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Phonetics in Phonology: The Case of Laryngeal Neutralization

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0. Introduction

The study identifies the factors responsible for the loss of laryngeal contrasts and the reflexes of these factors in individual grammars. The main result reported is that the site of laryngeal neutralization can be uniformly identified by reference to phonetic implementation factors. Many of these factors are perceptual: laryngeal categories are neutralized in positions where the *cues* to the relevant contrast would be diminished or obtainable only at the cost of additional articulatory maneuvers. Conversely, laryngeal contrasts are permitted (or *licensed*) in positions that are high on a scale of perceptibility. It is argued here that the main factor involved in neutralization and licensing is the distribution of cues to the relevant contrasts. This hypothesis, referred to as Licensing by Cue, is compared here to the idea of Licensing by Prosody (Ito 1986, 1989, Goldsmith 1990, Rubach 1990, Lombardi 1991, 1995) according to which the distribution of features in general - and of laryngeal features in particular - is controlled by their prosodic position. The general idea pursued here is that phonological grammars incorporate knowledge of the conditions under which feature contrasts are physically implemented[1]. The focus in this study is on the empirical evidence supporting such a view.

0. 1. Licensing: by cue or by prosody

An example that clarifies the difference between Licensing by Cue and Licensing by Prosody is that of voicing neutralization in word-final and pre-obstruent position. Consider one such case:

(1) One voicing neutralization pattern (Polish, Lithuanian, Slavic, Sanskrit)

a. Obstruents are distinctively voiced or voiceless before vocoids and consonantal sonorants.
b. Obstruents are neutralized (devoiced) word finally.
c. Obstruents are neutralized before any obstruent: they surface assimilated in voicing to the following obstruent.

In these languages, obstruents followed by vowels or consonantal sonorants are frequently located in onset - e.g. *a.ba, a.bra, a.pa, a.pra* - and thus it is tempting to characterize the position of licensing in (1.a) as the onset and the positions of neutralization (1.b-c) as the coda. The grammatical statements in (2) - representatives of Licensing-by-Prosody thinking - reflect this postulated correlation between syllabically defined positions and sites of licensing or neutralization:

[1]See Ohala 1983 and Westbury and Keating 1985 for explorations of the link betwen neutralization and articulatory difficulty. Kingston (1985, 1990) has drawn our attention to the phonological consequences of perceptual factors in the analysis of laryngeal features. The present study continues Kingston's line of work and focusses more narrowly on the grammatical description of the link between phonetic implementation and contrast maintenance.

(2) a. [Voice] is unlicensed in the coda, licensed in onset. (Goldsmith 1990, Rubach 1990)
b. [Voice] is licensed in a segment by a following *tautosyllabic* sonorant. (Lombardi 1995)

The pattern (1) is open however to a different interpretation: at least one of the major cues to the distinction between voiced and voiceless obstruents is the voice onset time (VOT) value observable on a following segment (Lisker 1957 ; Lisker and Abramson 1964; Keating 1984). Different VOT values - indicating different [voice] categories in the preceding obstruent - can be observed on a following vowel or sonorant but not on obstruents. Therefore pre-obstruent obstruents necessarily lack at least this one bit of information about their laryngeal category. In word-final position the situation is comparable: simplifying a bit, we can identify the word final site with the utterance final position. Clearly here too a distinctively voiced or voiceless obstruent will necessarily lack its VOT cue. The suggestion pursued in this study is that absence of a major cue - or articulatory difficulties in implementing it - represent the main factor responsible for this and other types of neutralization. Unlike the statements in (2), this line of analysis promises to explain the grammar of neutralization, by showing how independently known facts about the perception and production of speech interact with grammatical conditions to yield sound patterns.

0.2. Phonetics in phonology: the downward arrow and alternatives

In flow-chart synopses of grammatical organization, the phonological component is frequently depicted as linked by a downward pointing arrow to a level of phonetic representation, the latter to be fed to a component of phonetic implementation (e.g. Kenstowicz and Kisseberth 1978:7, fig. 1.1; Mohanan's 1995:27 reconstruction of the view presented in the Sound Pattern of English). Although the specifics of such flow charts are seldom made precise, the downward arrow from phonology to phonetics seems to mean this: the phonological component consists of various entities and conditions (the feature set, the OCP, sonority sequencing conditions, the crossing line condition, etc.) whose interaction determines which contrasts a language will have and where. The phonetic implementation component contains laws that map phonological representations onto articulatory instructions, and laws that compute the acoustic and perceptual consequences of articulatory gestures. The downward arrow connecting phonology to phonetics means that the decision to have a contrast and have it in a specific position is taken in phonology. It cannot be affected by "downstream factors", i.e. by physical conditions under which the contrast will be implemented. Phonetic implementation has to live with prior decisions taken in the phonology.

The view presented here is that phonological patterns can be understood only in the context of a different relation between grammar and implementation. The diagram in (3) illustrates this: I assume that speakers possess knowledge of the relative ease with which different types of featural contrasts can be implemented. For instance, it seems reasonable to attribute to speakers awareness of the fact that a *k/g* contrast is more easily detectable in intervocalic position than in inter-obstruent position. Similarly, that the same *k/g* contrast *can* in fact be conveyed in inter-obstruent position (e.g. as in *askta* vs. *asgta*), but only at the cost of additional articulatory effort. Knowledge of this sort enters the grammar in the form of implementational constraints. The interaction of these conditions with the rest of grammar determines whether the language maintains a given contrast in a given position. A similar conception is presented in studies by Flemming (1995), Jun (1995), Kirchner (1997) and Silverman (1995). The important issue of projecting phonetically based constraints from observed data is discussed by Hayes (1996).

(3) surface distribution of contrasts

G f G
implementational constraints — rest of phonology — all of phonology
a
G {knowledge of relative perceptibility conditions
knowledge of auditory consequences of gestural timing...}

0.3. An example of cue licensing: retroflexion

Some reason to explore the view in (3) can be provided by juxtaposing a phonetic fact and a phonological observation. The phonetic fact can be inferred from a pair of stylized spectrograms (formant transitions into and out of the apical stops of Gujarati: Dave 1977): observe that only the V-C transitions differentiate *t* and *Ê*. The C-V transitions are essentially identical in the two cases.

(4) Stylized spectrograms of Gujarati apical (retroflex and alveolar) stops (Dave 1977: 11)

The phonological fact is an implicational law emerging from an extensive survey of apical systems (Steriade 1995; see also Hamilton 1996) : if a language neutralizes the contrast between alveolars and retroflexes then it does so first in contexts where the helpful V-C transitions are missing, i.e. in stops that are either word-initial or post-consonantal. Conversely, if a language does allow the *t/Ê* contrast, it allows it in postvocalic position. Frequently, this is the only position where such a contrast is permitted. We can attach a causal interpretation to the connection between this phonological generalization and the representative spectrograms in (4): in contexts where the retroflex-alveolar contrast is hard to perceive, it is categorically suppressed, *because* it would be difficult to implement there.

Note that this case, unlike that of voicing neutralization in (1), is unambiguous in regards to the role of prosody in neutralization: there is clearly no connection between the syllabic or word-position of the apical and its ability to carry distinctive retroflexion. Neutralized word initial or postconsonantal apicals are onsets but then so is the distinctively retroflex intervocalic *Ê* in *VÊ V* sequences. In this case then, there is a directly observable connection between the distribution of cues to a contrast, the phonetic implementation fact, and the phonological distribution of the contrast. We shall see that exactly the same connection can be uncovered in the case of the laryngeal features.

In the case of retroflexion, the implementational constraint is the ban on inter-apical contrast in contexts lacking V-C transitions. The implementational constraint reflects directly knowledge of the conditions of physical implementation of the contrast: in fact the knowledge and the constraint are not easily separable and may turn out to be identical.

To the extent that implementational facts are constant cross-linguistically, the typology of neutralization will possess certain invariant properties, such as the implicational law on apical neutralization mentioned above. Markedness theory is then, in part, the study of such constant implementational factors. To the extent however that the conditions of phonetic implementation differ from language to language - or from feature to feature - the facts of neutralization will differ too, at least at the observational level. Thus the optimal contexts for the perception of the *t/Ê* contrast are not necessarily the optimal contexts for the perception of the *t/d* or *t/tS* contrast. This difference in the perceptibility of contrasts across contexts can be tied to language-specific or feature-specific differences in implementation. To understand markedness and phonological typology one must understand the implementational conditions that shape individual systems of contrast.

0.4 Cues

We consider now the facts that stand behind statements of relative perceptibility. The example considered is that of voicing.

One can classify the three contexts mentioned in (1) according to the acoustic correlates to voicing available in each one of them. At least some of these acoustic properties have been shown to influence the perception of voicing categories (Raphael 1981) and thus are cues to voicing; others are potential cues. The classification in (5) below characterizes the distribution of cues that *would* obtain if distinctive voiced and voiceless obstruents occurred in all three contexts in (1). The point is to show that even if the voicing contrast had been maintained word finally and before obstruents - as it is for instance in certain lexical classes in English (cf. *mob* vs. *mop*; *mo[b]ster* vs. *qui[p]ster*) - it would nonetheless be harder to reliably identify there. I propose then a correlation between positions of poor perceptibility and sites of neutralization. I add to the contexts mentioned earlier a few others, which reinforce this correlation. Cues to voicing other than the VOT and their distribution are discussed, among others, by Wang (1959), Summerfield and Haggard (1977), Wolf (1978), Barry (1979), Repp (1979), Lisker (1986), Raphael (1981), Port and Dalby (1982) , Westbury and Keating (1986), Hillenbrand et al. (1992), Kingston and Diehl (1994, 1995).

(5) Hypothesized distribution of cues to the [voice] category of a stop depending on context : (distinctively voiced and voiceless C's are assumed to occur in all contexts listed).

i. <u>possible cues to voicing for C after V and before sonorant</u>: e.g. *a**b**ra, a**b**a, a**p**ra, a**p**a*

closure voicing, closure duration; V_1 duration; F_1 values in V_1; burst duration and amplitude; VOT value; F_0 and F_1 values at the onset of voicing in V_2.

ii. <u>possible cues to voicing word initially or after an obstruent and before a sonorant</u>:
e.g. ***b**ra, **b**a, **p**ra, **p**a*; and *as**b**ra, as**b**a, as**p**ra, as**p**a*

closure voicing, closure duration (for post C obstruents only); burst duration and amplitude; VOT value; F_0 and F_1 values at the onset of voicing in the following V.

iii. <u>possible cues to voicing for C after V at end of the word</u>: e.g. *a**b**, a**p***

closure voicing, closure duration; V duration; F_1 values in V ; burst duration and amplitude.

iv. <u>possible cues to voicing for C after V and before obstruent</u>: e.g. *a**b**sa, a**p**sa*

closure voicing, closure duration; V_1 duration; F_1 values in V_1.

v. <u>possible cues to voicing for C between obstruents</u>: e.g. *as**b**ta, as**p**ta*

closure voicing, closure duration.

vi. <u>possible cues to voicing for C after an obstruent at the end of the word</u>: *as**b**, as**p*** closure voicing, closure duration.

vii. possible cues to voicing for C before obstruent word initially: ***b**sa*, ***p**sa*

closure voicing, closure duration.

The reader will observe that as we go down the list of contexts in (5), the set of typically available cues to voicing progressively shrinks. The positions where the identification of voicing categories emerges as the most difficult (5.iv - vii) are in fact positions where such contrasts have seldom been documented (Greenberg 1978:253): in particular, the cases in (3.v-vii) are highly significant because they involve obstruent clusters that are rather well attested, yet only one language - Khasi (Henderson 1976, Nagaraja 1985) - is known to allow distinctively voiced obstruents in sequences like *bsa*. The typical absence of distinctive voicing in these positions has been the subject of separate stipulation in recent work (Cho 1990; Lombardi 1991, 1995). The alternative view presented here is that a single factor - relative poverty of cues - induces neutralization in all the contexts listed in (5.ii-vii): the difference between contexts is not of kind but of degree.

Consider now the somewhat more informative context in (5.iii): V_Obstruent. In this position the voicing of an obstruent can in principle be identified more reliably on the basis of the duration and F_0-F_1 values of the preceding vowel: indeed a small number of languages do maintain a voicing contrast morpheme-internally in this position. Among them are Maithili (Yadav 1984), Lamani (Trail 1979), Shilha (Applegate 1958) and various Arabic dialects (Syrian: Cowell 1964, Eastern Arabic: Rice and Sa'id 1979, Moroccan: Harrell 1962, Heath 1987, Iraqi: Abeer Alwan p.c.) . These languages do not preserve the voicing contrast in the #_Obstruent, Obstruent _ #, or in inter-obstruent contexts (corresponding to (3.iv-vi) but they do maintain it when the obstruent is either left or right adjacent to a vowel.

An even more favorable environment for voicing identification is that of postvocalic, word final stops (e.g. *mob* vs. *mop*): final stops possess all cues to voicing that pre-obstruent stops do, plus a longer preceding vowel and the higher probability of an audible burst, whose amplitude and duration may be an additional voicing cue (Raphael 1981). Any bursts that pre-obstruent stops may have will possess significantly less acoustic salience than word-final ones (Henderson and Repp 1982) and may therefore be counted as unlikely cues to voicing. Related to this is the fact that voicing neutralization never occurs finally without also occurring in pre-obstruent position. In addition, the two contexts (before _# and before an obstruent) differ as follows: the perception of voicing in a sequence of intervocalic obstruents VO_1O_2V (O= obstruent) is likely to be influenced by the strong cues to voicing present in O_2. It appears that, all else equal, the cues present in the burst and C-V transitions have primacy over those carried by the V-C transition (cf. Ohala 1990 for place, Raphael 1981 and Slis 1986 for voicing): therefore the categorization of O_1 with respect to voice is likely to be influenced by that of O_2, the better cued obstruent in the cluster. In contrast, a word final obstruent can be identified as voiced or voiceless without comparable interference. This too contributes to explaining why neutralization in the _# context is less likely than - and therefore implies - neutralization in the _O context.

If the facts reviewed so far bear on the incidence of voicing neutralization, as claimed here, we expect that the voicing contrast will be maintained in some context as a direct function of the cues available there: all else equal, the better the cue package, the greater the likelihood of contrast preservation. This type of link between the relative likelihood of F neutralization and the relative perceptibility of F in a given context will be documented here and extended to contexts and features not yet discussed; the evidence will also show that the sites of neutralization have no uniform characterization in terms of prosodic (esp. syllabic) organization. For the moment, I provide initial evidence for correlation claimed using the data in (6), which illustrates the range of contexts in which voicing neutralization is attested.

(6) **Patterns of [voice] neutralization** (O = obstruent, R = sonorant, incl. vowel)

fewer cues <---> **more cues**

	#_ O, O_# e.g. **b**sa vs. **p**sa	R_O e.g. a**b**sa vs. a**p**sa	R_# e.g. a**b** vs. a**p**	_R e.g. **b**a vs. **p**a	R_R e.g. a**b**a vs. a**p**a
Totontepec Mixe (Crawford 1964)	no voice contrast	no voice contrast	no voice contrast	no voice contrast	**contrast**
Lithuanian (Senn 1966)	no voice contrast	no voice contrast	no voice contrast	**contrast**	**contrast**
French (Dell 1995)	no voice contrast	no voice contrast	**contrast**	**contrast**	**contrast**
Shilha (Applegate 1958)	no voice contrast	**contrast**	**contrast**	**contrast**	**contrast**
Khasi (Nagaraja 1985)	**contrast**	(sequence missing)	**contrast**	**contrast**	**contrast**

As usual, the significant part about a chart like (6) lies in the missing patterns: no language surveyed maintains the voicing contrast in a less informative context, unless it also does so in the more informative contexts identified in (5). Thus, using T as a symbol for a voice-neutralized obstruent, no system known to me neutralizes word finally after a vowel without also neutralizing medially in the V_obstruent context.

0.5. Cue weighting

I have described the difference between the contexts in (5) in terms of more vs. fewer cues to voicing. But one may also compare the cues themselves in terms of their quality. For this comparison, we adopt Wolff's (1978) distinction between voicing cues clustered at the onset of voicing (*onset cues*) and cues clustered at the offset of voicing (*offset cues*). Thus in a V_1-O-V_2 sequence, the onset cues involve the transition between the obstruent and V_2, while the offset cues involve the transition between V_1 and the obstruent. We will refer globally to onset and offser cues as *transitional* or *contextual* cues, since they are scattered over the external context in which the consonant occurs. A third type of cue - voicing or lack of it during closure - will be referred to as an *internal cue*, since it resides during the period of oral constriction of the consonant. Several studies of voicing (Raphael 1981, Slis 1986; and data in Duez 1995) suggest (a) that the onset cues have primacy over offset cues, in the sense that they may determine the categorization of the segment in the presence of conflicting information and (b) onset cues may have primacy over the combination of offset and internal cues. Slis (1986) shows that Dutch speakers listening to obstruent clusters differring in voice (e.g. [kd]) perceived more frequently regressively assimilated (e.g. [gd]) than progressively assimilated or unassimilated clusters. In this instance of perceptual assimilation, categorization of the cluster's voicing was more frequently determined by the onset cues of [d], which were able to override the offset cues of [k] and [k']s lack of closure voicing, the internal cue. Comparably, Raphael's (1981) results for English show that when the obstruent contains conflicting cues to voicing, the onset cues dominate the percept. These findings correlate clearly with the fact that the most common environments of voicing neutralization (_# and _O) share the absence of onset cues. The significant fact is that, in contexts where reliable onset cues like VOT exist, the absence of other voicing cues - such as V1 duration, closure duration, or F1, F0 values on V1 - is mostly irrelevant. Thus word initial prevocalic stops are seldom voice-neutralized: that's because the presence of onset cues may compensate for and outweigh the lack of the offset cues. We will assume then that an analysis based on cue licensing will have to incorporate a cue weighting mechanism.

We will also observe that, although infrequent, voice neutralization *is* attested in the #_V context: this relates to the fact that the offset cues (V1 duration, F0, F1 values in V1) are necessarily absent there. As table (6) indicates, however, neutralization in the #_V context occurs only in the languages that neutralize everywhere else, save possibly in the most informative V_V context.

0.6. Cue duration

A further point that will be developed here is that the relative duration of the string over which transitional cues are manifested plays a role in neutralization: we will compare the likelihood of neutralization in sequences where the obstruent is adjacent to a relatively long modal-voiced sonorant with sequences in which the obstruent is adjacent to a very short modal-voiced sonorant: e.g. [litra] vs. [litr]. The data suggests that cue duration also plays a role in identifying neutralization contexts.

0.7. The descriptive system

Before proceeding we must consider briefly the grammatical questions raised by the hypothesis of Licensing by Cue. The simplest implementation of this idea is to characterize in standard segmental terms the contexts where contrastive voicing is more or less likely to be identified. Such descriptions have been used in (5). Based on this list of contexts, a perceptibility scale for voicing may be postulated: this is a series of statements about the relative perceptibility of the voicing contrast depending on context. The sign **R** used in (7) indicates that voicing in one context is more perceptible than in the context listed to its right. The scale is partial, since not every conceivable context appears on it. We will expand the scale as the evidence is presented.

(7) Scale of obstruent voicing perceptibility according to context

V_[+son] **R** V_# **R** V_[-son] **R** {[-son] __[-son], [-son] __#, #__[-son] }

A central analytical move in this study is the assumption that this and other perceptibility scales project families of corresponding constraints. Corresponding to the scale in (7) we have a family of *voice constraints in (8): there is a constraint of the form *[α voice]/X_Y corresponding to every context or set of contexts occupying a distinct position on the perceptibility scale. The constraints are universally ranked in the order of inverse perceptibility: the lower the context is on the perceptibility scale, the higher ranked the corresponding *[α voice]/X_Y constraint:

(8) Constraints on the distribution of voicing: ranking is universally fixed by alignment to the perceptibility scale in (5).

(i) *αvoice / [-son] __[-son], [-son] __#, #__[-son]

(ii) *αvoice/ V_ [-son]

(iii) *αvoice/ V_ #

(iv) *αvoice/ V_ [+son]

The constraints in (8) represent the speaker's knowledge of the fact that voicing distinctions are harder to implement in certain contexts than in others. In this sense then, the scale in (7) and the constraint family in (8) are two facets of the same thing: (7) is a statement of the perceptibility facts related to voicing, whereas (8) is a model of the speaker's knowledge of these facts. Both (7) and (8) have a large speculative component, since our understanding of both actual perceptibility and of its mental representation is imperfect: but it is clear that at least scales like (7) are empirically verifiable, independently of their use in explaining neutralization patterns. In this sense, the approach to phonology pursued here is deductive (Lindblom 1990): the contents of the grammar are deduced from knowledge of the conditions in which speech is perceived and produced, to the extent that such knowledge is attributable to naive speakers.

One antecedent of the ranking scheme in (8) is Prince and Smolensky's (1993: 135) idea of aligning constraint hierarchies to harmonic scales. The notions of ranking, evaluation and related concepts in the formalization of constraint-based analyses are also adopted from Prince and Smolensky's work (cf. also McCarthy and Prince 1993, 1995 for further developments). Constraint rankings are indicated by the sign >> or, as in (8), by downward arrows (_) : the upper constraint is more highly ranked, meaning that it will determine which alternative realization of the same input string (which *candidate*) is more highly valued in a given grammar. Lower ranked constraints determine the outcome of such comparisons only when the higher constraints are moot or violated equally by some candidate pair.

It is fundamental in understanding what follows to bear in mind that the perceptibility scale (7) projects the hierarchy in (8). By this I mean that the constraints have no independent status from the scale: if the scale changes, the constraints change correspondingly. This follows from our view that the scale represents facts about perceptibility, while the constraints represent knowledge of these facts. This conception can be verified: we will observe that the perceptibility of laryngeal distinctions depends on inter-gestural timing and the magnitude of glottal gestures, factors which vary from language to language and from context to context. When the oral-glottal timing changes, the ranking of contexts on the perceptibility scale changes too: for instance a preaspirated stop is more perceptible in post-vocalic position, regardless of what follows, whereas a postaspirated stop is more perceptible in pre-vocalic position, regardless of what precedes. Thus the relative ranking of V_ and _V contexts on a perceptibility scale depends on how glottal abduction is timed relative to oral closure in a stop. The result then is that the same laryngeal feature (here aspiration) may be subject to different constraint hierarchies in different languages, precisely because its perceptibility conditions, and therefore the grammatical constraints reflecting them, change when oral-glottal timing changes.

To return to [voice] neutralization, this phenomenon will be modelled as the interaction between faithfulness to input voice values - the *Preserve [voice]* constraint below - and a fixed hierarchy of *voice constraints aligned to the voice perceptibility scale. Some relevant ranking options are shown below. The top constraint appears to be undominated in the three cases shown.

(9)

(i) voice licensed before sonorants	(ii) voice licensed before sonorants and word finally	(iii) voice licensed after V and before sonorants
	*voice / [-son] __[-son], [-son] __#, #__[-son]	
d	_	c
*voice/ V_ [-son]	*voice/ V_ [-son]	**Preserve [voice]**
*voice/ V_ #	**Preserve [voice]**	*voice/ V_ [-son]
Preserve [voice]	*voice/ V_ #	*voice/ V_ #
*voice/ V_ [+son]	*voice/ V_ [+son]	*voice/ V_ [+son]

An analysis equivalent to (9.i) will be justified for Lithuanian and a number of other Indo-European languages in section 1.1. The hierarchy in (9.ii) is appropriate for Hungarian and Kolami, as seen in section 3. The case of (9.iii) is that of the Arabic dialects mentioned earlier, where no voicing neutralization obtains in the usual "coda" contexts. Observe that the fixed hierarchy in (8) precludes the existence of grammars in which voicing is neutralized finally (V_#) but not before obstruents

(V_[-son]) and more generally grammars in which voicing is licensed in a less informative context than the ones where it is neutralized. This and other implicational predictions of the analysis appear to be borne out: for instance, all languages where voicing is neutralized word finally also neutralize it before obstruents, initially before obstruents and in inter-obstruent position.

The type of analysis sketched in (8) and (9) can obviously be generalized: for any given feature F, the contexts where F might in principle occur can be arrayed on a perceptibility scale, in which contexts containing more and/or clearer cues to F will rank higher. The typology of neutralization for F can then be modelled by simply referring to the *F constraint family projected by F's perceptibility scale. Whether this is in fact the right way to model both the typology of positional neutralization and its description in individual languages is the subject of a larger investigation, of which the present study is one part.

0.8. Excessive variability

Do neutralization patterns change with speed and style? They may well change in the sense that certain distinctions may be completely abandoned at faster speeds and in more casual registers. We could tell that this is so by observing that relevant gestures are not being performed at all at certain speech rates/registers. Before systematic work testing this has been carried out, it would be premature to exclude the possibility of rate-dependent neutralization[2].

But does a cue-based approach to neutralization predict an unrealistic amount of variability in the realization of phonological contrasts? For instance, what clearly does not happen is that when we slow down considerably - at an unnaturally slow rate or in unnaturally hyperarticulated speech - no new contrasts emerge[3]. No phonemic contrast between *s* and *z* will emerge in extra-slow and careful speech in English inter-obstruent positions (e.g. *ekstra* vs. *ekztra*) even though by slowing down we may provide two essential conditions for the detection of the *s/z* contrast, namely duration and lack of overlap.

This observation reflects a fact about language acquisition as well as a fact about the structure of adult grammars. There are standard speaking rates and styles and we learn the contrasts of our language at these rates

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[2]On the fact that certain contrasts emerge only in careful speech and are either imperceptible or perhaps not even attempted in hypo-articulated or fast speech, there is quite a bit of anecdotal evidence. For instance Shipley (1956: 236) notes that in rapid Maidu speech glottalized stops become so weakly glottalized that "the aspirated and glottalized series fall together to some extent". He goes on to note that the merging is incomplete, but that "only a practiced Maidu ear can clearly distinguish a glottalized from an unglottalized stop in an allegro utterance". Newman (1944: p) complains about Yokuts that most of the time the difference between glottalized and unglottalized consonants is imperceptible and that it emerges only in slow, careful speech. As already mentioned, these informal observations may reflect genuine rate-dependent neutralizations: but we cannot tell in the absence of articulatory data.

[3]Paul Smolensky first raised this worry with me (1993, p.c.).

and styles. We can obviously slow down beyond this standard, but since this is not the tempo at which we have been exposed to language, no new contrasts will emerge. Thus what must be built into any theory of phonology is the understanding that the contrasts of the language will be learned based on a limited range of rates and speech styles.

The conjecture about adult grammars that emerges from this discussion is that the effect of implementational factors on the system of contrasts is computed *relative to fixed standards of speech rate and degree of hyperarticulation* and then extended to other rates and styles through the effect of paradigmatic correspondence conditions (Burzio 1995, Flemming 1995, Kenstowicz 1995, Steriade 1995, 1996). I assume that the fixed standard corresponds to slow and careful speech, but this assumption is not essential for our purposes. What is essential is the existence of *some* standard, correspondence to which has the effect of limiting the degree of variation in realizing a contrast.

An illustration of this idea involves the Russian voicing distributions. The obstruents of this language occur as distinctively voiced or voiceless when, *in careful speech* , they are followed by vowels or sonorant-vowel sequences. Absence of such a right-hand context in the careful pronunciation results in voice neutralization: *goro[t]*, but *gorod-a* 'town'. In faster speech, vowels reduce and sometimes disappear completely, without however affecting the distribution of voicing: thus loss or compression of the medial stressless a in *sapag-á* 'boot' does not necessarily induce neutralization of the voiceless quality of [p]. I attribute this fact to the effect of constraints that require featural correspondence between the standard rate and style and all other rates and styles, including ultra-fast or hyper-careful speech[4].

0.9. Extensions

0.9.1 Direct reference to cues?

There are multiple reasons to view analyses like (8)-(9) as only first approximations. Revisions and extensions to other laryngeal features are discussed in later sections. This study begins by using the schema in (9) as a preliminary means of demonstrating the empirical interest of cue-based analyses. I sketch now what will be lacking in such analyses so as to anticipate the direction of the revisions to come. First, the characterization of the link between perceptibility and neutralization given in (8)-(9) is very indirect: if it's lack

[4]It is important to note that conditions inducing correspondence to a standard rate or style are required independently of one's views on the relation between phonology and phonetic implementation. The original observation establishing this is due to Mohanan (1986), who notes that some processes are immune to pause insertion between their participant segments: *divinity* undergoes Trisyllabic Shortening regardless of whether one inserts a hesitation pause between *divine* and *ity*. This shortening process, which can be viewed as foot optimization (Prince 1990), is immune to tempo- or pause-induced variation because, we argue, it is made invariable by reference to a standard pronunciation in which the [vini] substring is indeed a foot. In the realm of fast speech processes comparable correspondence effects are observed in English (Manuel et al. 1992), Korean (Jun and Beckman 1990) and French (Fougeron and Steriade 1997, Steriade 1996): the fast speech pronunciation of a word maintains selected articulatory properties, by correspondence to the careful speech variant.

of cues that causes neutralization, then one may wish to consider grammatical analyses where the cues themselves play an overt role, for instance by being referred to directly in constraints such as **[voice]/ if cue x is missing*. The possibility of direct reference to cues is discussed further in Part II.

0.9.2. Intersegmental timing

Second, the presence of cues to any feature F in some context depends frequently on the degree of overlap between segments carrying F and their neighbors. For instance, English pre-obstruent stops typically lack acoustically salient bursts because the canonical degree of overlap between adjacent consonantal gestures is quite extensive in this language (Browman and Goldstein 1992). This may explain the significant limitations on the composition of English obstruent clusters (Lamontagne 1993; Pierrehumbert 1994). In languages without significant interconsonantal overlap, contrasts cued by burst quality may be safer (Browman and Goldstein, 1992:176, and Lamontagne 1993). This conjecture can be verified by observing the lack of laryngeal neutralization in many Northwest American Indian languages, where adjacent consonants are impressionistically described as non-overlapped (Hoard 1978, Urbanczyk 1995, 1996). For instance, Lushootseed (Urbanczyk 1995, 1996), Twana (Drachman 1969) and Bella Coola (Nater 1984) maintain an ejection contrast in final, pre-obstruent and inter-obstruent position - in addition to all the more favorable contexts - presumably *because* all stops are audibly released in all positions in these languages. Since an audible release can be guaranteed only under certain timing conditions, it appears that the characterization of these Salish systems must refer explicitly to intersegmental timing patterns prevalent in the language. This then is another reason to view analyses like (9) as incomplete, since the connection of neutralization to gestural timing is not being explicitly modelled.

0.9.3. Intrasegmental timing

A further aspect in need of revision relates to the a different timing issue: the same pair of intrasegmental gestures, when differently timed, generate different cue packages. This can be observed by considering two ways of timing aspiration to a stop's oral constriction. The peak of glottal abduction may lead the onset of the oral closure, as the gestural score in (10.a) indicates, or else the abduction peak may align to the oral release, as shown in (10.b). Aspiration is cued, among other things, by its effect on the voice onset or offset of a neighboring sonorant: the diagrams in (10) show that when the timing relations change, the context carrying these transitional cues changes as well.

(10) a. Peak of laryngeal gesture timed to onset of oral constriction: e.g. ^{h}t

[-------glottal abduction-----]

[-----oral closure---release ----]

context cues for a
laryngeal feature here

b. Peak of laryngeal gesture timed to release of oral constriction: e.g. t^{h}

[--------glottal abduction--------]

[----oral closure ---------release-]

context cues for a
laryngeal feature here

We will observe in Part II that neutralization sites for glottalization and aspiration are essentially those lacking contextual cues: pre-aspirated and pre-glottalized consonants neutralize, if at all, in the absence of a *preceding* vowel or sonorant, whereas post-aspirated consonants and ejectives typically neutralize in the absence of a *following* vowel or sonorant. This general observation supports the proposed connection between cues and neutralization. But, once again, in order to turn this into a prediction of the model, we will have to factor in some reference to timing relations.

0.9.4. Variable timing

A last observation related to timing is that the languages surveyed exercise three options when faced with a conflict between preferred timing patterns and unfavorable contexts. An underlying postaspirated stop - the preferred timing pattern for aspiration in obstruents - may happen to occur word-finally, a context where the critical VOT cue will normally be unvailable. The conflict in such a case will be between enforcing the generally prevailing timing pattern - preserving the timing in (10.b) - vs. generating some other transitional cue to aspiration. The three options in this respect are: (a) to keep the timing pattern of (10.b) and rely on impoverished cues to postaspiration (Maithili: Yadav 1984; Bengali dialects: Kenstowicz 1993); (b) to modify the timing to (10.a), and thus generate other contextual cues to aspiration (Icelandic: Thráinsson 1978; other cases discussed in Steriade 1993); and (c) to do neither but rather neutralize the aspiration contrast word finally (Greek, Sanskrit: below section 2.1). The existence of option (b) - contextually variable timing - supports the idea that the grammar is responsive to the range of cues being generated in different positions and with different timing options (see also Silverman 1997).

With these provisos, I set out to establish the first step in the argument: namely that syllable structure does not begin to describe, let alone explain, the patterns of laryngeal neutralization. This is the main object of Part I.

Part I: Against syllable-based accounts of neutralization

I document now the fact that syllable position provides neither a necessary nor an adequate characterization of the sites of laryngeal neutralization. The focus is first on showing that many classic patterns of devoicing and de-aspiration operating in the contexts _ # and _ [-son] cannot be given a syllabic analysis. Second, I show that even ambiguous instances of neutralization - which could be described as coda devoicing/deaspiration - receive a better treatment under the assumption that syllables are irrelevant here. Finally we will verify that the perceptually more impoverished contexts are always the first to induce neutralization.

1.1. Lithuanian

Unlike better studied modern European languages, Lithuanian consonant clusters are heterosyllabic regardless of composition (e.g. *áuk.le*), yet the context of neutralization is identical to that observed in German or Russian: distinctive voicing is preserved before sonorants, lost elsewhere. My sources on Lithuanian are Senn 1966, Augustaitis 1964, the collective *Lietuviu7 kalbos gramatika* (vol.1: Fonetika ir morfologija) Vilnius 1965, and Dambriunas, Klimas and Schmalstieg 1966. Lithuanian voiced stops are fully voiced; voiceless stops are unaspirated (Senn 1966:67).

(11) a. **Lithuanian obstruent phoneme inventory**

p	t	c‹	k
b	d	j‹	g
f	s	s‹	
v	z	z‹	

Loss of distinctive voicing occurs before obstruents and word-finally[5].

(12) **Distribution of voicing in Lithuanian obstruents**

Acute, grave and circumflex accents indicate rime length and pitch accents: á = HL on V:, à = H, ã: = LH on V:.

b. Distinctive voicing preserved before sonorants

	Voiceless			Voiced	
i.	áu**kl**e	nu**kn**iau)ti		au**gl**ingas	dre**gn**a
	'governness'	'klauen'	'fruitful'	'feucht'	
ii.	vi**kr**ùs	cy**pl**ys	e**dr**us	z‹vìr**bl**is	
	'geschickt'	'??'		'glutton'	'sparrow'

[5] This is described by Senn and Augustaitis (1964) as neutralizing (Senn 1966:66 "stimmhaft wird stimmlos", where *stimmlos* is the term describing the non-neutral voiceless series. The term for non-neutralizingly devoiced is *entsonorisiert*.)

iii. te**s‹m**uo) a**sm**uo) z‹ie**z‹m**uo) ba**z‹n**y!c‹ia
'Euter' 'Schneide' (place name) 'church'

iv. sil**pn**as ry**tm**ety)s sko**bn**is bã**dm**etys
'weak' 'morning' 'table' 'year of famine'

v. a**km**uõ à**tm**inti au**gm**uõ liu)**dn**as
'stone' 'to remember' 'growth' 'sad'

c. Voicing neutralized word finally

dau**)g** [dau**k**] kà**d** [ka**t]**
'much' 'that'

d. Voicing neutralized before obstruents

i. a**t-g**al) [**dg**] mè**s-d**avau [**zd**] dìr**b-t**i [**pt**] dè**g-t**i [**kt**]
'back' 'work-inf' 'burn-inf'

ii. míela**s d**rau)gas [**zd**] dau)**g p**inigu) [**kp**]
'dear friend' 'much money'

Are there connections between syllable structure and the voicing neutralization? All Lithuanian grammars report that VCCV sequences are divided as VC.CV. A minor exception is the *Lietuviu7 kalbos gramatika* (LKG), which mentions variation in the assignment of s-stop clusters: *a-**st**a* ~ *a**s-t**a*. The following quote from Senn is representative of the other sources: "Wenn zwischen zwei Vokalen oder Diphthongen zwei oder mehr Konsonanten sind [...] so wird nur der letzte zur folgenen Silbe gezogen; z.B.: *áu**k-l**e, bar**s-t**y!-ti, ga-ny**k-l**à, giñ**k-l**as, z‹vìr**b-l**is*".

(13) Syllable divisions: use of - as an indication of syllable boundary follows Lithuanian practice

a. Reported in LKG (1965: 124-126); not glossed
à**t-n**e-s‹e, ìr**k-l**as, ge-rè**s-n**is, rak**s‹-t**is, be-du**g-n**e, c‹a**k-n**o-ti, c‹y**p-l**ys, ar**k-l**iõ-kas, ar**k-l**e-nà, am)**b-r**y-ti, añ**t-r**as, dum**p-l**es, dum**b-l**as, gañ**g-r**in-ti, krem**b-l**ys, krem**z-l**e.

b. Reported in Dambriunas, Klimas and Schmalstieg (1966:18):

gañ**d-r**as 'stork', pir)**s‹-t**as 'finger', res-pu**b-l**i-ka 'republic'

All obstruent + liquid clusters are heterosyllabic, indicating that at least some coda obstruents maintain distinctive voicing (cf. *dum**p-l**es*, *dum**b-l**as* in (13.a)).

Substantially the same conclusion is reached by considering phonotactic restrictions on clusters. Suppose that the divisions reported in (13) are interpreted as showing *ambisyllabicity* of C_1 in certain VC_1C_2V sequences, rather than coda status for C_1. One may then consider categorical phonotactic restrictions on possible initial clusters as an indication of what is a plausible Lithuanian onset. Many obstruent + liquid sequences are systematically disallowed initially as seen below.

(14) Initial cluster phonotactics (Augustaitis (1964))

Possible	Impossible
- sl, s‹l, z‹l, pl, bl, kl, gl	**no tl, dl**
- sr, pr, br, tr, dr, kr, gr, spr, str	
- sm, s‹m, z‹m, sn, s‹n, z‹n, kn, gn	**no tm, tn, dn, dm, km, gm, pm, bm, pn, bn**
- sv, s‹v, z‹v, kv, gv, tv, dv	**no pv, bv**[6]

Although disallowed initially, clusters like *tn, dn, dm, bn* do surface in the V_V context without neutralization: *skobnis, bãdmetis, liu)dnas, àtnes‹e.* One may infer from the restricted distribution of clusters like *dm*, that they occur only in contexts where they need not be tautosyllabic[7]. The fact that voicing is maintained in the coda *d* of *bãdmetis* shows then that there is no correlation between the sites of neutralization and either the reported syllable divisions or the divisions we may infer from cluster phonotactics.

A further argument can be based on the syllable alignment effects reported by all three Lithuanian grammars: in prefixation and compounding the prefix and stem boundaries are said to coincide with syllable boundaries (Senn 1966: 61, Dambriunas, Klimas and Schmalstieg (1966:18) and the LKG (1965:125-126)).

(15) ati-**tr**aukti (not *atit-raukti) 'drag towards'; a**t-i**m)ti (not *a-tim)ti) 'to begin from'
akì-**pl**es‹a (not *akip-les‹a) 'freche Person', siks‹no-**sp**arnis 'bat' (not *siks‹no**s-p**arnis)

---

[6] The phonetic realization of Lithuanian v in different contexts is not documented in my sources. As in some of the Slavic languages, Lithuanian v is said to pattern as a sonorant, in that it allows voicing distinctions to be maintained. I do not know whether - or how - this behavior is related to its phonetic realization.

[7] Inferring syllable composition from phonotactic restrictions is not always a sound procedure. But if this sort of inference is rejected then the basis for Licensing by Prosody vanishes also.

There are no cyclicity effects in devoicing: in compounds and prefixed words, the final consonant of the first member maintains distinctive voicing if followed by a sonorant in the second member, *despite the intervening syllable boundary*. The examples below come from LKG 1965:126.

(16) voicing preserved: sta**b-m**eldy)ste 'idolatry, heathenism' sil)**k-m**edis 'silk-tree'
voicing neutralized: smul**k-z**‹emis [**gz**‹] 'GLOSS'

Consider now a form like *stab-meldy)ste*. The discussion so far has established three distinct reasons to believe that the distinctively voiced **b** is an unambiguous coda: first, all comparable obstruent-sonorant clusters are intuited to be heterosyllabic by native grammarians. Second, *bm* is an impossible word initial cluster hence an implausible intervocalic onset. Third, the assignment of *b* in *stab-meldy)ste* to the onset of the second syllable conflicts with an otherwise unviolated syllable-to-morpheme alignment condition.

The option of ambisyllabicity should be pursued now more carefully (cf. Merchant 1995; Calabrese 1996). Consider *skobnis* and assume that simply preserving [voice] values in a properly licensed in the onset is a sufficient reason to generate an ambisyllabic obstruent in such a string. We may represent ambisyllabicity graphically as the improper bracketting $[_{\sigma 1}$sko$[_{\sigma 2}$b$]_{\sigma 1}$nis$]_{\sigma 2}$. Let us assume a grammar where [voice] is subject to prosodic licensing, in virtue of a constraint akin to Lombardi's, e.g. ***voice / unless followed by [+son] in same syllable**. We abbreviate this constraint as **License [voice]** . Suppose now that the preservation of input voicing as well as **License [voice]** outrank any competing constraints on syllable well-formedness (e.g. ***Obstruent-Nasal Onset**). The ranking (**Preserve[voice], License [voice] >> *Obstruent-Nasal Onset**) will generate syllable divisions such as *sko.bnis* with onset *b* rather than ambisyllabic *b*. This output conflicts directly with the reported syllable divisions and therefore invalidates the analysis considered. Note further that no ranking of the constraints discussed - and more generally no ranking of generally justifiable constraints - can generate an ambisyllabic result. The reason is that an ambisyllabic candidate contains both a closed syllable (hence a *Coda violation) and a complex onset. Therefore a candidate like *[sko[b]nis]* - with ambisyllabic *[b]* will always be be inferior to *[sko.][bnis]*, which satisfies at least ***Coda** and violates no additional constraint. This point is illustrated by a tableau that assumes the ranking mentioned above. But the argument is independent of the ranking assumed: candidate [V[C]CV] will violate both the constraints violated by the V.CCV parse and the *Coda constraint violated by VC.CV.

(17) No ambisyllabicity in **skobnis** (the á symbol marks a wrong winner)

		License [voice] >>	*Obst-Nasal Onset,	*Coda
á	[sko][bnis]		*	*
	[sko[b]nis]		*	*!*
	[skob][nis]	!*		**

Thus no general solution to the analysis of laryngeal neutralization can be obtained by appeal to ambisyllabicity because the necessary ambisyllabic parses cannot be enforced.

Having excluded the alternatives, I present the analysis of voicing neutralization in Lithuanian as an instance of (9.i), a ranking repeated below:

(18) *voice/ V_ [-son]

*voice/ V_ #

Preserve [voice]

*voice/ V_ [+son]

The derivations of neutralized *g* in *dau[k]* and non-neutralized *b* in *sko[b].nis* are shown below. I begin by assuming that the output of neutralization is identical to an underlying voiceless stop, a position reconsidered in the next sections.

(19) a. skobnis from /skobnis/

	Preserve [voice]	>>	*[voice] /V_[+son]
bn			*
pn	!*		

b. dau[k] from /daug/

	*[voice]/ V_ #	>>	Preserve [voice]
g#	!*		
k			*

The Lithuanian data indicates that there is no justification for characterizing the site of licensing or neutralization in terms of syllabic position. There are licensed onsets (***s****magùs* 'cheerful' vs. ***z‹****mogùs* 'man') and neutralized onsets (***sp****alvà* 'color'[sp], *lì**z**das* 'nest'); licensed codas (*au**g.**muõ* 'growth' ***ak****.muõ* 'stone') and neutralized codas (*dau)**[k]*** 'much'). Voicing in Lithuanian obstruents is neutralized in all and only the positions where the main contextual cues (VOT and other release-related cues) are missing.

1. 2. The representation of neutralized voicing

We may now look into some of the issues left open by the analysis. Consider first the nature of constraints like *[voice]/V_#. The analysis presented above relies on the assumption that this constraint bars voiced obstruents but not voiceless ones from the final position: for, if *[voice]/V_# is interpreted as applying to both [voice] values then neither candidate considered in (19.b) - *[dauk]* or *[daug]* - will satisfy the higher ranked constraint. I redo the relevant tableau to show the unwanted consequence of this interpretation: as above, á marks a wrong winner.

(20) Attempting to derive [dauk] from /daug/ with the hierarchy in (18) and an extended interpretation of [voice] as [α voice]

	*[αvoice]/ V_ #	>>	Preserve [αvoice]
á g	*		
k	*		!*

However, the interpretation adopted earlier - which views the *voice constraints as banning only voiced obstruents - was not satisfactory either. First, it is inconsistent with the basic idea that cues function as licensers of the voicing contrast. Most cues to voicing - or any other feature - involve an implicit comparison between two poles of some dimension. Thus, to evaluate the significance of a stop's burst amplitude for the stop's voicing category one must know both the range of values characterizing the bursts of voiced stops and the range for voiceless ones. It is the comparison between the two that yields information about the categorization of any given token. The same goes for VOT values: the same short lag VOT value of 20 ms cues voicelessness in French - by comparison to the even shorter VOT of the French voiced stops - but voicing in English - by comparison to the longer VOT values of the English voiceless stops (Keating 1984). Neutralization takes place word finally *because the relevant comparison between VOT values cannot be carried out* in that context: it is therefore arbitrary to select just one of the poles of the voicing dimension as being either the feature itself or the feature value banned in some position.

Of course, phonological grammars may turn out to be structured in ways that are arbitrary or unexpected from the standpoint of speech perception. In this instance, however, there is good reason to think otherwise: we know independently that the laryngeally neutralized obstruents involve different articulatory postures from distinctively voiceless ones (Hsu 1996). This then is a second reason to revise the analysis in (18), which fails to distinguish distinctive voiceless from neutralized stops. Hsu demonstrates, on the basis of Taiwanese data, that neutralized obstruents are, in Keating's (1990) terms, *targetless with respect to voicing*: they assume the laryngeal posture of a neighboring sound[8]. Devoicing in the V_# context is passive, an automatic consequence of equalization in transglottal pressure. In contrast, distinctive {p, t, k} achieve voicelessness actively through glottal abduction (cf. Dixit 1987). The difference between targetful voiceless {p,

[8]*Targetless* (with respect to some gesture) means more than *unspecified* (with respect to the corresponding feature): non-specification can be phonetically interpreted in various ways, including through the assignment of a fixed articulatory target. This is the interpretation of the frequent statement "Laryngeally neutralized stops are phonologically unspecified and phonetically voiceless" (Mascaró 1987, Clements 1985, Lombardi 1995). In contrast a segment that is targetless for feature F is both unspecified and lacking in an invariant articulatory realization for the corresponding gesture.

t, k} and neutralized targetless {P, T, K} has multiple consequences in the phonology of Taiwanese and other languages: in particular, the realization of neutralized stops is variable in context, precisely because they lack their own articulatory target, while distinctively voiceless ones are invariant in comparable positions. A case of this sort is discussed in section 7.

The facts reviewed suggest the following interpretation of neutralization: both distinctively voiced and voiceless stops possess specific auditory targets, to be implemented through specific articulatory routines. The positions of potential neutralization are those where the hearer is less likely to correctly evaluate the achievement of these auditory targets. For such positions the grammar may evaluate as optimal obstruent representations which place no perceptual burden on the hearer and require no articulatory effort from the speaker: there is no auditory target to achieve in the neutralized obstruent, no distinct auditory category to identify and therefore no specific, invariant set of articulatory gestures to perform. Under this interpretation, the neutralized obstruents are distinct from both the voiced and the voiceless ones and the *[voice] constraints exclude equally the distinctive voiceless and voiced series[9]. To show how this new interpretation of the *[voice] constraints operates, I revise the earlier tableaux in (19) below: [voice] is interpreted to mean [α voice] - both plus and minus - and {P, T, K} represent laryngeally neutralized stops whose phonological representations lack both the invariant auditory propeorties associated with [+voice] or [-voice] and the articulatory gestures used to implement these auditory targets.

(21) a. skobnis from /skobnis/

	Preserve [voice]	>>	*[voice] /V_[+son]
bn			*
Pn	!*		
pn	!*		*

b. dau[k] from /daug/

	*[voice]/ V_ # >>	Preserve [voice]
g#	!*	
K		*
k	!*	*

One more comment on *[α voice] constraints. The *[α voice] condition can be interpreted in at least three ways. The first possibility is that *[αvoice] is penalizes the *articulatory* effort expended in implementing distinctive voicing values: cf. Kirchner (1996). If this line is pursued, then our representations must be expanded

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[9]The position taken by Hsu (1995) and here conflicts with the idea that voicing is universally a privative feature (Mester and Ito 1989, Lombardi 1991; but cf. Rubach 1996 for evidence to the contrary): the representations of voice-neutralized stops must differ, in at least some languages, from those of distinctively voiceless stops.

to distinguish explicitly the articulatory from perceptual correlates of distinctive features: the articulatory interpretation of the *[α voice] constraints penalizes not the fact that the auditory correlates of voicing or voicelessness are being generated but the fact that specific articulatory gestures are required to do this. The neutralized stops do not violate the constraints because no specific gestures characterize them, insofar as voicing is concerned.

A second possibility is that *[αvoice] is used as a means to limit perceptual uncertainty: this accords with the fact that the ranking in (8) reflects a scale of information content. Distinctive voicing is least likely in the least informative contexts so we may also view these constraints as being listener-oriented, in the sense of Ohala 1981. What seems most likely, however, is that both the articulatory effort and the perceptual poverty are being referred to in these constraints, in the sense that what is penalized is an unfavorable ratio of effort expended to cues generated. For the same amount of articulatory effort spent in generating some degree of voicing across three contexts (_[+son], _#, _[-son]) the cues available to identify voicing are progressively worse or fewer and therefore the ratios of effort to cues differ in ways that mirror the perceptibility scale in (7). This ratio can be improved by spending less effort and falling short of the articulatory target or by categorically giving up on the distinction in the perceptually difficult context. The latter is the standard case of neutralization. The interpretation of constraints like *[αvoice]/X_Y along these lines seems both plausible and consistent with the documented existence of gradient reduction of oral constriction gestures in contexts of reduced perceptibility (Byrd 1994, Jun 1995). In order to formalize this type of solution, some specific quantification of effort as well as of the information content of cues will be necessary: these points cannot be addressed here. See Kirchner (1997) for part of the necessary solution. I will continue to employ in Part I statements like *[αvoice]/X_Y with the understanding that the rationale for such conditions is the fact that they prohibit progressively worse ratios of cues to effort.

1. 3. Word domain effects in voicing neutralization

A different issue that has arisen from the discussion of the Lithuanian data concerns the word-bound character of the voicing neutralization. Word final obstruents are reportedly neutralized regardless of whether a following word begins with an obstruent or a sonorant: e.g. *dau[k] akmens* 'many stones' from */daug/*. This phenomenon should not be tied to the aligned syllabification *daug.ak.mens.*, where the original /g/ is in the coda, for we have seen that other codas do maintain distinctive voicing in this language. My proposal is that in phrases like *dau[k] akmens* we're dealing with a cyclic effect. In procedural terms, */daug/* devoices on the word cycle, prior to the consideration of any licensing context offerred by the following word. The same suggestion can be modelled non-derivationally, with cyclic effects viewed as stemming from the action of constraints that limit paradigmatic alternations (Burzio 1995, 1997, Flemming 1995, Kenstowicz 1995, Steriade 1995, 1996, 1997). By having a constantly devoiced *k* in *dauk* and related forms, Lithuanian simplifies its phrasal paradigms and blocks the proliferation of allomorphs. This point is developed in section 5, where the phrasal realization of laryngeally neutralized stops is being considered.

2. Generalizing from Lithuanian

The next step in the argument is to show that Lithuanian is fully representative of the typology of voicing assimilation. I do this first by showing that identical patterns of devoicing are found in other languages: the aim here is to establish that any observable connection between being a coda and being laryngeally neutralized represents an accidental by-product of facts unrelated to syllable structure. Second, I show that the analysis proposed for Lithuanian extends straightforwardly to a related but distinct style of voicing neutralization: the case where voicing distinctions are maintained word-finally but eliminated before obstruents. Syllable-based analyses of this pattern are also shown to be untenable. Finally, the languages considered in this section permit an extension of the analysis to other laryngeal contrasts cued by VOT.

To determine what counts as relevant evidence in comparing cue-based to syllable-based licensing, the reader should note that many languages - such as Korean (Kim-Renaud1974) - disallow heterosyllabic obstruent-sonorant sequences. However this effect is analyzed (cf. Vennemann 1988), its consequence is that many languages will lack the very sequences whose behavior is differently predicted by the two analyses considered. The Licensing by Cue model presented so far predicts that strings like *Vp.rV, Vb.rV* may maintain distinctive voicing, whereas Licensing by Prosody, in all of its versions, predicts that the *p/b* distinction will be neutralized. If such sequences are either lacking (as in Korean), or must be tautosyllabic (as in modern Romance), then the data will not distinguish the proposals we compare. For this reason, languages like Korean will not be mentioned here.

2.1. Greek and Sanskrit

The distribution of laryngeal features in the older Indo-European languages has been taken to reflect syllable-based licensing conditions (Steriade 1982). Greek possesses the distinction between voiced, voiceless and voiceless aspirated stops but implements it only before sonorants. Sanskrit contrasts voiced, voiceless, voiced aspirated (murmured) and voiceless aspirated stops: here too the laryngeal contrasts surface only before sonorants. Examples of contrast and neutralization in both languages appear below. Stops are not allowed word-finally in Greek. I choose [-anterior] stops to exemplify the pattern because these segments occur with relatively fewer distributional restrictions.

(22) a. Greek laryngeal contrasts and neutralization in velar stops

	Voiceless	Voiced	Aspirated
a. Pre-sonorant:	dei**k**-nu:-mi	zeu**g**-nu:-mi	a**k**$^{\mathbf{h}}$-nu:-mai
	''I show'	'I yoke'	''I am troubled'
b. Pre-vocalic:	t^{h}o:ra**k**-os	laryn**g**-os	tri**k**$^{\mathbf{h}}$-os
	'thorax-GENsg''	'larynx-GENsg'	'hair-GENsg'
c. Pre-stop:	dei**k**-teos	zeu**k**-teos	he**k**-teos (cf. e**k**$^{\mathbf{h}}$-o: 'I have')
	'to be shown'	'to be yoked'	'to be had'
d. Pre-s:	t^{h}ora**k**-si	laryn**k**-si	t^{h}ri**k**-si
	'thorax-DATpl'	'larynx-DATpl'	'hair-DAT-pl'

(22) b. Sanskrit laryngeal contrasts and neutralization in [-anterior] stops

	Voiceless unaspirated	Voiceless aspirated	Voiced unaspirated	Voiced aspirated
a. Pre-sonorant	va**c**-mi	ca**k**$^{\mathbf{h}}$ya:-u	ti**g**-ma	da**g**$^{\mathbf{h}}$-nu:-yat
	'I speak'	'has seen'	'sharp-pointed'	'reaching'
b. Pre-vocalic	u-va:**c**-a	**k**$^{\mathbf{h}}$an-ati	ni-ne**j**-a	da**g**$^{\mathbf{h}}$-at
	'has spoken'	'digs'	'has washed'	'has reached'

	Voiceless unaspirated	Voiceless aspirated	Voiced unaspirated	Voiced aspirated
c. Word-final	va:**k**	no examples	var**k** (cf. var**j**-a)	d^{h}a**k**
	'voice'		'twisting'	'has reached'

	Voiceless unaspirated	Voiceless aspirated	Voiced unaspirated	Voiced aspirated
d. Pre-obstruent	u**k**-ta	no examples	ni**k**-ta	d^{h}a**k**-tam
	'spoken'		'washed''	you 2 reached'

These patterns of neutralization must be analyzed in the same terms as the Lithuanian facts. The observation establishing this will be that for both Sanskrit and Greek syllable divisions in obstruent-sonorant clusters were variable, depending on the dialect, the period, the literary style and the juncture separating the consonants. In contrast, and this is fundamental, there was no variation in the pattern of laryngeal neutralization: in styles or dialects where VC.CV divisions were the norm for all clusters, laryngeal neutralization did not take place before heterosyllabic sonorants. Therefore the syllabic assignment of clusters and the licensing of laryngeal features are independent of each other.

2.1.1. Sanskrit

According to Mishra (1972:200ff) - a compendium of the opinions on syllable divisions held by Sanskrit grammarians - "the most general rule is that the first member of the consonant group [...] consisting of either two or more than two consonants, belongs to the preceding vowel. Thus the word "pitre" will be divided as pit+re and not pi+tre. " The only exceptions to this statement are: (a) the opinions of certain grammarians that RigVedic Sanskrit had the option of syllabifying stop-liquid sequences as onsets and (b) the view expressed by commentators on the YajurVeda that stop-glide and stop-fricative sequences are tautosyllabic. Even if taken at face value, these exception statements leave us with possible heterosyllabic assignments for all sequences of stop-consonantal sonorant in the RigVeda and obligatory VC.CV assignments for all stop-consonantal sonorant sequences in the later language. This means that the aspirated voiced stop in *dag^h-nu:-yat* 'has reached' is, as a rule, a coda segment: what licenses its laryngeal features is something else than syllabic position[10]. I also note that, as in Lithuanian, most stop--nasal sequences present intervocalically are impossible initially, and thus implausible as onsets: they do however maintain distinctive voicing, as in *agni-* 'fire', *stabÓ-na:-* 'establish-present'.

Furthermore, the patterns of vowel lengthening in the intensive prefix suggest that in fact all clusters were heterosyllabic during all periods, an opinion shared by Mishra (1972) and supported by the metrical evidence. Thus the vowel-final reduplicating prefixes of the intensive are short before any consonant cluster and long before a single root-initial C (Whitney 1889:365). This rule, strictly obeyed in the earlier stages of Sanskrit, indicates that the syllable division was VC.CV in all cases. Below I highlight the pre-stem rimes containing the vowel with variable length.

(23) Pre-stem vowel length in the intensive

(i) Long vowel	(ii) Short vowel
gan-**i:**-gam- 'go'	gan-**i-g.**m-atam 'go'
mar-**i:**-mr`j-	kan-**i-k.**rand

[10]For a discussion of post-Vedic syllabification see Vaux 1992, who argues that a shift in boundaries took place in later Sanskrit. Vaux's arguments also support the point made in the text: despite the extensive variation in cluster assignment across styles and periods, the patterns of laryngeal neutralization do not change. They are therefore independent of syllable position.

'wipe'	'cry out'
b^har-**i:**-b^hr̀-	b^har-**i**-**b^h**ra-ti
'bear'	'bear'
tav-**i:**-tuat-	dav-**i**-**d.**yut-
'be strong'	'shine'

The requirement is clearly that pre-stem syllables be heavy in the intensive[11]. This condition is satisfied in the (ii) column by heterosyllabification: *ga.nig.ma.tam, da.vid.yut, b^ha.rib^h.ra.ti* and by lengthening in the (i) column: *ga.ni:.gam, b^ha.ri:.b^hr̀-*.

Note now that the coda stops *g, d, bh* in (23.ii) do not lose their laryngeal features: heterosyllabification - as in *b^ha.rib^h.ra.ti* - does not induce laryngeal neutralization. Note further that this argument is independent of the method of syllabification in the rest of Sanskrit: even if closed syllables were avoided in other contexts, the last syllable of the intensive would still have to be analyzed as heavy, and therefore the syllabic divisions *ga.nig.ma.tam, da.vid.yut, b^ha.rib^h.ra.ti* would still suffice to establish the fact that laryngeal licensing is independent of syllabic position.

2.1.2. Greek

The facts of Greek syllabic division have been discussed in Hermann (1924), Steriade (1982) and most recently by Devine and Stephens (1994:32-42 and passim). Certain Attic poets syllabify consistently the tautomorphemic stop-sonorant clusters as onsets. But this cannot be the basis for a syllable-licensing account of the laryngeal neutralization facts shown earlier in (20). First, the laryngeal neutralization pattern is pan-Hellenic, spanning dialects, literary styles and periods, whereas the syllabic divisions are highly variable. Homer tends to assign all word-internal intervocalic clusters to separate syllables, as shown by the weight of syllables reflected in the meter. Since forms like *dak.ru, ag.rion* and *ak^h.nu:mai* contain coda velars, laryngeal licensing for this variety of Greek cannot be syllable based.

Further, the attested voiced stop-nasal clusters (limited to *dn, dm* in most dialects) are scanned heterosyllabically in all literary styles (Koster 1952:34), without however losing distinctive voicing on *d*. In Attic both *dm* and *dn* are absent word-initially, a fact consistent with the assumption that they cannot be onsets. The voiced-stop-l clusters (*gl, bl*) are variably heterosyllabic in dialects like Attic, where other obstruent liquid

[11] This condition is also evidenced by the alternative form of the intensive, where no -i- intervenes between the reduplicated syllable and the stem: *can-krand-* (alternative to *kani-krand*), *ja:-gam* (alternative to *gani:gam-*) etc.

sequences form complex onsets (Steriade 1982): but this does not cause variable or even occasional loss of distinctive voicing.

Further arguments for a syllable-independent statement of laryngeal neutralization emerge from a consideration of allomorphy in the thematic comparative and superlative forms of adjectives (Devine and Stephens 1994:40, 104): the allomorphs are *-oteros* (comparative), *-otatos* (superlative) after a heavy syllable and *-o:teros*, *-o:tatos* after a light one. Below I highlight the syllable immediately before the comparative suffix:

(24) Comparative allomorphy in Greek

(i) After heavy syllable	(ii) After light syllable
de:.l-oteros 'clearer'	k^ha.**le**.p-o:teros 'more difficult'
sem.n-oteros 'more venerable'	**ne**.-o:teros 'younger'
pis.t-oteros 'more faithful'	**so**.p^h-o:teros 'wiser'
mak.r-oteros 'longer'	**p^{h}i**.l-o:teros 'dearer'

The argument here is exactly parallel to that based on the Sanskrit intensives. The allomorphy facts require syllabic divisions that place some of the non-neutralized obstruents in the coda (cf. *mak.roteros* vs. *ag.roteros)* . Therefore what is constant for all laryngeally licensed obstruents is not the syllabic position but rather the presence of a following sonorant. The constraint hierarchy generating laryngeal neutralization in Greek and Sanskrit is thus identical to that argued for in Lithuanian[12]. The fact that these languages have

[12]Steriade (1982) has argued that the reduplication patterns - which treat root-initial stop-sonorant clusters on a par with single consonants - establish the onset status of all such clusters. Thus *lu:-o:* reduplicates as *le-lu:-ka*, *graph-o:* reduplicates as *ge-graph-a*, *blapt-o:* as *be-blaph-a* but *ktiz-o:* reduplicates as *e-ktis-ma* and *stell-o:* as *e-stal-ka*. The point is that the clearly heterosyllabic *kt* and *st* clusters pattern differently from the arguably tautosyllabic *gr, bl*. Had *gr* and *bl* been heterosyllabic in all contexts, the facts of reduplication would remain unexplained: we wouldn't be able to predict the difference between *ge-grapha* and *e-ktisma*. This may well be true, but this argument does not establish that stop-sonorant clusters are onsets in all contexts. Root-initially, the cluster assignment was probably subject to additional constraints, which reflect the preference for alignment between root and syllable boundaries. Indeed, Devine and Stephens (1994) provide considerable metrical evidence for the tendency to avoid misaligned syllabifications in Greek poetry and prose, at all levels of the prosodic hierarchy. Clearly, the preference for aligned root and syllable edges was overridden by the dispreference for marked *kt, st, mn* onsets: hence *es.tal.ka* rather than *e.stal.ka*. This then explains the difference in the patterning of *st-*, *kt-*, *mn-* initials vs. *bl, gr*, etc. The alignment constraints were irrelevant in other positions: therefore *agr-oteros, pukn-oteros* must have been syllabified, as argued above, *ag.ro.te.ros, puk.no.te.ros* in the same language

occasional differences in syllable assignment only reinforces our argument for uncoupling neutralization from the syllable.

2.1.3. Aspiration neutralized

Note that Greek and Sanskrit aspiration is neutralized in the same contexts as voicing: word-finally and before obstruents. This is due to the fact that the aspirated stops of both languages are *post*-aspirated: meaning that the chief effect of aspiration is to prolong the voicing lag. Therefore VOT values must have played a major role in differentiating all laryngeal categories in Greek and Sanskrit and contexts where these values cannot be observed and compared are likely neutralization sites. This explains why the contexts of neutralization for voicing and aspiration are identical in the data observed so far. Had the aspirated stops been pre-aspirated, the context where *t: Ót* contrasts are lost may well have been different from the context where *t: d* contrasts are suspended, as we see in Part II.

The range of available cues to postaspiration has been studied less than those signalling voicing (cf. however Schiefer 1992). It is nonetheless quite plausible that the cues - and therefore the contexts where these cues can be observed - might differ. Schiefer (1992) does not mention either F0, F1 or durational differences that would reliably separate p from pÓ, or b from bÓ. It seems likely that all the cues to such contrasts are contextual (VOT and burst) and occur exclusively the vicinity of the release. Therefore, if this range of cues is characteristic of all postaspiration contrasts, we may predict that the neutralization of such distinctions will *always* occur in unreleased word-final and pre-obstruent stops. This prediction is confirmed by languages like Khasi (Henderson 1976), in which distinctive voicing is maintained initially before all consonants (cf. *bt, pd, pt,* *bt*^{h}*, bs, bn, bl, pl, pn* initial clusters) whereas distinctive aspiration is maintained only before sonorants (*t*^{h}*l,* *k*^{h}*m, t*^{h}*m, p*^{h}*n,* but * *t*^{h}*p, *p*^{h}*d,* etc.) Khasi also preserves a marginal voicing contrast finally, but not the aspiration contrast. The point here is that voicing and post-aspiration, although frequently parallel in licensing behaviors, are nonetheless different in their overall typology. They are different because their cue distribution is not exactly the same: voicing contrasts can be and are maintained in the absence of the onset cues, whereas postaspiration contrasts cannot be maintained - because they cannot be perceived - under the same circumstances. This strengthens the argument for cues as contrast licensers, since the cues are specific to the feature and timing relation involved.

2.2. Voicing neutralization in Russian and Polish

The evidence against a syllable-based analysis of laryngeal licensing in Russian has been gathered by Pilch (1967:1564) and Darden (1991). This pattern of voiced/voiceless neutralization is in fact identical to that

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where *gegrapha* was syllabified - frequently or invariably - as *ge.gra.pha.* The argument against syllable-based licensing of laryngeal features formulated earlier stands.

of Greek, Sanskrit and Lithuanian, modulo independent differences in phonotactics and laryngeal inventories. The facts of Russian have been analyzed by Jakobson (1962 (=1956):503), Halle (1959), Hayes (1984), Kiparsky (1985), Mascaró (1987) and Lombardi (1991). The core of the paradigm is the fact that the voiced/voiceless distinction in obstruents is neutralized in word-final position and before other obstruents. It is not neutralized before vowels or sonorants belonging to the same word or the same prefix-stem unit (cf. Jakobson 1962 for details). The neutralized obstruents surface as voiceless unless followed by voiced obstruents, in which case they are voiced.

Since this paradigm is otherwise identical to those observed in earlier sections, I will concentrate below only on the Russian evidence for laryngeal licensing of *coda* obstruents. Pilch (1967:1564) reports that non - neutralized voiced obstruents may occur as codas if followed within the same word or close-knit phrase by neutral elements with respect to voicing, i.e. by sonorants.

(25) a. Licensed voiced obstruents in medial Russian codas:

*z´mʲor**z**.l´*	'frozen'
*skor**b**.nij*	'full of grief'
*´**d**.no*	'one-neut.'

b. Licensed voiced obstruents in final Russian codas:

*tʲi**g**r*	'tiger'	(contrast mo**kr** 'damp')
*Zi**z**nʲ*	‘life’	(contrast pe**snʲ** ‘song’)

Darden (1991) makes some complementary observations. First, he notes that not all laryngeally neutralized obstruents occupy the coda position: *[g]zʲemlʲe* (from */k zʲemlʲe/* to-earth') does not begin with a coda. Nor can the non-neutralized obstruents seen in (25.b) be onsets: *n* is not syllabic in either *Ziznʲ* or *pesnʲ* and therefore the preceding fricative cannot be an onset. These observations render untenable a simple onset licensing analysis of Russian voicing along the lines proposed by Rubach (1990) for German. Pilch's data (25.a) also argue against Lombardi's (1991, 1995) version of laryngeal licensing, under which a tautosyllabic sonorant must follow any distinctive laryngeal value: *d* in *´d.no* is not tautosyllabic with *n*. Further, according to Darden, Russian displays the same stem-to-syllable alignment effects noted earlier for Lithuanian: e.g. *p´d-jexatʲ* 'to exit' has heterosyllabic *d.j* with non-neutralized *d*. (cf. contrasting *´t-jexatʲ* 'to enter'). Darden's evidence for this is based on the observation that regressive palatality assimilation always obtains within the same syllable, but fails to cross certain prefix-stem boundaries, such as the one in *p´d-jexatʲ*. Palatality assimilation applies only when the affix is monoconsonantal: e.g. *s-jes-tj* [sʲjesʲtʲ] 'to eat with'. I infer from this that prefix-stem boundaries align to syllable boundaries in Russian, unless the resulting syllable are grossly ill-formed (**[s.jes.tʲ]*. An analysis in terms of constraint ranking can be proposed, where the constraints of stem-to-syllable alignment are outranked only by avoidance of the worst syllable types (syllabic obstruents). The upshot is, in any case, that aligned candidates are optimal in forms like *p´d-jexat^j* and that this results in syllable divisions that block tautosyllabic palatality assimilation (**p´d^j-jexat^j*.) Most relevant here is that the syllabic division enforced by alignment is irrelevant to laryngeal licensing: voicing in the coda *d* is linearly licensed by the cues inherent in the following heterosyllabic *jV* sequence**.**

The paradigm of Polish voicing has been studied by Bethin (1984), Rubach and Booij (1990), Gussmann (1992), Lombardi (1991) and Rubach (1996). Rubach and Booij provide important evidence for stem-to-syllable alignment, even in cases where the resulting syllable structure is quite unusual: for instance the aligned syllabification of *o-mdlec*' 'faint' *[o.mdlec']* is an acceptable structure in Polish[13] along with [om.dlec']. Lesser violations of syllabic well-formedness result in an even greater likelihood of aligned boundaries: the subjects of Rubach and Booij's investigation were unanymous in preferring *bez.alkoholowy* 'alcohol free' to misaligned (but syllabically improved) *be.zalkoholowy*. Thus underlying **z** is viewed as a coda in this form, but preserves distinctive voicing[14] . Given this data, it is unnecessary to discuss the possible stem-internal syllabifications of the notoriously complex clusters attested in Polish: whether *Piotrka* is syllabified as *Pio.trka* (cf. Gussmann 1992, Lombardi 1991, 1995) or otherwise, we know, based on Rubach and Booij's alignment effects, that syllabic divisions do not condition laryngeal licensing in Polish either[15]. This point is in agreement with the major conclusion reached by Rubach (1996).

Both Russian and Polish display complex patterns of voice licensing and assimilation when the obstruent is followed by a non-prevocalic sonorant, as in Russian *bobr* 'beaver' . These cases have to be considered because they bear on the idea that a sonorant carries the VOT cue of a preceding obstruent and in that sense, licenses its voicing value. At first sight, one might expect that a sonorant following the obstruent will always insure the intact realization of the obstruent's voicing value. Since this is not always the case in these languages, additional analysis is called for. The paradigm for the two languages is assembled in (26): abbreviations used are O = obstruent and R = sonorant. The sources of this data are Jakobson (1956), Hayes (1984) Kiparsky (1985) and, for Polish, Rubach and Booij (1990), Gussmann (1992) and Rubach (1996).

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[13]I am grateful to Alicja Gorecka for verifying the judgments reported by Rubach and Booij.

[14]The final *z* of *bez* in *bez alkoholowy* is not voiced by assimilation to the following voiced vowel: although voicing assimilation initiated by sonorants is attested in Krakow Polish, the dialect described by Rubach and Booij (1990) and Rubach (1996) is that spoken in Warsaw, where only obstruents induce assimilation. Therefore the *z* in *bez.alkoholowy* is a coda that maintains its underlying voicing value. The same point is made by Gussmann (1992:33, fn. 4) a propos of *bez nadziei* 'without hope', another case where the distinctive voicing is maintained in a coda obstruent.

[15]Gussmann's suggestion that voicing is licensed in syllabified obstruents but not in stray ones is also inconsistent with the alignment data adduced by Rubach and Booij.

(26)	Russian	Polish
OR#	*optional devoicing,* *not neutralizing* (bobr, bobr9, bopr9 'beaver')	*obligatory neutralization* *when the sonorant is non-syllabic* (spa[sm], spa[sm9] /spazm/ 'spasm')
$O_1R\#O_2(R)V$	*no assimilation* my[sl^j z]e 'thought, though'	*obligatory assimilation to O_2* wia[dr z]achodni 'westerly wind' li[dr v]ody 'liter of water
$O_1\#RO_2$ (R)V	*obligatory assimilation to O_2* o[d mzd]y 'from the bribe' i[sm9ts]enska] 'from Mcensk'	*no assimilation* wido[k mg]:y 'sight of mist'
O_1 RO_2 (R)V	*obligatory assimilation to O_2* [g mzd]y 'with the bribe'	*obligatory assimilation to O2* kon[tr9f]ors 'contrefort' [drg]na4c' 'shudder' [str9f]onic' 'squander'

Reformatskij (1971, cited in Hayes 1984) notes that the transparent sonorants of Russian must be non-syllabic: syllabic *m*` in a sequence like [zm`ts] will block voicing assimilation. For Polish, most recent sources mention non-syllabic sonorants in the positions listed in (27) but A.Gorecka (p.c.) points out that her variety of Polish is characterized by facts very reminiscent of Reformatskij's generalizations: word final sonorants in forms like *spasm* are syllabic and block devoicing: *spa[zm`]* contrasting in voice with *pa[sm`]* 'stripes-Gen pl'. The syllabic sonorants of Gorecka's dialect also block assimilation: *litr wody* 'a liter of water' is realized as *[litr` vodÈ]*, with syllabic *r* and unassimilated *t*, in contrast with the standard pronunciation *[lidr vodÈ]*, with non-syllabic *r* and assimilated *d*. Rubach (1974) also mentions the option *spa[zm]* and the possibility of syllabic sonorants, although his subjects differ on this point. The phonetic realization of the Russian sonorants in (26) has been only partially documented, by Hayes (1984), who shows that they are variably voiceless in forms like *rta* and *bobr*. An impressionistic report to the same effect is made by Gussmann, Rubach and Booij about Polish forms such as *Pio[tr9]*, *spa[sm9]* and *[str9f]onic'* . Gussmann (1992:33) however reports that the initial sonorant of Polish *rte4c'* 'mercury' is fully voiced.

Before proposing an analysis of voicing in ORO sequences, let us note the major descriptive generalizations shared by Russian and Polish. First, distinctive voicing is maintained - regardless of syllable divisions - in OV and ORV strings, in both languages. Voicing is neutralized in ORO and OO strings in both languages. Syllabic sonorants - when allowed in either language - act exactly like vowels in blocking neutralization and assimilation of a preceding obstruent. The differences between Russian and Polish involve then only the status of OR# and #RO strings: final non-syllabic R allows voicing to be maintained in Russian OR#, but not in Polish; and initial non-syllabic R blocks assimilation in Polish but not Russian O#RO strings. The key observation for our analysis will be that the OV, ORV and OR` strings (where R` is a syllabic sonorant) allow optimal manifestation of the onset cues to voicing, esp. VOT: in these cases, the sonorant string following the obstruent is longer than in the case of ORO clusters, with non-syllabic R. In complementary fashion, we note that in ORO strings - with non-syllabic, word-internal R - the string potentially manifesting onset cues is shortest and doubly overlapped. Therefore, if the duration of the cues to voicing plays a role in the perceptibility of the distinction, then we expect that O_1's voicing in O_1RO_2 will be least perceptible. This corresponds to the fact that in O_1RO_2 strings both languages neutralize voicing in O_1. The corelation between overall duration of the sonorant string and neutralization is outlined below:

(27)			
	Obstruent followed by longest sonorant string		Obstruent followed by shortest sonorant string
	<u>O</u>V, <u>O</u>RV, <u>O</u>R` , <u>O</u>R` O	<u>O</u>R#	<u>O</u>RO
	Voicing contrast preserved	Variation	Voicing contrast neutralized

Further support for this correlation between the duration of the sonorant and its laryngeal-licensing abilities comes from Klamath (Blevins 1993, Barker 1964: 23, 26-27) where an O_1RO_2 sequence contains what Barker perceives to be a syllabic sonorant preceded by a laryngeally licensed O_1: contrast *makl`Ga* 'camps at' with *ntSik'l`Ga* 'drips down" and *wdogl`gi* 'comes to beat someone' (Barker 1964:23). This syllabic sonorant is however ignored for the purpose of metrical counting. As Price (1980) shows, duration is one of the correlates of syllabicity: sonorants perceived as syllabic differ from their non-syllabic counterparts primarily in being longer. Thus we may infer that the Klamath inter-obstruent sonorants are perceived by Barker as syllabic on acount of their duration alone. The fact that these longer sonorants help preserve the distinctive laryngeal qualities of the preceding obstruent - unlike their non-syllabic Polish counterparts - should be attributed to the effect of duration on the perceptibility of VOT distinctions.

In word final OR# sequences, where R is overlapped on only one side, Polish and Russian diverge: Russian counts this final R as a still valid licensing context - since devoicing in forms like *bobr* is gradient and non-neutralizing - whereas Polish does not: final OR# is neutralized in Polish, when the sonorant is non-syllabic. This difference in the treatment of final OR# sequences with non-syllabic R may relate to differences in the degree of temporal reduction of the final sonorant but it more likely reflects a different categorization of otherwise identical phonetic data. Assuming the latter, I expand the perceptibility scale proposed in (7) to distinguish three classes of contexts in which a sonorant follows an obstruent: (a) a context in which the obstruent is followed by a long sonorous stretch (either V, RV or syllabic R); (b) the context in which the obstruent is followed by a word-final, non-syllabic R; and (c) the context where the obstruent is followed by the shortest R, non-syllabic and doubly overlapped (ORO). The distinction between contexts (b) and (c) stems from the lesser extent of overlap in (b) and the likelihood of final lengthening, which may result in a longer R word finally. In both respects then, the _R# context emerges as more favorable for the perception of voicing that the _RO context.

(28) Scale of perceptibility in obstruent voicing according to context (revised)

Notation: [long son] = long sonorous stretch (V, RV, or syllabic R)
[son] = shorter sonorous stretch (R#)
[short son] = shortest sonorous stretch (_RO)

V_[long son] **R**V_[son,] **R** V_[short son] **R** V_# **R** V_[-son] **R**
{[-son] __[-son], [-son] __#, #__[-son] }

Corresponding to this expanded scale, we have an expanded set of *[α voice] constraints .

(29) Revised *[α voice] constraints corresponding to (28)

(iii) *αvoice/ V_ #

(iv) *αvoice/ V_ [short son]

(v) *αvoice/ V_ [son]

(v) *αvoice/ V_ [long son]

Both the scale in (28) and the corresponding constraints should be read by interpreting [short son], and [long son] to refer to the durational category of the overall string of sonorants that follows the obstruent. It does not matter whether an obstruent is followed by one or more sonorants provided that the overall sequence is such as to allow a reliable identification of VOT distinctions.

Given these additions, we may describe the variation between licensed Russian *bobr* and neutralized Polish *bopr* as a simple ranking effect: final r in /bobr/ for both languages corresponds to the sonorous string of intermediate duration ([son]) identified earlier.

(30)

Polish	Russian
*αvoice/ V_ #	*αvoice/ V_ #
*αvoice/ V_ [short son]	*αvoice/ V_ [short son]
*αvoice/ V_ [son]	**Preserve [voice]**
Preserve voice	*αvoice/ V_ [son]
*αvoice/ V_ [long son]	*αvoice/ V_ [long son]

Since Polish, but not Russian, neutralize O_1 in $O_1R\#$ sequences, it follows that Polish, but not Russian will assimilate O1 in $O_1R\#O_2$, as seen in (26). Following earlier work (esp. Kiparsky 1985; Mascaró 1987; Cho 1990), I assume that the target of assimilation is identified as the neutralized segment: therefore a non-neutralized obstruent (Russian *b* in *bobr,* for instance) will not be a target. This is then sufficient to derive the Polish-Russian differences on this point.

The last case to consider is the behavior of Polish and Russian $O_1\#RO_2$ sequences. Here again my remarks are speculative, in the absence of a systematic phonetic investigation. We should observe at the outset that in any context $O_1\#R$ - regardless of what follows R - O_1 is neutralized in both languages, unless it belongs to a prefix or proclitic: an example of neutralization in this context is a Russian phrase such as *gorod Moskva [gor´t m´skva]* 'the city of Moscow' , with devoiced /d/. This is a cyclic effect, as in Lithuanian: both Polish and Russian prefer to generalize to all contexts the devoiced quality that is justified phrase-finally. The only question is how the neutralized O_1 will be realized: fully voiceless, as expected phrase-finally, or partially assimilated to some other consonant. I claim that the occurrence of assimilation in this case depends on three conflicting factors: the preference for paradigm uniformity or morphemic invariance, whose effect would be to generalize phrase final allomorphs like [gor´t] to all contexts (Steriade 1996); the avoidance of increasingly faster articulatory adjustments, which militates against abutting voiceless-voiced sequences; and the need to preserve lexical contrasts. The last factor requires that, in an obstruent whose glottal state is distinctive, it must be initiated early so that the obstruent will be fully voiced or fully voiceless throughout its duration: therefore in $\#RO_2$ (with voiceless O_2) R is partially or fully devoiced (as shown by Hayes 1984 for *rta*). Similarly, in $O_1\#O_2$ sequences, the neutralized O_1 will reflect the transition to the glottal state of O_2 and thus will be categorized as belonging to the same laryngeal class as O_2. This is the basis of voicing assimilation in such cases. However, in strings like $O_1\#RO_2$, the glottal state of O_2 need not be initiated during O_1: a slow enough transition between glottal states is possible even if O_1 preserves its phrase-final voiceless quality. Whether the transition between O_1 and O_2 is slow enough depends on how long R may be: if we take seriously Gussmann's (1992) report that R in forms like Polish *rte4c'* 'mercury' is fully voiced and compare it with the partial devoicing found in Russian *rta* 'mouth-Gen. sg' , then this suggests a durational difference between the two languages which correlates as predicted with the facts of assimilation. The shorter R of Russian in O_1#RO_2 strings is an insufficient buffer between opposing glottal states and thus induces assimilation, whereas the longer R of Polish permits O_1 to maintain the devoiced quality that characterizes the phrase-final allomorph. The fact that Reformatskij (1971) explicitly rules out assimilation in Russian O_1#RO_2 when R is syllabic further supports this line of analysis: as suggested earlier, the syllabic R is the longest R and thus will necessarily allow O_1 to preserve its paradigmatically dictated voiceless state[16].

Summarizing then, I have suggested that two different phenomena are reflected in the paradigm in (26). One is the ability of a shortened and overlapped, non-syllabic R to offer useable transitional cues to a preceding O: Polish and Russian agree in categorizing the shortest instance of R (in ORO contexts) as an insufficient licenser. They differ in the categorization of final R: Russian, but not Polish, counts this R as a possible licenser of distinctive voicing. This is reflected in the ranking differences seen in (30). The other phenomenon is also related to the duration of R but involves not its licensing ability but rather its function as a buffer between the opposite glottal states of neutralized O_1 and distinctive O_2. When R is too short, O_1 will assimilate, as if it was adjacent to O_2; when R is sufficiently long, O_1 will maintain a voiceless quality.

To implement this analysis it was necessary to expand the perceptibility scale and the related set of *α voice constraints. These additions do not represent unwanted epicycles: the scale of perceptibility involves a ranking of contexts according to the quality of the information they offer for the identification of voice categories. We have started out with a small set of contexts (in (5) and (7)) but any realistic consideration of a larger set of contexts will result in refinements of the sort just introduced. What is constant throughout such revisions is the idea that the likelihood of neutralization is determined by the quality of information provided by the context.

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[16] The analysis presented here agrees with Rubach's (1996) important proposal that the distribution of Polish voicing is independent of the syllable. However the two analyses diverge on the mechanisms of assimilation in ORO, OR#O and O#RO strings. Rubach suggests that medial R in ORO and final R in OR are unsyllabified and, for this reason, lack a voicing value: therefore the voicing values of the surrounding obstruents in ORO, OR#O strings are in fact adjacent and this triggers assimilation. I do not pursue this line of analysis: nothing establishes that the non-syllabic sonorants of OR# or ORO strings are in fact unsyllabified (as against non-syllabic) and there is little reason to believe that unsyllabified segments will be ignored by redundancy rules, assuming that the latter exist at all (cf. Steriade 1995).

2.3. German syllabification and devoicing

The case of German devoicing is discussed because several syllable-based analyses have been offerred for this phenomenon (Vennemann 1982, Rubach 1990, Hall 1992): I will suggest that they are not supported by the evidence. A second reason to look at German is that neutralization here is clearly incomplete, with durational differences continuing to maintain a lexical contrast between {p, t, k} and {b, d, g} in stem-final position: this is relevant in the present context because the property being neutralized is the VOT, which loses its cues in the _# context. The property being maintained is the durational aspect of voicing, which continues to offer detectable differences in the _# position. Therefore, the German data strengthens the correlation proposed here between cue distribution and licensing sites. Finally, German devoicing is cyclic not only at the phrasal level, as in the languages discussed so far, but also at the stem level: devoicing affects stem final obstruents before all productive consonant-initial suffixes. The incomplete character of German neutralization and its cyclic aspects are discussed elsewhere (section 5; Steriade 1996). This section will consider only the relationship between syllable divisions and neutralization sites.

2.3.1. The facts

The facts of German have been assembled most recently by Rubach (1990) and Hall (1992). As Rubach points out (1990:83), there is no directly observable correlation between syllable positions and licensing sites, since voiced codas are found in forms like *ebnen* 'to even out' [e:b.n´n] or *Ordnung* 'order' [Ord.nuN]. Rubach himself draws a rather different conclusion from this fact, but the bare fact is significant when compared to the identical situation observed in Lithuanian, Greek, Sanskrit, Polish and Russian. We have seen that the syllable is irrelevant to voice licensing in these languages: it would therefore be surprising if the very similar German facts called for a different analysis. In linear terms, the paradigm of German devoicing is - modulo the cyclic effects - identical to that of the languages discussed earlier: the stops are partially neutralized word-finally and before obstruents. We will see that there is no reason to assume that German differs fundamentally from languages analyzed so far in its characterization of [voice] licensing contexts.

The contexts of potential devoicing we have to consider for German are shown below. There are several cases of particular interest. First, we must consider OR clusters that cannot occur initially or occur only marginally there (stop-nasal, alveolar-l; class (b) below): these are relevant because they are *a priori* implausible onsets and have been reported as heterosyllabic by at least some of my sources. A second relevant class are O#R sequences (where # is a stem or prefix boundary; class (c) below); these illustrate the cyclic effects in devoicing. Finally, we will consider the OR#V sequences, where R alternates between syllabic and non-syllabic (e.g. *neblig* 'foggy' *[ne:bliç]*, *Nebel* 'fog' *[ne:bl`]* ; class (d) below). The table in (32) provides a synoptic view of devoicing and licensing in various contexts. Since judgments on syllabification in most classes are debated, the issue of syllabic division is separately discussed below.

(31) Contexts of [voice] licensing in German
(data from Bithell 1952, Duden 1962, 1966, Cassell 1978, Vennemann 1982, Rubach 1990, Hall 1992):

	Underlying voiced	Underlying voiceless
a. ORV (OR allowed in #_):	I[gl]u 'igloo' ~[kl]	Eklat 'altercation'
distinctive voicing maintained;	Bi[bl]iothek 'library' ~ [pl]	Diplom 'diploma'
optional devoicing reported by some.		
b. ORV(OR disallowed/ marginal in #_)	Ma[gm]a ~ [km]	Akme
distinctive voicing maintained;	A[dl]er 'eagle' ~ [tl]	Atlas 'atlas; satin'
optional devoicing reported by some.	Mö[dl]ing ~ [tl]	Rütli (place names)
	Si[gn]al 'signal' ~[kn]	Akne 'acne'
	La[dn]er ~[tn]	Eitner (proper names)
	Teu[bn]er ~[pn] (proper name)	
c. OR#V	Han[dl]-ung 'action' ~ [tl]	
distinctive voicing maintained;	Ra[dl]-er 'bicyclist' ~ [tl]	Schüttl-er 'shaker'
optional devoicing reported by some	ne[bl]-ich 'foggy' ~ [pl]	Kuppl-ung 'coupling'
	Schul[dn]-er 'debtor' ~[tn]	
	Re[dn]-er 'speaker' ~ [tn]	
	re[gn]-en 'rain' ~ [kn]	Trockn-er 'dryer'
	e[bn]-en 'flatten' ~ [pn]	
	wi[dm]-en 'dedicate' ~ [tm]	Atm-ung 'breathing'

(32) Contexts of [voice] neutralization in German

d. O#RV	Bil[t]-nis 'picture'	
voicing neutralized	bil[t]-lich 'pictorial, graphic'	rät-lich 'advisable'
	Erlau[p]-nis 'permission'	
e. O# #	Lan[t] 'country'	bun[t]'colorful'
voicing neutralized	ga[p] 'gave'	kna[p] 'tight'
f. O_1O_2	geha[p]t 'had (ppl)'	geden[k]t 'thought (ppl)'
voicing neutralized	gesa[k]t 'said (ppl)'	gepa[k]t 'packed up'(ppl.)
	sa[k]te 'said (3sg.)'	

Devoicing in final and pre-obstruent position is predicted by all accounts considered here, and therefore offers no diagnostic value. Neutralization in the O#RV context is a cyclic effect:; this point is elaborated in section 5. It is therefore occurrence of devoicing in other VORV contexts that we must concentrate on.

Devoicing is reported in the Duden Grammatik (1966: 57) to apply optionally in the colloquial language (Umgangssprache) in all contexts: for forms like *sigmatisch*, *Ebne*, *Händler*, *regnet*, pronunciations like *[zi:kmatiS]*, *[e:pne]*, *[hEntl´r]*, *[rEkn´t]* are said to coexist with standard *[zi:gmatiS]*, *[e:bne]*, *[hEndl´r]*, *[re:gn´t]*. Devoicing is crucially not limited to certain clusters: it applies generally, including in simplex onsets, as indicated by data from the same Duden passage: colloquial *Greis* is transcribed as devoiced *[g9rais]*, *Bärchen* as *[b9erç´n] leide* as *[laId9´]*. Therefore this variety of colloquial devoicing does not distinguish theories of voicing neutralization, being essentially context-free[17]. In the Hochsprache, on the other hand, devoicing takes place only in the contexts (d), (e) and (f) above: before obstruents, end of word and at the end of cyclic domains[18].

2.3.2. Correlations between neutralization and the syllable

We may now consider the evidence for correlating the contexts of devoicing in the Hochsprache with the location of syllable boundaries. On this point, there appear to exist two traditions. One is implicit in the syllabifications given by Cassell's dictionary and by Rubach (1990). According to Cassell's transcriptions, at least the medial stop-nasal, stop-j clusters are heterosyllabic: *Magnet, Signal, Magnesia, Adjunkt, Dogma* are transcribed as *[mag'nEt]*, *[zIg'nal]*, *[mag'nezia]*, *[ad'jUNkt]*, *[dOgma]* (the latter with laxing in closed syllable indicating *Dog.ma*) whereas unmarked OR clusters are transcribed as tautosyllabic: *Diplom [di.'plo:m]*. Rubach (1990:83) reports subject responses to the question of syllabifying OR#V sequences that coincide with Cassell's: *Handlung [hand.lUN]*, *Ordnung [Ord.nUN]*. *ebnen [e:b.n´n]* Although Rubach does not consider monomorphemic strings like *Dogma*, the syllabifications he reports suggest, like Cassell's, that speakers divide the OR clusters in the same way as English and (most) Romance speakers: unmarked OR is tautosyllabic, marked OR (stop-nasal, alveolar-l) is heterosyllabic. On this view of German syllable

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[17] Duden's report of optional devoicing in the colloquial language appears in abbreviated form in Hall (1992), where devoicing is said to occur optionally, in fast speech, in OR sequences (I[gl]u ~ I[kl]u, Du[bl]in ~ Du[pl]in). Hall , who advocates a syllable-based theory of voicing neutralization, analyzes this devoicing as the effect of an optional boundary shift (I.glu -> Ig.lu -> Ik.lu). Note however that fast speech devoicing occurs in cases where no boundary shift is possible: e.g. *Bärchen* realized as devoiced [pErç´n].

[18] We must distinguish neutralization - i.e. wholesale loss of voicing contrast - from the devoicing of individual tokens of voiced obstruents: thus *Admiral* is reported as containing devoiced [t] by the Duden Aussprache Worterbuch (1962) but appears with voiced [d] in Cassell's German Dictionary. This is an individual lexical matter, since the t/d contrast is clearly maintained before m according to both dictionaries: *Bodmen* 'floor', *Bodmerei* 'bottomry' are transcribed with voiced [d] in both of these sources, as well as Bithell (1952), Jessen (1996). Similarly, *Abner* is sometimes reported as devoiced [apner] but the b/p contrast is maintained before nasals through lexical items such as *Ebner*, *Grabner* (Jessen 1996). The incidence of devoicing in individual lexical items and its causes has not been studied.

structure, voice neutralization is unrelated to the coda position, since voicing is licensed in many codas, exactly as in the languages considered earlier.

A different, more influential view of German syllabification goes back at least to the Duden Grammatik, where the claim is explicitly made that voiced obstruents cannot stand at end of the syllable, "haben keine Silbengrenze unmittelbar nach sich" (1966:49). This view inspires the Duden to dictate syllabifications such as *Ma.gma, Re.dner, He.dschra [he.dZra], Pilsner [pIl.zn´r], fa.sre [fa.zr´]* and, presumably, *Bo.dmen, A.dler.* We can identify this tradition as the major source for Vennemann's (1972, 1982) and Hall's (1992) theories of voice neutralization in German. It should be noted however that the Duden is not endorsing a general policy of maximizing onset clusters, since for *tm, tl, km* clusters, the assignment reported is heterosyllabic: we are told to divide *Hyp.nose* not *Hy.pnose* (1966:410), *At.mo.sphä.re* (1965:561) not *A.tmo.sphä.re, Ath.let, At.lan.tik ([at'lEt] , [at'lantik]* both in 1962:136), not *A.tlan.tik, Ak.me ([ak'me:],* 1962:106) not *A.kme, Drechs.ler* (1965: 559) not *Drech.sler, Tech.netium [tÓEç.'netsium]* (1962:729) not *Te.chnetium*[19]. Bithell (1952:375) reports that some speakers follow some but not all aspects of the Duden system: *Adler* 'eagle' is indeed syllabified *A.dler* by these speakers but *Redner* 'speaker' is syllabified *Red.ner.* The difference, according to Bithell, involves awareness of a connection to *Rede* 'speech': the syllable boundary in *Red.ner* is felt to coincide with the major morphological division. Bithell's data then also suggests that syllable boundaries are orthogonal to devoicing since the speakers that intuit *Red.ner* nonetheless fail to devoice the [d].

The truly puzzling question that has emerged from this discussion is the basis for the intuition codified by the Duden that syllable boundaries should always precede the voiced stop: why *Ma.gma* vs. *Ak.me,* why *Bo.dmen* vs. *At.mos.phä.re* , *Pil.[zn]er* vs**.** *Te[ç.n]etium* . Given what we know about the typology of onset clusters in other languages (Levin 1985, Clements 1990, Ito 1986, Steriade 1982) one would expect the exact opposite assignments. Thus *dm, dn* are heterosyllabic in Attic Greek while *tm, tn* are possibly tautosyllabic. In Icelandic no voiced stop can form a complex onset with a following liquid: *Vg.rV but V.krV.* Why is German different?

I suggest that the intuitions of syllabification reported in the Duden reflect the use of phonetic vowel length as the unique cue to syllable divisions: vowels are generally shorter in closed syllables and this is a readily useable indication as to how clusters are divided (Maddieson 1985). Since vowels are also significantly longer before voiced obstruents, the extra length of the vowel in sequences like *Ma[:gm]a,*

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[19]The unmarked OR clusters are reported as tautosyllabic at least in: *Di.plom, Zy.klus, Sa.krament* (1965:560), although for native words the division sanctioned by the Duden is such that only the last consonant in a cluster opens the second syllable: *zweifenst.rig,* (1965:559). The heterosyllabic division of *pn, km, tm, tl* is not borrowed from the Greek sources of these words and must be counted as reflecting an aspect of German grammar: the Greek tradition on how to divide these clusters varies with dialect and period, as pointed out earlier.

Bo[:dm]en may be misanalyzed as cueing syllable boundaries rather than simply voicing. It is likely that for many speakers - including Bithell's, Cassell's and Rubach's - vowel length is just one of several conflicting indications of syllable assignment and may be overridden. Morphemic composition appears to be the overriding factor in Bithell's reported divisions such as *Red.ner*. For Cassell's and Rubach's speakers, considerations of onset markedness, as well as morphemic divisions appear to have a higher priority in deciding how to divide the clusters. On the other hand, for the Duden speakers, it appears that vowel length is either the only or the decisive cue to syllabification: if the vowel is tense in V:CCV, then the following cluster cannot close its syllable. Thus, by assuming that different speakers give different weight to various diagnostics of syllabification, we can understand the nature of the variation reported in the literature without rejecting any of the judgments. The very fact that the syllable divisions are murky and variable across individuals, whereas voicing neutralization in the Hochsprache is remarkably invariant, supports the idea that no interesting connections exist between the two[20].

To flesh this out, we suggest that the variability in syllable assignment should be modelled by the use of variably ranked constraints on syllable structure, such as *[tense V] in closed syllable, *obstruent-nasal onset, Align (root, R, syllable, R) (cf. McCarthy and Prince 1993)[21]. The category [tense V] abbreviates the durational category to which vowels in pre-voiced contexts belong. An undominated condition requires tense vowels of this category to occur before voiced obstruents. The difference between the Duden division (e.g. *Re.dner, Ma.gma*), the Bithell division (*Red.ner, Ma.gma*) and the Cassell-Rubach division (*Red.ner, Mag.ma*) emerges in this case as a simple matter of ranking:

[20] This point was verified for the present study when three speakers of German with identical devoicing patterns were asked to pronounce and then syllabify the critical sequences VORV (*Dogma, ebnen, Adler, Redner)*. All three speakers had voiced obstruents in their pronunciation of these words but all three reported uncertainty and variation with respect to the location of the syllable boundaries: two speakers (of Alemannic and Bavarian respectively) reported syllabification judgments identical to the Duden's except that *ebnen* and *Redner* were felt to be more likely heterosyllabic ['e:b.n´n], ['re:d.n´r], as reported in Rubach's study. A third speaker (of the Hesse dialect) reported heterosyllabic assignments for all clusters. All three speakers agreed that the marked OR clusters with a voiceless first member (e.g. *pn* in *Hypnose*, *tm* in *atmospherisch*) are heterosyllabic, as indicated in the Duden.

[21] I use the Align constraint here as shorthand for a set of intraparadigmatic correspondence conditions whose indirect effect is to generate the perception of aligned syllable and morpheme boundaries.

(33) Variable cluster divisions in German as the effect of variable ranking of cues to syllable structure :

a. The Duden division (*R[e:].dner, M[a:].gma*):

*[tense V] in closed syllable >> *obstruent-nasal onset, Align (root, R, syllable, R)

b. The Bithell division (*R[e:]d.ner, M[a:].gma)*:

Align (root, R, syllable, R) >> *[tense V] in closed syllable >> *obstruent-nasal onset

c. The Cassell-Rubach division (*R[e:]d.ner, M[a:]g.ma*):

*obstruent-nasal onset >> *[tense V] in closed syllable

I should emphasize, in closing this part of the discussion, that not even Duden's syllabification can be taken to support the idea of [voice] being licensed by the onset: what we have seen is that the Duden assigns the boundaries on the basis of the surface voicing of the obstruent. Therefore it is the voicing - or its consequences for the tense quality of the vowel - that induces the perception of syllable boundaries, rather than the syllable position dictating voicing possibilities. Only a circular theory of Licensing by Prosody may take comfort in the Duden data[22]. Since the surface distribution of voicing in German is either independent of the syllable (for Bithell's, Cassell's and Rubach's speakers) or actually dictates syllabification (for the Duden), we must characterize in syllable-independent terms where the voicing contrast is possible and where it's not. The same constraints that were justified for Lithuanian, Russian, Greek and Sanskrit are operative here: these are the cue-based constraints in (8).

3. A second voicing neutralization pattern: before obstruents only

The voicing contrast is frequently preserved word-finally, but not before obstruents. The analysis of this pattern will be based on three observations all of which justify the global statement that distinctive voicing is less perceptible and harder to implement before obstruents than in final, post-vocalic position. The first observation is that word-final obstruents have an advantage in the identification of the offset transitional correlates of voicing relative to word medial obstruents, since they are preceded by longer vowels: durational differences between final vowels, as well as F1 and F0 differences are probably easier to evaluate. Second, word final stops are more likely to be audibly released than stops in word internal stop-obstruent clusters: the quality of the burst itself may cue voicing or voicelessness (Lisker 1986; though see Hillenbrand et alii 1992). Third, the perception of voicing in word-medial obstruent clusters (e.g. *agta, akda*) may be determined by the laryngeal category of the second,

[22] The circularity is apparent in some characterizations of German syllable divisions: "The syllabification [...] is based on the non-application of Devoicing to the medial obstruent." (Hall 1992:89). Similarly, when discussing forms like *Ordnung*, whose voicing fluctuates ([OrdnuN] ~ [OrtnuN]) Hall attributes the fluctuation to differences in syllabification and states (1992:92-93): "Phonetic evidence for the two possible syllabifications [*Ord.nung and Or.dnung*] is that [...] voiced obstruents can surface as either voiced or voiceless." In other words, the devoicing is caused by the syllable structure, and the phonetic evidence for the syllable structure is the devoicing itself.

prevocalic obstruent, as documented by Slis (1986): *agta* may be perceived as *akta* and *akda* as *agda*. We can speculate that this is because the second obstruent benefits from the more informative release and VOT cues, whereas the first lacks them[23]. In contrast, the perception of voicing in a word-final stop preceded by a vowel (e.g. *ag*) will not be affected by the voicing of any other segment. In addition to this perceptual advantage of word final obstruents, there is an articulatory one: in a word-internal obstruent cluster whose members disagree in voicing (e.g. *agta, akda*) a fast transition is required between opposite states of the glottis (Hsu 1996). This is not the case when the obstruent stands alone at the end of the word. All these points justify the ranking of the two contexts V_# and V_[-son] on the perceptibility scale in (7). As anticipated earlier, there are no cases in which voicing is licensed before obstruents but not word-finally: this unattested pattern of devoicing is one that our ranking schema cannot in fact generate. There are numerous neutralization patterns of the sort anticipated in (9.ii), where voicing is neutralized before obstruents but not word-finally after vowels. They are discussed in this section.

Although this second voicing neutralization type has been documented (Mascaró 1987, Cho 1990, Lombardi 1991, 1995) the cases discussed in the recent literature involve only languages in which the site of neutralization could be roughly identified with the medial coda. This is the case with most contemporary Romance languages: French, for instance, has regular voicing neutralization before obstruents (e.g. *absent [apsa)];* Dell 1995) but maintains the contrast word finally (*laide [lEd]* 'ugly-fem' vs. *Lette [lEt]* 'Latvian'; *laisse [lEs]* 'let' vs. *lèse [lEz]* 'injures'). Thus, non-final codas are mostly neutralized in French and only phonotactically marginal forms like *dogme [dOg.m´]* 'dogma' show that the licensed voiced stops can also be medial codas.

The languages considered in this section neutralize voicing in the same contexts as French but are markedly different in syllable structure: I present here Hungarian and Kolami data that support a purely linear, syllable-independent analysis of this type of voicing neutralization. Both languages lack complex onsets, both initially and medially. Both languages preserve voicing before heterosyllabic sonorants as well as word-finally.

The Hungarian data (from Vago 1974, Njeki 1988) below shows neutralization before obstruents as well as *h*, a voiceless sonorant. This is exactly what we might expect if the absence of distinctive VOT values is a relevant factor in defining the context of voicing neutralization: a non-modal sonorant like *h* or or *n9* or *w0* will delay the onset of modal voicing and thus act like an obstruent in removing the VOT cue. No neutralization is observed before consonantal sonorants despite the fact that all CC clusters are heterosyllabic:

(34) Hungarian: a. Neutralization before obstruents

[23]This reasoning is modeled on Ohala's (1990) results involving the primacy of release place cues over V-C transitions.

abcug [aptˢug] 'resign!'
habcsók [hapc‹o:k] ' meringue'
lakzi [lagzi] 'wedding'

b. Neutralization before h:

hívhat [hi:fhat] 'he may call'
alábbhagy [ala:p:haJ] 'diminishes'

c. No neutralization word-finally:

rab [rOb] 'prisoner'
kalap [kOlOp] 'hat'

d. No neutralization before heterosyllabic R:

vedmeg [ved.meg] 'buy it !'
halottnak [halot.nak] 'death-elative'
átmegy [a:t.meJ] 'to cross
továbmegy [tova:b.meJ] 'to go forward'

The Kolami pattern is identical (Emmeneau 1955):

(35) Kolami a. Neutralization before obstruents:
va:Nk-tan 'I poured' va:Ng-dun 'I was pouring'

b. No neutralization word finally :
novvod '90' kudug 'thigh', ga:z 'bangle', sa:yeb 'sahib'

c. No neutralization before (heterosyllabic) sonorant:

voiced	voiceless
saye:b.na 'of the sahib'	te ep.ne 'of cloth'
bag.li.ak 'white heron'	paÊ.lak 'sharp edge'
sib.le 'man of exogamous division'	kop.li 'mouth'
saye:b.ral 'European woman'	tok.re 'shell'

sa:z.re 'good'	tis.re 'third'
pand.ri 'bathhouse'	kebut.ri 'pidgeon'
ad.ne 'of her'	put.niak 'brother's son'
	paȆ.lak.net 'of headman'

Voicing neutralization can be modelled in both of these languages as anticipated in (9.ii) above: the critical ranking is shown below.

(36) *α voice/ __[-son]

_

Preserve a voice

_

*α voice/ __#

_

*α voice/ __[+son]

For Hungarian, the analysis in (36) is incomplete, as the role of h is ignored. I defer the discussion of modal and non-modal sonorants as laryngeal licensing contexts to Part II.

In closing this section, we should consider two alternatives to the analysis proposed here. One is the possibility of accounting for the behavior of final obstruents by manipulating the boundaries of the prosodic word, in line with suggestions by Inkelas (1987): if the word-final consonant falls outside the boundaries of the prosodic word, then one might think that the context _# does not characterize its position. The diagram in (37) illustrates this mode of analysis (cf. also Lombardi 1991, 1995).

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(37)    Final C extraprosodicity:    morpho-syntactic word
                                     / / | \ \\  \
                                     CVCVCV  Cf
                                      \ \| / //
                                     prosodic word
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C_f in (37) is not at the right edge of the prosodic word and therefore no constraint mentioning that site will be applicable to C_f. This then appears to provide an alternative account for the difference in voice licensing between Russian-German and Hungarian-Kolami: C_f may be said to be effectively final in Russian but not in Kolami, if the representation in (37) applies to the latter. However, this suggestion is unworkable for practically all languages of the Kolami class: most of these impose minimality conditions on the size of the prosodic word, conditions that can be met only if C_f is counted in. Hungarian and Kolami lack C_0V content words, a fact normally interpreted as a symptom of undominated minimal size requirements. If C_f is excluded from the prosodic word in items like [rOb] - to describe its voicing - then we cannot explain the absence of equally sized words like *[rO]. Further, if the option to ignore C_f is introduced, then one predicts patterns of neutralization in which final obstruent clusters (i.e. VO_1O_2#) require O_1 to be neutralized but not necessarily O_2: this means hypothetical contrasts like *makt* vs. *makd.* Such cases are unattested (Greenberg 1968; cf. Cho 1990 for discussion). Finally, C_f is not systematically extra-prosodic in either Hungarian or Kolami: it triggers epenthesis in both languages when the word ends in an impermissible cluster. This damages even more the prospect of describing the voicing facts by declaring C_f selectively extraprosodic.

The second alternative is that pursued by Cho (1990), who distinguishes syllable-based from cluster-based laryngeal neutralizations (cf. also Rubach 1996). For Cho, German exemplifies the syllable-based pattern: but we have seen in section 2 that the facts do not support this option. Hungarian can be analyzed, in Cho's terms, as cluster devoicing. What remains unexplained, under this theory, is why the segmental environments of voice neutralization are so remarkably similar in languages with cluster-based and syllable-based neutralization: German-Russian-Polish-Greek-Sanskrit-Lithuanian and Hungarian-Kolami-French differ only, as far as voicing is concerned, in the status of word-final obstruents. It is unjustified to invoke fundamentally different neutralization mechanisms for these two patterns. Our analysis accounts for this minimal difference in terms of a minimal ranking change, (9.i) vs. (9.ii).

Thus the only viable analysis seems the one proposed here: voicing in French, Hungarian and Kolami is licensed word finally, not before obstruents, because the V_# position is superior to the V_O context in the range of cues it offers for the detection of contrastive voicing. Equally important is the fact that this analysis is the only one that explains the data by reference to independently observable facts: the different cue-to-effort ratios required for implementing contrasts in different contexts. In contrast, alternative analyses either fail to provide the principles of a general typology of voicing neutralization or else rely on representational properties like (37), the only evidence for which is the very data they are meant to derive.

4. Further patterns of voicing neutralization

The cases considered so far indicate that many apparent instances of coda devoicing should be reanalyzed as final or pre-obstruent neutralization. One argument against syllable-based statements in such cases was that codas can possess distinctive voicing, when they are followed by a sonorant, as in Polish *bez.alkoholowy,* Sanskrit *tig.ma*. or Hungarian *ved.meg*.

This observation raises however some further questions. First, are there cases of voicing neutralization before all consonants, regardless of obstruency: are there languages where inputs like *tig.ma* are realized as *tiK.ma* with a laryngeally neutralized stop in pre-sonorant position? Can such patterns be analyzed without reference to the syllable? Should they be so analyzed? Second, do we also find instances of voicing neutralization in the onset? We predict that such cases may occur if certain onset positions present diminished cues to voicing relative to the contexts where voicing is maintained.

This section takes up these questions with a view to expand our inventory of voice neutralization cases beyond the two positions (_ #, _ [-son]) studied so far.

4.1. Neutralization in the absence of following vowel

Voicing is reportedly neutralized in a number of languages in final and all pre-consonantal positions. Wantoat (Davis 1969), a New Guinea language, contrasts two stop series - {p, t, k} vs. {b, d, g} - prevocalically but allows only one undifferentiated class in other contexts. The consonant clusters contain at most two members, the first of which is always transcribed as voiceless, regardless of what follows: *jak.Na* 'leaves', *u.jap.ma* 'my younger sibling', *pa.kap.zon* 'you all bring them', *put.da* 'let us two break them'. The clusters *pn* and *tn* are also attested with voice-neutralized obstruents. A similar pattern is attested in West Tarangan (Nivens 1992), a language of Indonesia: the voiced-voiceless contrast in stops is lost word finally and before all consonants: thus intermediate *ke-b-laba* 'plank' is realized as *[kep.la.ba]* (p. 220) while *mata-b-sebar* 'eye discharge' surfaces as *[ma.tap.se.bar]*. As in Wantoat, final stops are neutralized to voiceless: *pit* 'night', *guk* 'suck', *tOp* 'short. Dialects of Quechua are also reported to possess this sort of neutralization.

In these languages, it appears that voicing is indeed limited to onsets: a heterosyllabic sonorant does not help maintain the contrast, since sequences like *bl, bn* are impossible. Before concluding that onset-licensing remains a necessary ingredient in the analysis of laryngeal neutralization, we must note that laryngeal contrasts are sometimes neutralized before consonantal sonorants even in languages where the relevant clusters form complex onsets. While Tarangan and Wantoat simply lack these, languages like Pacoh (Mon-Khmer: Watson 1964) and Sre (Mon-Khmer: Manley 1972) have complex onsets of the form stop-liquid but limit laryngeal contrasts to the immediately pre-vocalic position, as seen below. All consonants, including the voiced stops, occur as simple onsets in Pacoh but only the plain voiceless stops occur finally and pre-consonantally.

(38) a. Pacoh consonants:

p	t	tS	k	/
		s		
	b	d	dZ	g
	m	n		N
	w	l	r	y

b. Pacoh clusters:

(i) onsets:

pÓ	tÓ		kÓ
pr	tr	tSr	kr
pl			kl

(ii) $C_1.C_2(C_3)$: {l, r, m, n, , N} + { any onset)

It is also possible to view Pacoh as possessing unit aspirated stops, rather than stop-h clusters. Either way, the conclusion that *obstruent laryngeal contrasts are allowed only in prevocalic position* is clearly warranted: only this explains the systematic absence of onset clusters like *br, bl, pÓr, pÓl.* What is significant here is that laryngeal neutralization occurs both in codas (only plain voiceless stops are allowed word finally) and in complex onsets (when a liquid follows the stop). Coda devoicing can be invoked, but is neither sufficient nor necessary to characterize the distribution of voicing and aspiration. The Sre facts discussed by Manley (1972) are comparable: a three-way laryngeal contrast among the stops (plain, voiced-implosive, aspirated) is allowed only prevocalically. Complex onsets include laryngeally neutralized stops in C_1 position. All other pre-consonantal or final stops are also neutralized. Mikir (Grüssner 1978) is said to contrast voiceless unaspirated, voiced and voiceless aspirated stops before vowels, but only plain and aspirated stops before liquids. The partially neutralized Mikir stop-liquid sequences are tautosyllabic[24].

The Tarangan and Wantoat facts now appear in a very different new light: what looked at first like coda devoicing in these languages turns out to be an instance of a more general phenomenon of laryngeal neutralization caused by the absence of a following vowel. We conclude that this process is just as unrelated to syllable positions as the devoicing facts studied in earlier sections.

What remains unclear are the factors differentiating the pre-vocalic position - where distinctive voicing and post-aspiration are always permitted - from the pre-liquid, pre-nasal position, where some languages

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[24] The survey of laryngeal neutralization on which this study is based includes languages where voicing but not aspiration contrasts are neutralized pre-consonantally - including before tautosyllabic sonorants - as well as languages where aspiration is neutralized in the same positions but not voicing. I do not understand the basis for this variation and would conjecture that it may involve differences in transcriptional practices rather than actual production. Chepang (a Tibeto-Burman language; Caughley 1970) contrasts before vowels voiceless, voiced, aspirated and voiced aspirated stops, but limits the contrast to voiced-voiceless before liquids and neutralizes to a unique voiceless series in all other contexts. As in Mikir, the stop-liquid clusters of Chepang form complex onsets, indicating that this partial collapse of laryngeal categories may target the onset.

neutralize voicing/aspiration. One possibly relevant observation is made by Docherty (1992: 44ff) who notes significant increases in VOT between a given stop class before non-syllabic sonorants (OR) as compared to the same class in pre-vocalic position (OV). While in English this increase in VOT caused by the following sonorant is non-neutralizing, it is conceivable that in other systems this phenomenon renders the VOT values harder to interpret as voicing cues in the OR context, precisely because the voicing lag is different in the OV and OR strings. This is pure speculation. What is important is that, whatever the source of the difficulty in maintaining a voicing/aspiration contrast in OR sequences, it has nothing to do with syllables.

We may ask then: what would count as genuine evidence for syllable final devoicing? The simple answer is: any system that allows us to compare voicing maintenance in onset OR sequences with voicing neutralization in heterosyllabic O.R[25]. Thus the hypothetical language in (39) - inspired by but critically distinct from French - distinguishes voiced obstruents in the OR sequences functioning as onsets, but neutralizes voicing in every other obstruent-C sequence, including in heterosyllabic OR. The reader will find the comparison between fictitious and real French quite instructive since the facts of the real language are unintelligible under prosodically based analyses of voice neutralization[26]:

(39) a. Fictitious language similar to French: voicing neutralized in all codas
b. Real French: voicing neutralized before O

	a.		b.
onset obstruents	a.bri vs. a.pri		a.bri vs. a.pri 'shelter' 'learned'
	a.vr´ vs. a.fr´		a.vr´ vs. a.fr´ 'haven' 'terrors'
	e.kl´ vs. e.gl´		sjE.kl´ vs. E.gl´ 'century' 'eagle'
coda obstruents		doK.m´	dog.m´ vs. ak.me

---

[25]Cases like German *Liebling* (with heterosyllabic *b.l* and a laryngeally neutralized stop [li:plIN]) require a cyclic analysis, rather than coda devoicing: this point is discussed in section 5.

[26] Catalan is cited by Cho (1990:150) as possessing a pattern of voice neutralization similar to the fictitious language in (39). Cho analyzes Catalan on the assumption that this is a syllable-based neutralization. However, the data cited is very limited and involves segmentable prefixes like *sub* (*supmari* 'submarine') whose devoicing can also be attributed to a cyclic effect. Another language cited by Cho as possessing syllable-final devoicing - Dutch - turns out to pattern like Lithuanian: obstruents are neutralized word-finally and before obstruents, but not before heterosyllabic sonorants, in forms like *Ariadne* (vs. *Etna*) or *Abner* (vs. *hypnose*). This observation is due to Harkema (1997).

		'dogma'	'peak'
	maT.len	mad.lEn vs. (name)	Sat.lEn castle-lady
	aK.sa		ak.sa) 'accent'

We may conclude this section by reiterating the essential point: coda neutralization is insufficient, unnecessary and inadequate as a general account of the voicing typology. It is an insufficient account for languages like Pacoh, where onset stops are also neutralized preconsonantally; it is unnecessary for languages like Wantoat, whose devoicing patterns can be characterized in linear terms identical to those needed for Pacoh: all obstruents neutralize unless prevocalic. Finally, coda devoicing is drastically inadequate for all other languages studied so far, since the codas in O.R sequences do not neutralize in any of them. This class of cases is by far the most abundantly documented.

4.2. Onset devoicing

The existence of onset neutralization in Pacoh requires us to turn now to one of the key predictions of the model presented here. We have focussed so far on two classes of contexts where the voicing contrast necessarily lacks VOT and other release cues: these are the final and pre-consonantal position. In both of these contexts a stop is most likely to be syllabified as a coda. But certain unambiguous onset positions can also be identified in which the perception of voicing is made difficult by the absence of - or difficulty in implementing - other voicing cues. We predict for such cases as well a greater likelihood of neutralization relative to the contexts in which all voicing cues are equally available: the fact that these are onset positions is immaterial.

Thus utterance initial as well as post-obstruent onsets will lack all cues normally residing in the preceding vowel or sonorant (V_1 duration, F_0, F_1 values at the onset of closure) and may lack the closure duration cue. Therefore the #_V context is less likely, ceteris paribus, to maintain voicing contrasts than the V_V context. Since the utterance-initial properties of words are frequently extended to the utterance-medial realizations, we have here the potential source of word-initial voicing neutralization. Moreover, vocal cord vibration during the obstruent's closure will be more difficult to insure in utterance-initial (and, by paradigmatic extension, word-initial) position, because of insufficient subglottal pressure (Flege 1982, Flege and Brown 1982, Westbury and Keating 1985). This is a second reason why we might expect word-initial stops to be targetted for voicing neutralization. After a voiceless obstruent, voicing during closure will also be difficult to implement: in a cluster such as *asda*, if *s* is truly voiceless, vocal cord vibration can be obtained for *d* only through precisely timed articulatory maneuvers that create a sudden transglottal pressure drop. As Westbury and Keating (1985:162) point out, "expenditures of the latter sort are articulatorily costly." If such efforts are not undertaken, then all post-voiceless stops will lack voicing during closure. The investigations of Flege (1982), Docherty (1992) for English and Jessen (1995) for German indicate that in languages where the voicing contrast is maintained in initial and post-obstruent stops, it is maintained mostly without the benefit of the closure voicing cue.

With this in mind, let us consider the fate of the voicing contrast in the word-initial and post-obstruent context. We limit the discussion to two contexts where voicing is in principle identifiable on the basis of VOT distinctions and other release-bound cues: #_(R)V and O_(R)V. Consider now the comparison between the #_(R)V context and the V_(R)V context. We have seen that the #_(R)V context benefits from fewer cues to voicing relative to the V_(R)V context; and also that the closure voicing cue, which is potentially available in both contexts, is articulatorily harder to obtain in #_(R)V than in V_(R)V. Therefore a cue-based model of neutralization predicts the existence of systems where distinctive voicing is maintained intervocalically but lost initially. The conflicting preference for deploying feature contrasts word-initially (Bosch 1992; Casali 1995a, b; Hsu 1995; MacEachern 1995; McCarthy and Prince 1995; Steriade 1993, 1995) softens somewhat the strength of this prediction and explains why initial neutralization is considerably less frequent than one might otherwise expect. But the prediction stands.

That initial voice neutralization does exist has already been pointed out by Keating et al. (1983) and Westbury and Keating (1985). Here are two cases not included in their survey. Lac Simon (Kaye 1979, 1981, Iverson 1983), an Algonquian language, has an intervocalic voice contrast among obstruents, and voice-neutralized obstruents initially. The initial neutralization affects loan words: [pa:na:n] is Lac Simon for *banana*[27]. In addition, Lac Simon neutralizes voicing word finally and in all obstruent clusters: attested obstruent sequences are *sk, sp, St, Sk, Sp*. The other case is found in Totontepec Mixe (Crawford 1963), a Mixtecan language of Oaxaca. The Totontepec obstruents contrast for [voice] intervocalically but not initially. The clearest reflex of this limitation involves the fricatives: *ß* and contrast in *wø oy* 'embroidered' vs. *nøßoya* 'shirt' but only **ß** occurs initially, finally, as well as before or after obstruents: *ßu:ßpa* 'musician', *tødøpuß* 'he already cut it', *mnøhkßup* 'you're going' . The same holds for all other obstruents, with the only difference that voiced stops are lenited intervocalically, hence VtV contrasts with VDV rather than VdV.

Note that this pattern of neutralization is also impossible to characterize in syllabic terms: what neutralizes in Lac Simon or Totontepec are all the codas plus a subset of the onsets. The initial neutralization can be straightforwardly analyzed by observing the difference between V_V and #_V contexts on the perceptibility scale, with #_V inferior to V_V. This is mirrored by the ranking of constraints: *α *voice/ #_V* >> *α *voice/ V_V***.** What distinguishes Lac Simon and Totontepec from the languages studied so far is the fact that *Preserve*

[27]The neutralized initial stops of Lac Simon are realized as voiced when preceded by a vowel across certain boundaries. We discuss this effect in section 5.

voice ranks in this language below *αvoice/ #_V* but above *α voice/ V_V.* Both contexts mentioned are relatively favorable to the identification of voicing, but this class of languages apparently maintains voicing only under the most favorable circumstances, namely only when all internal and transitional cues are easily implemented.

A different instance of onset neutralization is progressive devoicing, a process attested in Basque (Hualde 1991, Artiagoitia 1993): after a voiceless sound, all obstruents surface as voiceless. The directionality of the process can be determined by observing the [+voice] value of the second obstruent after vowels or after **r**, contexts where distinctive voicing is maintained in Basque. Progressive devoicing applies both word-internally and across the boundaries of certain function words, but does not normally affect the initial of content words. The voicing contrast in Basque is limited to the contexts #_V, V_V and R_V: no voicing distinctions occur finally or in obstruent clusters. Progressive devoicing is illustrated below:

(40)	a.	-garren	(ordinal morpheme)	(Artiagoitia 1993: 267)
		amar-garren	'tenth'	
		/boçt-garren/ [boçkarren]	"fifth'	
	b.	da	"is"	
		laguna da	"it's a friend"	
		es ta [esta]	"is not"	

The same progressive devoicing process results in incomplete and/or variable neutralization in Dutch (Slis 1986) and for certain German speakers (Jessen 1995). The German voiced stops following a voiceless sound (as in the *[kd]* of *Ma[kd]eburg*) are realized without closure voicing but maintain a shorter VOT sufficient to distinguish them from the underlyingly voiceless stops. The German data confirm that the primary cause of post-voiceless neutralization is the difficulty in implementing closure voicing, possibly combined with the absence of offset cues such as V_1 duration. What happens in Basque is then simply the categorical version of the same process.

The analysis of the Basque pattern appears in (41). The constraints in the left column are projected by an expanded version of the voice perceptibility scale in (7), one which includes the difference between implementing voicing in the optimal V_V context vs. the #_V or [-voice]_ V contexts. The difference between V_V and #_V or [-voice] _V involves the possibility of generating and sustaining the closure voicing cue. This difference accounts for the ranking between (41.v) and (41.vi). The right hand column in (41) contains two **Preserve voice** constraints. The second, ranked at the top, is the more specific condition requiring preservation of voicing in word- initial position: **Preserve voice in #_** . The tendency to preserve *all* attributes of the word's left edge is well attested: this is formalized here as the ranking **Preserve voice in #_ >> Preserve voice** (cf. Casali 1995, Beckman 1995, MacEachern 1995, McCarthy and Prince1995). I assume here that the Basque function words subject to progressive devoicing are part of the prosodic domain defined by the preceding content word (Selkirk 1995): therefore /da/ in /es-da/ is in effect word-medial and the constraint **Preserve voice in #_** does not protect /d/'s voicing in this context.

(41) <u>Voice Perceptibility Conditions</u> <u>Faithfulness Conditions</u>

(i) *αvoice / [-son] __[-son], [-son] __#,
#__[-son]

(iii) *αvoice/ V_ [-son]

(iv) *αvoice/ V_ #

Preserve #[αvoice]

(v) *αvoice / #_ V, [-voice] __ V

Preserve [αvoice]

(vi) *αvoice/ V_ V

The hierarchy in (41) will derive the following aspects of the Basque voice contrast: (a) neutralization before obstruents and word-finally is induced by the ranking *αvoice/ V_ [-son] >> *αvoice/ V_ # >> Preserve [voice]; (b) preservation of voicing in the #_ V context is due to the ranking Preserve #[αvoice] >> *αvoice / #_ V, [-voice] __ V; (d) neutralization of voicing in post-voiceless contexts derives from *αvoice / #_ V, [-voice] __ V >> Preserve [αvoice]. I postulate a single constraint *αvoice / #_ V, [-voice] __ V - whose source is the difficulty of implementing closure voicing in these contexts - and derive the difference between word-initial and post-voiceless positions by letting this constraint interact with the principles of faithfulness (Preserve [α voice]) and positional faithfulness (Preserve #[αvoice]). I have not offerred here any evidence for the ranking between the constraints (iii) and (v); the facts of Basque could have been generated under alternative rankings. What may justify this aspect of the hierarchy is the observation that initial and post-voiceless neutralization is known to happen only in languages like Totontepec or Lac Simon, where final and pre-obstruent stops are also neutralized. And similarly, post-voiceless neutralization happens in Basque, where final and pre-obstruent stops are neutralized as well. A more general way to formulate the conjecture that underlies the ranking of *αvoice constraints in (41) is that voicing is less perceptible in contexts lacking onset cues (burst-plus-transitions) than it is in contexts lacking closure voicing and the offset cues.

5. Cyclicity, uniformity and related effects in voice neutralization

Most voice neutralization processes are word-bound: the obstruent is neutralized by reference to word boundary domains, regardless of potential cues to voicing that might lie outside of its word domain. The typical case, that of Lithuanian phrases like *dauk akmens* has been mentioned earlier: the underlying */g/* of */daug/* is word-final and neutralized here despite the fact that a vowel follows that would have permitted recovery of the voicing correlates[28]. The converse case occurs as well: Lac Simon obstruents are neutralized word-initially as well, even when preceded by vowels within the phrase.

The suggested analysis for these facts will appeal to the notions of morpheme invariance or paradigm uniformity that have recently resurfaced in an OT context (cf. Kiparsky 1970, 1968; and Benua 1995, Flemming 1995, Kenstowicz 1995, Steriade 1995, 1996). I suggest that in the languages where obstruents neutralize at word edges, regardless of the larger syntactic context, their realization is determined by the interplay between phonetic implementational factors and constraints promoting morpheme invariance or minimization of allomorphy. More specifically, the suggestion is that the voice-neutralized word edge takes on invariably *the form that would be phonetically natural in the citation form*. Consider again the case of Lithuanian *dauk*. In the citation form of this word, the underlyingly voiced /g/ occurs utterance finally, where onset cues to voicing cannot be detected. We assume it is neutralized utterance finally for this reason, in virtue of the ranking in (9.i), as shown earlier. All utterance final consonants show a general tendency to devoice, due to the loss of subglottal pressure (Westbury and Keating 1985). The neutralized utterance-final stops - which lack a voicing specification - will therefore be subject to passive devoicing and perceived as voiceless. Constraints promoting paradigm uniformity are then responsible for generalizing the properties of the citation form to utterance-medial positions. In the case of */daug/*, the devoiced *[k]* is extended to those allomorphs of /daug/ that stand in a productive paradigmatic relation to the citation form. For our purposes, simplifying somewhat, we'll assume that this type of paradigmatic extension takes place only between word-forms. Therefore citation form properties will not be extended to allomorphs created through affixation (e.g. *daug-a*) , but they will be extended to utterance-medial, word-final instances of /daug/. This accounts for phrases such as *dau[k] akmens*. The specifics of this proposal are justified elsewhere (Steriade 1996). One relevant constraint is (42).

(42) **Paradigm Uniformity (right edge)** - abbreviated **PU edge**

Assume that the string Σ represents the last demisyllable in the citation (utterance-final) form of morpheme μ; and that the string Σ' represents the correspondent of Σ in a word-final, utterance medial position; then Σ and Σ' must be identical in feature composition.

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[28]It should be noted that voicing distinctions *can* be licensed by the larger phrasal context. In Czech, for instance, distinctively voiced stops occur before a sonorant, even across word boundaries, as in /naro:d roste' 'the nation grows', which may be realized as [naro:d roste] (Kucera (1961:59).

To obtain invariably neutralized word-final stops, as in *dauk akmens*, regardless of utterance position, we must let **PU edge** outrank **Preserve [voice]** in the constraint hierarchy of (7.i). The effect of this ranking is illustrated below. We evaluate simultaneously the citation form of */daug/* and the realization of */daug/* phrase internally in forms like */daug akmens/*. Each mini-paradigm is a distinct candidate. We will correspondingly change our assumptions about the meaning of the context __# : henceforth, we assume that _# means final in the utterance, rather than followed by the end of the word. End-of-utterance properties may become invariant end-of-word properties through the effect of uniformity conditions like (42).

(43) PU edge , *α voice/V_ # >> Preserve [voice]

	PU edge,	*α voice/V_ # >>	Preserve [voice]
daug		!*	
daug akmens			
======			
dauk			*
dauk akmens			*
======			
dauk	!*		*
daug akmens			

We must consider now the difference between Lithuanian, where neutralized stops are invariably realized as voiceless, and languages like Sanskrit in which the word-final stops are neutralized, but their realization varies with the syntactic context. I discuss this case below, because it continues our argument that references to the syllable are unnecessary in laryngeal neutralization, and because it sheds some light on an assumption made earlier that laryngeally neutralized consonants differ from distinctively voiceless unaspirated stops.

Consider a Sanskrit root like */dÓagÓ/* 'reach to' realized as *[dÓak]* in pre-pausal context. This word possesses a voice-neutralized final stop in all phrasal contexts where it occurs. This fact is to be accounted for in the terms suggested above: the citation realization of the stop is extended to all other syntactic contexts. However, unlike Lithuanian *k* in *dauK*, the neutralized Sanskrit *K* is contextually variable: all word-final stops, regardless of derivational origin, are realized as voiced before voiced segments, and as voiceless before voiceless ones. As the data below indicates, this contextual voicing process affects only the neutralized stops, not the distinctively voiceless ones.

(44) Laryngeally neutral stops in sandhi (data from Allen 1955)

	Underlying	Phrase final	Before sonorant	Before obstruent
a.	/trißÊub^h/	trißÊu[p]	trißtu[b] nu:nam	trißÊu[p]-tu
b.	/arwa:c/	arwa:[k]	arva:[g] ra:dhah	
c.	/gamat/	gama[t]	gama[d] wa:jebhih	
d.	/ßaß/	ßa[Ê]	ßa[ ] aßi:tayah	
e.	/tat/	ta[t]	ta[d] asti	

f.	Word-internal, non-neutralized stops no voicing assimilation	Word-final neutralized stops voicing assimilation
	stab^{h}noti, apnuvanti	trißtu[b] nu:nam

Let us first understand the variability in the realization of neutralized stops. The puzzle here is this: we claim that the word-final stop is neutralized utterance-finally in a form like *trißÊu[p]***,** and that the neutralized stop is generalized through **PU edge** to other positions within the utterance. But **PU Edge** requires featural identity between utterance final *[p]* and its utterance-medial correspondents: therefore **PU Edge** should inhibit voicing in *trißtu[b] nu:nam***,** contrary to fact. A general constraint inducing voice assimilation and outranking **PU Edge** cannot be invoked here because, as the data in (43.f) shows, only neutralized stops assimilate.

The solution will invoke the distinction between auditory and articulatory features (Flemming 1995). I suggest that paradigmatic conditions like (42) may require uniformity either with respect to auditory properties or with respect to articulatory properties. In languages like Lithuanian, the **PU Edge** condition requires *auditory* identity between the devoiced utterance-final stops and their utterance-medial corespondents. This means that all word-final stops must *sound* voiceless, even though this result will have to be obtained through different articulatory means in different positions of the utterance. In languages like Sanskrit, I suggest that the paradigmatic uniformity effect involves articulatory posture rather than auditory results: all word-final stops, regardless of utterance position, must possess articulatory representations that lack a glottal target. In the gestural terms of Browman and Goldstein (1992) word-final stops must be identical to utterance final stops in possessing an articulatory scores whose glottal tier is empty of all action. The result will be, as suggested by Hsu (1995) for Taiwanese, that word-final stops will be realized with laryngeal states interpolated from neighboring segments. When surrounded by voiced segments, the neutralized stops will be realized with an adducted glottis: the pre-sonorant voicing shown in (44) is due to this interpolation effect.

The same proposal may account for the voice alternations observed by Kaye and Iverson in Lac Simon, the Algonquian language in which word-initial obstruent are voice-neutralized. The word-initial stops are normally realized as voiceless, but they voice when prefixed with a vowel. This is the mirror image of the

Sanskrit alternations in (44): the two languages share the fact that only positionally neutralized stops are subject to contextual voicing.

The last remark on the cyclicity effects in voicing neutralization involves the German paradigm mentioned section 2.3. The German datum in need of explanation is the difference between vowel initial and consonantal sonorant-initial suffixes. The latter induce final devoicing, the former do not. Compare the forms in (45):

(45)	word-final	before +V	before -r, -l or -n suffixes
	Bil[t]	bild-en	Bil[t]-nis, bil[t]-lich
	ga[p]	geb-en, Ergeb-ung	Erge[p]-nis

We assume that the voiceless stops in *Bil[t]nis* and *Erbe[p]nis* are PU effects: the stops will have voiceless realizations when utterance final and voicelessness is generalized to other allomorphs. But then it appears that we should also expect **bil[t]en*, **ge[p]en*, by the same argument. A possible solution will take the following form. Paradigmatic uniformity is more stringently enforced between allomorphs that are already very similar to each other, in phonological or morphosyntactic properties. This point is illustrated abundantly in the literature on analogical extension (cf. Hock 1986 for review). Conversely, allomorphs that are necessarily different in one respect, accentually or segmentally, are under less pressure to be strictly identical in their other phonological properties (Steriade 1997). Note now that the stem final stops in (45) are syllable-final in word-final and pre-consonantal position (*ga[p]*, *Erge[p].nis*) but syllable-initial before V-initial suffixes (*Er.ge.[b]ung)*. It is then possible that the paradigm uniformity condition responsible for the distribution of voicing in German stem-final stops, requires featural identity only between stops that occupy the same position in the syllable: this will require then that the coda labial stops be featurally identical, but will allow onsets (as in *Er.ge.bung*) and codas (as in *ga[p]*) to differ in voicing.

Note that this analysis invokes the syllable only to require that corresponding segments with identical syllabic positions also be featurally identical. Syllable assignment is not invoked as the explanatory factor in the distribution of voicing.

6. Summary to this point and transition to Part II

The discussion so far has established several points. First, voicing neutralization is not driven by syllabification in any context. We have not encountered a single genuine instance of devoicing that can be said to be caused by the coda assignment of the obstruent. We have observed languages with different syllable structures but identical linear contexts for voicing neutralization (Lithuanian vs. Sanskrit; French vs. Kolami). We have also observed that fluctuations in the syllabic assignment of OR clusters (V.ORV ~ VO.RV) are not accompanied by fluctuations in the application of voice neutralization. Distinctive voicing is frequently maintained in codas (e.g. Lithuanian *skob.nis*) or lost in onsets (e.g. Lac Simon *pana:n*), thus disconfirming in multiple ways the predictions of Licensing by Prosody. Further, we have observed an implicational relation between contexts of neutralization (e.g. if devoiced in _# then devoiced in __[-son] but not vice versa) which relates clearly to cue distribution rather than prosodic assignment.

These findings are all consistent with the hypothesis of Licensing by Cue. As noted earlier, however, there are several ways in which contrast perceptibility, the factor identified here as the key to neutralization, may be reflected in the grammar. So far, we have provided only descriptions based on statements like ***[a voice]/ #_ [-son],** which identify indirectly, in standard featural vocabulary, a context prone to neutralization. There is no mention of the missing cues in the description #_ [-son]. The alternative yet to be explored is that the grammatical statements refer directly to the quality of the information provided by the context: for instance, a conceivable substitute for ***[a voice]/ #_ [-son]** is ***[a voice]/ in contexts where voicing lacks transitional cues** . This is a plausible interpretation in the context of our claim that ***[a voice]** conditions are projected from perceptibility scales: if the latter are truly observations about relative perceptibility, then it is more likely that they refer directly to cues, rather than indirectly, through mention of the features that facilitate their perception. We consider in Part II the advantages of this second type of description, as we extend the study of laryngeal neutralization to contrast types not considered yet.

One argument developed in Part II will be based on the observation that the contexts of neutralization depend on the distribution of transitional cues in the surrounding context, which in turn depends on the timing of laryngeal gestures relative to oral constrictions (cf. Kingston 1985). The timing facts differ from language to language: aspirated stops are postaspirated in Sanskrit but pre-aspirated in Tarascan. Timing differences engender drastic differences in cue distribution, which in turn entail differences in neutralization contexts: indeed Tarascan and Sanskrit neutralize their aspiration contrast in very different contexts. We will suggest that direct reference to the quality of cues can provide unified descriptions for languages that differ in laryngeal timing, descriptions that allow a better recognition of the ways in which grammars do and do not differ from each other. Thus, we will suggest that Tarascan and Sanskrit differ from each other in the choice of laryngeal timing patterns, but not in the range of constraints relevant to the description of neutralization: those constraints may be the same, but their interaction with timing conditions yields different surface results.

A different argument for cue-based descriptions will have to do with the adequacy of features like [sonorant] for the description of laryngeal neutralization contexts. A statement like ***[a voice]/ _ [-son]** is useful to the extent that [-sonorant] encapsulates the correct class of neutralizing segments. However, we have seen that the segments inducing voice neutralization to their left include [h], a sonorant under most assumptions (Chomsky and Halle 1968:305), as well as strings in which the potential duration of modal voicing following the obstruent is too brief to serve as a useable indication of VOT category. The last point has been established in the analysis of Russian and Polish voicing: word medial O_1RO_2 sequences - with shorter R - neutralize O_1 whereas word final OR# - with longer, less overlapped R - maintains distinctive voicing in Russian. Similarly, non-syllabic R in the O_1RO_2 context fails to license voicing in O_1 whereas syllabic R does: the difference between the class of sonorant strings allowing distinctive voicing to their left and those which do not is a function of the duration of the string on which transitional cues like VOT are manifested. The global conclusion then is that we cannot adequately characterize the context that licenses voicing in languages like Hungarian or Polish as _[+sonorant], since a short, overlapped or inherently voiceless sonorant will not be a licenser. The invariant licensing factor is the ability of the context to express transitional onset cues such as VOT, F0 and F1 values. This argument is extended in Part II.

Part II: Cue-based descriptions of laryngeal neutralization

1. Outline of Part II

The discussion of laryngeal licensing focusses now more narrowly on the nature of grammatical statements that model neutralization. This second part of the study examines to what extent phonetic implementational factors must be directly referred to in grammatical descriptions of neutralization. The argument made here is that laryngeal licensing patterns result from the interactions of grammatical conditions, some of which refer directly to phonetic implementation. These factors involve: intergestural timing, gestural magnitude, and contrast perceptibility, i.e. the nature and relative duration of cues available in a given context for the identification of a specific contrast. It is arguable that these implementational factors must not only play an indirect, evolutionary role in shaping grammars but must also be reflected in the formulation of synchronic grammatical statements.

One central point to be established is the connection between the contexts of laryngeal neutralization, the timing of oral-to-glottal gestures, and the distribution in the surrounding context of transitional cues to the laryngeal features. This correlation is formulated below. The reader is reminded of the distinction used in Part I between *internal* cues to a laryngeal feature (cues residing during the period of oral constriction of the corresponding segment) and *transitional* or *contextual* cues (cues perceptible outside the period of oral constriction).

(1) Consider a segment x defined by an oral constriction feature G and containing a laryngeal feature F.

a. **When F leads G**:

(i) Effect of timing on contextual cue distribution:
If the onset of F in x precedes the onset of G, and the offset of F does not follow the offset of G, then transitional cues to F may occur only or primarily in the context preceding x.

```
[-------F----------]          or      [---------F----------]
    [----G-------]                          [-------G---------]
```

(ii) Effect of cue distribution on neutralization:
The context preceding x will determine primarily whether F is neutralized.

b. **When F lags behind G**:

(i) Effect of timing on contextual cue distribution:

If the onset of F in x follows the onset of G, and the offset of F does not precede the offset of G, then transitional cues to F may occur only or primarily in the context following x.

```
[----F------------]          or          [----F-----------]
[----G-------]                       [-------G---------]
```

(ii) Effect of cue distribution on neutralization:

Then the context following x will determine primarily whether F is neutralized.

The diagrams in (2)-(3) - from Part I - illustrate these hypotheses. As is implicit in (1), the features we refer to are articulatory features and they are given representations inspired by the gestural scores of Browman and Goldstein (1992 and references there). The diagram in (2) illustrates (1.a). The laryngeal feature represented there is aspiration, whose gestural counterpart is glottal abduction: in (2), the onset of abduction precedes the onset of the oral constriction and the abduction offset does not follow that of the stop's oral gesture. If a glottal abduction feature timed in this way generates any transitional cues, then such cues will necessarily be found in the context that precedes the segment. This follows from the timing relation postulated. Note that (1.a) does not predict that a pre-aspirated stop will always possess transitional cues in the preceding context: whether such cues are present or not depends on what segment precedes and on the timing relations between that segment and the abduction gesture depicted in (2). However, if any transitional cues do exist, then they will have to be located in the preceding context. The testable hypothesis in (1.a) is that the survival of the contrast between [Ót] in (2) and unaspirated [t] will depend on the context carrying the transitional cues, which in this case is the preceding context. Note that in the absence of transitional cues, preaspirated [Ót] and unaspirated [t] are essentially indistinguishable.

(2) Peak of laryngeal gesture timed to onset of oral constriction: e.g. ^{h}t

```
                [-------glottal abduction-----]
                     [-----oral closure---release ----]
transitional cues for a
abduction here
```

The diagram in (3) illustrates (1.b). In the case of the *tÓ* depicted in (3), the onset of glottal abduction follows the onset of the oral constriction and its offset does not precede that of the stop's oral gesture. Aspiration timed in this way may generate transitional cues only in the context that follows the segment. Once again, whether *tÓ* will in fact possess transitional cues in some context will depend on additional factors, such as the nature of the following segment and its timing relative to *tÓ* . The hypothesis formulated in (1.b) is that the contrast between a segment like *tÓ* in (3) and an unaspirated *t* will be preserved or neutralized depending on the nature of the following context, the context that carries transitional cues to aspiration.

(3) Peak of laryngeal gesture timed to release of oral constriction: e.g. t^h

[--------glottal abduction--------]
[----oral closure ---------release-]
context cues for a
laryngeal feature here

A version of (1.b), as the link between oral-glottal timing and cue distribution, has been noted by Kingston (1985: 246), in the context of his theory of articulatory binding (cf. also Kingston 1990). The statements in (1) will be documented here by comparing post-aspirated with pre-aspirated stops (e.g. *tÓ* vs. *Ót)* and post-glottalized with pre-glottalized consonants (e.g. *t'* vs. */n*). Post-aspirated and post-glottalized consonants (*tÓ*, *t'*) are typically neutralized depending on what follows; pre-aspirated and pre-glottalized consonants (*Ót*, */n*) neutralize depending on the preceding context. The connection between timing, cue distribution, and directional asymmetries in neutralization has also been observed for other features, such as retroflexion and palatality (Steriade 1993, 1995), and is thus likely to reflect a general property of contrast maintenance.

Based on the generalizations in (1), we will reconsider in this part the format of contextual constraints provisionally used in Part I, such as ***[aspiration]/ __[-sonorant]** or ***[aspiration]/[-sonorant]__** in favor of statements such as ***[aspiration]/ in contexts lacking transitional cues.** The argument for direct reference to cues will be based on the ability of various constraints to generalize across differences in oral-glottal timing: *tÓ* fares best when followed by a sonorant and *Ót* fares best when preceded by a sonorant. We can describe both situations in a unified way by saying that distinctive aspiration, however timed, must possess transitional cues. Language-specific timing conditions will determine independently where transitional cues are found. The idea then is that by opting for cue-based statements like ***[aspiration]/ in contexts lacking transitional cues** we locate more precisely the source of cross-linguistic differences: languages that neutralize the aspiration contrast T/ÓT after obstruents differ from those that neutralize the T/TÓ contrast before obstruent primarily in their timing patterns. Differences in neutralization sites between the two types of languages should follow from the timing difference, under the appropriate theory of neutralization. Timing and neutralization differences should not be separately stipulated.

A related point involves the grammatical interaction between the constraints that characterize oral-glottal timing and perceptibility constraints such as ***[aspiration]/ in contexts lacking cue X.** We will observe two types of interactions: (a) the oral-glottal timing varies with context, such that changes in timing are induced by the demands for transitional cues; and (b) the oral-glottal timing is invariant across contexts and leads to neutralization in the positions where transitional cues are absent or diminished. The need to characterize both type (a) and type (b) systems will also be seen to support direct reference to perceptibility factors in the statement of grammatical conditions leading to neutralization.

The languages considered in this part - selected primarily for their relevance to the cue-timing connection in (1) - also bear on a different issue in the grammar of neutralization: data involving neutralization differences between longer and shorter sonorants, or between sonorants and obstruents, will suggest that the overall duration of the string on which cues are expressed also plays a role in neutralization. It will be suggested that perceptibility scales rank contexts also according to the relative duration of the cues they offer for a given contrast. The grammatical reflex of such scales will be constraint families such as ***F/ in contexts with shorter cues >> *F/ in contexts with longer cues,** where *longer* and *shorter* will refer to the relative duration of the entire string over which the perceptual correlates of F are manifested.

2. Aspiration contrasts

It was anticipated that the cues for any contrast depend on the timing relations between the feature and the context, both inter- and intrasegmental. If the contrast is signalled primarily by transitional cues and these reside in the preceding context, then that side of the context will determine whether the contrast is licensed or neutralized. Similarly, if the contextual cues are manifested in the vicinity of the consonantal release, then the following context will determine the likelihood of neutralization.

Post-aspiration contrasts (T/TÓ) were briefly considered in section 2.1.3, where we noted that the context following the TÓ has the most potential to induce neutralization: Greek, Sanskrit and Khasi neutralize aspiration distinctions in the absence of a following sonorant, i.e. at the ends of words and before obstruents. To these languages, we may add Wiyot (Teeter 1964 and Gensler 1986), Takelma (Sapir 1922), Quechua (MacEachern 1995), Korean (Kim-Renaud 1974) and Chiricahua Apache (Hoijer 1944) as further examples of the loss of distinctive *post* -aspiration in final and pre-obstruent position. To reiterate a point made in Part I, contrasts based on post-aspiration are not conditioned by the syllabic context: clusters such as Greek *tÓm* and Sanskrit *bÓn* can or must be heterosyllabic, without any syllabic effect on the survival of aspiration. This cannot be shown for all languages that display the T/TÓ contrast, since some lack the heterosyllabic obstruent.sonorant (TÓ.R) sequences, while others may block all TÓR clusters, regardless of syllable boundaries. But all the post-aspiration data is at least consistent with a non-syllabic interpretation such as (1.b), while some of it - the Greek, Sanskrit and Khasi facts - unambiguously requires an analysis in those terms.

We now set out to establish the generalization in (1.a) by considering laryngeal neutralization in systems with preaspiration (T/ÓT), where it is the voice offset time (VoffT) cue that represents the primary factor distinguishing contexts in terms of contrast perceptibility.

3.1. Tarascan

This section documents the relevance of the VoffT cue in the analysis of the Tarascan tense/lax contrast. Two different dialects of Tarascan, a language isolate of Michoacán, have been described: Tzintzuntzán, by Foster (1969) and Cochuco, by Friedrich (1971a,b and 1975). My analysis deals with the more complex pattern found in Tzintzuntzán. A list of consonantal phonemes appears below, based on data from Foster and Friedrich:

(4) Consonant phonemes of Tarascan (Tzintzuntzán):

tense	pÆ	tÆ	cÆ	c‹Æ	kÆ	
lax	p	t	c	c‹	k	
			s	s‹	x	
	m	n			N	
	w	r	«	y		h

Foster refers to the tense series as *aspirated* but writes pÆ, tÆ, kÆ instead of the more common pÓ, tÓ, kÓ. Friedrich writes pÆ, tÆ, kÆ, calls the category *tense* and describes it as follows (1975: 24):

"Tense stops are produced with tension and occlusion of the laryngeal oral and lingual muscles and are acompanied by aspiration when in initial (post-pausal) position.". Based on their distribution in Tzintzuntzán, as well as on Friedrich's comments, I will conclude that the tense stops are realized with glottal abduction and tense oral musculature, to prevent voicing: they are therefore both tense and aspirated, though not systematically *post*-aspirated. In what follows I use Friedrich's term *tense*, to emphasize the fact that the Tarascan contrast does not involve the standard distinction between long and short VOT values.

Foster distinguishes the aspirated or tensed series from the plain lax one based on three tests[29]. The tense plosives are realized with:

(5) (a) initial (post-pausal) aspiration and fortis articulation: pÆa = [pÆa]

[29]"After word juncture and voiced vowels as after pause PÆ actualizes as [PÆ]. After medial vowels, aspirated phonemes occur as preaspirated allophones. After word juncture, except in unnaturally slow speech, and zero final vowel allophones, word-initial consonant allophony is dependent on the preceding consonant. " (p. 15)

(b) postvocalic pre-aspiration: apÆa = [ahpa]
(c) postnasal voicelessness: ampÆa = [ampa]

In contrast, the plain series is realized with:

(6) (a) lack of initial aspiration: pa = [pa]
(b) lack of postvocalic pre-aspiration: apa = [apa]
(c) postnasal voicing: ampa = [amba]

The difference between tense and lax stops in undergoing postnasal voicing is observed below:

(7) Lax stops: ta«e!rI 'snake' s‹a!n da«e!ric‹A 'many snakes'

(8) Tense stops: kÆe!rI 'big' s‹a!n ke!rI 'very big'
tÆire!nI 'to eat' s‹a!n tire!nI 'to eat much'

Word-internally one finds the same contrast between postnasal voiced and voiceless stops:

(9) Postnasal voicing No postnasal voicing

(lax stops)	(tense stops)
ambé 'something'	kécentA 'go down (you sg.)!'
inj‹a!nI 'to enter'	kÆwínc‹anI 'to wish to sleep'

Further justification for Foster's analysis is that *h* occurs only after a vowel and before a voiceless stop: it is unattested initially, intervocalically, before voiced C's or word-finally. This accords with the idea that surface *h* in Tarascan is simply the preaspiration part of an allophone of the tense stops (Foster p. 13). Examples of postvocalic tense and lax stops follow. Note that the preaspiration on coronal stops is sometimes realized as frication and recorded as *[s]* (10.c). Preaspiration on non-coronals is sometimes recorded as lengthening of the preceding vowel (10.b). All these realizations are discussed by Foster as free variants of the *ÓT* allophones of tense stops. It should also be noted that underlying **s** occurs before stops in Foster's dialect, and is invariably realized there as a fricative: *xósku [xO!skU]* 'star', **[xO!ÓkU]*. Thus the source of *h* in Tzintzuntzán is not *s*. The defective distribution of *h* establishes that the tense stops are realized with preaspiration when preceded by a vowel in the same word, exactly as Foster claims.

(10) <u>Tense stops: pre-aspiration Lax stops: no preaspiration</u>

a. atápÆeni [atáÓpEnI] 'to kill' cÆawápiti [cÆawápitI] ' thin'

b. cÈkÆúni [cÈÓkúnI] ~ [cÈ:kúnI] 'to drop from one's hand' — pÆikúni [pÆikunI] 'to harvest'; pakárani [pakáranI] 'to remain'

c. kac‹u!c‹Æani [kac‹u!Óc‹anI] ~ [kac‹u!sc‹ani] 'cut off one's braid' — kwarác‹eni [kwara!c‹enI] 'to fall'

pÆatÆáni [pÆaÓtánI] ~ [pÆastánI] 'to touch the metate' — kÆamáta [kÆamátA] 'finish it'

To summarize then: tense or aspirated stops are realized in Tzintzuntzán with postvocalic preaspiration ([ahpa]) , with postnasal voicelessness ([ampa]) and with phrase initial allophones characterized as fortis and aspirated ([pÆa]). They contrast in all three contexts with lax stops.

The tense contrast is neutralized initially before a consonant and after oral consonants .

(11) Neutralization of the tense/lax series in oral clusters

Initial clusters: lax stop + tense stop, fricative + tense stop:

tpÆákwa 'canoe in deep water'
ktÆá 'house'
s‹kÆu!ri 'leaf'

(12) Medial clusters of two oral consonants: oral C + tense stop

lax stop + tense stop	tense stop + tense stop	fricative + tense stop
xapt'i 'he had been there'	it'k'u 'still thus'	ás‹p'eni 'to be good'
porótk'u 'just a hole'		xósk'u 'star'

Foster observes that all postconsonantal stops - other than those occuring after nasals - are aspirated or tense (p. 30-33). The reader will note that the tense/lax contrast is not neutralized *before* a consonant, when a vowel precedes the cluster: cf. *porotk'u* vs. *it'k'u* above. Also to be noted is the fact that in initial stop clusters *both* members will be neutralized: the first stop is initial pre-consonantal, while the second follows an obstruent. Foster transcribes the neutralized stops as lax in initial, pre-C position, and as tense in post-obstruent contexts: thus in *kt'a* 'house' both stops are neutralized but different symbols are employed to record them. The rationale for this transcription policy probably has to do with differences in burst amplitude: in O_1O_2V sequences, O_2 is likely to have a louder burst - because of the greater build-up of oral pressure - and for this reason O_2's burst may sound more similar to that of a tense stop. Neutralized O_1 in the# O_1O_2V sequences is unlikely to share any auditory property with the distinctive tense stops and therefore is categorized as closer to the lax class and transcribed accordingly. The important point however is that neither O_1 nor O_2 contrast laryngeally in initial clusters. Further, there is no reason to assume that their laryngeal postures differ.

Alternations in tenseness stemming from postconsonantal neutralization can be found in the body of the grammar: the data below is given in Foster's phonemic transcription. We observe both underlying tense and underlying lax stops, both written as tense, i.e. neutralized, in post-obstruent position.

(13)	Underlying lax stops	Postconsonantal tense neutralization
-ka - verbal active (p112, 162)	awá-ka-ni 'I will eat'	xu«a!-s‹- kÆa-ni 'I came'
-kware- 'self' (p.124)	ni-cÈ-kwa«é-ni 'to go alone'	wantoc-kÆwa«e-t'i 'they conversed with e.o'

(14)	Underlying tense stop	Postconsonantal tense neutralization
-k'a- 'side' (p.134)	k'wani-k'a-ni 'to throw it on the other side'	wikis‹-kÆa-ni 'left, left side' (p.134)

Tenseness alternations occur also when a word-initial stop follows a word-final obstruent, always the consequence of the loss of word-final stressless vowels. This case is illustrated below: the underlyingly tense stop is transcribed as tense after a vowel, and as neutralized when the vowel is lost. In this case, however, the neutralized category is transcribed without the tenseness diacritic, perhaps because Foster could not find a more consistent way to signal the loss of distinctive tenseness.

(15) má ác‹a c'awápiti 'a thin man' (p.17)
[ma ac‹A cÆawápitI] ~ [ma ac‹ cawápitI]

yásÈ p'áara 'now touch it!' (p19)
[yásÈ pÆáarA] ~ [yáß páarA]

Although Foster does not mention this explicitly, no consonants occur word-finally, except through the optional loss of the stressless devoiced vowels observed above.

The table in (16) summarizes the contexts relevant to the realization of the tenseness contrast. The ## notation indicates the phrase-initial position; # stands for the word boundary. Under every context, I indicate what auditory properties would in principle cue a tense/lax contrast in that position, *if* such a contrast had been implemented there. Then directly underneath I indicate whether the tense/lax contrast is in fact implemented or neutralized in the relevant position.

(16) Contexts of tenseness licensing and neutralization in Tarascan

	(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**
context:	## _V	(#)#_ Obstr	V(#)_	N(#)_	Obstr (#)__
possible cues:	VOT	-----	Voice offset time	Voice offset time	------
	burst amplitude	(burst amplitude but burst is unlikely)			-------
contrast:	preserved	neutralized	preserved	preserved	neutralized

The licensing contexts shown in (16) are directly related to the statement of positional allophony given by Foster: tense and lax stops differ as preaspirated/unaspirated after a vowel (cf. (16.iii); they differ as voiceless/voiced after a nasal (16.iv), and they differ as post-aspirated/unaspirated phrase-initially (6.i). Since no further phonetic differences between the two series are listed by Foster, we may safely assume that no other salient cues support the contrast in any position. For the phrase-medial sites, this means that in contexts where pre-aspiration or post-nasal voicing cannot be observed, the contrast lacks its main cues. This explains the lack of distinctive tenseness in (#)#_C (16.ii) and C(#)_ contexts (16.v). As table (16) indicates then, there is a direct correlation between the positions of neutralization and the positions from which all reliable contextual cues are absent.

The one context that requires further comment is the post-pausal, prevocalic one (##_V), where tense stops are realized as fortis and *post*-aspirated. We need to explain why the stops are reportedly realized as preaspirated in all contexts but this one: the glottal abduction clearly leads the onset of oral closure in word medial contexts - otherwise we wouldn't get pre-aspiration - but must apparently reverse its timing utterance-initially, where post-aspiration is perceived. I suggest that, appearances to the contrary, the timing may well be constant in all cases: what is likely to vary with contexts is the magnitude of the glottal opening gesture, which is known to increase significantly following major boundaries (Pierrhumbert and Talkin 1992). A larger glottal opening movement will correspondingly delay the onset of voicing in the following vowel, because it may take longer for the glottis to reach the position where modal voicing can resume (Kim 1970). In the absence of any evidence for an early onset of glottal adduction (in ##_V contexts) this increase in VOT values will give rise to the percept of post-aspiration even if the oral-glottal timing is identical to that found in other contexts. (Alternatively, as M.Beckman points out (p.c.), some early generation of Tarascan speakers may have heard utterance-initial postaspiration, for the reasons given above, and learned to produce it by changing the oral-glottal timing in this context.)

Since the timing between oral and glottal gestures determines the cue distribution, which in turn determines the context of neutralization, we must assume that the timing is invariant and the constraints generating it outrank preservation of the tense/lax contrast. This point can be examined once the relevant conditions are formulated. A preliminary characterization appears below:

(17) a. Constraints on oral-glottal timing (abbreviated **Timing**)
The peak of glottal abduction in tense stops must lead or coincide with the onset of oral closure:

```
[-------glottal abduction-----]
       [-----oral closure---release ----]
```

(18) *[tense]/ in positions lacking contextual cues (abbreviated: **Context cues (tense)**)

Stops cannot be tense (invariably pre-aspirated) or lax (invariably unaspirated) in positions where contextual cues to this contrast are necessarily absent.

A position lacking contextual cues is one in which the difference between tense and lax stops cannot be determined on the basis of their VOT or VoffT values. This then leaves open the possibility that tense and lax stops might differ in other respects (closure duration or burst amplitude): if they do, it is clear that such differences are not counted as sufficient to support the contrast in Tarascan.

If (17) is undominated in Tarascan, then the contextual cues referred to in (18) will necessarily represent the voice offset time value in a sonorant-obstruent string. I do not incorporate this fact into (18), since it represents the necessary effect of the Timing constraint. The function of (18) is simply to state that a particular contrast - here tense/lax - is cancelled when lacking transitional cues. *Where* those cues may be found is determined by Timing.

We may now consider the interaction between *Timing*, the perceptibility condition *Context Cues* and the conflicting faithfulness constraint *Preserve tense/lax* constraint . The ranking is indicated below and is illustrated in (20):

(19) Timing Context cues (tense)
c d
Preserve tense/lax

The ranking *Timing >> Preserve tense/lax* indicates that the timing mandated by (17) will not be manipulated to improve the perceptibility of tenseness in contexts lacking the voice offset cue. To see this, consider the evaluation of the following three timing possibilities for underlying */k'/* of *k'a* 'side' in the string *wikis‹k'ani* where *k'* surfaces neutralized for tenseness. One option (20.a) is to maintain a tense pre-aspirated stop in this context, whose timing is identical to that indicated in (17): I record this option below as ^hk. The other possibility (20.b) is to adjust the timing, shifting the aspiration to the release, so as to generate cues that are audible in this context: this option results in a post-aspirated stop, written below as *kÓ*. Had this option been selected, the tense contrast would have been preserved, though in modified form, in the O_ context. The third option (20.c) is to neutralize the contrast, thus failing to produce any significant glottal abduction in this context: the result of the neutralizing option is recorded below as *K*, a symbol that avoids the ambiguities of Foster's *k'* notation.

(20) Neutralization of tenseness in post-obstruent position

		Timing	Context cues (tense) >>	Preserve tense/lax
a.	wikis‹**Ók**ani		!*	
b.	wikis‹**kÓ**ani	!*		
c.	wikis‹**K**ani			*

Given the ranking in (19), the properly timed ^hk candidate (a) loses in (20) because the string generated lacks contextual cues to aspiration: after an obstruent, no voice-offset time differences can be observed. The better cued candidate *kÓ* (b) loses because Tarascan does not allow the oral-glottal timing to vary with context. The only solution then, given the ranking and the context, is neutralized *K*. As indicated earlier, the burst quality of this *K* in *s‹K* will make it similar to a tense stop: this is why Foster writes *s‹k'*. The same hierarchy models neutralization in the #_C context (utterance medial), where tense and lax stops are indistinguishable in the absence of a preceding nasal or vowel. Finally, the V_C and N_C contexts possess contextual cues in the form of distinct voice-offset time values. The preservation of an underlying tense stop in the V_C context can be verified below:

(21) No neutralization in post-vocalic position: input t' (= Ót) in it'k'u (= [iÓtKu])

		Timing	Context cues (tense) >>	Preserve tense/lax
a.	i**Ót**Ku			

b. iTKu			!*
c. itóKu	!*	(!)*	

A distinct set of constraints may be used to model differences in the magnitude of the glottal opening gestures in tense and lax stops. We have reasoned above that Foster may perceive *post* -aspirated tense stops in utterance initial contexts because such stops contain sufficiently large abduction gestures to generate a voicing lag after the stop's release. On this interpretation, the timing constraint in (17) is constant across contexts and the difference between utterance-initial and utterance-medial positions must be attributed to a systematic difference in the size of the abduction gestures. I do not pursue this point, since the Tarascan evidence presented by Foster does not establish unambiguously whether utterance-initial stops differ from utterance-medial ones in abduction size, in timing or in both ways at once.

3.2. Extensions

The connection between preaspiration as the main perceptual correlate to a laryngeal contrast and neutralization in the #_ and O_ contexts is not unique to Tarascan. Virtually identical patterns are encountered in Cree (Ellis 1983), Lule Sami (Engstrand 1987), Tohono O'odham (Saxton 1963, Fitzgerald 1996). Although transcribed with different symbols, all three languages contrast two types of voiceless stops - voiceless and pre-aspirated - in post-sonorant position. Another correlate of the contrast may be closure duration, at least in Sami. The phonetic investigations of Engstrand (1987, for Sami) and Fitzgerald (1996, for O'odham) indicate that VOT differences do not distinguish the two stop series. Rather, in all three languages the lexical contrast is signalled primarily through differences in VoffT.

The O'odham tense and lax stops, transcribed as *p, t, k* and *b, d, g,* contrast after a vowel or nasal - the best carriers of the voice offset time cue - as well as word initially, but then only if the preceding word or clitic ends in a vowel (Fitzgerald 1996). As in Tarascan, the contrast is attested *before* an obstruent (provided there is a preceding vowel) but not *after* one: all post-obstruent stops are neutralized and recorded as tense.

(22) Distribution of Tohono O'odham (Papago) tenseness : data from Saxton 1963:31-33
[Saxton's notation: tense and neutralized stops transcribed as voiceless; lax stops as voiced.]

	tense	lax
after a vowel:	ka!psidÈ 'causing to pop'	skuubsigÈ 'to be dusty'
after a nasal:	wa!anko 'bank'	tSa!ango 'monkey'
after an obstruent:	contrast neutralized, stop transcribed as tense	

ma!askÈ hÈ!taspÈ mi!ißtÈ
'will appear', 'five', 'make a table'

The Sami data is similar: according to Engstrand, the word-initial stops are neutralized in all but a small group of "young loanwords" (1987:104). Neutralized stops in Sami are written with the symbols used for the lax series: *b, d, g*. In internal position, the contrast is attested after sonorants: e.g. *bálkáv ['pa:lÒka:w]* 'salary' vs. *bálges ['pa:lke:s]* 'path'. The sonorant preceding the preaspirated stop is partly devoiced and fricated - *[lÒ]* - since it is overlapped by the stop's glottal abduction. The information available for Cree is less complete, but the following observations suggest that the pattern is identical to that of the other languages discussed here: a contrast based exclusively on pre-aspiration exists between stops, as described by Ellis (1983: 18). This contrast is attested after vowels, in word medial and final positions (s‹*wa:pihk* 'at the store' vs. *nipa:wak* 'they sleep'). The contrast is systematically absent initially and after obstruents (Kevin Russell, p.c.).

The analysis needed for these languages should be virtually identical to that offerred for Tarascan. A related pattern of preaspirate distribution is attested in the Toreva dialect of Hopi (Whorf 1945), where the **Ó**T/T contrast is found only intervocalically, after stressed vowels. The preaspirates are in contrast with h-C clusters (Whorf 1945: 160) and therefore must be viewed, in this language as well, as mono-segmental units. Stress shifts induce loss of preaspiration, as in: *tál-wìÓpi* (approx. ' a lightning flash' , Whorf 1945:182) vs. *tál-wipì-ki (*approx. 'a lightning-like design'). The same alternation between distinctive preaspirate and neutralized plain stop is attested, according to Whorf, in all instances where an underlying preaspirate is placed in any context other than V'__V (V' = stressed V). The information provided by Whorf is insufficient to clarify why preaspirates require, in addition to the preceding vowel, also a following one. I would speculate that, although the primary transitional cues to the contrast reside in the V_C transition, there may also exist minor release cues, and these are better perceived when the consonants precede a vowel. The fact that the preceding vowel must carry stress may be related to its increased duration: a longer vowel will reflect preaspiration without becoming completely aspirated itself (cf. Gordon 1996).

At least one language possesses a T/**Ó**T contrast in initial position, in addition to the V_V contexts: this is Huautla Mazateco, an Otomanguean language of Oaxaca (Pike and Pike 1947; cf. Steriade 1994 for the phonemicization assumed here). Huautla does not allow pre-consonantal stops and therefore it cannot be determined whether the contrast would be allowed pre-consonantally. All Huautla words end in a vowel, thus the distribution of the preaspirates is not in fact clearly distinct from that of Tarascan: both languages allow the contrast in utterance initial position, and Huautla lacks the clusters necessary for determining any contextual restrictions on preaspirates.

3.3. Significance of the preaspiration data

I outline below the attested variation regarding contexts that permit the ÓT/T contrast. The contexts listed in (23) range from positions where no transitional cues to aspiration would be expected (#_O) to contexts where aspiration is in principle perceptible in both the preceding and the following context (R_R). The abbreviations are: O = an obstruent, R = a sonorant, including a vowel, R' = a stressed sonorant, including a vowel; # _ = utterance initial.

(23) Patterns of neutralization of the ÓT/T contrast

(O = obstruent, R = sonorant, incl. vowel, R' = stressed sonorant; #_ = utterance initial)

	O _ ; #_O e.g. ak**Ót**a vs. ak**t**a	#_ R e.g. **Ót**a vs. **t**a	R_ O e.g. aÓ**t**pa vs. a**t**pa	R_R e.g. a**Ót**a vs. a**t**a	R'_R e.g. áÓ**t**a vs. á**t**a
Toreva Hopi	no contrast	no contrast	no contrast	no contrast	**contrast**
Sami, Cree, O'odham	no contrast	no contrast	**contrast**	**contrast**	**contrast**
Tarascan	no contrast	(contrast but perceived as TÓ/T)	**contrast**	**contrast**	**contrast**
Huautla Mazatec	(no relevant clusters)	**contrast**	(no relevant clusters)	**contrast**	**contrast**

The fact that no language maintains an aspiration contrast in the #_O position and that all languages with distinctive aspiration manifest it in the R_R context comes as no surprise. More interesting is the difference between the O_R and R_O contexts: all languages we know of neutralize preaspiration in the O_R context (which appears as O_ in (23)) while a majority maintains the contrast in the R_O context. Therefore the context preceding the preaspirate is more significant for the maintenance of the contrast than the context following it, as anticipated in (1.a). This point is also supported by the observation that preaspiration is severely limited in word- and utterance-initial position (#_R): we know of only one language - Huautla - where utterance-initial preaspirates are reported, and in this case we lack detailed descriptions of the realization of ÓT in context. Every other language abolishes the contrast utterance- and word-initially (as in Sami and Cree), or else utterance-initially but not word-initially after vowels (O'odham) or else realizes the utterance initial aspirates as postaspirates and maintains word-initial preaspirates after vowels (Tarascan). Two of the languages sampled possess word-final stops (Cree and Sami) and the distribution of preaspirates in the R_# context is as predicted: they are be allowed in the R_# context, since they are also allowed in the equivalent R_O context.

The data summarized in (23) largely substantiates the statement made earlier in (1.a): the absence of a sonorant or vowel before the stop is the single most common factor determining neutralization of the ÓT/T contrast. For postaspirates, we have already noted that principal factor leading to neutralization is quite different: it is the absence of a sonorant *after* the stop. The difference between pre- and post-aspirates follows from the idea that neutralization proceeds from the least perceptible positions, where it is most likely, to the more favorable ones, where it is least likely. The segmental definition of neutralization contexts differs for the T/ÓT and T/TÓ contrasts, precisely because timing affects cue distribution.

Let us consider now the significance of these observations for the ways in which we formulate grammatical descriptions of laryngeal neutralization. Observe the difference between the formulation of **Context Cues** (18) and earlier constraints used in Part I. We will compare here **Context Cues** with conditions like *** aspiration/ R_#** which adopt the format of earlier statements (e.g.***[a voice]/ R_#).** Both *** aspiration/ R_#** and **Context Cues** have the effect of banning distinctive aspiration in certain positions. Since they do so in very different ways, we will consider now the basis for a choice between them.

Context Cues classifies contexts on the basis of the range of cues they offer for the detection of feature contrasts. The condition*** aspiration/ R_#** classifies contexts in terms of the proximity of various segment types: in this case, a sonorant to the left and no segment to the right. The effect of these context elements on the perceptibility of the contrast is not explicitly mentioned in the constraint. We had assumed in Part I that the link between perceptibility and neutralization resides in the relation between the perceptibility scale - the list of contexts where a given contrast is more or less perceptible - and the constraints this scale projects. Since the formulation of earlier perceptibility scales also failed to mention cue distributions directly, the perceptibility effects on neutralization were in fact left largely implicit.

What the preaspiration data has revealed is that that perceptibility scales are specific to a particular timing pattern: when the timing changes, the perceptibility facts change as well. To perceive postaspiration, the context #_R is more favorable than the context R_O. For the preaspirated stops, the relation between contexts is reversed: correspondingly, there is frequent neutralization in #_R but not in R_O. Therefore if the contexts on the perceptibility scale are described segmentally *then we must have as many scales as there are timing patterns*. At the very least, we must have a scale such as (24) for the plain/postaspirate contrast, and we must have a scale such as (25) for the plain/preaspirate contrast.

(24) Partial perceptibility scale for the contrast between plain voiceless and post-aspirated stops

_ [+son] **R** all other contexts

(25) Partial perceptibility scale for the contrast between plain voiceless and pre-aspirated stops

[+son] _ **R** all other contexts

But this is unlikely to suffice: we had noted earlier that differences in inter-segmental timing may also determine how perceptible a given contrast is in some context. This was conjectured by Browman and Goldstein (1992) and Lamontagne (1993) for place features, and there is good reason to believe that this conjecture holds for laryngeal features as well. It was noted earlier that glottalization contrasts are permited in pre-obstruent position in languages where adjacent consonants largely fail to overlap (cf. Urbanczyk 1995); whereas glottalization contrasts are generally banned pre-consonantally in languages like Korean, where significant interconsonantal overlap is the norm (Kim-Renaud 1974; Jun 1995). Similarly, postaspirated stops may be distinguishable from plain voiceless ones when followed by an obstruent which does not overlap them to the extent of masking their release: therefore the degree of permissible overlap between adjacent consonants may well determine the likelihood of neutralization for certain features. The types of constraints envisaged so far do not allow us to characterize any relation between inter-segmental timing and neutralization.

Finally, gestural magnitude factors may also add to the complexity of the picture. We were led to this conjecture when noting that the tense stops of Tarascan may be identified as distinctively tense utterance initially because of the typically greater magnitude of the glottal opening movement in that position. If this is the right interpretation, then we will have to have *as many perceptibility scales as there are distinct combinations of timing (inter- and intrasegmental) and gestural magnitude options*. Since each perceptibility scale projects its own constraints, we see now that there is a very serious danger of constraint inflation associated with the strategy pursued thus far. It is therefore wise to consider the alternatives.

The alternative is that of formulating cue-based constraints such as **Context Cues.** A constraint like **Context Cues** is satisfied as long as either the preceding or the following context permit a differentiation of stop classes for the relevant contrast: therefore **Context Cues** is equally applicable to pre- and post-aspirates. For instance, this condition is equally satisfied by a pre-vocalic TÓ and by a post-vocalic ÓT since in both cases the context (a neighboring vowel) manifests the distinction between aspirated and non-aspirated stops. And the constraint is equally violated by an utterance initial *ÓT* as by an utterance final distinctive *TÓ*. The wider applicability of a constraint like **Context Cues** stems from the fact that it invokes directly and without notational intermediaries the factor that identifies a context as superior to another context in realizing a feature: this factor is cue availability.

Having observed this, I turn now to the discussion of glottalic consonants, whose patterns of licensing and neutralization lend further support to the cue-based approach.

4. Neutralization and timing for ejection and creak

The phenomena reviewed in this section allow us to extend the results obtained to glottalic consonants and, in some cases, compare the consequences of two distinct timing patterns for one gesture in the same language. The main point here too is to document the fact that laryngeal neutralization is determined by implementational conditions such as gestural timing and by perceptibility factors.

Glottalization is a feature used in many American Indian languages to generate distinctions among both sonorants and obstruents. The timing of the glottal closure relative to the edges of the oral constriction is frequently different for the two classes, as noted by Sapir 1938 and Kingston 1985. When such a difference in oral-glottal timing exists, the laryngeal constriction is timed to the onset of the oral closure in sonorants, and to its release in obstruents. The timing difference is probably motivated by auditory considerations (Kingston 1985, Goldstein 1990, Silverman 1995) although the specifics of this are still unclear. The two timing patterns are diagrammed below[30]:

(26) Preferred timing for oral and glottal constriction in glottalized sonorants : square brackets indicate onset and offset of gesture.

	contextual cues	internal cues
Glottal gestures:	...adduction..][........constriction............]	
Oral gestures:	[........vowel..........][...consonantal sonorant ....]	

[30]The diagrams in (70-71) do not attempt to account for the substantial language specific variation involving the extent of delay between oral and glottal releases (cf. Flemming, Ladefoged and Thomason 1993).

(27) Preferred timing for oral and glottal constriction in glottalized stops

contextual
cues

Glottal gestures: ... constriction...][...adduction..

Oral gestures: [...obstruent ...release...][........vowel ....]

The timing difference seen in (26-27) is attested, among others, in Montana Salish (Flemming, Ladefoged, Thomason 1994; Ladefoged and Maddieson 1996), Shuswap (Kuipers 1974 and below), Klamath (Barker 1964, Blevins 1993 and below), Ventureño, Barbareño, and Ineseño Chumash (Whistler 1984), Pit River (Achumawi; Whistler 1984), Yokuts (Newman 1944, and below), Heiltsuk (Rath 1981), Kashaya (Buckley 1993) and the languages discussed by Sapir (1938; Nootka, Haida, Tsimshian, Kwakiutl) although Sapir's details are not always clear. In all of these languages preglottalized sonorants cooccur with ejectives, i.e. postglottalized obstruents. Aoki (1970) presents instrumental evidence for pre-glottalized sonorants in Nez Perce, without however comparing the sonorants with the glottalized obstruents.

The hypothesis of Licensing by Cue predicts that these timing preferences may result in distinct licensing possibilities: a preglottalized segment (say *[n0],* timed as in (26)) will depend for optimal identification of its laryngeal category on the left-hand context: a *preceding* vowel or sonorant will provide this *[n0]* with saliently encoded and lengthy contextual cues. A following vowel will be less helpful. In contrast, optimal identification of an ejective (e.g. *[t']* timed as in (27)) will depend on the nature of the right-hand context, i.e. on the presence of a following vowel or sonorant. This is not to say that a preceding vowel is indispensible for the occurrence of *[n0]* nor that a following vowel is indispensible for *[t']*: but the contexts of optimal perceptibility will clearly be different for the two segment types, and this will affect the typology of neutralization in each case. This is indeed what we observe: glottalized sonorants neutralize typically in the absence of a preceding vowel whereas obstruents neutralize in the absence of a following one. The argument presented here will be parallel to that based on pre-aspiration, but the data considered next will also allow a language-internal comparison of the consequences of different timing.

Independently of the timing difference between sonorants and obstruents, it is also clear that glottalization has different perceptual correlates in the two classes. Most glottalized obstruents are what Sapir (1922, 1938) calls 'fortes', and involve "decided stress of articulation[...] followed by explosion and momentary hiatus" (1922:33). On the other hand, the most prominent auditory property of the glottalized sonorants appears to be the creaky voicing heard during the sonorant itself and on neighboring vowels. There is, necessarily, no explosion and no hiatus in the vicinity of a glottalized sonorant. There are corresponding articulatory differences between ejectives and glottalized sonorants: the upward movement of the larynx, which increases air pressure behind the point of oral constriction, occurs only in ejectives (Ladefoged and Maddieson 1996). Similarities between glottalized sonorants and obstruents can be ascribed to the fact that both types are realized with glottal constriction. To the extent then that *[t']* and *[n0]* form a natural class, this can be attributed to their shared *articulatory* feature [constricted glottis] (Halle and Stevens 1971). To the extent that they pattern differently, this may stem (a) from the difference in auditory properties, or (b) from the fact that the articulatory property of upward larynx movement is used only in obstruents or (c) from the difference in the timing of glottal constriction. The use of both articulatory and auditory features in phonological analysis is defended by Flemming (1995). I assume that (at least) two auditory features must be used in the analysis of glottalization: for obstruents, I will refer to [ejective release] as the composite of characteristic burst and long VOT which jointly identify the ejective (cf.also MacEachern 1997). For glottalized sonorants, I will refer to [creaky voicing]. The proposed featural analysis of glottalic consonants is summarized below:

(28) Some properties of glottalic consonants

	Articulatory features	Auditory features	Timing
sonorants	[constricted glottis]	[creaky voicing]	(26)
obstruents	[constricted glottis] [larynx up]	[ejective release] (possibly also [creaky voicing])	(27)

4.1. Yokuts

Yokuts distinguishes plain and glottalized consonants (Newman 1944; Archangeli (1984:284), Archangeli and Pulleyblank (1994:346-350)) but limits the glottalized sonorants to postvocalic position. The glottalized obstruents occur in all contexts where single consonants are permitted. To anticipate, the Yokuts data allows us to document the statement in (1.a) with respect to creaky voicing. The difference in neutralization patterns between stops and sonorants is not however directly attributable to timing differences in this case.

The glottalized stops and sonorants of Yokuts are timed along the lines of (26)-(27). The glottalized stops are described by Newman in terms that indicate they are post-glottalized, probably ejectives: "In all dialects the glottalized stops and affricatives are articulated with a light degree of glottal plosion. Glottalized stops are pronounced with a simultaneous release of the glottis and stop closure." (Newman 1944:14;). The glottalized series (*p', t1', t', k' t1s', tS'*) contrasts with a post-aspirated set (written *p, t1 , t, k, t1s, tS*) and a series characterized by zero or negative VOT (*b, d1, d, d1z, dZ, g*) called *intermediate* . The description of glottalized stops as possessing simultaneous glottal and oral releases suggests that the cues differentiating them from the other two series reside in absence of closure voicing, VOT values, burst amplitude and the creaky ("rasping") quality of following vowels (Newman 1944:19). Since Newman's data displays the multiple contrast in (29.b), we must assume that the glottalized obstruents can be identified - at least in slow speech - on the basis of their release alone: the contrast between *Vp'/V* and *Vp'V* suggests that the release quality is sufficient to identify ejectives. There is no indication that glottalization in obstruents has any effect at all on the *preceding* vowel; this and the description of geminate glottalized obstruents as posessing long closure and simultaneous oral-glottal releases (*k'-k'* = *[kk']* 1944:18) supports the timing shown in (27).

(29) Glottalization in Yokuts obstruents

a. initial: c'uum 'destroy'

final: p'axaat' 'mourn'; bok' 'find'

postconsonantal: s1aalk' 'wake up'

preconsonantal: tol'ok'dollos‹ 'will cause to perforate it repeatedly'

b. contrasts between glottalized obstruents and clusters with /:

VC'V	V/CV	VC/V	V/C'V	VC'/V
yuk'ulhan' 'be buried'	yO/ke 'cause to arrive'		sudu/k'o: 'cause to remove'	bOk'/O: 'one who has found'
lap'- 'whip'		lap'/a/ 'one who has whipped'		

The glottalized sonorants (written by Newman as *w', y', l', m', n', N'*) have a range of timing possibilities, all of which can be seen as variants of (26): for the glottalized laterals and nasals, Newman (1944: 16) reports two medial realizations ([l/l] or [/l], [m/m] or [/m]) that seem to differ only in the extent to which the glottal catch - the peak of the glottal gesture - precedes or follows the onset of oral closure. No variant is reported in which the glottal catch follows or is simultaneous with the oral release. This is then the first respect in which glottalized obstruents and sonorants differ in their timing. Secondly, Newman observes (p.18-19) that the glottal stop produces a rasping quality on adjacent vowels and that "[the] consonants *y', w', l', m', n', N'* give the same rasping effect [as plain [/]) *especially to those that precede* " . This indicates that the incomplete glottal closure responsible for the rasping or creaky quality the sonorant begins and is most saliently noted during the preceding vowel. Since some rasping effect is occasionally observed on a following vowel, this means that the offset of the glottal gesture is not strictly aligned to the end of the oral gesture, again a fact consistent with (23).

The following timing constraints formalize the observations made so far on the oral-glottal timing of laryngealized sonorants and obstruents in Yokuts:

(30) Oral-glottal timing constraints for Yokuts glottalized sonorants (abbreviated **SonTiming**)
a. The onset of glottal constriction must precede the onset of oral closure.
b. The peak of glottal constriction - the glottal catch - must precede the oral release.

(31) Oral-glottal timing constraints for Yokuts glottalized obstruents (abbreviated **ObstTiming**)
a. The onset of glottal constriction must follow the onset of oral closure.
b. The release of the glottal constriction must coincide with the oral release.

These two timing patterns result in two distinct perceptibility scales:

(32) Perceptibility scale for glottalized sonorants timed according to (26):
[+son] __ R #__ , [-son]__

(33) Perceptibility scale for glottalized obstruents timed according to (27):
__[+son] R __#, __[-son]

These scales predict that potential neutralization positions will be different for glottalized sonorants and obstruents: sonorants will be most likely to neutralize in the absence of a preceding vowel or sonorant, whereas obstruents will be most likely to neutralize in the absence of a following vowel or sonorant. This prediction is partially verified in Yokuts, where glottalized sonorants are disallowed after consonants and word-initially, that is in all contexts where they would be lacking context cues. Yokuts offers only partial confirmation for our conjecture because it allows the ejective stops in all contexts, including in those of sub-optimal perceptibility.

The analysis will proceed as follows: we assume that the features of glottalized sonorants and obstruents are partly distinct, and invoke distinct constraint families for the two types of glottalic consonants. Thus, a class of ***creak** constraints corresponding to the scale in (32) limits the distribution of distinctively creaky sonorants; a faithfulness condition **Preserve [creak]** penalizes loss of underlying glottalization in sonorants. For the obstruents, we assume a class of **ejection* constraints corresponding to the scale in (33), and a faithfulness condition **Preserve [ejection].** Since the exact details of the articulatory implementation of the Yokuts glottalic consonants are unknown and immaterial here, we will simply assume that any representation that satisfies ***Preserve [creak]*** non-vacuously will contain a sonorant that possesses the features [creak] and [constricted glottis]; and every representation that satisfies **Preserve [ejection]** will contain a stop with the properties [ejective release], [creak], [constricted glottis] and [larynx up]. Neutralized consonants - either sonorants or obstruents - will lack each and every one of these features. Preliminary constraints and rankings appear below.

In the figure below, we posit a distinct ***creak** or ***ejection** constraint for every context mentioned in the perceptibility scales.

(34) Glottalization constraints corresponding to the scales in (32)-(33).
Ranking is specific to Yokuts. Timing constraints (27), (28) undominated.

*creak constraints	faithfulness conditions	*ejection constraints
	Preserve [ejection]	
	c	
*creak/ {[-son], #}_		*ejection/ _ {[-son], #}
_		_
_	c	_
_	**Preserve [creak]**	_
*creak/ V_	d	*ejection/ __V

The undominated ranking of **Preserve [ejection]** insures that all underlying ejectives will be preserved as such. In contrast, **Preserve [creak]** outranks only the bottom ***creak** condition (***creak/ V_**) and this insures that only postvocalic glottalized sonorants will surface.

We now consider the empirical reflexes of glottal neutralization. The chief consequence of neutralization is the distributional limitation noted by Newman (1944: 15): "[they] can never appear initially in a word or in a syllable that follows a closed syllable," i.e. after a consonant. Neutralization is also responsible for the alternations below:

(35) Alternations between plain and glottalized (creaky) sonorants (Newman 1944:19,165)
a. c‹Oy'nim'ni 'a Choynimni' (tribal name) vs. c‹Oy'en'man'i 'Choynimnis' (pl.)
b. xaya:-hal'iy' 'one who is placed' vs. xamit-hay'l-a ' scythe-objective'

The loss of a vowel (35.a) or grammatically conditioned metathesis (35.b) cause an underlying glottalized sonorant to appear in postconsonantal position, where its laryngeal features are consequently lost: [...Vn'im'...] -> [...Vn'm...] and [...Vl'i'y...] -> [...Vy'l'...] -> [...Vy'l...] . The effect of the ranking in (34) is observed below:

(36) Creak neutralization in [...en'im'a..] -> [...en'm'a..] -> [...en'ma...]

	*creak / [+son, -syllabic] __ >>	Preserve creak
en'm'a	!*	
en'ma		*

The third reflex of creak neutralization is the fact that it determines the outcome of morphologically governed processes of glottal association. These have been discussed by Archangeli (1984) and Archangeli and Pulleyblank (1994) in different terms. The contemporaneous gerundial *-(/)n'ay* and consequent agentive suffix *-(/)a/* contribute each a feature of glottalization which associates to postvocalic sonorants in preceding stems. If the root does not contain a postvocalic sonorant the suffixal glottal feature remains unrealized or is realized as a glottal stop.

(37) Glottal association in the contemporaneous gerundial -(/)in'ay (Archangeli 1984:308)

(i) post-V C is obstruent or aspirated: no glottal association

dub-/un'ay 'while leading by the hand' (root dub)
lihm-in'ay 'while running' (root lihm)

(ii) postvocalic C is sonorant: glottal feature associates

c'ow'-in'ay 'while grasping' (root c'oow)
hiw't-in'ay 'while walking' (root hiwiit)
tan'-in'ay 'while going' (root taan)

(38) Glottal association in the consequent agentive - (/)a/ (Newman 1944:15)

(i) no post-V sonorant: no glottal association

wis1-/a/ 'straighten' (root wis1)
/ugn-/a/ 'drink' (root /ugn)
picw-a/ 'catch' (root picw-)

(ii) postvocalic C is sonorant: glottal feature associates

t'oy'x-o/ 'give medicine' (root t'oyx)
/am'l-a/ 'help, get aid' (root /aml)

The phonology of suffixes associated with floating glottals confirms two aspects of the analysis proposed in (38): the floating feature in this case must be defined specifically as [creak] and must be kept distinct from ejection. Otherwise we would fail to understand why roots like *picw-* (38.ii) do not become glottally infected by ejection: **pic'wa/*. This detail confirms then the idea that the glottal features for obstruents and sonorants are distinct, as assumed here. Second, the absence of glottal infection in post-C sonorants (**picw'a/*) is yet another reflex of the ranking proposed in (34)[31].

One last aspect of the analysis needs to be clarified. In a string like *yawl*- 'follow' both *w* and *l* are in comparably good positions to receive a creak specification, since both follow a V(Glide) sequence. Yet only *w* - the directly postvocalic segment - is recorded by Newman as subject to glottal association: *yaw'l-a:hin*. The same question arises with underlying glottalized sonorants, which are never allowed to surface when following a V-Glide sequence: there are no forms like **yawl'*- in Yokuts. This question is inspired by the fact that contextual creaky or raspy voicing, which represents an indispensible cue to creak in Yokuts, can be audibly extended across an intervening glide and into the preceding vowel: if /*yawl'aahin*/ had been the intended form, the creak could have been manifested as [yaa0w0l0laahin]. Note however that when the creaky voiced portion of the string reaches the vowel, it necessarily affects the *w* in its entirety: thus even if creak "originates" on *l',* the most strongly affected segment will necessarily be the directly postvocalic *w*, since *w* will surface as completely rather than partially glottalized. Had Yokuts maintained a contrast between forms like *yaw'l* and *yawl',* the perception of this contrast would have depended on a small timing difference: offset of glottalization during *w* in *yaw'l* vs. offset during *l* in ***yawl'*** **.** It appears that the perceptually more robust contrast simply requires the hearer to locate creak during the vowel, without a need to determine its offset at all. It is this type of contrast that Yokuts selects.

We observe now that this analysis can be translated into one that eschews reference to specific contexts such as {[-son], #}_ in favor of reference to the range of cues available in different positions. Here too, reference to *Context Cues* will be sufficient to characterize the context of neutralization, since glottalized sonorants timed as in (27) will possess extensive context cues only in postvocalic position. The core of a cue-based analysis of Yokuts glottal features is given in (39):

(39) a. Context cues (creak):
*[creak] in positions where context cues to [creak] are absent.

b. Context cues (ejection):
*[ejection], *[larynx up] in positions where context cues to [ejective release] are absent.

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[31] In this case however the specifics of the analysis will depend on the constraints that model "floating" features. Clearly, however, the fragment of the hierarchy in (31) that is decisive for the tableau in (33) will play a comparable role.

c. Ranking: ObstTiming Preserve (ejection)

c d

Context cues (ejection)

SonTiming Context cues (creak)

c d

Preserve (creak)

We summarize now the points contributed by the Yokuts analysis. We have observed here too the irrelevance of syllable structure for laryngeal neutralization: neither neutralizing nor licensing sites can be identified in syllabic terms, since there are licensed onsets (*di.n'a/*), licensed codas (*/am'.la/*) as well as neutralized onsets (*/ug.na/, wis1a/*). (Neutralized codas fail to occur only because Yokuts lacks CC coda sequences.) The idea that implementational factors - timing and perceptibility - determine the grammar of neutralization is also illustrated by Yokuts: the timing constraint SonTiming (30) is undominated in this language. Had timing been alterable, it would have been possible to generate *post*- glottalized sonorants which wouldn't be subject to any of the *creak constraints. This is illustrated below, where I consider the possibility of preserving the floating creak feature in *lihm-in'ay* by producing a postglottalized sonorant *l'*.

(40)	SonTiming	Context cues (creak)	>>	Preserve creak
lihm-				*
'lihm- creak timed to onset of l's oral constriction		!*		
l'ihm- creak timed to offset of l's oral constriction	!*			

Here too neutralization emerges as the product of implementational conditions: timing and perceptibility.

4.2. Shuswap

Kuipers (1974) describes Shuswap glottalization in terms very similar to Newman's Yokuts: the non-syllabic glottalized sonorants occur only postvocalically, whereas the obstruents are positionally unrestricted. The comments on glottal timing provided by Kuipers are less clear than Newman's, but they do indicate a timing difference between ejectives and glottalized sonorants similar to that of Yokuts. Thus the correlation between timing and neutralization seems to hold for this language as well. The differences between Yokuts and Shuswap are equally revealing. Unlike Yokuts, the Shuswap sonorants can be syllabic. When syllabic, they can be distinctively glottalized regardless of context, presumably because they are considerably longer than their non-syllabic counterparts: for instance *xpln`'tes* 'he puts rocks in the sweathouse' (Kuipers 1974:25) displays a syllabic, postconsonantal, distinctively glottalized [n`']. Non-syllabic sonorants, in contrast, pattern exactly like the Yokuts sonorants.

A further durational effect is that creak is attracted in Shuswap to the stressed syllable: a suffix containing creak or / "yields its glottalization to the final sonorant of a stressed root." (Kuipers 1974:30). Thus the suffix *-ke/* 'implement' is realized as *xi!c-ke/* 'scythe', after a root lacking an eligible sonorant, but as *xWu!l'-ke* 'fire-drill' (*xWu!l-* 'rub fire') after a stressed postvocalic sonorant. In *xWu!l'-ke* the suffixal / has moved to the immediately post-accentual position. I attribute this to the fact that the stressed vowel is longer, louder and thus better able to carry the contextual cues for creak. Thus the interpretation suggested here is that stress attracts creak because the acoustic attributes of the stressed syllable improve the perceptibility of this feature. Formally this will mean an addition to the creak perceptibility scale (V' _ R V_) and a corresponding expansion of the *Creak family of constraints
(*Creak/ V[-stress] _ >> *Creak/ V[+stress]_) .

To confirm this interpretation of the link between stress and creak licensing, let us consider a string with two postvocalic sonorants flanking the stressed vowel : $V_1R_1V_2' R_2$. Here we predict that only R_2 will be able to attract glottalization. The reasoning is as follows: like R_2, R_1 in $V_1R_1V_2' R_2$ is both postvocalic and belongs to a stressed syllable. However, R_1 is inferior to R_2 as a potential carrier of glottalization: the cues for creak in R_1 will be carried by the shorter, less loud, unaccented V_1. In contrast, the cues for R_2 will be carried by the longer and louder accented V_2. Kuipers provides several forms that confirm this connection between stress and the licensing of creak. Thus *x-cwiwe!y'-tn`* 'graveyard' (1974: 267), consists of *cwiwey* 'corpse' and the suffix *-/t (e)n* 'place' (1974: 62). In the root *-cwiwe!y*, there are two postvocalic sonorants in the stressed syllable, *w* and *y* , but the glottal feature contributed by *-/t (e)n* lands on the *y* precisely because what matters is not simply being in the stressed syllable but rather the specific effect of stress as an enhancer of glottalization cues .

4.3. Kashaya

In describing the realization of Yokuts glottalized sonorants, Newman (1944:19) mentions the fact that the glottalization is stronger when the sonorant occurs in coda position, i.e. stronger on *w'* than on the *n'* of *hiw'.ti.n'ay*. It appears that in Yokuts the contextual effects of creak on a preceding vowel are stronger under tautosyllabicity. Kashaya, a Pomo language, turns this into a categorical limitation on contrast: aspirated and glottalized sonorants occur there only in the coda, that is when tautosyllabic with the vowel that carries the contextual cues to their laryngeal category. I discuss the Kashaya facts here, drawing on Buckley's (1992) analysis, because they illustrate the conditions under which laryngeal neutralization may apply to onsets. A further point of interest of the Kashaya data is the realization of laryngeal features in clusters. The typical phenomenon elsewhere is that laryngeal neutralization affects most clusters whose members possess distinct laryngeal gestures: e.g. *bt* -> *pt* (as in Russian), *mp* -> *mb* (Japanese), $b^h t$ -> bd^h (Sanskrit). Kashaya is remarkable in that many clusters of laryngeally distinct consonants are preserved as such: thus *m't1Ó* is preserved without neutralization of either member, while a sequence like *l-Óc* is neutralized with *l9c*. The cue-based theory of licensing will shed light on the difference between assimilating and non-assimilating sequences.

Kashaya (SW Pomo) contrasts aspirated, voiceless and ejective obstruents; and aspirated, plain and creaky sonorants. The latter occur only in coda (Buckley 1992:39).

(41)

aspirated sonorants	glottalized sonorants
cam9ci/ 'shrink'	pÓa/am'so 'type of greens
way9 'just walked out'	kelkel' 'peer repeatedly'
lan9c'a 'six'	may'ma 'separate, apart'

Word-final glottalized sonorants become plain when resyllabified as onset to a following vowel (cf. (42.a); Buckley,1992:49). A similar phenomenon affects morpheme-final glottalized and aspirated sonorants: when resyllabified as onsets they lose aspiration and creak (cf. (42.b); Buckley 1992:78). Glottalized nasals syllabified word-internally into onset position lose not only glottalization but also nasality:

(42) a. Effects of phrasal resyllabification:

m' -> m do.lom' 'wildcat' do.lo.me.mu 'it's a wildcat'
n'> n man' 'her' ma.ne.mu 'it's her'

b. Effects of word internal resyllabification:

l9 -> l n0a-/c'ol9-ic'-/ -> da/c'oli/ 'pick one's nose'
n'> d can'-i -> ca.du 'look'
(cf. can'pÓi -> can'.pÓi' 'if he sees')

The same constraint against glottalized sonorants in the onset is demonstrated by the differential effect of */*-initial suffixes on stops and sonorants. Word-final sequences of stop-*/* yield ejectives (43.a); word-final sequences of sonorant-*/* yield creaky sonorants (43.b). Before a vowel, however, the derived sequence sonorant-*/* is reduced to a plain sonorant (43.c), while the stop-*/* sequence continues to yield an ejective (43.d). This is attributed by Buckley to the fact that the prevocalic sonorant-*/* cluster would have to be syllabified as an onset, and creak is impossible in the Kashaya onsets; ejectives, on the other hand, are permitted both as codas and as onsets.

(43) a. qahmat1-/ -> qah.mat1' 'angry-Assertive' ('he's angry')

b. c‹is‹kan-/ -> c‹is‹.kan' 'pretty-Assertive' ('it's pretty')

cahaw-/ -> ca.haw' boil-assertive' ('it's a boil')

c. c‹is‹kan-/-emu -> c‹is.‹ka.ne.mu 'that's pretty'

balay-/-emu -> ba.la.ye.mu 'that's a frog'

d. wat1ac-/-emu -> wa.t1a.c'e.mu 'that's a frog'

The analysis of the glottal merger phenomenon in (43) must refer to minimal distance constraints on contrast (Flemming 1995): the contrast between *t/* and *t'*, *n/* and *n'* is eliminated because not sufficiently distinct. We will not however analyze explicitly this aspect of the Kashaya system, since the details are tangential to understanding the licensing of creak and aspiration. A further point left out of the analysis is the difference between glottal stop and the realization of creak in sonorants: creak, although distinct from a glottal stop, is sufficiently similar to it that a creaky *n'* may count as a partially faithful realization of the underlying *n-/* sequence. To implement this idea we will have to distinguish several acoustic consequences of glottal constriction, at least one of which will be the feature shared by creaky segments and */*. Here, to simplify matters, we will assume that *n-/* and *n'* differ only in the timing of their component features, with the glottal gesture overlapping *n* in *n'*. Finally, the difference between the word-internal and phrasal treatment of onset *n'* and *m'* (42.a) vs. (42.b)) will also be left unanalyzed: the only important point is that both lose glottalization.

The fact that aspiration and glottalization in sonorants are neutralized in onset position indicates that the preceding vowel, which carries the contextual cues to these features, must be not only be present but also tautosyllabic with its licensee, the sonorant. This type of condition may be viewed as referring to prosodic locality as a condition on the distribution of cues. The relevant constraints appears in (44). The timing condition is the one motivated earlier for Yokuts (SonTiming): the new element in the analysis is the italicized heterosyllabicity clause in (44.b).

(44) a. Context cues (creak):

*creak/ in position where context cues to creak are absent.

b. Context cues (creak; heterosyllabic)

*creak/ in position where the context cues to creak are absent *from the syllable to which the creaky segment belongs.*

c. Ranking

Context cues (creak)

Context cues (creak; heterosyllabic)

c

Preserve [creak]

I illustrate the analysis first with the example of *do.lom'* 'wildcat' and *do.lo.me.mu.*

(45) *m'e -> me (do.lo.m'-emu => do.lo.me.mu)*

	*Context cues (creak; heterosyllabic) >>	Preserve [creak]
dolom'emu	!*	
dolomemu		*

(46) *do.lom'*

	Preserve [creak]
do.lom'	
do.lom	*!

The same types of conditions and rankings characterize the implementation of aspiration in Kashaya sonorants. The case of aspirated obstruents is discussed below.

Kashaya has glottalized and aspirated obstruents, which may cluster with the glottalized and aspirated sonorants under certain conditions. Although the entire paradigm is too complex to be analyzed here, two points will be illustrated. First, the ejectives and post-aspirated obstruents neutralize under very different circumstances from the creaky and aspirated sonorants; and second, laryngeal neutralization in clusters is determined entirely by the position of the transitional cues of each cluster member.

I illustrate first the existence of sonorant-obstruent clusters whose members possess distinct and non-neutralized laryngeal values (data from Buckley 1992:39 and passim).

(47) a. modal sonorant + aspirated stop: kÓomkÓolo 'river eel'

b. creaky sonorant + aspirated stop: s‹inam't1Óe 'top'

c. aspirated sonorant + aspirated stop: yem9tÓe 'gill net', hay9cÓa 'dry brush'

d. modal sonorant + ejective: na:nc'a 'sixteen'

e. aspirated sonorant + ejective: lan9c'a 'six', hay9t'a 'redbud'

f. creaky sonorant + ejective: qÓam's'udu 'strawberries', way'c'in 'repeatedly'

g. aspirated sonorant + plain obstruent: s‹u/bun9ciw 'twitch once'

h. creaky sonorant + plain obstruent: hay'ko 'wigglers', pÓa/am'so 'type of greens'

The reason why laryngeal features are preserved intact in clusters of this type is that the cues to these features appear at opposite ends of each sequence, and hence do not interfere with each other. Aspiration and creak on the sonorant are present on its closure and probably on the preceding vowel as well[32], while aspiration and ejection in the obstruent are manifested at release. The following diagram of the cluster *m't1Ó* in *s‹inam't1Óe* illustrates these points: segment labels are added in for easier identification. Major cues to the laryngeal category of the consonants are indicated with bold characters.

(48) Hypothesized sequence of acoustic events in *am't1Óe*

modal voice **creaky voice** silence burst **aspiration** modal voice
---------------|-----------------|-------------------|--|----------------|---------------
a a) a)0 m0 t h e9 e

a **a**

context cues for creak   context cues for aspiration

The order of the consonants can interfere with the manifestation of cues to laryngeal categories. In such cases neutralization occurs. This takes place in two circumstances: when a pre-aspirated or pre-glottalized stop[33] follows a sonorant (e.g. *yÓt -› y9t*) and when an aspirated stop precedes another consonant (e.g. *tÓq -› tq*). (Ejective stops are preserved in all circumstances, while aspirated stops are neutralized word-finally as well.) The essential point of these observations is to note that Kashaya consonantal clusters permit only combinations of distinct laryngeal categories *whose cues are manifested at opposite ends of the sequence*. In

[32]Buckley (1992) reports that creaky nasals are heard with modal voicing followed by creaky voicing optionally followed by a glottal stop. I take this to mean the following: the vowel preceding the nasal is both creaky and heavily nasalized, but the onset of nasalization on the vowel leads the onset of creak. This interpretation is reflected in the diagram in (89). No information is provided about the phonetic realization of creaky oral sonorants.

[33]The pre-aspirated and pre-glottalized stops are referred to by Buckley (1992) as laryngeal increments.

clusters like *yÓt*, both *y* and *Ót* need the preceding vowel to manifest the context cues for their laryngeal category: where such competition takes place, one consonant necessarily loses.

In the case of clusters like *y Ót -› y9t* the shift in the timing of aspiration can be attributed to the fact preaspiration is necessarily realized on the sonorant's closure: and this leads to the neutralization of the contrast between modal and aspirated sonorants in that position, since the contextually aspirated sonorant is partly indistinct from an underlyingly aspirated sonorant. Similarly, a stop's pre-glottalization is necessarily realized on the sonorant that precedes it and this leads to neutralization for the same reason. There is a class of aspirated or creaky sonorants which have comparable effects on preceding sonorants: these are called *laryngeally incremented* sonorants by Buckley. These differ from the normal aspirated and creaky sonorants only in the fact that they allow their glottal features to be realized outside of their own syllables: thus h-incremented *Ón* is realized intervocalically as *ahna*. Like other aspirated and creaky sonorants, these laryngeally incremented ones lose their glottal feature in the absence of a preceding vowel: *Óla* -> *la, *l9a*. When incremented sonorants follow a modal sonorant, the latter is neutralized in the same way as when it precedes pre-aspirated and pre-glottalized stops: the sonorant becomes aspirated or creaky, as the case may be: *n-Óm* -> *n9m, y-'n* -> *y0n*. This type of data, incidentally, supports the idea that the timing constraint resulting in preglottalized sonorants is a phonological phenomenon, since it is responsible for the neutralization between modal and non-modal sonorants in cases like *y-'n* -> *y0n.*

(49) a. modal sonorant + pre-aspirated stop: *yowal Óco/li* 'when he shot the former ..."

[yowal9co/li]

b. modal sonorant + incremented aspirated sonorant: *c'is‹kan m9i* 'really pretty'

[c'is‹kan9mi]

c. modal sonorant + preglottalized stop: *balay /t'ow* suck blood' [**balay0t'ow**]

The diagram in (50) clarifies the difference between sequences like *l-Óc* (49.a), which yield through neutralization *l9c*, and sequences like *m-kÓ ,m0-tÓ* (47.a, b) which are preserved intact.

(50) a. Hypothesized sequence of acoustic events in al Óco

```
modal voice    aspiration  silence   burst  modal voice
---------------|--------------|-------------------|--|----------------
a    l    l9              c                  o
```

b. Hypothesized sequence of acoustic events in al9co

modal voice **aspiration** silence burst modal voice
-----------|------------------|-------------------|--|----------------

a **a9** **l9** **c** **o**

As can be seen in (50), the difference between intact, non-neutralized *l-Óc* and neutralized *l9c* is the extent of aspiration on *l* and on the preceding vowel, essentially a small difference in the duration of the aspirated vs. modal portion of the string. What's important here is that in clusters like *l-Óc* both modal voiced *l* and pre-aspirated *Óc* compete for the same string on which to express their laryngeal categories: therefore one of consonants must be neutralized, to reliably implement the laryngeal feature of the other. In contrast, in cases like *mkÓ, m0tÓ, m9t*, both laryngeal categories present in the cluster can be realized without damage to either, since their cues lie at opposite ends of the sequence.

Consider now the other case of laryngeal neutralization in Kashaya. This involves neutralization between plain voiceless and post-aspirated stops in "coda", i.e. before another consonant or word-finally. Buckley identifies the neutralized stop category occurring in coda as aspirated and therefore writes all non-ejective coda stops as aspirated: I have doubts about this identification[34], so I will use the capital letters to indicate a laryngeally neutralized stop. Some examples of this type of neutralization appear below (from Buckley 1992: 61, 89 ff); underlyingly aspirated stops do not appear pre-consonantally in Buckley's data, but his statements indicate that clusters such as *tÓk,* or *tÓm* would be realized with neutralization as *Tk, Tm*.

(51) a. n0ahyuti -> dahyuti 'break it! (sg.)
n0ahyut-me/ -> dahyuTme 'break it! (formal.)
b. ce-mac-a -> cemaC 'is open in from here'
c. s‹ubilic'-tÓ -> s‹ubili/T 'didn't blaze up'

The important point to note here is that for postaspirated stops it's the right-hand context that determines neutralization because the primary cue is the VOT value, expressible on a following sonorant. In Kashaya, the sonorant bearing the VOT cue to post-aspiration must be tautosyllabic with the stop: this explains

[34]The reason to doubt the identification of coda stops with the aspirated category is that in clusters like **cÓaTqati** 'going to go trapping' (written **cÓatÓqati by** Buckley 1992:86) the coda T cannot have a VOT value that's even remotely similar to that of an aspirated **tÓ** in onset position, e.g. **moma:tÓela** 'I didn't come in' (Buckley 1992:168). The same goes for word final stops, e.g. **ca/T** 'didn't look' (written **ca/tÓ by** Buckley 1992:92). Clearly, the impression of aspiration is given by the voiceless release of the coda stop, but this is insufficient to determine its laryngeal category. Since there are no non-neutralized aspirated stops in coda, we have no empirical basis for deciding whether T = tÓ or T = t.

why in a string such as *tm* (51.a) *t* is laryngeally neutralized. The absence of a right-hand sonorant also explains the neutralization of word final *tÓ* in (51.c) *s‹ubili/T*.

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5. Cue duration and sonorancy: Klamath

The syllable structure and laryngeal neutralization of Klamath have been analyzed by Clements and Keyser (1983), and subsequently by Kingston (1985) and Levin (Blevins) (1985, 1993). Klamath has glottalized, aspirated and plain sonorants, glottalized, voiceless and "voiced" obstruents. The voice contrast in obstruents involves differences between short and long VOT, rather than genuine closure voicing (Barker 1964). I therefore follow Blevins (1993) in viewing both the sonorant and the obstruent contrasts as involving glottalized-aspirated-unaspirated sets rather than glottalized-voiceless-voiced sets. Obstruents have all laryngeal values neutralized before other obstruents, before glottalized or aspirated sonorants[35], and word-finally. The transcription followed here is Blevins's (1993):

(52) Klamath laryngeal contrasts and neutralization in obstruents
contrasts before plain sonorant

(i)	mp^het'-i:qi	'floats up'
	mp^het'-wa	'floats in water'
(ii)	p^hec‹^{h}-ne:ka	'puts a foot into a hole'
	p^hec‹^{h}-wa	'puts a foot into water'
(iii)	l^hep-l^hep'-a	'becomes flat'

(53) Neutralization before obstruent

(i)	mp^hat-planc‹'a	'floats downstream'
(ii)	p^hec‹-k'wa	'puts a foot across'

(54) Neutralization before aspirated sonorant

(ii)	phec‹-l^ha	'puts a foot inside'
(iii)	l^hep-l^hep'-a	'becomes flat'

(55) Neutralization before glottalized sonorant

(ii)	phec‹-l'a	'gets a foot as a wooden leg'
(iii)	l^hep-l^hep-l'i	'flat'

[35]The more complex pattern of laryngeal neutralization in sonorants will not be dealt with here: see Blevins (1993).

(56) Word-final neutralization

(i)	n'ep^h	'hand'	(n'ep^h-e:/a 'puts on glove')
(ii)	nc‹'ek^h	'in little bits'	(nc‹'ek'-a:ni 'small')
(iii)	nkak^h	'turtle sp.'	(nkak-am 'turtle's')

The question considered now is the characterization of the context where neutralization occurs. Since the obstruent-plain sonorant clusters that preserve laryngeal values look like plausible muta-cum-liquida onsets, it is tempting to say that only onsets may license the occurence of distinctive laryngeal features (cf. Kingston 1985). A pre-final ejective such as k' in /nc‹'ek'/ contains an unlicensed laryngeal node and must therefore lose it; the other contexts of neutralization will be explained along similar lines. A slight variant on this analysis would invoke Lombardi's (1995) Laryngeal constraint which requires laryngeal nodes to be followed by a *tautosyllabic* sonorant. Such an analysis would have to be coupled with the assumption that glottalized or aspirated sonorants are not true sonorants - perhaps in the sense that *actual* modal voicing (as against potential modal voicing, as assumed in SPE) is a defining characteristic of sonorants - and therefore cannot count as licensers. However, as Blevins (1995) shows, the only analysis consistent with our understanding of Klamath syllable structure is that the laryngeally specified obstruent must be followed by some sonorant, not necessarily in the same syllable: all VCCV clusters are heterosyllabic. Blevins - following in this earlier proposals by Clements and Keyser (1983) - shows that the the distribution of schwa, the reduction of vowels and the location of stress all require VC.CV divisions, even when the interlude is an obstruent-sonorant cluster. This means that ejection and aspiration are licensed in (52) regardless of syllabic boundaries: examples like *p^{h}ec‹^{h}-wa* (i.e. [p^{h}ec‹^{h}.wa]) display both intra- and inter-syllabic licensing.

As suggested earlier, plain sonorants in the right-hand context are necessary for the perception of laryngeal features to the extent that the VOT and the burst quality are among the main cues to the contrast. This is clearly the case for Klamath obstruents: the plain stops differ from the aspirated stops in VOT values; the ejectives differ from the other two series in possessing a glottal release that clearly follows the oral release (Barker 164:22, 24). Like the aspirated stops, the ejectives must also be assumed to carry longer VOT than the plain stops. In addition, the ejectives will differ from the aspirated stops in showing no formant structure following the moment of oral release. Thus at least one aspect of the difference between Klamath *p, p*Ó and *p'* is the voicing lag and the presence of formant structure after oral release. Both of these cues require a right-hand modal sonorant context in order to manifest themselves.

Let us consider now why the glottalized and aspirated sonorants fail to license laryngeal distinctions in the preceding consonant. My claim is that they induce laryngeal neutralization not because they lack true sonorancy, but rather because they must implement their own distinctive laryngeal features. This point becomes clearer when we note that aspirated and laryngealized sonorants have their laryngeal gestures timed towards the onset of the oral constriction: Barker (1964:25-29) observes that the aspirated nasals glides and liquids are pre-aspirated and that the glottalized ones are synchronously glottalized, with complete glottal closure occurring early during the sonorant. Assuming that the timing constraints responsible for phasing oral and laryngeal gestures are undominated in Klamath, it becomes clear that the initial portion of the laryngealized sonorant is not available to express the cues to a preceding laryngeal gesture. This means that if a Klamath speaker insists on producing an aspirated stop before a laryngealized sonorant, the cues to aspiration will have to reside in the duration of the stop's closure and in the burst quality: but the cues are so limited now that there's little incentive to produce the glottal gesture at all. These considerations are reflected in the hierarchy in (57). [VOT] abbreviates below the two categories [long VOT] and [short VOT]. Ejectives and aspirated stops belong to the first class, plain stops belong to the latter. The constraint *[VOT]/X_Y indicates that no VOT distinctions should be maintained in the X_Y context. Additional auditory properties - abbreviated here as [ejection] - differentiate ejectives from aspirated stops. The relevant family of constraints is *ejection/X_Y. Since the cues to ejection and aspiration in stops reside almost exclusively in the burst and a following modal sonorant, the perceptibility scale for ejection and aspiration will involve the following ranking of contexts: __[modal sonorant] R __ # R ____[obstruent], [non-modal sonorant]. The constraint rankings observed below mirror this scale in reverse.

(57) *VOT/ __[-son] | *ejection/ __ [-son]
[non-modal sonorant] | [non-modal sonorant]

*VOT/ __# | *ejection/ __ #

Preserve VOT | **Preserve ejection**

*VOT/ __ [modal sonorant] | *ejection/ __[modal sonorant]

The neutralizing effect of non-modal sonorants on neighboring stops is not limited to Klamath: Silverman (1995) observes similar patterns for Jalapa Mazateco and Gujarati. In fact, none of the languages surveyed by Silverman, Lombardi (1991) or myself has obstruents and non-modal sonorants which pattern differently in the neutralizing effect they have on preceding obstruents: if both types exist in a given language they will have identical effects on preceding obstruents. The broader significance of this phenomenon was noted earlier in the discussion of Hungarian pre-h devoicing (Part I): we cannot refer to the element that licenses laryngeal contrasts in obstruents as a sonorant, since non-modal sonorants fail to license. Rather, the most general characterization of the licensing element is a string on which laryngeal cues - VOT, F0 and F1 values - are optimally manifested. I consider next additional Klamath data that supports this point.

We compare now the patterns of laryngeal neutralization sonorants with the obstruent data just examined. The generalizations to be discussed are due to Blevins (1993). As we will see, the distribution of voiceless and glottalic sonorants is significantly less restricted than that of corresponding obstruents. This is due to the fact that sonorants possess internal as well as contextual cues to their laryngeal categories: the sonorant's voiceless or glottalized quality can be ascertained during the period of oral closure. In contrast, the silent phase of a stop cannot distinguish among the ejective, aspirated and plain series. For this reason, the plosives' laryngeal features must possess contextual cues, whereas the same features in sonorants need not. This difference in potential perceptibility translates into different neutralization patterns.

There are three classes of sonorants in Klamath: the modal, the aspirated and the glottalized. Syllabic sonorants - limited to contexts where they represent local sonority peaks - are modal. The aspirated non-syllabic sonorants are almost entirely free in distribution. The only possible gap may involve the scarcity of final *y9, n9, m9, l9* , likely due to a general process of final devoicing.

(58) Aspirated sonorants in Klamath:

a. word final: c‹iw9 (sound of hot rock plunged in water)

b. word initial: n9aykst'a 'on one side'

c. before obstruent: sk'a:w9tki 'be cold' /c‹k'a:w9/

/am9k'a 'maybe'

d. after obstruent: l9ap'akl9as 'shoulder'

e. before non-modal sonorant: kuw9y'asqs 'venereal disease' /kuw9/

f. before / : hay9/ay9a 'tracks in front of'

The glottalized sonorants are limited in two respects only: they cannot occur before stops and non-modal sonorants. They can occur - unlike the ejectives - at the end of the word and before non-stop obstruents.

(59) Glottalized sonorants in Klamath

a. word final tal' 'toward';

sway' 'red deer'

b. word initial n'ephe:/a 'puts on a glove'

c. before obstruent /u:l's 'dove':

sqÓel/am'c‹ [m's] 'big Old Marten'

d. after plain obstruent qÓaqn'u:l's 'armor shirt'

e. after non-modal sonorant kuw9y'asqs 'venereal disease'

I turn now to the distribution of cues in non-modal sonorants. Barker (p. 25, 27, 28) reports hearing "consistent glottal stricture and voicing throughout" the glottalized nasals, laterals and glides. The peak of glottal constriction is reached at the onset of the consonantal closure - hence narrow transcriptions such as */m, /y, /l* - but the creakiness persists audibly throughout the sonorant: this, I claim, is the reason for the wider distribution of Klamath glottalized sonorants relative to ejectives. The articulatory features of the two series are clearly related, but their identifiability differs. Aspirated sonorants are similarly reported as voiceless throughout (Barker p. 25, 27, 28); the timing of the glottal abduction peak varies with context, but it normally yields *pre*-aspirated phones. The lack of distributional restrictions on aspirated sonorants is also due to the presence of internal cues to aspiration, which are entirely lacking in the the aspirated stops.

Two points must be settled now: one is formalizing the difference noted between the internal cues in sonorants and their absence in stops; the other is accounting for the distribution of glottalized sonorants. The latter seems to stem from avoidance of the following sequences of glottal states:

(60) Banned glottal sequences in Klamath

a. glottis: *[constricted][abducted]

e.g.	/	tÓ
	n'	t
	w'	yÓ

b. glottis *[constricted] [constricted]

e.g.	/	n'
	t'	n'
	n'	t'
	y'	n'

Note that I assume that plain voiceless stops involve some glottal abduction, with the difference between aspirated and plain voiceless attributable to either timing or magnitude differences in the abduction gesture: thus the absence of *n' t* sequences in Klamath is due to the same constraint as the absence of *n'tÓ*. The nature of the constraint responsible for (60.a) remains unclear, but it seems unlikely that it can be related to perceptibility factors, since the glottalized character of a sonorant is equally identifiable before *s* (where it is attested) as before *t* (where it is not). The process in (60.b) is a familiar dissimilation phenomenon.

We can turn now to the more revealing issue of formalizing obstruent/sonorant differences in the licensing of glottal features. One possibility is that this is a function of the *duration* of cues: longer cues are, all else equal, better cues[36]. Since the cues to aspiration and glottalization are present during the period of closure in sonorants, as well as in the surrounding context, the sonorants offer longer cues than the obstruents, whose glottal cues are exclusively contextual. Therefore by simply stating that F is more perceptible in a context where it's cues are longer we in effect distinguish the sonorants from the obstruents in a case like Klamath . The general form of this addition to the perceptibility scales must then be: F/ longer cues R F/ shorter cues. It then follows that *F/ shorter cues >> *F/ longer cues. Without pursuing this in greater detail, I will assume then that an expansion of the constraint system along these lines can account for the obstruent/sonorant difference[37].

I have considered in this section differences in the neutralization patterns of sonorants and obstruents that arise not from timing but from cue duration: the length of the string over which the laryngeal quality of the consonant is overtly manifested[38]. Cue duration has also been the factor invoked in the analysis of Slavic voicing neutralization of Part I: in that case the longer sonorant string (RV, syllabic R or word final R#) was seen to function as a more likely licenser of voicing in a preceding obstruent. The sonorant itself was non-distinctive for voicing. The cases discussed in this section fall into a different class since the sonorant carries cues to its own, marked laryngeal category. However for this class of cases as well, cue duration is critical: this is what explains the Klamath contrast between aspirated and plain stops is severely limited while that between aspirated and modal sonorants is completely unrestricted.

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[36]See also Flemming's (1995) and Kaun's (1995) related proposals on the effect of cue duration in triggering coarticulation and harmony.

[37] A relevant implicational law (Maddieson 1985) is that the existence of distinctive glottalization in sonorants implies, in any given language, the existence of glottalization in obstruents. This may stem from the relative salience of laryngeal features in the two segment classes: most laryngeal features are timed to release in stops and the release cues are more salient in stops than in sonorants, because they are linked to the abrupt transition from silence to burst (Goldstein 1990, Stevens 1994). This seems to be the dominant factor in choosing what segments to combine with which laryngeal features. However, cue duration - which favors sonorants over obstruents as carriers of aspiration and glottalization - matters too: it matters precisely in the cases where the segments are placed in contexts with impoverished cues, where duration may make a difference. This explains why glottalic sonorants may survive non-neutralized in contexts where glottalic obstruents do not.

[38] Lombardi (1991) assumes that both the obstruents and the sonorants are subject to the same laryngeal licensing condition: the need for a following tautosyllabic sonorant. Thus she predicts that the neutralization contexts will be identical for the sonorants and obstruents, in cases where both sound classes neutralize. We have seen that this is not so for either Kashaya or Klamath. Are there languages in which laryngeally marked sonorants and obstruents neutralize in the same contexts despite differences in timing and cue distribution? Lombardi's data suggests that such languages exist, but a second look indicates otherwise. The instances she cites of "syllable final" neutralization in sonorants involve either *word final* or *word non-initial* sonorants (as in Gbeya, Sui, Kammu, Lushai) or else the loss of a preconsonantal glottal stop (as in Klamath and Maidu). The cases where the word rather than the syllable position is implicated suggest an analysis in which the word initial position is the selective licenser of laryngeal features, for reasons related to lexical access facilitation rather than perceptibility (MacEachern 1997). The case of glottal stop in Klamath and Maidu appears in a very different light when we note that this sound is disallowed not only pre-consonantally but also post-consonantally in these languages: it appears that / occurs precisely where an onset is required, initially and between vowels. There is no need to invoke syllable-conditioned laryngeal neutralization in such caess either.

6. Summary

We summarize now the main points made here. We have presented arguments establishing that syllable position does not condition laryngeal neutralization. It would in fact be surprising if it did: there is no a priori reason why being in the onset is better for any feature than being in the coda or indeed somewhere outside of the syllable. More generally, it remains to be seen whether the syllable as a constituent is at all a relevant factor in controlling phonotactic possibilities (cf. Lamontagne 1993, Steriade 1995).

We have also noted that licensing contexts for laryngeal contrasts cannot be characterized segmentally: ***voice/ __[-son], _#** is not an appropriate substitute for a statement such as ***voice/ in contexts lacking VOT cues**. We have seen that [-sonorant] does not cover the appropriate class of sounds, since non-modal sonorants function exactly like obstruents in neutralizing the laryngeal distinctions in preceding stops. In contexts where the sonorant string is too brief (as in the ORO strings of Russian and Polish) the VOT-dependent laryngeal contrasts are not maintained: this too indicates that mere mention of obstruents and boundaries does not characterize the correct class of contexts. If we are to produce a general, cross-linguistically valid description of the contexts that typically induce neutralization, then direct reference to cues and cue duration is necessary.

This study has sketched a general characterization of licensing and neutralization contexts by reference to scales of perceptibility. The composition of the scales is determined by several factors. The relative number of cues plays a clear role since contexts with more cues to F count as more perceptible and hence as less likely to induce F's neutralization. The relative duration of cues is a different factor, since the context with longer cues to F counts as more perceptible. It is also possible that the relative salience of cues plays a role: cues located in the vicinity of a major spectral discontinuity may be more salient than those located elsewhere (Ohala 1990, Goldstein 1990, Stevens 1994). It was noted that perceptibility scales for F can be given only relative to some timing pattern of F relative to other features in the context, and only relative to size of F's gestures. Therefore constraints derived from perceptibility scales interact with constraints specifying gestural magnitude and intergestural timing. This chain of reasoning has led us to conclude that the constraints inducing phonological neutralization are deduced from knowledge of phonetic implementation and actively interact with other implementational constraints in yielding a characterization of contrast distributions.

More generally, we have observed here that the space of phonological possibilities is determined by anticipated facts about the physical realization of contrasts: gestural timing, and gestural magnitude and contrast perceptibility.

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