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Shekgalagari Stops and Theories of Phonological Representation

K.C. Monaka

University of Botswana, Gaborone

Introduction: VOT and F0 Perturbation

VOT: VOT involves the temporal relations between the release of a stop consonant signalled by the burst and the onset of voice pulsing for the subsequent segment, and may be specified by a single value. It has been shown to be highly effective in delineating contrast in most stops with different voicing structures in many languages. (Lisker and Abramson, 1964, 1967). In initial CV context, commencement of phonation may happen prior to the release of the burst (voicing lead, also known as prevoicing), it may coincide with the release (coincident phonation) and it may be considerably delayed after the release of the burst (delayed phonation). Stops with voicing lead are assigned negative VOT values. Those with (almost) coincident phonation are assigned (zero or, mostly) short positive VOT values and those with delayed phonation long positive values. This variation in VOT varies from language to language. Some languages have a two-way variation in their stop systems and others are three-way systems, and yet others manifest a four-way contrast.

Two category languages include English and Spanish. In English, the relevant phonemic distinctions are manifested by the delayed voicing, for example the sound [p], as in [pʰɪn], and coincident phonation, for example the sound [b], as in [bɪn]. Thai is an example of a language with a three-way contrasting system: namely; voicing lead, coincident phonation and delayed phonation. Hindi and Gujarati are four-way category languages with voicing lead, coincident phonation, delayed phonation, and a fourth category exhibiting aspiration and voicing concurrently.

The fact that 'speakers can exploit very complex co-ordination of laryngeal behaviour

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K. C. Monaka obtained her Ph.D. from the University of London. She lectures in the Department of English, University of Botswana.

in relation to supraglottal articulations to achieve phonological distinctions' (Clark & Yallop, 1990) means that phonological systems have a rich diversity of stop types — so much that the parameter of VOT alone may not be able to effectively distinguish between them in a system. For instance, Korean belongs to the category of three-way VOT contrasting languages, with all of its stops falling on the positive half of VOT. However, 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 (Abramson, 1977). Similarly, four-way contrasting systems have 'murmur', where phonation and turbulence occur simultaneously (Hirose *et al.*, 1974). These languages have voiced aspiration contrasting with voiceless aspiration, and the timing dimension falls short in distinguishing these particular stops from the voiced stops and the aspirated stops in the relevant systems. Marathi, Hindi and Gujarati are some of the languages, which have 'murmured' sounds.

F0 perturbation: The other voicing cue in stops relates to the aspect of F0 perturbation and contour at the onset of the following vowel. This deals with the fundamental frequency of vocal fold vibration during the initial portion of the vowel and the F0 contour from the start of the vowel to the steady-state portion of the vowel. Stops with different voicing structures affect the pitch perturbation of the subsequent vowel in different ways (Ohde 1984, Lea 1973, Ladefoged, 2001). F0 can either rise or fall as a function of the VOT property of stops (Ohde 1984). Voiceless stops, especially voiceless aspirated stops, may manifest higher F0 ranges than voiced stops in word initial context. This variation in pitch ranges may serve as an acoustic cue to the voicing structure of the stops (Hombert *et. al.* 1979, Ohde 1984, Lea 1973).

Theories on the Representation of the Voicing Structure of Stops

There have been many theories on the specification or representation of the voicing of segments in the world's languages, and the scope and focus of these theories have been varied, none of which has been all sufficient to account for the sounds of the world's languages. In this subsection, not all of these theories are discussed, and not even the ones discussed are dealt with in exhaustive detail. Most theories discuss the representation of the complete range of speech sounds in the languages of the world. This paper, however, focuses only on stop consonants.

The Sound Pattern of English model (SPE)

The SPE representation of speech sounds is feature based; where features 'represent the phonetic capability of man' (Chomsky & Halle 1968: 299). Segments are described in terms of inventories of features, often called feature matrices, each feature being binary-valued e.g. [± anterior]. There are different types of phonetic features used to specify segments: major class features, e.g. [± sonorant], [±vocalic], [± consonantal]; cavity features, e.g. [± coronal], [± anterior]; manner of articulation features, e.g. [± continuant],

[± tense]; source features, e.g. [± voice], [± strident], and prosodic features, e.g. [± stress], [± length] (*cf.* Ibid. 299-300).

The specification for the (say French) voiceless unaspirated stop [p], would resemble (1).

(1) [p]
[+ consonantal]
[- sonorant]
[- vocalic]
[- coronal]
[+ anterior]
[- tense]
[- voice]
[- stress]
•
•

(where the dots at the end indicate that the specification for the stop is not complete). In a complete inventory of features, or representation of a sound, the rows represent features and the column represents the segment [p]. It is because of this manner of segment specification that this model has often been referred to as a *linear* representation of speech sounds.

The phonological component of this theory comprises two types of rules: phonetic rules and phonological rules. Phonetic rules, on the one hand, operate on the features in a language specific manner. They give detailed systematic phonetic description of sounds in such a way that may differentiate one language from another. For instance, they may specify quantitative values for a phonetic parameter (e.g. VOT) of a particular language. The terminal output of the phonetic rules in this model is the phonetic transcription, which also encodes information relating to the pronunciation of the output as determined by the grammar of the language concerned. A further 'universal' phonetic component will then convert the output of the phonetic rules into their articulatory correlates. This 'universal' phonetic component, unlike the phonetic rules just discussed above, is 'not technically part of the grammar' and, given its universal nature, its output is taken to be automatic and not language dependent (Keating 1984: 287).

Phonological rules, on the other hand, may alter the values for the features, they may insert or remove segments, but they may not change the content of the feature matrices — which specify segments. Distinctive description between the natural classes of segments is done by this component of the grammar.

There have been a number of criticisms levelled against the SPE model of segment specification and representation. One has been the framework's endless list of features in specifying segments. Also, as has been apparent from the discussion above, the features used here are meant to convey both unique phonetic categories of individual languages and the phonological representations of those categories at a cross-linguistic level. Another criticism, which is also relevant for the Halle and Stevens and the Lisker and Abramson feature systems discussed below, relates to the fact that the SPE feature system does not have a single phonological feature of 'voicing' which distinguishes, say, 'voiced' sounds from 'voiceless' sounds across languages. The framework also suffers from an over-generation of features, some of which are never utilised contrastively in the world's languages.

Lisker & Abramson (L&A) (1964): voice onset time (VOT)

The L&A framework of laryngeal distinctions in stops is based on timing (VOT), and has been described above.

Halle and Stevens (1971) (H&S): laryngeal features

The H&S approach characterizes the voicing of stop consonants in terms of two independent parameters of vocal fold activity at the moment of stop release: the tension of the vocal folds (i.e. slack/stiff folds) and glottal aperture (i.e. aspirated, unaspirated, etc.). When these two parameters are adjusted in various ways distinctive acoustic consequences result, and hence distinctive phonetic characteristics. The various manipulations of the vocal cords thus give the following four features: [spread glottis], [constricted glottis], [stiff vocal cords] and [slack vocal cords], which, according to H&S appear to be sufficient to classify sounds in the languages of the world, and which H&S propose should therefore be incorporated into the universal phonetic feature framework (H&S: 201). By means of combination, these four features produce nine distinctive phonetic categories of segments. These phonetic categories and their feature specification are summarised in Table1 obtained from Halle and Stevens (1971:201). Here, only stops are focused on, although the H&S feature geometry is for all obstruents.

	1	2	3	4	5	6	7	8	9
Obstruents	b_l	b	P	p_k	b	p		b	p
Spread glottis	-	-	-	+	+	+	-	-	-
Constric. glott	-	-	-	-	-	-	+	+	+
Stiff voc. folds	-	-	+	-	-	+	-	-	+
Slack voc.folds	-	+	-	-	+	-	-	+	-

Table 1: Segment specification for obstruents under the H&S (1971) feature system. Notes: b_l represents a lax (plain) voiceless unaspirated stop; p_k - the lightly aspirated stop, e.g the so-called 'tense' stop in Korean; b - the voiced 'murmur' stops found in

Hindi and Marathi; p' - ejectives, found in, for instance Xhosa; and - an implosive found in Xhosa; b - a laryngealized stop which is not truly implosive.

In this feature theory stops are divided into three broad groups by using the features [spread glottis] and [constricted glottis]. They may be: *plain* [-spread, -constricted] (*cf.* columns 1 to 3), *aspirated* [+spread, -constricted] (*cf.* columns 4 to 6) and *glottalized* [-spread, +constricted] (*cf.* columns 7 to 9). These three groups are further subdivided into three groups by using the features [stiff vocal cords] and [slack vocal cords]. These subdivisions are the voiceless stops, voiced stops and a third group which incorporates implosives, lax stops such as the Danish [b] and the Korean moderately aspirated stop. Voiceless stops are marked by the features [+stiff, - slack], and examples include voiceless unaspirated stops, voiceless aspirated stops and ejectives (*cf.* columns 3, 6, 9). Voiced stops are marked by the features [-stiff, +slack] and they include traditionally voiced stops, e.g. the French [b] (*cf.* column 2), 'murmured' stops, e.g. the Hindi [bh]] (*cf.* column 5), and a third class of stops which, as opposed to the other two stop types, is glottalized (*cf.* column 8). As opposed to true implosives where both the lowering of the larynx *and* laryngealized voicing occur, these particular glottalized stop are reliably indicated by accompanying laryngealized voicing only, but the downward displacement of the larynx may not always happen. The third class of stop types has the configuration [-slack, -stiff] and includes the true implosives shown in column 7, the 'lax' voiced stops [b_1] such as the one found in, for example, Danish and 'may occur in initial position for many speakers of English' (H&S 1971:206) (*cf.* column 1), and the Korean slightly aspirated 'tense' stop [p_k].

To a limited extent, Halle and Stevens also discuss acoustic correlates of their features which have not been discussed here, since the generation of their feature system is largely based on articulatory information.

Some of the objections raised against this model of segment specification are made by, for example, Keating (1984) and Lombardi (1990). Keating (1984) argues that, apart from its relation to pitch, the H&S feature system is not adequate for the representation of voicing in stops of the world's languages. The idiosyncratic pattern of some English speakers in producing the utterance initial 'voiced' stop as a 'voiced' and as a 'voiceless lax' stop is one example of this. Keating argues that the difference between these two types of stops is not one of glottal configuration (i.e. vocal cord slackness) as H&S suppose, but that of the amount of oral air pressure. Similarly, the difference between English [p] and [b] as in *rapid* and *rabid* is not one of glottal stiffness as H&S presume, but rather, the [p] stop appears to be produced with an opening of the folds in word medial context, and at the moment of release the configuration of the folds may well be similar to that of the [b] stop. This, therefore, may require an addition of more features to the H&S feature system to accommodate other distinctive characteristics of stops, which happen at moments other than release (Keating 1984:288-289). But this would disadvantageously lead to the generation of more features by the theory in an attempt to describe in accurate phonetic detail exactly how individual sounds in the languages of the world are articulated.

Another problem of the H&S feature system is the representation of voicelessness. This is represented with the features [+stiff, -slack] although a spreading of the vocal folds appears to be more appropriate. But this spreading gesture, however, represents ‘aspiration’ in the H&S geometry (Lombardi 1990: 6). The other point is that segment specification is always done using a combination of features. No one feature seems adequate to distinguish one stop type (e.g. voiced) from another stop type (e.g. voiceless). Like the SPE model, the H&S feature geometry is plagued with the problem of over-generation of features capable of specifying segments which never code contrast in languages; e.g. voiced laryngealized stops *vs.* true implosives.

Keating on voicing contrasts

In the 1984 article, Keating argues that in deciding phonological feature systems for sounds in the languages of the world, the inclusion of detailed phonetic information regarding these sounds should be removed. She proposes three kinds of representation. First, there should be as many phonological features e.g. [± voice] and feature values, e.g. {voiced}, {voiceless (vls) unasp} and {vls.asp} as are required to distinguish between natural classes in a system. Secondly, there should be as many phonetic categories as are needed to distinguish between segments in any given language. The third and last one deals with the pseudo-physical component, which deals with as many parameters as are necessary to provide acoustic description of the segments. Two of these, the phonological feature and feature values and phonetic categories are addressed shortly below.

Part of Keating’s work builds on that of Lieberman (1970, 1977) which proposed the binary phonological feature [± voice] as a feature which could be implemented differently in different languages ‘along the continuous dimension of V[oice] O[nset] T[ime]’ (*pg.* 290). Modifying this work, Keating (1984) proposes a fixed universal and specified set consisting of three phonetic categories coding possible contrasts in stop consonants: {fully voiced}, {voiceless unaspirated} and {voiceless aspirated}, where these have acoustic and articulatory correlates, and the binary phonological feature values (i.e. [± voice]) which may be implemented in the languages of the world as categories selected from this fixed phonetic universal set. These phonetic categories directly map onto VOT lead, short-lag and long-lag respectively for stops in word initial context. Keating (1984:290) goes on to say that ‘these mappings will be part of the definition of the phonetic categories, and therefore universal; e.g., {voiced} will involve vocal-fold vibration and low periodicity during consonant closure. To some extent, however, they will be language specific….’ Just how these phonetic categories are language specific is the subject of the following paragraph.

Consider, for instance, English and Polish, two-way category languages, which have phonological contrast between [+ voice] i.e. /b, d, g/ and [- voice] /p, t, k/ stops. The implementation of the phonetic categories by these languages will be as follows. Depending on context, [+ voice] stops in English would be {vls. unaspirated}, while in Polish they would be {+ voice}. Similarly, English [- voice] stops would be {vls. aspirated} while in Polish they would be {vls. unaspirated}. So, phonologically, the two languages are the same in that they are two-way contrasting languages, and thus could be described using the phonological feature [± voice], but they are phonetically distinct since they implement the phonetic categories differently. However, on this point, Keating (1984)'s analysis is limited to two-way contrasting languages. Three-way and four-way systems such as Thai and Hindi are excluded from her discussion 'largely because it is unclear whether such languages should be analysed as having a single non-binary feature [voice], or more than one binary feature'.

Going back to the three kinds of representation mentioned above, Keating pointed out the need to use a phonological feature as well as feature values which would be adequate to distinguish contrast in natural classes in a language. We will now consider this point.

The phonological feature. Keating (1984) argues that a more accurate account of segment representation for two-way contrasting languages could be done by way of levels of representation. There is the phonological level of representation and the phonetic category level of representation, which, actually, is the level of implementation. At the phonological level of representation, phonological rules are applied to binary feature values (e.g. [± voice]), and their output is the phonetic category values (e.g. {voice}, {vls. aspirated}, {vls. unaspirated} which are different in different languages. These phonological rules cannot anticipate their phonetic output, in which case they can work with whatever output a language allows. Thus a two level representation helps to keep phonetic details separate from phonological considerations, and also allows for different implementations of the binary phonological features across linguistic systems.

Keating points out experimental data from other researchers, which supports her theory. Some of these studies investigated vowel duration before 'voiced' and 'voiceless' stops in several languages, mostly two-category languages, and observed that vowels tended to be longer before 'voiced' stops than before 'voiceless' stops. This, according to Keating (1984:291,292) appears to show that the relationship between vowel duration and voicing was conditioned by the underlying phonological feature [± voice], rather than being mechanically determined by the phonetic voicing during the occlusion of the stop. This thus further buttresses the need for separating phonetic and phonological levels of representation.

Phonetic categories. Another of the levels of representation proposed by Keating deals with phonetic categories. It is proposed that there should be as many phonetic categories as are needed to distinguish between stop segments in any given language. The phonetic categories dealt with here are described in word initial context, in terms of VOT 'and the voicing dimension', and is limited to three contrasting categories since it is thought that languages only have these categories. Keating also proposes that the *three* categories proposed here 'is the right number', and 'are the same three in various languages'. As already discussed above with respect to VOT, there could be voicing lead: when voicing precedes the stop release; short-lag: when voicing coincides with the release; and long-lag: when voicing is considerably delayed after the release of the stop. Stops with voicing lead are associated with the {voiced} category, those with short-lag are associated with the {vls. unaspirated} category and those with long-lag are associated with the {vls. aspirated} category.

Keating's proposition of *three* as 'the right number' for phonetic categories is based on a study by Lisker and Abramson (1984) which concluded that the languages of the world exhibited no more than a three-way contrast in their stop systems. The study also pointed out that where a system appeared to display more than a three-way contrast, there would be overlap in VOT values between at least two of the categories, and that these could be distinguished through some other dimension, e.g. tension of the articulators. Thus the three phonetic categories: {voiced}, {vls. aspirated} and {vls. unaspirated} appear to be the basic ones implemented by the languages of the world, 'And in fact, they are also sufficient elsewhere, since no greater number of contrasts is found in any other position'.

Phonetic categories: the rules. In the theory, the implementation of phonetic categories is different in different languages. Keating, therefore, says that the phonetic category implementation rules are thus language-specific. She proposes that these phonetic rules would not be essential if different implementation of phonetic categories by the languages of the world were derived by a general principle, which could be 'polarization of two adjacent categories along the voicing dimension.... According to this principle, within the limits of the implementation chosen - i.e. the phonetic categories - there is maximal separation of the distributions of values'. Consider, for example, the English and Polish stops discussed above (also Keating, 2003). It was pointed out that, depending on context, [+ voice] stops in English would be {vls. unaspirated}, while in Polish they would be {+ voice}. Likewise, English [- voice] stops would be {vls. aspirated} while in Polish they would be {vls. unaspirated}. However, when the timing for the voiceless unaspirated stops for these languages are compared, Polish stops show 5 ms higher VOT values (and therefore slightly aspirated) than the English ones. According to the polarization principle, the contrast between the stops in Polish can be explained by polarizing the 'slightly aspirated' short-lag stop away from the long-lead voiced stop. But the situation with English, however, is slightly complicated, since the so-called 'voiced' stops may have lead values (which are not as in truly voiced stops), and they may have lag values (which are not as in voiceless aspirated stops). Keating (1984:309) believes that this situation could be resolved by regarding English as having a bicategory distribution of VOT values: lead and short-lag. In this way, the English short-lagged 'voiced' stop can then be polarized away from the long-lagged voiceless stop.

Keating is careful to point out that the polarization principle may not always adequately address the contrast in all languages. For instance, different VOT values may be obtained for the same phonetic category implementations in a language, making it difficult for the polarization principle to apply.

In the 1990 article, 'Phonetic representations in a generative grammar' the two levels of representation: phonological and phonetic, are still maintained. Phonological representations describe *overall* contrast between segments in a language. Phonetic representations express contrast *in a given context* in a language. But this time phonetic representation has three levels. The first level, categorical phonetic representation, is still the output of the phonology in that it is the implementation of the phonological contrast as discussed above. It is regarded as neutral with regard to articulation and acoustics/perception, which are the concerns of the other two levels of phonetic representation. Here it is defined as 'clusters of feature values aligned with elements of internal segment structure', where the feature may be unary or binary. The features adopted here are for voicing, aspiration and glottalization. These are [voice], [spread glottis] and [constricted glottis]. These features may be related to particular landmarks during the production of the stop. For example, [voice] expresses events during the closure phase and is therefore associated with the closure node. It distinguishes truly voiced closure periods from voiceless ones. The value [+voice] then indicates vocal fold vibration and low frequency periodicity during stop closure. [spread glottis] and [constricted glottis] do not necessarily relate to a particular point in the articulation of the stop, but rather to the configuration of the vocal folds at the moment of release. [spread glottis] describes whether aspiration is present or not. The feature value [+ spread glottis], indicates the fact that the vocal folds are open at the release of the stop, leading to the presence of aspiration. The reverse is true with the value [- spread glottis], which explains that the vocal folds are closed at the moment of release, leading to lack of aspiration.

The other two levels of phonetic representation deal with the physical dimension, where segments are described within a specific domain - in continuous time and space. One of these levels is the output of articulatory rules, and is called articulatory parametric representation, and the other one is the output of acoustic rules, called acoustic parametric representation. Both of these parametric representations are derived from the categorical phonetic representation, which as we have seen, is also derived from the phonological representation.

Kohler (1984) Fortis and Lenis Stops

Kohler (1984) proposes a single feature [± fortis], (where [- fortis] is also known as lenis (*cf.* Roach, 2000)) as a feature adequate to account for phonological contrasts between obstruents such as /p, t, k/ and /b, d, g/ in the languages of the world. This feature, according to Kohler, is not abstract, but is rather a "power feature ... realized in articulatory timing and/or phonatory power/tension ... thus providing a phonetic basis for the fortis/lenis dichotomy". This 'power' refers to the intensifying of movements by the organs of speech, or of 'energy expenditure' during the production of sounds. It is also discussed in relation to the strength of the air stream and to glottal tension. Other factors which may be associated with the [± fortis] feature include articulatory timing and laryngeal power/tension. Articulatory timing deals with the speed of the formation and release of the stricture for obstruents and may be language universal, and laryngeal power/tension refers to properties such as aspiration, voicing and glottalization, and may be language specific. To what extent a component may contribute to the fortis/lenis distinction of sounds is also a function of the context of the sounds being studied. This is discussed below.

Kohler starts by arguing that 'all phonological theories have treated the /b, d, g etc./ versus /p, t, k etc./ opposition as an atemporal distinction at a static point in a segment chain'. That is, the approach of some accounts of the phonological representation for the /b, d, g etc./ versus /p, t, k etc./ distinctions has been to describe these abstract phonological entities in physical phonetic terms. He further argues that adding an intermediate level of 'possible phonetic category mappings' between the phonological features and their phonetic properties as Keating (1984) proposes does not alleviate inherent problems in this kind of approach. Rather, 'the time dimension should be integrated into the phonology'.

Secondly, Kohler points out that the /b, d, g etc./ versus /p, t, k etc./ contrast is usually represented using the feature [± voice], even when both categories lack vocal fold vibration. This provides the basis for continuing confusion between phonetic and phonological voicing. If the feature [± voice] could be left to the phonetics, where it represents periodic vibration of the glottis, and if the feature [± fortis] could be assigned to phonological categories, this confusion could be resolved.

Thirdly, Kohler also proposes that the feature [± fortis] is sufficient to represent phonemic variation in properties such as aspiration, laryngealization, preceding vowel duration, gemination, etc. This feature is also proposed to be of a gradient nature, so that different states on the scale can be assumed in various contexts and languages, particularly languages with more than a two-category distinction.

The main distinction between fortis and lenis across the world's languages and across contexts in Kohler's account is what he calls the 'phonetic power.' The fortis segments are produced with more intensity and are auditorily more salient than the lenis series. Contrast in the stops of the world's languages and across different contexts is presented in the following way. For two-category languages, the difference between the [+ fortis] series, /p, t, k etc./ and the lenis, [- fortis] is described with reference to co-ordination between the oral, velopharyngeal and glottal valves. For the fortis series, a narrower or tighter constriction in the vocal tract has to be developed relatively faster than when the lenis stops are being produced. Also, the velopharyngeal closure has to be tighter for the fortis stops than for the lenis ones. Vocal fold vibration may occur for the lenis stop if appropriate aerodynamic factors are met. 'The three valves form a coordinative structure … for obstruents productions, characterized as a whole by the [± fortis] feature'.

Aspiration and voicing are correlates of the [±fortis] feature, and distinguish between distinctive segments by means of relative and co-ordinative timing of the oral velopharyngeal and glottal states, VOT and intensity differences in the oral cavity. As pointed out earlier, the timing and the laryngeal components contribute towards the fortis/lenis distinction of sounds to varying extents depending on the context of the sounds being studied. This is addressed as follows.

Utterance-initial stops: In Kohler's theory, the influence of the laryngeal element is most prominent in this position. Stops produced in this context are distinguished primarily by adjustments in the glottis: the presence versus absence of aspiration and vocal fold vibration. Fortis stops may be signalled by the aspiration element at the release phase, and lenis stops may have vocal fold vibration followed by a weak release. Two-way contrasting languages often utilize only one of these feature-signalling mechanisms. If aspiration is present, then there is no need to emphasize the lenis signalling feature.

Intervocalic stops: Both the timing and the laryngeal components have about equal influence in distinguishing stops in this position. Closure for the stop as well as the speed of the occlusion in intervocalic position is what signals the fortis-lenis distinction. Fortis stops achieve closure faster and have longer closure periods than lenis stops.

Utterance-final and before silence: If phonemic distinctions are preserved in this position, they may be signalled by the articulatory power of the closure phase. In most cases, glottal adjustments, i.e. voicing and aspiration, are highly less reliable. For instance, in the pre-pausal position, the glottis may be anticipating subsequent breathing and may therefore open. This may neutralize aspiration, which is the basic correlate of the fortis feature. Similarly, it is more difficult to keep the vocal folds vibrating when silence is being anticipated.

Kohler gives a detailed description of the behaviour of the organs of speech during the articulation of the fortis and lenis sounds in different contexts and in different languages. This is summarized in Monaka (2001: 64-65)

Where VOT overlap occurs in a language, as for instance in Korean, and in four-way contrasting languages, as in for instance Hindi, this can well be accounted for in terms of the activities of the organs of speech as follows. Korean has a three-way category stop system, all falling on the positive half of the VOT continuum. These are the aspirated stop, the weakly aspirated stop and the lax stop. According to Kohler (1984:162), both the aspirated and the weakly aspirated stop are fortis stops, and the lax stop is the lenis one. In order to solve the overlap between the two fortis stops, another aspect of the fortis/lenis distinction, 'laryngeal tensing,' is introduced. The weakly aspirated stops are distinguished from the aspirated stops in that 'they are accompanied by a strong and sharp activation of the vocalis muscle immediately before the stop release …. This body tensing of the vocal folds, combined with a decrease in stiffness of the vocal fold cover … is absent from the … aspirated ones' (Kohler 1984:161). The aspirated stops are realized by 'wide glottal opening with its maximum at the moment of release, resulting in a substantial increase in airflow' (*pg.* 161).

Hindi is another language with a similar overlap to that of Korean, with voiced and voiceless stops and their aspirated cognates. These four types of stops are accounted for in terms of the size of the glottal width and also the timing of the glottal opening. The voiceless unaspirated stops have a narrow glottal width opening *before* the release burst whereas their aspirated counterparts have a wide opening. The voiced aspirated stops have a narrow glottal width *after* the release burst, whereas their voiced cognates do not have any glottal opening after the release. In Kohler's theory, the voiceless unaspirated stops and their aspirated counterparts belong to the fortis category, whereas the voiced stops and their aspirated cognates are lenis stops.

The Element based Theory

In the Element Theory approach, contrast in consonants is represented in terms of elements. Adopting some of the terminology used by Halle & Stevens and Lisker & Abramson, the phonetic exponents and acoustic signals for the stop categories are as follows. Truly voiced stops are characterised by slack vocal cords, long VOT lead and lowered fundamental frequency (voice bar). Voiceless aspirated stops are characterised by stiff vocal cords, raised fundamental frequency and long VOT lag. Voiceless unaspirated stops have short VOT lag. Voiced aspirated stops are characterised by both the slack vocal cords found in truly voiced plosives and the raised fundamental frequency found in aspirated stops. The element specification for stops with lowered fundamental frequency is L. Those with raised fundamental frequency possess the element H. And those with both the slack vocal cords and raised fundamental frequency have the specification LH. Voiceless unaspirated stops are regarded as having no element specification. Element specification for the various linguistic systems has been summarised in Table 2, adapted from (Monaka, Abberton & Harris 1997).

		short lag	*long lead*	*long lag*	*breathy*
Type	*Language*	*No spec*	*[L]*	*[H]*	*[LH]*
I	*S*[1] *German*	/p/			
IIA	*French*	/p/	/b/		
IB	*English*	/b/		/p^h/	
III	*Thai*	/p/	/b/	/p^h/	
IV	*Gujarati*	/p/	/b/	/p^h/	/b^h/

Table 2: Element specification for some linguistic systems. Note: the blank areas show that the system does not have the relevant element specification. ([1] That is, Southern

German).

Shekgalagari Stops: Distinctive Features

This section focuses on Shekgalagari stops, assessing which of the phonological theories discussed above can adequately account for the contrasts revealed by the acoustic experiments performed on the stops. In order to explore the phonetics and phonology of Shekgalagari stops in greater detail, the results of the experiments will first be reviewed briefly. More information on the recording procedures and results could be found in Monaka (2001).

VOT: VOT values for the three stop types in Shekgalagari showed long negative values for the voiced stops, short positive values for the voiceless unaspirated stops and long positive values for the voiceless aspirated stops. No overlapping values were obtained between any of the categories. The ranges of the means between the three stop types were considerable.

The Spectrogram, Speech and Lx Waveforms

In the analysis of the waveforms, three main categories of stops were identified from the data: voiced, voiceless unaspirated and voiceless aspirated, conforming to the VOT results obtained above.

The voiced stops were characterized by modal phonation during the occlusion of the stop, which continued after the burst into the vowel. Although irregular vibration (creaky voice) was observed for some tokens and for some speakers, the total number of these was very small number and could be attributed to random variability in the production of tokens, considering the fact that the majority of voiced stops were produced with modal voice. On the whole the waveform characteristics for these stops conformed to their traditional description as 'voiced' stops.

For two of the speakers the voiced stops manifested decay of voicing towards the release explosion and a brief delay of voice onset after the burst for tokens produced in isolation and within a frame sentence. It was interesting to observe that the cessation of voicing did not only remain for the rest of the stop up to the burst but continued for a brief period after the release burst until the start of the subsequent vowel. Voicing did not actually start immediately after the release burst. This decay of voicing was also observed in a pilot study. Thus from the burst to the vowel these voiced stops seemed to behave more or less like the voiceless unaspirated stops in this language (cf. Lindau 1984:148-149 for Dedema; Jessen 1999:2, Jessen & Roux 1999:5 for Xhosa). Cross-linguistic study has shown that sounds that are categorized similarly, e.g. 'voiced', may often be produced differently in different languages and may even be produced differently by different speakers in a given language (Shimizu, 1990). Shekgalagari voiced stops (at least for the two speakers of this study) may be considered to be an example of this.

Nevertheless, we pointed out that Shekgalagari voiced stops may still be regarded as truly voiced stops since even when there is voicing decay, active voicing happens for most of the stop duration.

The voiceless unaspirated stops, which have traditionally been described as ejectives, were produced with modal phonation on the Lx signal prior to the stop closure and at the following vowel onset (at least for the subjects used in this investigation).

As regards the voiceless aspirated stops, the results showed turbulence after the burst and vowel onset displayed breathiness. This seems to conform to, as well as confirmed their traditional description as voiceless aspirated stops (Monaka, forthcoming).

Evaluation of Feature Theories in the Light of the Results Obtained for Shekgalagari Stops

The Sound Pattern of English model (SPE)

In the SPE model of representation of speech sounds specification for Shekgalagari stops would be as follows:

(2) The voiceless unaspirated stop

[p]
[+ consonantal]
[- sonorant]
[- vocalic]
[- tense]
[- voice]
[- stress]
[- aspiration]
.
.

(3) The voiceless aspirated stop

[p]
[+ consonantal]
[- sonorant]
[- vocalic]
[+ tense]
[- voice]
[- stress]
[+ aspiration]
.
.

(4) The voiced stop
[b]
[+ consonantal]
[- sonorant]
[- vocalic]
[- tense]
[+ voice]
[- stress]
[-aspiration]
.
.

(where the dots at the end indicate that the specification for the stop is not complete). Similar feature matrices could be drawn for stops produced at other places of articulation.

It is obvious that an endless list of features would be required to provide, if it were possible, a complete specification of the stops. Both unique phonetic description and phonological information is provided by one and the same matrix for any given stop.

Lisker & Abramson (L&A) (1964): Voice Onset Time (VOT)

Long VOT lead values were obtained for voiced stops, short-lag values for voiceless unaspirated stops and long-lag values for the voiceless unaspirated stops in Shekgalagari. There were no overlapping values between any two categories of the stops, and the ranges of the means between the three stop types were considerable. VOT was therefore considered to be an effective distinguishing cue for the three stop types in Shekgalagari.

Halle and Stevens (1971) (H&S): Laryngeal Features

Within the H&S feature geometry, Shekgalagari stops may be described as follows. The voiced stops, with relaxed vocal folds to facilitate vibration and fairly regular mode of vocal fold vibration during the stop occlusion, may have feature specification [-stiff, +slack], [-spread, -constricted]. The voiceless aspirated stops, observed to have modal voicing before the stop, no voicing during the stop and considerable delay of voice onset after the stop, may have the features [+stiff, - slack], [+spread, -constricted]. The unaspirated stops, which showed regular mode of phonation before and after the stop and no phonation during the stop, may have the features [+stiff, - slack], [-spread, -constricted].

Some of the problems that may be encountered with the H&S feature specification for Shekgalagari stops is that, as the feature system is based on laryngeal activity, it seems that more features may be necessary for every laryngeal activity in the production of the stops, leading to the problem of over-generation of features. For example, the tendency for some speakers to produced the 'voiced' stops with no voicing during the stop occlusion, which would require the use of the feature [+stiff, -slack] instead of [-stiff, +slack]; or with creaky voice instead of modal phonation, where the specification [–spread, +constricted] would be more appropriate than [-spread, -constricted]. More complication rise where voicing decay that continued after the burst was observed. The model would have to generate more features to capture the laryngeal configurations in the course of the production of these stops as observed in this study.

Keating on Voicing Contrasts

The results obtained for Shekgalagari stops appear to bear out Keating's theory as explained in terms of the phonological feature [± voice] and the phonetic features {voiced}, {vls. unasp.} and {vls. asp}.

For the [b, d, g] series, as an acoustic correlate, long VOT lead values were obtained. Also, as an articulatory correlate, a voice bar representing vocal fold vibration and low frequency periodicity at the gap corresponding to the stop closure were observed on the spectrograms. Within Keating's framework, this series could be represented by the phonological feature [+ voice] and realized as {voiced}. For the [p, t, k] series, short-lag VOT values were obtained and gaps corresponding to the stop occlusion on spectrograms were essentially empty. This series could be represented by the phonological feature [-voice] and realized as {vls. unasp}. The [ph, th, kh] series showed long positive VOT values indicating the presence of aspiration or turbulence after the burst, which, in the spectrograms, appeared as aperiodic noise after the burst. This series could be represented by the phonological feature [- voice] and realized as {vls. asp}.

The three basic phonetic categories proposed by Keating certainly appear to be 'the right number' for Shekgalagari stops.

The Principle of Polarization

According to the polarization principle, the contrast between word initial stops in Shekgalagari can be described by polarizing the long lead stops from the short-lag ones, and the short-lag ones from the long-lag ones. This principle also seems to be applicable in the Shekgalagari situation.

Kohler (1984)'s Fortis and Lenis Stops

In Kohler's framework of phonemic representation, Shekgalagari voiceless aspirated and unaspirated stops would be classified as [+ fortis], and the voiced stops as [- fortis]. There is, therefore, an overlap between the voiceless unaspirated and aspirated stops. Although this overlap may be resolved by reference to timing relations between glottal and supraglottal events and the size of the glottal widths, it still remains unclear how the contrast between the two voice types can be represented in terms of Kohler's [± fortis] feature. The aspirated stops, as noted above, are realized by 'wide glottal opening with its maximum at the moment of release, resulting in substantial increase in airflow' (Kohler 1984:161). The unaspirated stops have a narrow glottal width opening before the stop is released. In the theory, similar stops in other languages, e.g. Hindi, were both classified as [+ fortis].

The main problem with Kohler's proposal for the presentation of phonemic distinction is the use of only one feature. The premise for this is that features like [voice], and timing (VOT), which have otherwise been used by phonologists to represent phonemic distinction, belongs to the phonetics and should not be incorporated into phonological feature geometry. Inevitably, languages with more oppositions than the feature can account for end up with unresolved overlap. An example of this could be Hindi, where, although the voiceless unaspirated and aspirated stops may be differentiated in terms of glottal width, they are both categorized as [+ fortis]. A similar explanation is given for the voiced and the voiced aspirated stops in the language, which are [- fortis]. Phonetic descriptions are brought up to redeem the insufficiencies of the single feature, but since they are not permitted to express phonemic contrast, the theory remains in intense shortage of adequate distinctive features.

The theory also appears to be more suitable for languages with not more than a two-way distinction, and does not appear to be able to satisfactorily classify Shekgalagari stops.

The Element Theory

As discussed earlier, the results obtained for Shekgalagari stops in word initial position showed long negative VOT values for the voiced stops. A voice bar in the low frequency regions was also observed on the spectrogram at the gap corresponding to the stop occlusion for these stop types. This may be regarded as the 'lowered fundamental frequency' phonetic exponent of the element. Although physiological investigation on vocal fold vibration for voiced stops in Shekgalagari still needs to be done, it is generally understood that voicing is produced with rather relaxed (slack) vocal fold configuration instead of stiff configuration. Where there was voicing decay, active voicing happened for most of the stop duration. This category of stops could be adequately be represented by the element L in the Element Theory.

Voiceless aspirated stops showed long positive VOT values. Again voiceless stops are understood to be produced with stiff (as opposed to slack) vocal folds configuration. This category of stops may be represented by the element H. The voiceless unaspirated stops showed a short positive VOT lag and are therefore unspecified. The results obtained for Shekgalagari stops are compatible with the Element Theory of segment representation. Shekgalagari therefore falls into the same category of languages as Thai in Table 2, i.e. type III languages, with element specification L, H and unspecified element.

Conclusion

Shekgalagari has a three-way contrasting stop system, adequately represented by VOT, the Element theory and Keating's theories of two and three levels of phonological representation as well as the principle of polarization. The other theories, namely the SPE model and the laryngeal feature system of Halle and Stevens need to generate more features in order to adequately capture phonological contrasts in the language.

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