On the feature [spread glottis]

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Main sources
[spread glottis] has been formally proposed as a phonological laryngeal feature for the first time by Halle & Stevens (1971). The study which "inspired" this proposal (and others after) was Kim's seminal article published a year before on aspiration (Kim 1970). [spread glottis] has achieved since then a notable success among both phonologists and phoneticians. Here are some of the main studies, including phonetic and phonological ones, which have worked or continue to work on this feature: Ladefoged (1973), Lombradi (1991, 1995), Iverson and Salmons (1995, 2003), Avery (1996), Jessen (1998), and Avery and Idsardi (2001). A good review of the use of this feature is provided by Keating (1988, 17-22) (See the references below for other studies).

1. Overview
Laryngeal features for consonants are used to define the following phonetic dimensions: voicing, aspiration, and glottalization. Aspiration has been defined either by the feature [tense], [hightened subglottal pressure], or more commonly by the features [aspirated], or [spread glottis]. Jakobson, Fant & Halle (1952) use the feature [tense] to distinguish aspirated from unaspirated stops in Germanic languages, such as English for example (See Jessen 1998 for the same analysis in German). Languages using both voicing and aspiration distinctively employ both the feature [voice] and the feature [tense]. This is, for instance, the case of languages with three-way or four-way distinctions, such as Thai and Hindi, respectively. Another standard framework of laryngeal distinctions is that of the "Voice Onset Time" framework of Lisker & Abramson (1964). This theory is based on phonetic data and relates the contrast of aspiration mainly to a different timing of laryngeal activity relative to the supralaryngeal constriction, VOT being longer in the case of aspirated stops. VOT measurement is used because it is an acoustic manifestation of laryngeal timing which it is possible to measure accurately. However, Lisker and Abramson made no attempt to provide an explicit form of representation of this timing. At the exception of Browman & Goldstein (1986), which incorporated this framework into phonological analysis, it had no impact on phonologists (Keating 1988, Lombradi 1991).

Chomsky & Halle (1968) use the feature [Heightened subglottal pressure]. This feature was proposed to represent the extra energy for aspiration. This feature was highly controversial and has never been widely used. Data on subglottal pressure on several languages, such as Hindi (see Dixit & Shipp 1985), have in effect shown that aspirated stops are not systematically produced with heightened subglottal pressure, compared to their unaspirated counterparts.

As noted by Keating (1988), the most important innovation in the SPE model was the decision to represent the glottal configuration but not the result of the configuration. This new perspective is visible in the model proposed by Halle & Stevens (1971), where aspiration is approached from the laryngeal configuration that causes it to occur (i.e. a spread glottal opening) rather than the resulting activity (aspiration noise generated following the release). The feature [spread glottis] was first proposed by Halle & Stevens (1971) and has achieved a large success among phonologists. The majority of linguists working within current nonlinear phonology assume that this laryngeal feature exists as part of the universal set of features. The status of [spread glottis] as a laryngeal feature is formalized within a feature geometric model by proposing a class node 'Laryngeal' which dominates [spread glottis] (Clements 1985, Rice 1994, Clements & Hume 1995). As shown by Clements (1985), proposing this class node accounts straightforwardly for neutralization phenomena involving more than a single laryngeal feature. The neutralization phenomenon observed in Thai, for example, is accounted for by delinking the entire laryngeal node, instead of delinking each laryngeal feature individually. Some deviations from Halle & Stevens original account have been proposed. Lombradi (1991, 1995), for example, employed the feature [aspirated] to account for aspiration, though this feature has the same scope as Halle & Stevens feature [spread glottis]. As will be stated below, another departure from Halle & Stevens model is that of Avery and Idsardi (2001).

2. Phonological use

The following questions are pertinent to the discussion of the phonological use of the feature [spread glottis]:

1. Is this the feature which is contrastively used in the laryngeal system of a given language, or is it another feature (say [voice] or [stiff/slack vocal folds])?
2. Can stops and fricatives be defined with the same feature? If so do they pattern together in the laryngeal phonology?
3. Is [spread glottis] a privative or binary feature?

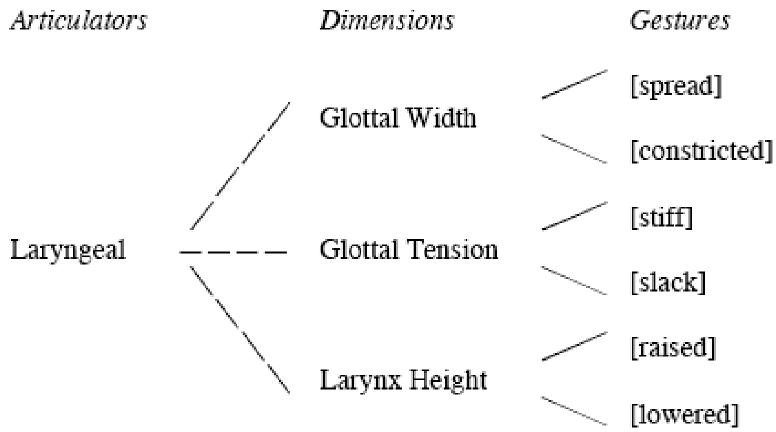
For Halle & Stevens, the feature [spread glottis] is a binary feature used to distinguish aspirated from unaspirated stops. As shown in table 1, they also use this feature to define voiceless glides, breathy and voiceless vowels, as well as /h/. Among the stop series, this feature contrasts /p/ and its aspirated counterpart in languages such Icelandic and /b/ and its aspirated cognate in languages such Hindi. For Halle & Stevens, this feature is not distinctive for obstruents in English and therefore does not appear in the phonological representation specifying any given English obstruent. Rather, the features distinguishing the two series of stops in English are [stiff/slack vocal folds]. In English, glottal spreading is used as an enhancing gesture in onset-initial pretonic voiceless stop consonants (see below).

(1) *Distinctive features for glottal state*

	1	2	3	4	5	6	7	8	9
obstru-ents	b̥	b	p	p*	bʱ b̤	pʰ	ɓ	ʔb	p'
glides	w, y				ɦ	h, w̥, y		ʔ	ʔ, ʔw, ʔy
vowels	V (mid tone)	V̀ (low tone)	V́ (high tone)	voice-less vowels ḁ	breathy vowels a̤			creaky voice vowels a̰	glot-talized vowels aʔ
spread glottis	−	−	−	+	+	+	−	−	−
constrict-ed glottis	−	−	−	−	−	−	+	+	+
stiff vocal folds	−	−	+	−	−	+	−	−	+
slack vocal folds	−	+	−	−	+	−	−	+	−

As mentioned above, Avery & Idsardi (2001) propose a modification of Halle & Stevens model. In their model, the laryngeal control is regarded as having three dimensions, each of which is associated with two terminal elements called *gestures* (2). These gestures are interpreted as motor instructions to the articulators.

(2) Avery and Idsardi's (2001) model of phonological representations of laryngeal dimensions.



An important claim in Avery & Idsardi's model is that only dimensions are relevant to phonological distinctions, not gestures. They assume along with Lombardi (1995), Rice (1994), and Iverson & Salmons (1995) that [spread glottis] is a privative feature. This means that for any contrasting pair, at the phonological level, they differ only by the presence versus the absence of a single node. Iverson and Salmons (1995) present both synchronic and diachronic evidence that the voicing contrast in Germanic languages is best analyzed as a two-way distinction between an unmarked segment and one that is commonly aspirated. Avery and Idsardi adopt the same view while proposing that the contrast is at the level of the Glottal Width (GW) dimension node. According to them, English contrasts unmarked segments with GW segments. Support for the claim that GW segments are marked is found in the stability of the phonetic cues for these segments as opposed to the unmarked segments. Using privative features, such an asymmetry can be represented by appointing the stable segment as the specified member, and the unstable segment as the unspecified member. Without any specification, the surface realization of the unspecified member largely depends on the surrounding segments.

One of the questions raised above was to determine whether stops and fricatives can be defined with the same feature [spread glottis]. According to Rice (1988, 1994), the answer is yes. She uses this feature to represent not only aspirated stops, but also voiceless fricatives (underlyingly in Rice 1988, redundantly in Rice 1994). Iverson & Salmons (1995) adopt the same view. Their argument is that this allows a unified treatment of stop deaspiration after fricatives, and sonorant devoicing after stops and fricatives. They claim that these clusters represent a sharing of the feature [spread glottis], as illustrated in (3).

(3) (a) s p (b) p l (c) f l

\/ \/ \/

[spread glottis] [spread glottis] [spread glottis]

Close correlations between glottal opening duration, aspiration, and sonorant devoicing are posited. Specifically, the claim is that there is only one glottal opening per onset and that the glottal aperture is constant for all cases and is aligned differently for stops and fricatives. As illustrated in (3a) the cluster /sp/ shares the same feature. In this cluster, no aspiration occurs after /s/ since the glottis is closed by the time of stop release. When a liquid follows a stop (3b) or a fricative (3c), it is devoiced since the glottis is still open during its production. According to Iverson & Salmons, there is considerable phonetic evidence that the [spread glottis] specification in clusters is shared (See Browman & Goldstein 1986 for the same assumption). The [spread glottis] specification in consonant clusters is outlined in the following paragraph, where it is shown that the actual glottal patterns are more complicated than what is suggested by Iverson and Salmons' assumptions.

3. Phonetic definition

As the name of the feature suggests, the basic articulatory correlate of the feature [spread glottis] is large glottal opening. In acoustic terms, spread glottal opening is mainly reflected in aspiration duration of stops and in the total voiceless portion of fricatives. As already mentioned, Halle and Stevens' proposal of this feature was mainly based on data from Kim (1970). This author, and others after, made explicit that a wide glottal opening is an important physiological explanation for the occurrence of aspiration (see Ridouane 2003 for a review). Adopting the feature [spread glottis] has thus the advantage that such a feature would have a straightforward articulatory correlate.

Important remarks concerning the phonetic implementation of this feature should be mentioned, however. For a stop to be aspirated, the glottis must be wide open, but this is not enough. As fibroscopic and photoelectroglottographic (PGG) data from Berber showed (Ridouane 2003, Ridouane et al. 2006), a stop may be produced with a large glottal opening without being aspirated. This is the case, for instance, for the unaspirated uvular stop which is produced with a wide open glottis, but with a VOT of no more than 20 ms. As shown in figures (1) and (2), the degree of glottal opening during the production of this unaspirated stop is larger than that of the aspirated velar stop /k/.

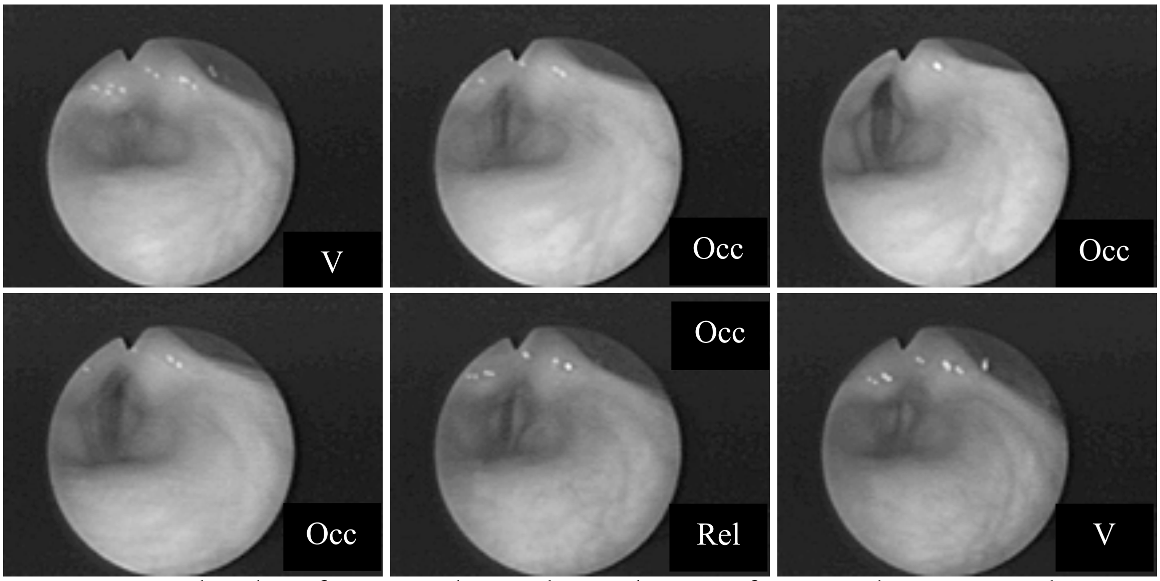


Figure 1. Glottal configuration during the production of intervocalic unaspirated /q/.
V = Vowel, Occ= Stop closure, Rel = Stop release. (From Ridouane 2003).

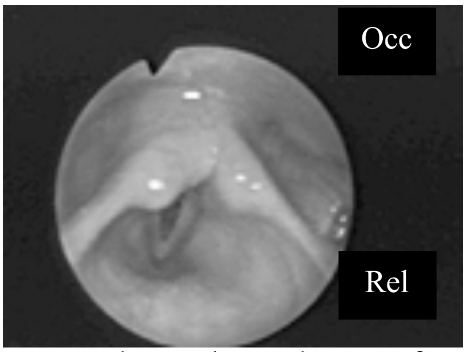


Figure 2. Peak glottal opening during the production of intervocalic aspirated /k/.
Symbols as in Figure 1. (From Ridouane 2003).

Another argument showing that aspiration is not only a function of the degree of glottal opening is drawn from a comparison between singleton and geminate stops in Berber. It was shown in Ridouane (2003) that, accoustically, aspiration duration is not a significant criterion for distinguishing between these two series of stops, both being produced with virtually identical aspiration durations. For dentals, measurements showed that aspiration duration varies between 45 to 65 ms for singletons and between 35 to 50 ms for geminates. For velars, aspiration duration varies between 45 to 70 ms for singletons and between 45 to 65 ms for geminates. A PGG study, based on the productions of one subject, showed important differences between singletons and geminates both in terms of timing and amplitude of glottal opening. Concerning glottal opening amplitude, data showed that geminates are systematically produced with a larger glottal opening than singletons. Concerning the coordination between laryngeal and supralaryngeal articulations, data showed that the interval between peak glottal opening and oral release is longer for geminates than for singleton stops. For dentals, this interval varies between 0 to 10 ms for singletons and between 55 to 120 ms for geminates. For velars, the interval varies between –10 to 20 ms for singletons and between 55 to 70 ms for geminates.

These results show that laryngeal abduction for geminates is much larger in amplitude and longer in overall duration compared to singletons. However, the glottal opening at stop release appears to be similar for both. Figure 3, which is arranged so as to show the glottal opening of a minimal pair involving a geminate and a singleton stop, shows that the size of glottal opening at stop release is nearly identical for both singletons and geminates. This may thus explain the fact that aspiration duration for both stops is virtually identical. In other words, it is the timing of laryngeal and supralaryngeal articulations that control aspiration rather than the laryngeal gesture per se.

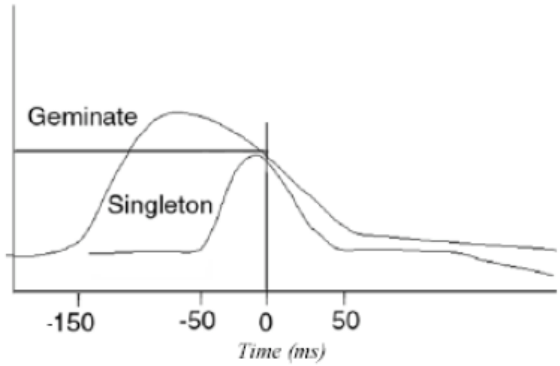


Figure 3. Illustration of the amplitude and the timing of glottal opening during the production of the stops in /ittili/ and /itili/. The vertical bar indicates the onset of oral release (adapted from Ridouane 2003).

As outlined above, [spread glottis] specification, according to Iverson and Salmons, is shared in fricative-stop clusters (for e.g. /sp/ in (3a)). They cite several experimental studies using PGG on voiceless obstruents, both singly and in clusters, from several languages—Swedish, Japanese, Icelandic, as well as English (Löfqvist & Yoshioka 1981, Yoshioka, Löfqvist, & Hirose 1981). These studies show that in single fricatives the peak of glottal opening is coordinated with the beginning of oral constriction. In single stops the peak occurs later, at the point of oral release. During the production of voiceless-obstruent clusters, only one glottal opening-closing gesture is produced. The peak glottal opening during such clusters is quite systematically located during the fricative. Two different strategies can explain the fact that the location of peak glottal opening follows the location of the fricative in such clusters. First, this might be caused by aerodynamic conditions. The fricative requires a higher oral airflow than the stop and hence the peak glottal abduction occurs during the /s/. Second, this might be caused by two underlying glottal opening gestures which overlap – a larger one for /s/ and a smaller one for /k/. This latter view is advocated by Munhall and Löfqvist (1992) on the basis of an experimental exploration of gestural aggregation, showing that such clusters consist underlyingly of two gestures. For Browman and

Goldstein (1986), the single-peaked glottal opening observed in word initial fricative-stop clusters is a phonological regularity of syllable-initial position in English, suggesting that the single peak is a property of the whole syllable onset. They capture the relevant timing of laryngeal-oral coordination in the following rule:

- If a fricative gesture is present, coordinate the peak glottal opening with the midpoint of the fricative. Otherwise, coordinate the peak glottal opening with the release of the stop gesture.

This rule, tested over various voiceless clusters in different languages, does not appear to be completely accurate (see Hoole et al. 2003). Berber material also shows that the peak glottal opening is not systematically coordinated with the midpoint of the fricative (Ridouane et al. 2006). The generalization that is drawn from Berber data is that peak glottal opening is almost always located within the fricative both for stop-fricative and for fricative-stop sequences. The timing of this opening peak tends to shift to a relatively earlier point in the fricative when it follows a stop (at 23.49 % of the fricative) and to later point in the fricative when it precedes a stop (at 66.06% of the fricative), regardless of the word boundary location. Figure 4 illustrates these timing patterns for the two subjects examined.

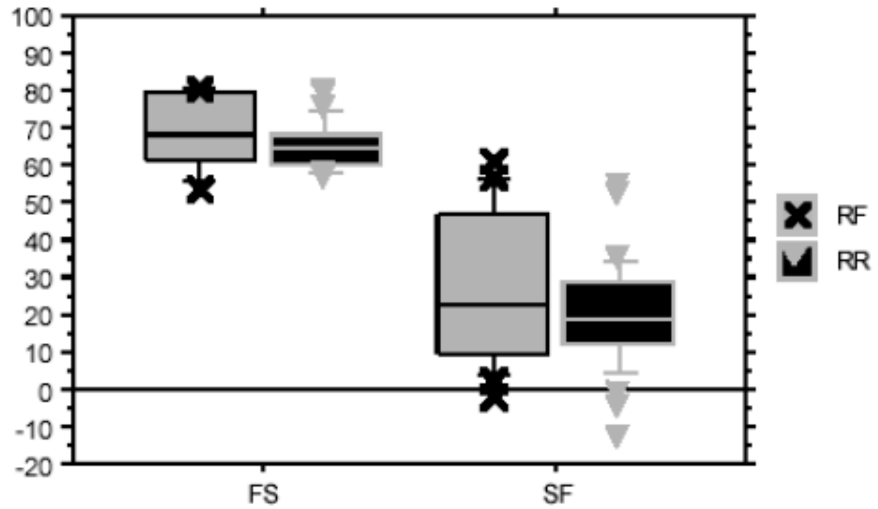


Figure 4. Timing of peak glottal opening during the fricative in two-consonant clusters: fricative + stop (FS) and stop + fricative (SF) sequences (From Ridouane et al. 2006).

Contrary to what has been observed in different languages (e.g. English and Swedish), in Berber /k/ can be acoustically aspirated after /s/ whether separated or not by a word boundary. Previous work (e.g. as summarized by Löfqvist 1980) suggests that typically each fricative and aspirated plosive requires a separate laryngeal peak. In Swedish (Löfqvist and Yoshioka 1980) and English (Yoshioka et al. 1981), a sequence of voiceless fricative + voiceless aspirated stop usually contains two separate peak glottal openings located during the fricative and just before stop release. In Berber, this generalization has to be qualified since interestingly the language shows aspirated plosives following fricatives in initial position, but nevertheless the results make clear that only one opening peak occurs. One might speculate that the somewhat atypical aspiration in initial fricative-plosive clusters is using the same timing pattern that has emerged for the geminates, suggesting that aspiration is not a function of glottal opening per se, but rather a function of the degree of glottal opening at stop release.

In addition to Berber, other languages present aspirated stops after /s/. Pettursson (1976), for example, cited cases observed in some Indian languages as well as in some Colombian Spanish dialects. The absence of aspiration in such segments is thus not a universal phonetic feature, contrary to what was assumed by Lindqvist (1972). This aspiration is rather exceptional, not only because it is not attested in the most widely studied languages, but also, at least in the case of

Berber, because it seems totally independent of word boundaries. The Berber case is thus typologically interesting, making it possible to determine the two possible laryngeal mechanisms accounting of stop aspiration after /s/: on the one hand a large amplitude and a delay in peak glottal opening relative to fricative onset; on the other hand, two peak glottal openings, each corresponding to one of the two obstruents. The second realization is the one produced in /s/-stop heteromorphemic sequences in some Germanic languages. In sum, different combinations of interarticulatory timing and glottal opening size can result in similar amounts of aspiration.

4. Quantal Feature?

Is [spread glottis] a quantal feature? In other words, can we identify an articulatory continuum between say /p/ and its aspirated counterpart that gives rise to a sharp discontinuity at the acoustic level? Clements & Ridouane (2006) suggest the following 4-point for quantal feature definitions:

1. It must identify an articulatory continuum associated with one or more acoustic discontinuities, and must specify the range within this continuum that corresponds to relatively stable regions in the related acoustic output. The range is the articulatory definition of the feature, and the associated output is the acoustic definition.
2. A feature definition must also identify the stable region in terms specific enough to distinguish it from other regions, yet general enough to apply to all articulations within this region, allowing for observed crosslinguistic variation.
3. It must effectively distinguish segments bearing this feature (e.g. /t^h/) from otherwise similar segments that do not (e.g. /t/).
4. Finally, it must identify the classes of sounds in which the definition holds. This will usually be the class in which the feature is at least potentially distinctive.

The definition proposed identifies an articulatory continuum (spreading of the glottis and the arytenoids cartilages) that corresponds to a relatively stable region in the acoustic output (aspiration noise generated following the release). During the 50-odd ms following the release, the glottis moves toward a configuration appropriate for the voicing of the following vowel. In this time interval, aspiration occurs without glottal vibration since the glottal spreading inhibits glottal spreading. Spread glottal opening is the articulatory definition of the feature and aspiration noise duration the acoustic definition. It is not clear, however, how should the temporal alignment between laryngeal and supralaryngeal gestures (necessary for the production of aspiration) be represented within this definition. As shown above, glottal opening per se is not enough to account for aspiration.

5. Variability

Aspiration is often bound in its occurrence to specific contexts in several languages (see Keating et al. 1983). In English, for example, aspiration is an important factor in the opposition of the stop series word-initially but less so in other positions such as word-final position (where other cues are used such as preceding vowel duration). In other words, the feature [spread glottis] is too narrow to account for all the ways the stop series differ across contexts in several languages. This is one of the reasons Halle & Stevens consider that [spread glottis] cannot account for voicing contrast in English.

6. Enhancement

According to Keyser & Stevens (2001) spreading of the glottis may serve as an enhancing gesture for the [stiff/slack vocal folds] contrast in English. This enhancement is produced in pretonic, onset-initial position. In Keyser & Stevens' view: "… enhancement may take place whenever a given distinction can be made more salient than it might otherwise be" (2006: 12). In syllable-initial position pretonically, the distinction threatened is that between /p/ and /b/, for example. The distinction between these two stops is only weakly represented in the sound (both /p/ and /b/ being unvoiced, the pre-voicing of /b/ is presumably weakened because of the vocal-fold stiffening in anticipation of the following stressed vowel). Because the distinction between these two series of stops is threatened, it is made more salient and enhanced by the spreading of the glottis for /p/ and thus by extending the voiceless interval into the beginning of the following vowel.

The above example illustrates the case where spreading of the glottis serves as enhancing gesture, now can the feature [spread glottis] be enhanced by other features or gestures? According to Clements (ms), the feature [+strident] may enhance the feature [spread glottis] in aspirated *vs* plain stop contrasts. In a number of languages, including Nepali, certain aspirates are realized with heavy but phonologically redundant affrication. Similarly, palatalized stops are sometimes realized with redundant strident affrication.

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