharchhop/Tshangla. We have been deliberately ambivalent about whether the aspirated stops of Sharchhop might pattern with the fortis or the lenis stops. The facts are still unclear; Kohler (1984) proposes that aspiration is a phonetic manifestation of fortis manner, yet Sharchhop aspirates undergo intervocalic weakening, often manifesting as fricatives in this environment. If this is so, to what degree can aspiration be linked to fortis manner cross-linguistically? In any event, the study of languages like Sharchhop is essential to providing further evidence for the notion that 'tension' is cross-linguistically a primary phonetic parameter.

APPENDIX
Utterance corpus

The following is a list of the Sharchhop words used in the investigation.

Word initial obstruents:

[palaŋ]	'bamboo flask'
[baŋmɪ]	'to carry'
[pʰalɛ]	'to bring'
[tam]	'story'
[dani]	'cat'
[tʰamɛ]	'to lay (eggs)'
[tsa]	'veins'
[dzampa]	'bridge'
[tsʰampa]	'a level of monkhood'
[tʃatpɪ]	'to cut'
[dʒamɪ]	'to drink'
[tsʰam]	'a religious dance'
[ʈa ʔalɪ]	'ostentatious'
[ɖama]	'weak'
[ʈʰapa]	'a breed of cattle'
[karba]	'ladle'
[gʌɾi]	'vehicle'
[kʰa]	'bird'
[sa]	'soil'
[sam]	'three'
[za]	'son'
[zamin]	'girl'
[um]	'dirt; sheath'
[ʒumpu]	'tasty'

Intervocalic obstruents:

[apa]	'father'
[ibi]	'who'
[sapʰɪ]	'to insert'
[kota]	'younger brother'
[gotʰam]	'spade'
[patʃala]	'eggs'
[madʒiktʃo]	'don't shout' (Imperative)
[paʈa]	'artist's imprint'
[namɖu]	'airplane'
[nakɪr]	'earring'
[bago]	'hut'
[losar]	'new year'
[daza]	'small'
[aʃam]	'maize'
[aʒaŋ]	'father-in-law'

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