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Voice Onset Time in Shekgalagarhi Stops

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Abstract
The aim of this paper is to determine the efficacy of Voice Onset Time (VOT) in distinguishing a series of word initial homorganic stop consonants in Shengologa, a dialect of Shekgalagarhi, a South-eastern Bantu language of the Western Sotho-Tswana group. Issues pertinent to VOT are also addressed: namely VOT as a function of place of articulation; and the effect of phonetic context on VOT; specifically the influence of the following vowel. Compared with other stops, ejectives have often manifested long VOT values in some languages with VOT values of around 80+ ms in duration being not uncommon. The argument is that in Shengologa, the voiceless unaspirated stops are pulmonic stops rather than glottalic. Voiceless aspirated stops in general manifest long duration of aspiration.

Introduction
The present investigation is a quantitative analysis of Shekgalagarhi stop contrasts, and deals specifically with VOT. VOT relates to the co-ordination of vocal fold vibration and articulatory events in the vocal tract and is exploited differently in different languages for contrastive purposes. It may be affected by the quality of the following vowel and the place of articulation of the stop. It is defined as the time interval between the release of a stop and the onset of vocal fold vibration in the following vowel, and may be specified as a single value in milliseconds. The beginning of phonation may happen during the stop closure and prior to the release of the burst, as in certain voiced stops, or it may occur after the burst as in voiceless stops. Where phonation follows the burst, it may coincide with the release (coincident phonation), or it may be considerably delayed after the release of the burst (delayed phonation). These three divisions of Voice Onset Time effectively divide stops into three main categories of voice lead, short lag and long lag respectively; which in turn correspond to the phonological categories of voiced, voiceless unaspirated and voiceless aspirated. Sounds with voicing lead, such as those in French, Italian, Dutch and Ilwana, where energetic vibration of the vocal folds is maintained throughout the articulatory interval corresponding to the stop occlusion, are assigned negative VOT values. Voiceless stops, where onset of glottal pulsing follows the release burst for the stop, fall on the positive half of the VOT continuum; with variation in duration ranging from 0 ms to 20 ms for

those with coincident phonation, and from above 20 ms upwards for those with delayed phonation (Lieberman and Blumstein 1988: 197, Kent and Read 1992:108).

Languages exploit the voicing manoeuvres of the larynx in different ways to distinguish between the phonemic categories of their stops. Some languages have a two-way variation, others a three-way, and yet others manifest a four-way contrast. Two category languages include English and Spanish. In English, the relevant phonemic distinctions are manifested by delayed voicing (for example the sound [π], as in [π Iν], and coincident phonation (for example the sound [β], as in [β0Iν]).Thai is an example of a three-way contrasting language: namely voicing lead, coincident phonation and delayed phonation. Hindi and Gujarati are four-way category languages, which, in addition to the three phonemic contrasts of Thai, have a fourth category exhibiting aspiration and voicing concurrently.

Korean belongs to the category of three-way contrasting languages, with all of its stops falling on the positive half of VOT. But VOT values for the unaspirated and the so-called 'tense' stops in this language overlap, indicating that the VOT parameter is insufficient to distinguish the contrast (Han andWeitzman 1970:114, Hardcastle 1973:266, Shimizu 1990:78). Similarly, four-way contrasting systems have 'murmur', also called breathy voice, where phonation and turbulence occur simultaneously (Hirose *et. al.*, 1974, Shimizu 1990:149). These languages have voiced aspiration contrasting with voiceless aspiration, and the timing dimension on its own falls short in effectively distinguishing these particular stops from the voiced stops and the aspirated stops. Marathi, Hindi and Gujarati are some of the languages that have 'murmured' sounds.

Measuring VOT

There has been a variety of opinion with respect to ways of measuring VOT, particularly for voiceless aspirated stops. The main problem hinges on defining the end of aspiration in the stop and the beginning of periodicity in the vowel. These various methods are detailed in Monaka (2001). This study follows Lisker and Abramson (1964) in measuring VOT from the burst release of the stop to the start of vocal fold vibration, determined from the Lx signal. The beginning of vocal fold vibration in the vowel is considered to signal the end of the stop, and the aspiration superimposed on the vowel is an inevitable consequence of vocal fold configuration at the start of voicing. Fig 1-3 show the measurement criteria for the different types of stops followed in this study.

Procedure: data, recording conditions and subjects

Data

The data used in this study consisted of real meaningful disyllabic words of the structure CV:CV, where the first consonant of the first syllable was the only stop under investigation and the second consonant, in the second syllable, could be any consonant in the language, including stops, and was not meant to participate in the study. The corpus consisting of real meaningful words was preferred for ease in natural production, with correct tone patterns and vowel lengths. Word samples contained the stops in word initial position produced at five different places of articulation: bilabial, dental, palatal, velar and uvular. They were homorganic stops with different voice types followed by various vowels where the vowel could be [ι, ε, E, α, O, ο, υ], although not all stop and vowel combinations were possible for all the stops. The words were produced at a normal speaking rate in citation form and within a frame sentence [θαρε X Ξα:τσ ι] ‘I say X again’.

Each of the 4 subjects recorded the material (61 real words) once, yielding a total of 244 words. And the material was stored in a computer for analysis.

Subjects and recording conditions

Four native subjects, two males and two females, (EN, MK and TM, CM) were involved in this experiment. They were all students in various fields of study, except one of the female speakers who is the author of this article. Three of the subjects speak the Shengologa dialect of Shekgalagarhi, and the fourth speaker the Sheshaga dialect. All of the speakers have no known history of speaking or hearing disorders.

The informants were seated comfortably in a chair and the electro-laryngograph electrodes were placed on either side of their necks and secured with an elastic band behind the neck, taking special care to ensure that they were not choked and could speak comfortably and naturally. The subjects were then asked to read a few words from the list presented to them prior to the recording process as the level of recording was adjusted to avoid overloading the signals or producing signals that could be too low and rather less useful for analysis. Each subject recorded the data individually in an acoustically sound-treated anechoic room at the Department of Phonetics, University College, London, and an experienced technician monitored and controlled the recording process throughout.

The recording was a three-channel acquisition, using a Data translation acquisition PC card for storage on the hard disc of a PC. The signals were one speech (Sp) and two laryngograph signals: the Lx and the Gx. The speech signal was recorded onto Channel 1 using a Bruel and Kjaer half-inch free field condenser microphone (cartridge 4165) in conjunction with a sound level meter (No. 2231). The Lx signal was recorded onto Channel 2.

Both of these signals were first passed through variable gain amplifiers and analogue anti-aliasing filters set to 8.2 KHz, before being applied to the data translation card. The sample rate was set to 20 KHz. The data was processed in an acoustic laboratory using a computer and the Speech Filling System (SFS) software program written by Mark Huckvale, UCL.

Processing

The SFS program used for analysing the data time aligned the Lx and Sp waveforms so that there was no need for manual manipulation. After displaying the waveforms on the monitor, Voice Onset Time was measured by placing one cursor (cursor 1) at the onset of the burst, which was marked by abrupt, aperiodic energy after the stop occlusion on the acoustic waveform. The other cursor (cursor 2) was placed at the commencement of the steep rise of the first recognisable Lx trace on the laryngograph waveform (which marks the beginning of voicing for the following vowel) for the voiceless stops. For the voiced stops, prevoicing was measured by placing one cursor at the beginning of voicing for the stop occlusion on the Lx signal and the other cursor at the start of the burst on the speech signal. This included the period of voicing decay, where there was any, since this is a common practice, although voicing decay is not often reported in other languages when and if it occurs. SFS programs then automatically computed the measurement between the cursors by subtracting the time at one location (e.g. the burst) from the time at the other location (the beginning of voicing in the case of voiceless stops). Where necessary, voicing decay was also measured for the voiced stops. Measurement criteria for the stops are illustrated in Fig 1-3 for the three types of stops.

Results

The results of the experiment for each voice type pooled across all the four informants are shown in Table 1. The values recorded for the vowels represent the averages for each vowel, and were calculated from the values obtained for the four speakers. The ranges represent the range of values for each vowel per stop. Mean 1 represents the means for the stops per place of articulation calculated from the whole data, and not from the averages for the vowels. Similarly, SD 1 represents the standard deviations for the stops per place of articulation calculated from the whole data. Mean 2 represents the means for the vowels across the places of articulation for the stops. It was also calculated from values for the whole data, and not from the averages for the vowels. SD 2 also represents the standard deviations for the vowels across the places of articulation for the stops. It was also calculated from values for the whole data.

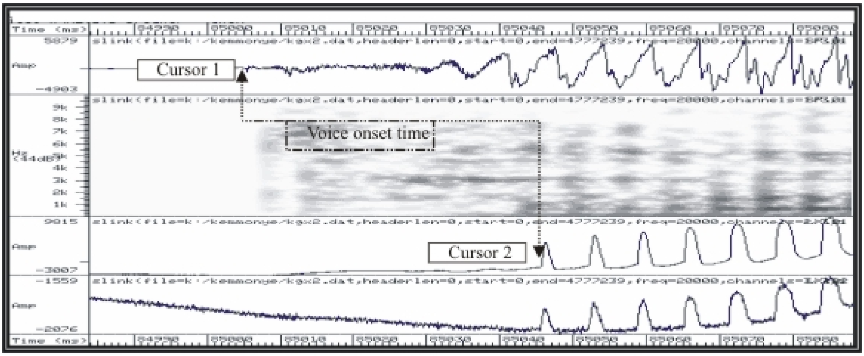


Figure 1: The determination of voice onset time for a voiceless aspirated stop

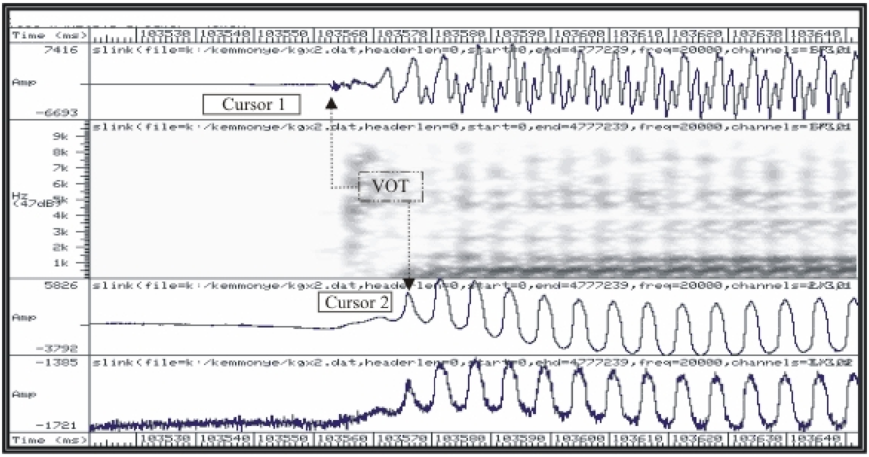


Figure 2: The determination of voice onset time for a voiceless aspirated stop

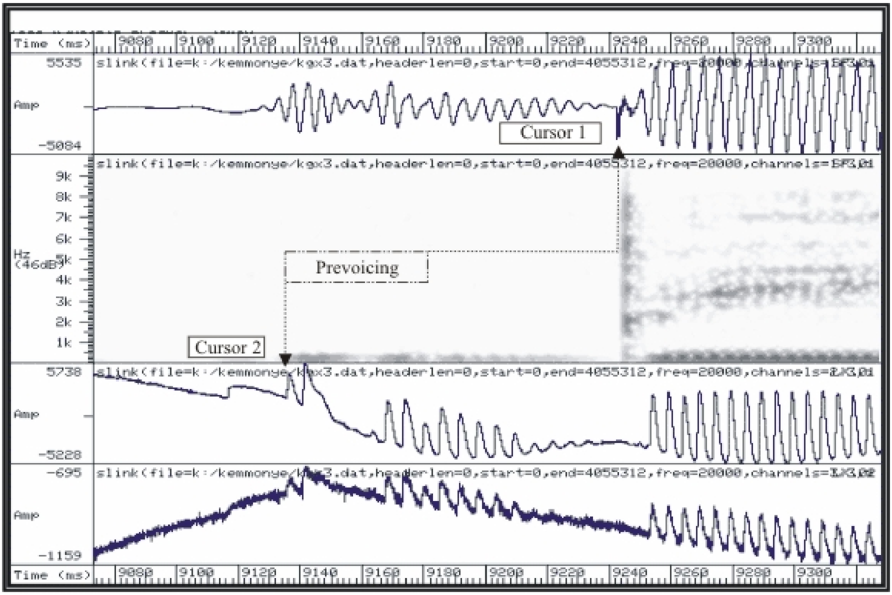


Figure 3: The determination of voice onset time for a voiced stop

Table 1 shows *average* prevoicing and VOT values for the vowels per stop, the *means* for the stops per place of articulation, the *means* for the vowels across the places of articulation for the stops and the standard deviation of the means for data pooled across all the four informants. The averages were calculated for the stops per vowel context in the following way. For each consonant type by place, the averages per vowel context were calculated by adding prevoicing and VOT values for the speakers and dividing the result by the total number of the speakers. Then the means for the stop types were calculated for each place from the values obtained for the informants, and not from the averages calculated for the vowel contexts. Mean values for the vowels were also calculated from the values obtained for the informants and not from the averages. Thus the means recorded on the table are not the means of the averages (means of the means). This criterion was adopted because calculating the means from actual values obtained for the data is more reflective of the time values and ranges than calculating it from the averages, which tend to narrow down the time and time ranges. These calculations, the averages, means for the averages and the standard deviations, were calculated by means of the SPSS program and then recorded.

It can be observed from Table 1 that the voiced stops in Shekgalagarhi manifest a rather long voicing lead. This is generally consistent with values reported for voiced stops in other languages; e.g. Thai (Shimizu 1990). The standard deviations indicate that the ranges for the stops in the table are quite wide.

Further, timing values for the voiceless unaspirated stops fall on the positive half of the VOT continuum and manifest short positive voicing lag. This is distinctly different from the time values obtained for the voiced stops, which were on the negative half. There is clearly no overlap in VOT values obtained for the voiced stops and the voiceless unaspirated stops. Mean time values for the two stop types were subjected to a two tailed t-test for statistical significance, and the t-value = 9.54, p < 002, indicating that the difference between the mean values is statistically significant.

VOT values for the voiceless aspirated stops fall on the positive half of the VOT continuum but, unlike the voiceless unaspirated stops, the aspirated ones show a long positive lag. This makes them quite distinct from the voiceless unaspirated stops. VOT mean values for the voiceless unaspirated and the voiceless aspirated stops were subjected to a two-tailed t-test for statistical significance, and the t-value = 32.4, p < 0.000 indicates that the difference between the mean values is statistically significant.

A comparison of the average prevoicing and VOT values presented in Table 1 indicate that Voice Onset Time may well serve as an adequate basis for distinguishing the three voicing categories in Shekgalagarhi. VOT resolution for the three stop categories is very clear. Shekgalagarhi appears to locate its stops between, approximately, the means –108.0 and –80.7 ms for the voiced stops, +12.6 - +40.4 for the voiceless unaspirated stops and +63.7 - +97.0 for the voiceless aspirated stops.

The time values for the stop types in Table 1 are summarised in a graph of time distribution in Graph A. Graph A summarises the variation between Shekgalagarhi stop consonants by way of Voice Onset Time. The stop categories are plotted on the X-axis and the time distribution (ms) on the Y-axis. It is immediately clear that VOT values for the three categories are well distinguished from each other. Aspirated sounds display high positive VOT values, voiced sounds high negative values and the unaspirated sounds short positive VOT values.

	Vowel context											
	[ι]	Range	*[ε/E]*	Range	*[α]*	Range	*[ο/Y]*	Range	*[υ]*	Range	*Mean 1*	*SD 1*
[β]	*-125.3*	-141 - -106.4	*-78.25*	-101.3 - -57.3	*-68.9*	-99.9 - -39.4	*-84.9*	-110.0 - -63.2	*-79.9*	-85.2 - -68.1	*-88.5*	*26.9*
[δ]	*-105.6*	-142.2 - -82.5	*-97.1*	-114.5 - -75.9	*-68.0*	-108.0 - -41.6	*-83.7*	-105.8 - -68.1	*-103.1*	-113.1 - -90.2	*-80.7*	*50.3*
[□]	*-128.5*	-143.7 - -80.5	*-109.9*	-122.1 - -84.5	*-89.2*	-110.4 - -89.9	*-102.5*	-110.4 - -89.9	*-107.9*	-121.1 - -95.2	*-108.0*	*27.0*
[γ]	*-105.3*	-140.9 - -79.8	-	-	*-65.4*	-64.6 - -55.3	*-84.4*	-95.3 - -70.9	*-79.2*	-111.9 - -54.8	*-83.6*	*24.8*
Mean 2	*-116.9*		*-95.2*		*-73.8*		*-88.6*		*-92.7*			
SD 2	*31.2*		*22.4*		*24.0*		*16.3*		*19.9*			
[π]	*15.9*	8.3 – 22.6	*10.5*	7.1 – 14.8	*6.1*	4.1 – 9.9	*15.1*	10.3 – 19.4	*22.9*	12.3 – 33.9	*14.1*	*7.8*
[τ]	*16.5*	7.5 – 31.0	-	-	*6.9*	4.1 – 9.0	*10.3*	4.9 – 14.3	*16.5*	12.1 – 19.4	*12.6*	*7.0*
[χ]	*54.7*	35.4 – 69.4	-	-	*25.7*	17.9 – 33.2	*34.0*	22.9 – 44.1	*47.1*	26.3 – 70.7	*40.4*	*17.7*
[κ]	*44.5*	34.4 – 53.5	*31.7*	19.2 – 44.1	*25.0*	12.6 – 41.1	*26.2*	19.6 – 37.6	*31.7*	17.7 – 41.1	*31.8*	*12.3*
[θ]	*19.5*	10.8 – 26.5	*17.4*	7.4 – 26.5	*9.6*	7.0 – 12.1	*14.7*	7.7 – 24.8	*17.4*	13.3 – 20.1	*15.7*	*6.8*
Mean 2	*30.2*		*19.8*		*14.6*		*20.0*		*27.1*			
SD 2	*19.4*		*13.0*		*11.0*		*11.2*		*15.2*			
[π□]	*60.5*	52.8 – 66.0	*58.7*	44.8 – 66.3	*50.6*	43.2 – 60.3	*67.4*	54.4 – 77.2	*87.0*	79.4 – 91.1	*64.5*	*14.6*
[τ□]	*72.9*	57.3 – 93.0	*73.2*	64.8 – 80.1	*46.3*	30.3 – 63.5	*59.4*	50.5 – 64.4	*66.5*	55.3 – 74.1	*63.7*	*14.4*
[χ□]	*119.8*	98.3 – 140.3	*87.1*	78.8 – 100.4	*75.3*	68.0 – 80.8	*90.6*	68.8 – 107.4	*112.1*	80.8 – 145.6	*97.0*	*22.6*
[κ□]	*91.2*	82.0 – 98.2	*78.9*	73.1 – 85.2	*66.3*	61.3 – 75.5	*72.0*	61.1 – 92.4	*97.4*	76.8 – 128.0	*81.3*	*16.5*
Mean 2	*86.2*		*74.1*		*59.6*		*72.3*		*90.8*			
SD 2	*25.9*		*13.3*		*14.9*		*16.2*		*23.5*			

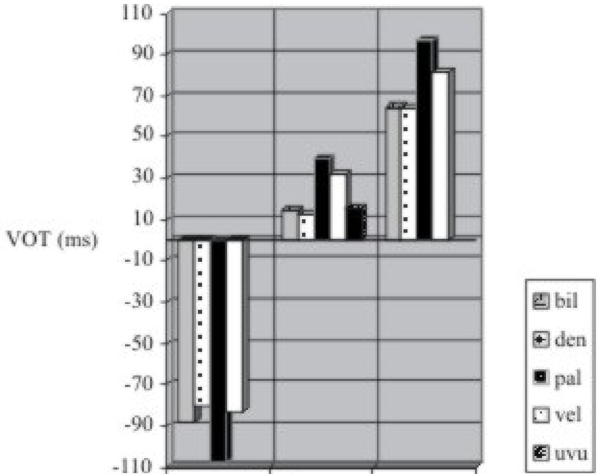
Table 1: Averages, ranges, means and standard deviation (SD) for prevoicing and VOT for all the four speakers.

Thus different stop types, which are produced at the same place of articulation, are produced at non-overlapping places along the timing dimension. For the stops produced at the bilabial place, for instance [β], may be found on the long negative half of the timing parameter, and [π] and [p] on the short and long positive half, respectively.

Graph A also shows the effect of place of articulation on the duration of prevoicing and VOT. For the voiceless stops, both unaspirated and aspirated, the palatal stops show longer mean VOT duration than the stops produced at other places of articulation. Graph A indicates that the places of articulation are ranked in the following order: /χ > κ > θ > π > τ / for the unaspirated stops, and /χ > κ > π > τ / for the aspirated stops. For the voiced stops the effect of place of articulation on VOT appears to be in the following order: / β > γ > δ > /. Below, the interaction between values for prevoicing and VOT and place of articulation is discussed and a possible explanation of this relationship is pointed out in terms of vocal tract configuration, the speed of the body of the tongue, and aerodynamic conditions which may be involved. The mean duration for Shekgalagarhi stops as a function of vowel identity are plotted in Graph B. This is followed by suggested explanations for the effect of vowel identity on the values for prevoicing and VOT for the stops.

Graph B clearly shows that stops which are followed by high vowels manifest longer prevoicing (if they are voiced) and longer lag (if they are voiceless) than stops that are followed by non-high vowels. The extent to which different vowels affect these values comes in the following order: the voiceless unaspirated stops, / ι> υ > ο/Ο > ε/Ε > α /; voiceless aspirated stops: / υ > ι > ε /Ε > ο/Ο > α /; the voiced stops: / ι > ε /Ε > υ > ο/Ο > α /. Below, the relationship between vowel context and VOT values for the stops is discussed in the light of two hypotheses postulated as possible explanations for this observation: vocal tract configuration and the speed of the body of the tongue.

Mean prevoicing and VOT for Shekgalagari stop contrasts



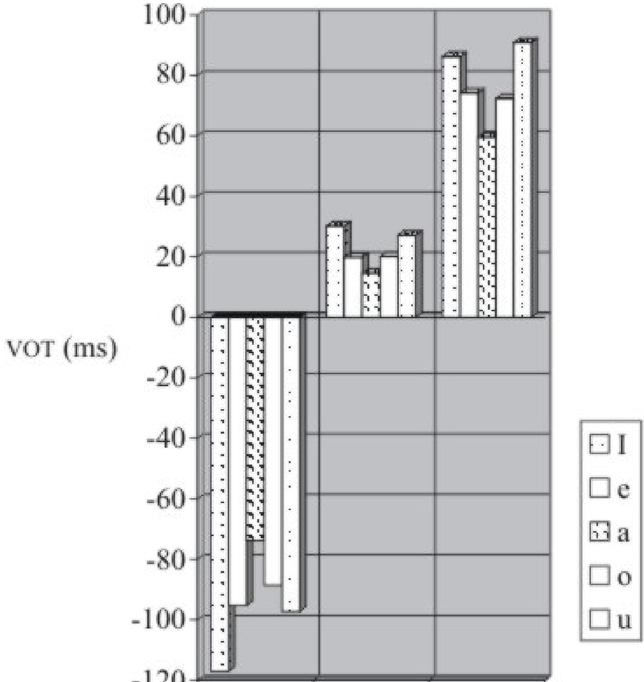
	voiced	vls unasp	asp
bil	-88.5	14.1	64.5
den	-80.7	12.6	63.7
pal	-108	40.1	97
vel	-83.6	31.8	81.3
uvu		15.7	

stop categories

Graph A

Voicing was explored with VOT and prevoicing values as a dependent factor. The results, as well as the associated graph, are shown on Table 2 and Figure 4.

The effect of vowel quality on prevoicing and VOT for Shekgalagari stops



	voiced	vls unasp	vls asp
I	-116.9	30.2	86.2
e	-95.2	19.8	74.1
a	-73.8	14.6	59.6
o	-88.6	20	72.3
u	-97.2	27.1	90.8

stop categories

Graph B

Table 2: Exploration of voicing contrast: case-processing summary. N represents the number of cases.

Case Processing Summary

		Cases					
		Valid		Missing		Total	
	VOICING	N	Percent	N	Percent	N	Percent
VOT	asp	64	100.0%	0	0%	64	100.0%
	unasp	63	98.4%	1	1.6%	64	100.0%
	voiced	56	87.5%	8	12.5%	64	100.0%

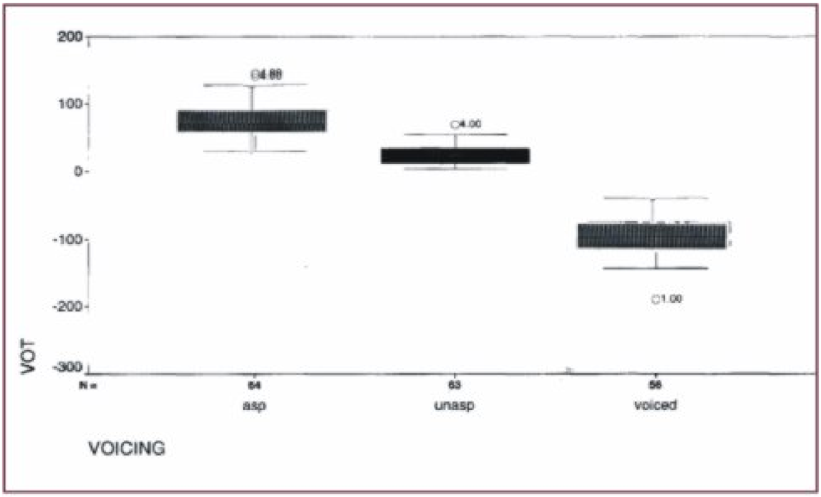


Figure 4: Exploration of the voicing contrast with VOT as a dependent feature. N represents the number of cases for each category.

The horizontal line in the middle of the black bars represents the mean. The top edge of the bars represents the standard deviation (SD) above the mean, and the bottom edge the SD below the mean. The top-most horizontal line represents the highest measured value(s) for the category, and the bottom-most the lowest value.

It can be observed from Figure 4 that there is no overlap between the three voicing contrasts. The aspirated stops show high VOT values, the unaspirated low values and the voiced show values that are below 0 ms.

Discussion

Effectiveness of VOT in distinguishing Shekgalagarhi voice types

VOT values for the three stop types presented in the results subsection above show long negative values for the voiced stops (which included voice decay during the stop occlusion, but not the short positive VOT after the burst), short positive values for the voiceless unaspirated stops and long positive values for the voiceless aspirated stops. There is no overlapping in time values between the three stop types, and the ranges of the means between the three stop types are considerable. We may, therefore, consider VOT to be an effective distinguishing cue for the three stop types in Shekgalagarhi.

The effect of place of articulation and vowel quality on VOT

As has often been observed for other languages and reported in the literature, this investigation has shown that there is some interaction between VOT and place of articulation, and the quality of the following vowel. With respect to the relationship between VOT and place of articulation, results obtained here have consistently showed that the palatals manifest larger VOT values than stops produced at other places of articulation for the voiceless stops. The velars, in most cases, come second to the palatals, which are then followed by the uvulars and the dentals and the labials. This observation does not conform in any simple way to the two hypotheses that have so far been used to account for differences in VOT as a function of place of articulation. The first hypothesis is related to the aerodynamic factors involved due to the volume of the cavities above the larynx, and the second to an articulatory factor based on the size of the tongue body involved and its relative speed in the production of the stop.

If we follow the first hypothesis, we should expect VOT values for the stops to increase as the place of articulation moves further back in the mouth. However, this prediction does not hold in the results obtained in this study, both for individual results and for pooled data. The VOT values obtained for Shekgalagarhi stops in this study rank the stops in the following order: /χ/ > /κ/ > /θ/ > /π/ > /τ/. Contrary to expectation, uvular stops do not manifest larger VOT values than the stops uttered at anterior places of articulation. Rather, an interpretation leaning towards agreement with previous conclusions is achievable only if we regard the bilabial and dental stops as front articulations and the palatal, velar and uvular stops as back articulations. Also, whereas the classification of the velar place has always been clear – dorsal , that of the palatal has remained largely uncertain. Ladefoged (1993:7) writes that ‘palatal sounds are sometimes classified as coronal articulations, and sometimes as dorsal articulations’. Taking the side that classifies them as dorsals, then VOT values for the palatals may well be in accordance with the expectation.

According to hypothesis two, palatals manifest longer VOT values than stops produced at other places of articulation because they are made with a relatively large size of the tongue body compared to the other stops. This means that the speed of the tongue is greatly reduced and thus it takes longer to move towards and away from the palate after making contact, making the oral cavity remain constricted for a relatively longer time. The direct consequence of this is that it takes longer for the air pressure inside the mouth to balance with that which is outside the mouth. At the glottis, the development of airflow required for voicing thus also takes longer, resulting in longer VOT (and prevoicing) values for the palatals. High vowels exert a similar influence on VOT values because their manner of articulation (i.e. raised tongue position) means that the oral cavity is narrowed. This configuration delays the achievement of the transglottal air pressure drop necessary for voicing, and VOT is longer than elsewhere. Palatal stops display similar articulatory configurations to high vowels, and this, in addition to the slower speed of the tongue, means that palatals manifest higher VOT values than those for other places of articulation.

As mentioned earlier, most of the languages investigated in the literature do not have palatal and uvular articulations, and the contribution of these particular places of articulation to VOT has therefore not been studied. We may still speculate that the velar position in these languages may possibly be a little fronted than in languages like Shekgalagarhi, giving them longer VOT values.

For the bilabial stops, Table 1 reflects some relationship between tongue position for the vowel and VOT. For these stops the tongue is only involved in the production of the vowel, since it is the lips that make a constriction against each other for the stop. Consequently VOT values reflect interaction with tongue height for the vowel: bilabials that are followed by high vowels manifest longer VOT values than those that are followed by non-high vowels. In the results obtained here, bilabial stops show VOT and prevoicing values which are higher than those of the dental stops, when in fact the tendency in other languages has been the reverse: dental > bilabial. This result was not expected for physiological reasons. Since there is no cavity in front of the mouth, it is expected that once the constriction made at the lips is released, the oral air pressure will quickly balance with the atmospheric pressure and transglottal air flow quickly restored to the level required for voicing. This should produce VOT and prevoicing values that are lower than those for the dental place, which is posterior to the lips. That results here do not follow this pattern possibly means that these stops should be investigated further. Nevertheless, overall, hypothesis two discussed above seems to account for the results obtained here better than hypothesis one.

The other factor that may affect VOT relates to the effect of the following vowel. It has been observed that, generally, stops (the velar stop

/□/ being the most commonly reported) in syllables with high vowels tend to manifest greater VOT values than those in syllables with non-high vowels (cf. Klatt (1975) and Port (1979)). As pointed out above, a possible explanation that has commonly been given for this is that the raising of the tongue for the high vowel narrows the oral cavity and creates some resistance to the flow of air from the lungs. This in turn delays the development to transglottal air pressure necessary for vocal fold vibration.

The data also shows that there is some interaction between the height of the vowel and VOT value for the stop in the syllable. The influence of the vowels has shown that [υ] and [ι̢] have always exerted more influence on VOT than [o/O] and [ε/E], with [α] showing the least influence on VOT, and, for the voiceless stops, this trend appears to be fairly consistent in these data.

The VOT values obtained here for the voiceless unaspirated stops in Shekgalagarhi have generally been low (cf. Table 1). Although higher values were obtained in some cases, this seems to accord more with the effect of place of articulation than with the voice type for the stops, as we explained above. Had high VOT values been a feature of these stops in this language, it would have occurred across all the five places of articulation. Even the high values obtained for some of these stops were nowhere near the values obtained for the voiceless aspirated stops, as has been reported for ejectives in some North American Indian and Caucasian languages. This is strongly suggestive of the possibility that the voiceless unaspirated stops in Shekgalagarhi may not be ejectives, at least as far as VOT in this investigation suggests. The values obtained for the voiceless unaspirated stops seem to be consistent with those that are reported for other languages (cf. Shimizu 1990).

With regard to the voiced stops, voicing occurred for a considerable duration during the stop occlusion. Where there was voicing decay (for some of the speakers), this was relatively small. These stops may therefore be regarded as truly voiced.

Summary

On the whole, the findings of this study with respect to VOT have demonstrated that this timing dimension can effectively distinguish Shekgalagarhi homorganic stops in word initial position. The three types of stops manifest considerable significant variation in VOT values: long prevoicing values for the voiced stops, short VOT lag for the voiceless unaspirated stops, and long VOT lag for the aspirated stops; and this has been remarkably consistent for all the data.

VOT may be affected by place of articulation and vocalic context. In this study, palatal stops have manifested higher VOT and prevoicing values, followed by the velar stops and then by the uvulars. This has not been reported in the literature because most languages, which have been analysed, do not have palatal (and uvular) stops. Stops followed by high vowels also show duration values that are higher than those shown by stops followed by non-high vowels. Other factors that may affect the value of VOT as mentioned in Monaka (2001).

From the findings of this investigation, it seems reasonable to conclude that Shekgalagarhi is a three-way category language, with voiced, voiceless unaspirated and voiceless aspirated stops. It may also be concluded that the voiceless unaspirated stops in Shekgalagarhi may be simple plain voiceless unaspirated stops, and not ejectives. This conclusion is, however, tentative, since more investigation needs to be done on these stops, as well as more cross-linguistic analysis made, in order to determine whether these stops may possibly be weak ejectives. For example, such research could focus on measurement of the burst amplitude, closure duration, intra-oral air pressure during the hold phase, amongst other things.

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