The Role of Prosody in Laryngeal Neutralization *

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Final Laryngeal Neutralization (FLN) in German is shown to be a prosodic process. I propose FLN occurs at the end of the phonological word, and illustrate why alternative syllabic and morphological accounts fail to capture the pattern appropriately. The crucial evidence is provided by affixes which depending on their prosodic shape may induce or fail to induce neutralization on a preceding stem-final obstruent. The analysis is compared with the proposal made by Steriade (1997), where prosody is argued to be irrelevant in patterns of FLN and FLN is analyzed as a phenomenon that is driven by markedness constraints ranked according to relative perceptibility of a contrast in different segmental environments.

1. Introduction

German employs a contrast between lenis and fortis[1] obstruents to distinguish words. This paper will explore the phonetic realization of the contrast and its relation to phonological processes. The phonetic implementation of the fortis stops involves, among other cues, an opening gesture of the glottis, henceforth for historical reasons somewhat inadequately called 'aspiration'. This aspiration occurs both in onsets and codas, and both in stressed and unstressed syllables, as is evident from the acoustic correlates in these positions.

The phonetic evidence presented will provide the means to evaluate accounts for Final Laryngeal Neutralization (FLN). I propose an analysis that characterizes the right edge of the phonological word as being the relevant environment for neutralization. The prosodic bracketing defended in this paper receives independent motivation from other segmental processes in the phonology of German. Alternative hypotheses that characterize FLN as syllable final or morphologically conditioned can be ruled out based on morpho-phonological interactions between FLN and affixation.

I compare my analysis to an analysis of FLN based on perceptibility in a given segmental context as it was suggested in Steriade (1997), which tries to account for the neutralization without making reference to prosodic structure.

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[1] I employ the terms 'fortis' and 'lenis' not to make reference to a phonological feature [fortis] but as a neutral term to refer to the two natural classes of segments distinguished by the laryngeal contrast.

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This analysis relies on a notion of paradigm uniformity to force neutralization where perceptibility considerations fail to predict it – namely in the environment where FLN systematically occurs.

The data presented show where this approach fails to correctly capture the observed pattern of neutralization. Stem-final obstruents neutralize before certain suffixes even when they start with a sonorant. The class of suffixes inducing neutralization can be correctly characterized by the prosodic shape of the suffix – a generalization unaccounted for in an analysis based on paradigm uniformity. I will furthermore illustrate that stem-final obstruents may neutralize when they precede derivational affixes even when they do not neutralize in any other form of the paradigms they occur in. Therefore, no notion of output-output correspondence such as paradigm uniformity can explain the pattern correctly.

The Licensing by Cue proposal proposed in Steriade (1997) needs to be revised as to its treatment of FLN patterns. FLN does not provide motivation for Output-Output correspondence constraints. Reference to prosodic structure is necessary and sufficient in order to explain the neutralization pattern.

2. The Contrast and Its Phonetic Realization

In the following I want to illustrate that German fortis stops (both underlying and neutralized lenis) are distinguished from lenis stops by an opening gesture of the glottis, with varying acoustic correlates in different prosodic and segmental contexts. Even in codas, stops are aspirated, unless an obstruent follows at the beginning of the next phonological word within the sam phrase. This pattern of regressive assimilation will not be addressed in this paper (cf. Wagner 2000) for discussion). Consider first the realization at the beginning of stressed syllables.

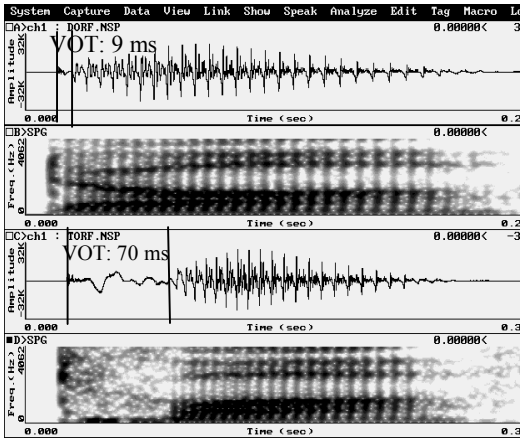
(1) Onsets – Stressed Syllable Initial[2]

Fortis			*Lenis*		
torf	[tʰoɐf]	‘peat’	dorf	[d̥ɔɐf]	‘village’
pause	[ˈpʰauzə]	‘break’	bauer	[b̥auɐ]	‘peasant’
katze	[ˈkʰatˢə]	‘cat’	garn	[g̊a:n]	‘thread’
applaus	[aˈp̥laʊs]	‘applause’	rabauke	[raˈb̥aʊkə]	‘scoundrel’
titan	[tʰɪˈtʰan]	‘titan’	radau	[raˈd̥aʊ]	‘uproar’
schikane	[ʃiˈkʰa:nə]	‘handicap’	regatta	[reˈg̊atʰa]	‘regatta’’
platz	[p̥latˢ]	‘place’	blitz	[b̥lɪtˢ]	‘flash’
trick	[t̥rɪkʰ]	‘trick’	drachen	[d̥raxən]	‘dragon’
kreis	[k̥raɪs]	‘circle’	greis	[g̊raɪs]	‘old man’

[2] The data reported generally correspond to the transcriptions in the standard pronouncing dictionaries Duden (1990), GDWA (1982), Siebs (1969). I depart from these only where indicated in the text. The evidence both in arguing for prosodic word final neutralization and against output-output correspondence is drawn from these sources and is furthermore corroborated by the data recorded for the purpose of this paper.

Lenis:[3] **[d̥oɐf] 'village'**
- slack vocal folds
- no closure voicing
- opening gesture of glottis
- low amplitude release burst
- ♦ short lag in VOT
- ♦ pitch lowered

Fortis: **[t^{h}oɐf] 'peat'**
- stiff vocal folds
- no closure voicing
- opening gesture of glottis
- ♦ high amplitude release burst
- ♦ long lag in VOT
- ♦ aspiration noise
- ♦ pitch raised



The main acoustic correlate of the contrast is a lag in Voice Onset Time (VOT) induced by an opening gesture of the glottis (cf. Kim 1970 for English), voicing does not play an important role (Stock 1971), and there is variation between speakers in whether some voicing occurs in the closure of lenis stops or not. This is analogous to the case on English (Lisker & Abramson 1964). Although there are a number of phonetic cues involved in marking the contrast (Lisker 1986, Braunschweiler 1997 & references therein), the percept changes from fortis to lenis when VOT is shortened below a certain level.

The above transcription indicates that if a sonorant follows the fortis obstruent, the opening gesture of the glottis induces a devoicing of the sonorant (Kim 1970). Aspiration is not restricted to the beginning of stressed syllables. Consider the following examples (cf. Braunschweiler 1997). I use the [^{h}] sign here to indicate that there is a lag in VOT which is responsible for the contrast; aspiration noise is of course much less than in the case of a stressed syllable. The point is that the lag in VOT can be attributed to the opening gesture of the glottis.

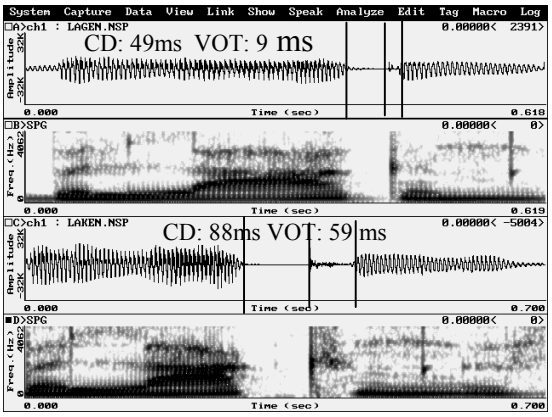
(2) Onsets – Unstressed syllables, after Long Vowels

Fortis			*Lenis*		
hupe	[ˈhuːp^{h}ə]	'horn'	taube	[ˈtaʊb̥ə]	'pidgin'
miete	[ˈmiːt^{h}ə]	'rent'	lieder	[ˈliːd̥ɐa]	'songs'
laken	[ˈlaːk^{h}ən]	'sheet'	lagen	[ˈlaːg̊ən]	'layers'

[3] The words were recorded as part of the sentence 'ich habe X gesagt.' I recorded 6 speakers. The examples given are representative of the recordings, and function as an illustration of the qualitative findings reported in the text. Bullets list artculatory correlates, diamonds acoustic correlates. I have listed phonetic correlates reported in various studies: Schmidt (1947), Kohler (1977), Braunschweiler (1998), Jessen (1998). The lines in the above spectrograms do not exactly correspond to the points measurements were made at. They were inserted with a word processor.

Lenis: lagen 'layers'
- longer vowel duration
- slack vocal folds
- some closure voicing
- short closure duration
- low amplitude release burst
- ♦ short lag in VOT
- ♦ pitch lowered

Fortis: laken 'cover'
- stiff vocal folds
- no closure voicing
- long closure duration
- high amplitude release burst
- opening gesture of glottis
- ♦ long lag in VOT
- ♦ aspiration noise
- ♦ pitch raised



Along with vowel duration and closure duration, aspiration marks the laryngeal contrast also in unstressed syllable onsets.[4] Aspiration in German is thus not foot-initial (as suggested in Yu 1992, Wiese 1996, Féry 1999), under the uncontroversial assumption that an unstressed syllable does not constitute the beginning of a foot. It also applies word internally and at the onset of unstressed syllables. The fact that pronouncing dictionaries do not transcribe aspiration in those environments is due to the lesser degree of aspiration (as is explicitely discussed in Duden 1990, Siebs 1969). The stops that some studies of German phonology (Wiese 1996 & references therein) have characterized as 'ambisyllabic', namely those following a short stressed vowel, do not differ in this respect[5].

(3) Onsets – Intervocalic After Short Vowels

Fortis			*Lenis*		
rappe	[ˈraˡpʰə]	'horse'	ebbe	[ˈɛb̥ə]	'low tide'
ratte	[ˈratʰə]	'rat'	kladde	[ˈklad̥ə]	'songs'
locke	[ˈlɔkʰə]	'curl'	knigge	[ˈknig̊ə]	*name*

[4] Braunschweiler (1997) shows that length of the vowel preceding the stop, closure duration, and lag in VOT are all independent cues. The longer vowel length before a lenis stop is not simply a compensation for the shorter closure duration.

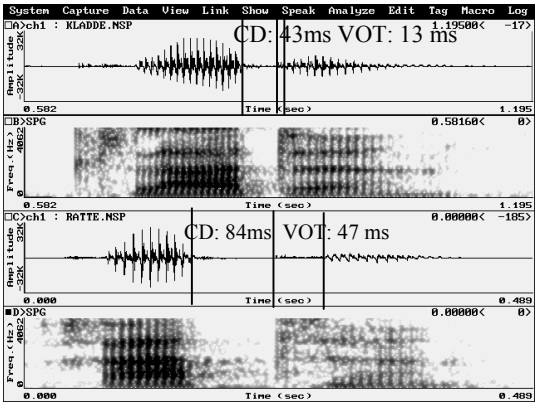
[5] Davis (1999) argues that in English, the distribution of aspiration is parallel to that of the segement [h]. German differs in that it shows aspiration in environments where [h] is disallowed, e.g. in the onset of unstressed syllables.

Lenis: Kladde 'booklet'
- longer vowel duration
- slack vocal folds
- cont. closure voicing
- short closure duration
- low ampl. release burst

♦short lag in VOT
♦pitch lowered

Fortis: Ratte 'rat'
- stiff vocal folds
- no closure voicing
- long closure duration
- high ampl. release burst
- opening gesture of glottis

♦long lag in VOT
♦aspiration noise
♦pitch raised



The data presented so far is consistent with an analysis that takes aspiration to be syllable initial. Aspiration, however, also occurs in codas. In FLN it is precisely the aspirated stops that surface in the neutralized codas.

(4) Codas (Word Final)

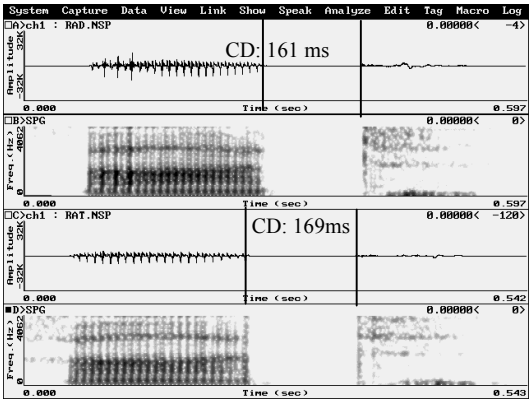
Fortis			Lenis (pronounced as fortis)		
Stopp	[ˈstɔp^{h}]	'stop'	laub	[ˈlaʊp^{h}]	'foliage'
tritt	[ˈtrɪt^{h}]	'kick'	lied	[ˈliːt^{h}]	'song'
stock	[ˈstɔk^{h}]	'stick'	steg	[ˈsteːk^{h}]	'pier'

(cf. Moulton 1962)

Fortis: rad 'wheel',
rat 'advice'
- stiff vocal folds
- opening gesture of glottis
- no closure voicing
- long closure duration

♦ release burst

♦aspiration noise



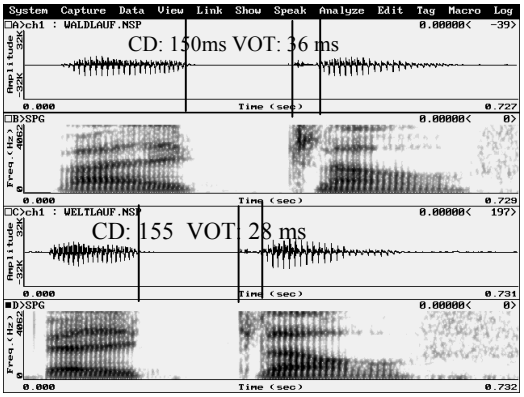
Coda aspiration does not only occur phrase finally. This is evidenced by the realization of final obstruents in compound words in German. The examples below illustrate that a final obstruent in the first member of a compound in German induces devoicing on a following sonorant at the beginning of the

second member of the compound.[6] I observed speaker variation between the presence and degree of devoicing. The main point of importance here is that in careful speech, coda stops are often aspirated; therefore aspiration cannot be a syllable-initial process.

(5) Codas: Devoicing of Following Sonorant[7]

Fortis
- stiff vocal folds
- no closure voicing
- long closure duration
- release burst
- opening gesture of glottis

♦Devoicing of following sonorant



Note that although there is no laryngeal contrast in this environment, there are acoustic cues relevant for the identification of fortis stops. In fact, if one reduces the lag in VOT following the /d/ in the phrase *Rat und Tat* 'advice & help', the result sounds as if *Rat* and *und* were part of the same morpheme, indicating that the fortis-ness is indeed perceived and the lack thereof has the effect that the string of segments is parsed in a different way. The contrast is thus neutralized only in the sense that lexical contrasts are not made, not in the sense that occurring fortis stops are indistinguishable perceptually from the lenis category occurring in other environments and that they do not encode relevant information (here: the prosodic boundary). In fact, in his pronunciation dictionary, Siebs (1969) explicitly warns against not aspirating word final stops.

To summarize: Fortis stops are realized with an opening gesture of the glottis, in onsets of stressed syllables, onsets of unstressed syllables, and codas. In obstruent clusters, which I will not discuss in this paper, a reduction to one phonological feature occurs, reducing the number of possible obstruent clusters distinguished by the fortis lenis contrast to two observed types: fortis and lenis.[8]

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[6] Some speakers had variation in both underlying fortis and neutralized lenis in coda position before sonorants between aspirated and non-aspirated realization.

[7] The devoiced sonorants in this example are lateral fricatives (cf. Ladefoged & Maddieson 1996: 205).

[8] In establishing a phonological representation for the fortis lenis contrast, the fricatives have to be taken into account. Fortis ones involve an opening gesture of the glottis (Vaux 1998), while lenis ones are voiced (Jessen 1998). If the laryngeal contrast among stops and fricatives is to be represented with a uniform feature, some level of abstractness is necessary along with a non-trivial mapping from phonology to phonetics. An appealing way to capture the uniformity of different correlates of fortis-ness is the suggestion in Halle & Stevens (1971) to invoke glottal tension (slack vs. stiff vocal folds) instead of the category 'voice'. As for the representation of the contrast, both in

3. Final Neutralization: Prosodically Conditioned

In this section I will show that the environment in which FLN occurs has to be characterized in prosodic terms. FLN occurs at the end of prosodic words. The following examples illustrate that FLN occurs at the word end and at the end of a morpheme preceding certain affixes, namely affixes that can minimally form a CV syllable. It does not occur if a vowel initial affix or an affix just consisting of a consonant follows.

(6) Neutralization at the 'Word End'

Stem		Gloss	V-Suffix C-Suffix	Gloss	CV-Suffix	Gloss
/liːb/	[liːp^{h}]	'nice'	[liːb + l + ə]	flirt, 1st sg.	[liːp ˌlɪç]	sweet
/raːd/	[raːt^{h}]	'wheel'	[rɛːd + ʁ]	'wheels'	[raːtˌ ˌlos]	'without _'
/taːg/	[taːk^{h}]	'day'	[taːg + ə]	'days'	[tɛːkˌ ˌlɪç]	'days'
/braːv/	[braːf]	'good'	[braːv + əs]	'good' neut		
/glaːz/	[ɡlaːs]	'glass'	[glɛːz + ʁ]	'glasses'		
/hɛmd/	[hɛmt^{h}]	'shirt'	[hɛmd +ən]	'shirts'		
/bund/	[bunt^{h}]	'alliance '	[bynd + ə]	'alliances'		
/tyːp/	[tyːp^{h}]	'type'	[tyːp^{h} + ən]	'types'		
/raːt/	[raːt^{h}]	'advice'	[rɛːt^{h} + ə]	'advisers'	[raːtˌ ˌlos]	'without _'
/werk/	[wɛʁk^{h}]	'work'	[wɛʁk^{h} + ən]	'to build'	[wɛʁkˌ ˌlos]	'without _'
/schlaːf/	[ʃlaːf]	'sleep'	[ʃlaːf + ən]	'to sleep'	[ʃlaːfˌ los]	'without _'
/groːs/	[ɡroːˈs]	'big'	[groːs + ən]	'big'		
/amt/	[amt^{h}]	'office'	[amt^{h} + əs]	'offices'		
/bunt^{h}/	[bʊnt^{h}]	'colorful	[bʊnt^{h} + ə]	'colorful'		

I propose that the phonological environment for FLN is a prosodic edge, namely the edge of the prosodic word.

(7) Prosodic Word Final Neutralization

[(marked) Laryngeal] → [(unmarked) Laryngeal] / __)$_{\omega}$[9]

Descriptively speaking, stems do not devoice in front of affixes that either start in a vowel or consist only of a consonant. The fact that the classification of affixes is only based on their prosodic shape is reminiscent of the observation made by Dixon (1977) in a paper on the phonology of Yidin^{j} where affixes can

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an aspirating language like German and in a voicing language such as Dutch, Idsardi & Avery (1999), Iverson & Salmons (1995), Jessen (1998), and Wagner (2000) have made different proposals, and derive the phonetic and phonological differences in different ways. Since the actual representation of the contrast does not bear on the argument of this paper, I will not review these approaches. Many of the arguments given in this paper, however, carry over to the data reported on Dutch by Trommlen & Zonneveld (1979) and Booij (1995).

[9] I assume clusters to share one laryngeal feature, such that clusters devoice just as single segments.

be classified in two classes based on the number of syllables. I will use his terms cohering and non-cohering affixes to classify the relevant affixes.[10]

(8) Descriptive Classification: Cohering vs. Non-Cohering Suffixes

a. All prefixes are non-cohering (not syllabified with segments of the string they attach to, FLN induced) and suffixes iff they start with a consonant and contain at least an additional sonorant.[11]
Examples: +ling, , +tum, +heit/keit, +bar, +haft, +lich, +los, +sam, +çn

b. Suffixes that consist only of one segment or start in a vowel are cohering (syllabifiation across stem-affix boundary, FLN not induced)
Examples: +l, +t, +ər, +ung, +ig, +ə...

I want to propose that this classification and the prosodification of affixed structures are due to the way prosodic structure is built up. While there are different conceivable ways to get to the correct prosodic structure (not all of which are derivational) I would like to emphasize that my emphasis lies rather in the output of the algorithm that in its details. I will motivate the prosodic boundaries it predicts on independent grounds. A discussion of the German foot structure and stress would be necessary to explore the details of the derivation of prosodic structure in German and decide between various alternatives. I will assume the following tentative algorithm: An lexical root that enters phonology is mapped into a prosodic word, which is the domain of syllabification and the construction of of foot structure. Within this domain, syllabic structure is predictable based on sonority and phonotactic considerations:

(9) Prosodic Word Mapping

$/\lambda_{1,}\, \lambda_{2,\ldots}\lambda_{i}\, /_{root} \rightarrow (\lambda_{1,}\, \lambda_{2,\ldots}\lambda)_{\omega}$

An affix attaches to the root prosodic word recursively forming a new prosodic word with it: (stem)affix). If a suffix starts in a vowel, or if it consists only of a consonant, the right bracket of the prosodic word it attached to erases and the segments of the affix are syllabified with the preceding segment: (stem suffix) . Otherwise, the brackets are matched yielding the following structure, essentially corresponding to that of compounds: ((stem)(suffix)). Prefixes always form a syllabification domain of their own: ((prefix)(stem)). Different derivational algorithms of syllabification have been proposed for German (cf. Rubach 1990, Giegerich 1992), which would need to be modified to give the correct results. The important point is not the label I give to the domain in question but simply

[10] A similar proposal was made by Grijzenhout & Krämer (1998), however, their classification (which was intended for Dutch), failed to group affixes that consist only of a consonant with the cohering class. I think this is descriptively correct both for Dutch and for German.

[11] 'artig' is also a non-cohering affix although starting in a vowel. This might be due to the fact that it itself is derived and contains sufficient melodic material to form a syllabification domain.

that there is a domain in which syllabification is predictable; that the setting of the boundaries of this domain interacts with morphology; and that the boundaries of this domain are what characterizes the pattern of FLN.

(10) Affixation and Prosodic Structure

a. CV-Affix
$(\lambda_1, \lambda_{2,...}\lambda_i)_\omega + /\beta_1, \beta_2, ...\beta_j/_{affix} \rightarrow (\lambda_1, \lambda_{2,...}\lambda_i)_\omega (\beta_1, \beta_2, ...\beta_j)_\omega$

b. C-Affix (C only, j = 1) or V-Affix (starts in a V, β_1 = V)
$(\lambda_1, \lambda_{2,...}\lambda_i)_\omega + /\beta_1, \beta_2, ...\beta_j/_{affix} \rightarrow (\lambda_1, \lambda_{2,...}\lambda_i\ \beta_1, \beta_2, ...\beta_j)_\omega$

Examples of the prosodic structure that I argue for are given in (11).

(11) The Prosodic Structure of some Examples

/raːd + l + ə/	'(I) bike'	$(raːd̥lə)_\omega$
liː/b/ + /l/ + /ə/	'(I) flirt'	$(liːb̥lə)_\omega$
/reːd/ + /n/+ /ər/	'speaker'	$(reːd̥nər)_\omega$
fol/g/ + lɪç	'consequently'	$(fɔlk)_\omega$ $(l̥ɪç)_\omega$
/staːt + lɪç/	'governmental'	$(staː)_\omega(l̥ɪç)_\omega$
liː/b/ + lɪç	'lovely'	$([liːb)_\omega$ $(l̥ɪç]_\omega$

There is independent evidence for the prosodic domains I propose. That indeed prefixes cannot syllabify with following material is generally assumed (Wiese 1996) and is evidenced by glottal stop insertion in examples such as Verein 'group' $(vər).(ʔaɪn)_\omega$. Instead of using the prefix /r/ as an onset, a glottal stop is epenthesized. The same happens between prefix boundaries: (vər). (ʔab).(reichen) 'to administer'.

A segmental process active only in the prosodic word is dorsal fricative assimilation. Consider the following examples: *kuchen* 'cake' $(ku:xən)_\omega$ vs. kuh + chen 'little cow' $(ku:)_\omega(çən)_\omega$. The diminutive affix /xn/ is predicted to be non-cohering, thus yielding the correct bracketing. The segmental assimilation of the fricative to a preceding vowel in frontness cannot apply across word boundaries. The suggested prosodic analysis thus yields the appropriate domain for dorsal fricative assimilation.

Another segmental process sensitive to the same domain is laryngeal assimilation. Within this domain assimilation (Dutch & German affixes and clitics) always applies towards the unmarked, i.e. is always towards a voiceless obstruent cluster if one of the two obstruents is voiceless; across prosodic word boundaries it is regressive. Examples of assimilation in this domain are *jagden* 'hunts' vs. *jagten* 'we hunted'. The level one nominalizing affix *–d* assimilates just like the English past tense or the Dutch past tense to a preceding obstruent. The German past tense always yields voiceless clusters, just as the English past tense *–t* (as in *left*) and the Dutch level I nominalizer *–t* (as in *leexte* 'emptiness'). The domain in which this pattern of assimilation can be observed to occur is exactly the prosodic word. If assimilation occurs across this domain (as, e.g., in Dutch

phrasal assimilation), it is always regressive. For a more detailed account of these patterns see Wagner (2000).

An alternative interpretation of the FLN data was proposed in Vennemann (1972), Hall (1992), and Giegerich (1992), who suggested that FLN is a syllable-related process, and neutralization applies to coda obstruents.

(12) Syllable Final Neutralization, Syllabification in Word Domain ([14))

[(marked) Laryngeal] → [(unmarked) Laryngeal] / __]$_\sigma$

A problem for this proposal is that not all apparent coda stops actually neutralize. Consider the following examples.[12]:

(13) Word Internal Coda stops that do not undergo devoicing

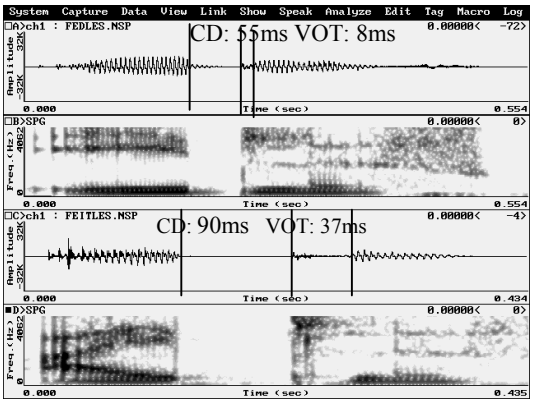
Lenis		*Gloss.*	*Fortis*		*Gloss*
ed.les	[d̥]	'noble'	eit.ler	[t̥l]	'vane'
Loeb.ner	[b̥]	*name*	Leip.niz	[pn̥]	*name*
Ad.ler	[d̥]	'eagle'	A.tlas	[t̥l]	'atlas'
Mag.ma	[g̊]	'magma'	ak.me	[km̥]	'acme'

The clusters in which the contrast fails to neutralize are not attested as possible onsets word initially. That indeed the contrast is not neutralized is shown in (14).[13]

(14) Syllabification Domain Internal Contrasts

Lenis edl+es 'noble'

Fortis: eitl+er 'vane'



Since the constrasts in (13) are all tauto-morphemic, one way to interpret the failure of neutralization would be to invoke some notion of underived environments. However, this will fail to block neutralization in derived

12 Some dialects in fact are reported to have syllable final devoicing, all obstruents in coda position in (13) surface as voiceless. Cf. Duden (1990), Vennemann (1972).

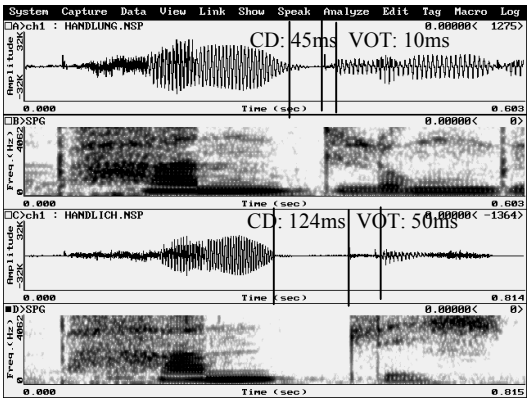
13 As was pointed out to me by Tracy Hall, there are some German names in the south of Germany with [gm-] (e.g. '[gm]ynd'), and 'km' and 'pn' seem to be marginally possible (e.g. '[km̥]äer', [pn̥]eu). /bn/, /dl/, /tl/ are unattested though.

environments where the clusters are derived by the addition of a single-consonant affix. Consider for example the example 'rad + l + e' *I bike*. Although the cluster is not a possible initial cluster, and although the cluster is not tauto-morphemic, no neutralization occurs.

(15) Morpho-Phonological Effects

a. Cohering
handl + ung - han[d̥l]ung

b. Non-Cohering
hand + lich - han[t̥l]ich



Vennemann (1972), aware of the problem, suggests that a language may or may not obey the Law of Initials. He thus posits the following syllabifications.

(16) Disobeying the Law of Initials

e.dles, ei.tles

However, this analysis leaves several questions open. Other instances of exceptional consonant clusters in German and other languages are usually attributed to edge phenomena (syllable appendices etc.). These exceptional clusters usually involve sonority violations, whereas the examples discussed here do not. Still, since cross-linguistically [dl], [tl], [gm] are rather rare as onset clusters, the Law of Initials approach does not seem very attractive. A second reason not to assume the exceptional syllabifications in (16) is that in cases such as *dogma,* the quality of the vowel is lax, indicating a closed syllable, thus syllabification as *dog.ma* and not as *do.gma*. Short vowels are lax in German iff they are in a closed syllable (Wagner 2002).

Henning Reetz (and more recently David Braun independently) pointed out to me that in fact, neutralization does occur in cases where the coda stop is preceded by a long vowel. I believe this is true at least in monomorphemic words (not, e.g., in *edles* 'noble'). Consider Zeu[k].ma *rethorical figure*. These examples are special also in that they seem to include a trimoraic word internal syllable, which is otherwise prohibited in monomorphemic German words. The contrast between *do[g]ma* and *zeu[k]ma* is exactly opposite to what would be predicted by a syllable final analysis: The consonant is in the coda in the case of the former, as evidenced by the quality of the vowel, so neutralization should occur; it would have to be in the onset in the case of the latter, under the assumption that the Law of Initials is violable, so no neutralization should occur.

These examples can be dealt with if one assumes that trimoraic syllables induce insertion of a right bracket. Then a word like zeu[k]).ma induces a right bracket insertion. FLN is then predicted to occur. This is solution is furthermore supported by an interesting fact about [g] deletion. The underlying cluster /ng/ is reduced to one segment at the (prosodic) word end. Interestingly, the same reduction occurs in words like *engma* [ɛŋma] or *ingmar* [ɪŋmɐ] *name.* This contrasts with words that contain licit onset cluster, such as *anglo* [aŋglo]. These examples corroborate that onst clusters like [gma] are ruled out in German word internally, and also that a right bracket is inserted in words that contain trimoraic syllables. The only environment where a vowel can be followed by more than one segment is thus adjacent of a right bracket.

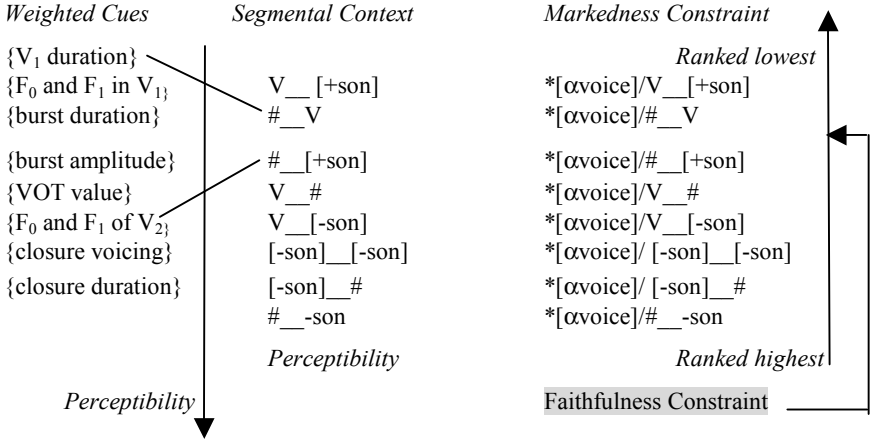
Apart from these empirical problems, the syllable-based analysis of FLN is unappealing because the only reason to assume these exceptional onsets word-internally is precisely the FLN data. The main reason why the earlier proposals referred to the coda as the relevant environment are cases such as Mä[k]de 'maids', Ja[k]den 'hunts' , le[p]ten: 'lived'. When preceding another obstruents, neutralization occurs. The analysis based on prosodic words I have suggested here relies on the assumption that stem-internal assimilation is independent of FLN. As outlined above, the fact German, Dutch, and English have the same pattern of within-word laryngeal assimilation suggests that there is no indication that FLN forms any part in explaining these cases anyway.

Arguments in favor of this approach are given in Wagner (2000). A cross-linguistic argument against linking cluster assimilation to prosodic neuralization is given in Wetzels & Mascaró (2000). A similar point is made in Rubach (1996). For the argument of the next section the issue of whether FLN is syllable or prosodic word final does not need to be resolved. The crucial point is that the environment has to be characterized in prosodic terms.

4. Paradigm Uniformity

According to the cue-based approach to laryngeal neutralization proposed in Steriade (1997), the distribution of a laryngeal contrast across segmental contexts covaries with the perceptual salience of cues available to mark the contrast in a given language. In this approach segmental contexts are evaluated as realization sites for contrasts according to the perceptibility and availability of the relevant acoustic cues in that environment. FLN is claimed to be independent of prosodic structure. In German, as outlined above, word internal coda obstruents before sonorants do not neutralize, even when they stand in the coda – so indeed, at least the syllable coda does not seem to be the correct generalization for FLN. The following diagram illustrates the model.

(17) The *[αvoice] Constraint Family



The implementation of the cue-based approach involves markedness constraints which make reference to segmental environments. These constraints are ranked according to a perceptibility scale. Faithfulness constraints then interact with this fixed ranking, in that no neutralization occurs in any environment whose corresponding markedness constraint is outranked by the relevant faithfulness constraint.

This model of constraint interaction is able to capture implications between neutralization environments. Thus whether or not '[...] the voicing contrast will be maintained in some context is a direct function of the cues available there. All else being equal, the better the cue package, the greater the likelihood of contrast preservation.' (p. 8). In defining neutralization environments, the argument goes, there is no need to invoke prosodic structure: 'The evidence will […] show that the sites of neutralization have no uniform characterization in terms of prosodic (esp. syllabic) organization.' (p. 8).

The characterization of FLN, however, calls for some complication in non-phonetic terms. Note that FLN languages often (Polish, Russian, German, Dutch) neutralize at the word end irrespective of whether a segment follows that could provide the necessary cues. So while a word-final obstruent followed by a word starting in an obstruent might be in a segmental context that has a low perceptibility value, the same obstruent stands in a highly favorable environment if the following word starts with a vowel. In Lithuanian, Steriade argues, there is indeed no neutralization in such a case, although there is neutralization in absolute final position[14]. The cue-based approach defines the word final environment by invoking the notion of a paradigm, using output-output constraints which require featural faithfulness with the 'citation' form of a stem.

[14] Possibly this environment is in fact the edge of a phonological phrase, as seems to be the case in several dialects of Yiddish (Birnbaum 1979). There would thus different types of FLN languages depending on the size of the phonological domain: Phrase-final (Lithuanian, Yiddish) and Prosodic-Word-final (Polish, Russian, and German).

(18) Paradigm Uniformity (right edge) abbreviated **PU Edge**[15]

> 'Assume that the string Σ represents the last demisyllable in the citation (utterance final) form of the 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.' (p. 56)

The idea is that in cases where neutralization occurs although the segmental environment would allow contrast preservation, the neutralization is 'imported' from the citation form, inducing neutralization of word final obstruents even if a vowel follows.

The obvious question in the light of the data presented in the preceding section is how the interaction with morphology can be made to follow from a paradigm uniformity constraint. Note that in the cases where FLN occurs preceding a segment starting in a sonorant, the cue-based segmental approach would predict that no neutralization occurs. Why is there neutralization in *lieb* + *lich* 'lovely', but not in *lieb* + *e* 'love'? In both cases the same type of morpheme boundary intervenes between stem and affix, and in both cases the segmental environment is one where German would allow the realization of the laryngeal contrast. The revision of the notion of paradigm suggested to solve this problem is one that actually does make reference to the syllable:

(19) Revised Paradigm Uniformity

> '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 in ga[p]) to differ in voicing.' (p.58)

Does this notion of paradigm necessary to account for FLN correspond to independently motivated notions of paradigms in the morphology of German? In the following I want to look at a number of examples where (19) may be at work. The goal of the discussion is to illustrate why not only the notion of paradigm uniformity defined in (19) fails to make the right predictions, but in fact no notion of output-output correspondence can be used to make FLN work, and prosody necessarily has to be invoked to explain the pattern.

[15] In languages with FLN and subsequent laryngeal assimilation PU Edge has to be qualified to induce only articulatory vs. perceptual paradigm uniformity.

(20) Example: /folg/

Nominal Paradigm: No Neutralization
die Fol[g̬]e (Sg. Nom), die Fol[g̬]en (Pl. NOm), .Fol[g̬]en.....

Verbal Paradigm: Neutralization in some forms
folgst (2nd Sg), (folgt 3rd Sg) and folg! (Imperative)

Derived Adjective: Neutralized
fol[k]lich 'consequently'

The affix *-lich* attaches to adjective, noun, and verbal stems (Fleischer 1995: 260). The stem *folg* occurs in a nominal paradigm *folge* 'consequence' and in a verbal paradigm *folgen* 'follow'. The only contexts where FLN applies to this stem are certain forms in the verbal paradigm. Both morphologically and semantically, the derived adjective *folglich* is related to the nominal form. Nevertheless, the stem undergoes FLN, 'importing' the neutralization from a form in the verbal paradigm. The next example is even more puzzling.

(21) Example 2: /liːb/

Stem: /liːb/			
Noun Paradigm:	liːb̥ə	'love',	no neutralization
Verb Paradigm:	liːb̥ən	'to love'	neutralization when final
Adjective Paradigm:	liːpʰ	'nice'	neutralization when final
When Derived:			
/liːb/ + /los/	neutralization:	liː [pl̥]los	'sweet'
/liːb/ + /l/ + /ə/	no neutralization	liː [b̥l] ə 'flirt'	

The affixes *-los* almost exclusively attaches to nominal stems (Fleischer 1995: 264). The suffix *-l* also almost only attaches to nominal bases. Nevertheless, only *-los* but not *-l* induces neutralization of the stem-final obstruent, although the segmental context is in both cases nearly identical: The obstruent is followed by a lateral which is part of an affix. Based on any notion of paradigm uniformity, one would expect FLN either in both or neither of the two cases – unless there is reason to believe that the crucial difference between the two affixes is a morphological one. The only difference between the two types of affixes, however, is their different prosodic shape, if my argument above is correct. Consider now the example in (22), in which the stem-final obstruent undergoes FLN even though no form in any paradigm has the relevant obstruent in final position.

(22) Example 3:/schad/

Verbal Paradigm: *schade...* (1st SG, schadest 2nd SG) no neutralization 'to damage'
Nominal Paradigm: *der Schaden...* (Nom Sing) no neutralization 'damage'

Adjectival Paradigm: *schade, schaden…* no neutralization
'unfortunate'

Under any definition of paradigm uniformity or output-output correspondence one would predict that FLN does not apply in this case. The account based on the prosodic word predicts FLN to apply.

(23) Devoicing in Paradigm vs. No Devoicing in Paradigm: Examples[16]

Suffix	*Underlying Lenis* Not Neutralized PU predicts no FLN	*Underlying Lenis* Neutralized in Paradigm PU predicts FLN	*Underlying Fortis*
-lich	schädlich 'harmful'	leidlich 'acceptable'	gütlich 'by comp.'
	klaeglich * 'pitiful'	vertraglich 'by treaty'	kraenklich 'ill'
	buchstaeblich 'literally'	leiblich 'body'	?
-los	Friedlos 'restless'	neidlos 'without envy'	zeitlos 'timeless'
	farblos* 'colorless'	laublos 'without foliage'	?
	fraglos* 'definitely'	erfolglos 'with. success'	streiklos 'w.o. strike'
-lein	faedlein 'little thread'	rädlein 'small wheel'	pfötlein 'small pad'
	knäblein 'little boy'	weiblein 'small woman'	?
	vöglein 'little bird'	berglein 'small hill'	tränklein 'sm.drink'

There are actually a fair number of examples corresponding to the three classes listed above, some of which are given in the above table. Contrary to the predictions of Paradigm Uniformity, FLN applies in all forms.[17]. If indeed the contrast was not neutralized in any of the examples, we would expect a contrast like the one in (15) between *handl + ung* and *hand + lich*. The two stops involved in these two examples clearly contrasted in terms of vowel length, closure duration, and VOT. Consider now first the cases where both theories, Paradigm Uniformity and the Prosodic account, make the same prediction. An affix attaches to a stem, and the citation form in the paradigm of the stem undergoes FLN. As expected, neutralization occurs.

[16] The starred examples are those in which the stem does undergo FLN in some forms of the verbal paradigm - but not in the paradigm which should be relevant for the derivation in question (compare example (20) above.

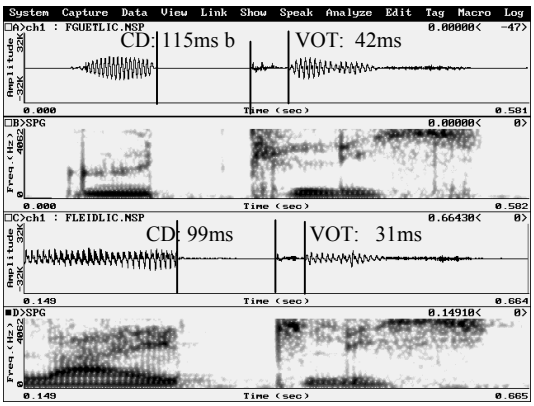
[17] Not all instances of these examples actually showed clear aspiration. I assume this is due to the fact that the cues of fortis-ness are not all realized if a sonorant consonant follows a stop in non-careful speech. The point can still be made since there is no systematic difference between any of the three classes of examples: underlying fortis, underlying lenis with paradigmatic neutralized form, underlying lenis without paradigmatic neutralized form. My findings are corroborated by the transcription given in pronouncing dictionaries, e.g., in Duden (1990)

(24) Non-Cohering Stem Level Suffix. Neutralization in Paradigm.

Underlying fortis

Underlying Lenis

Neutralization in Paradigm: *das Leid*

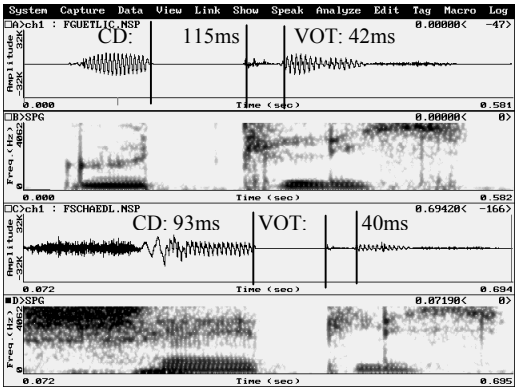


The crucial cases are the ones where no neutralization occurs in any paradigm. Any notion of paradigm uniformity would predict that FLN does not apply. The prosodic account outlined above predicts neutralization.

(25) Non-Cohering Stem Level Suffix. No Neutralization in Paradigm.

Underlying Fortis

Underlying Lenis
No Devoicing in Paradigm:
schade, schade... (adjective)
schaden, schaden... (noun)
schaden, schadest... (verb)



We may conclude from these cases that in German, neutralization occurs preceding non-cohering sonorant initial suffixes *even if the stem is not neutralized anywhere else in any paradigm*. No Notion of Paradigm Uniformity or output-output correspondence can capture the neutralization environment appropriately. Reference to prosodic structure seems unavoidable, given that the prosodic shape of the affixes is what is crucial to predict neutralization[18].

[18] For reasons of space I could not discuss several earlier proposals. (rule based, prosodic: Vennemann 1972, Rubach 1990, Giegerich 1992, Hall 1992, Brockhaus 1995: rule based, morphological: Wurzel 1970, Kloeke 1982; constraint based, prosodic: Merchant 1996, Noske 1997, Ito & Mester 1998, Lombardi 1999, Féry 1999). A thorough discussion of whether they can account for all the data discussed, and which modifications would be necessary and possible to save any of these proposals is beyond the scope of this paper.

5. Conclusion

Prosody can play a role in accounting for segmental patterns of neutralization. The example of German illustrates that laryngeal final neutralization cannot be explained by invoking the notion of relative perceptbility in segmental contexts and output-output correspondence defined on paradigms. The presented analysis conforms with the one in Steriade (1997) in that FLN is not considered to be syllable final. However, it puts German together with Slavic languages (Rubach 1996) in characterizing the environment of laryngeal neutralization as the phonological word.

Since in the neutralization environment the perceptual cues of the contrast are in fact realized, and since there is evidence that listeners do identify the neutralized stops as belonging to the fortis category, a reconsideration of whether FLN is driven by perceptual considerations and indeed groups with patterns of laryngeal assimilation in segmental contexts is necessary. The same point could have been made for Dutch. Dutch final devoicing occurs in essentially the same environements as FLN in German. Consider the following examples (Trommelen & Zonneveld 1979; Trommelen 1984: 8; Booij 1995):

(26) Dutch Final Devoicing

da[ɤ]+en	'days'	da[x]. + je	'little day'
oo[ɤ]+en	'eyes'	oo[x]. + je	'little eye'
sta[d]+en	'cities'	sta[t]. + je	'little city'[19]
ba[d]+en	'baths'	ba[t]. + je	'bath' (dim)

Note in (26) that the affix that starts in a vowel is syllabified with the stem, bleeding final devoicing. The affix that consists of both a consonant and a vowel, as in German, induces final devoicing. Another prosodic context for FLN is phrase final position, as it is attested in Yiddish (Birnbaum 1979), and based on the data in Steriade (1997) might be also be an environment for neutralization in Lituanian.

The lesson that can be learned from these languages is that there is more to neutralization processes than meets the ear. They are not entirely driven by phonetic considerations of articulatory difficulty or acoustic perceptibility; nor are they explicable by correspondence relations between attested outputs; abstract prosodic structure may provide the context for segmental neutralization.

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[19] These actually surface as [ʃ]. The point is that the result is voiceless.

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