Onsets and non-moraic syllables in German

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Introduction[1]

This paper considers the status of non-appendical word-final consonants and proposes an analysis in which they project a nonmoraic semi-syllable (see Cho & King, this volume, for a similar proposal for Georgian, Polish and Bella Coola). More specifically, such consonants are onsets of syllables with no nuclei. This analysis improves on alternative proposals on several grounds. First, syllables are maximally bimoraic, which renders the assumption that German has trimoraic syllables unnecessary. German behaves in this respect like most other languages in obeying a bimoraic maximum for syllables. Second, puzzling properties of laryngeals and of [g] after a dorsal nasal are accounted for. In a nutshell, the laryngeals, [h] and [ʔ], as well as [g] after a dorsal nasal are only realized when they are the onsets of higher prosodic constituents, like Prosodic Word, Foot, and moraic syllables, but not as onsets of nonmoraic syllables, like schwa syllables and semi-syllables. Finally, the fact that some final consonants contribute weight can be accounted for. The semi-syllable they project is the weak member of a final syllabic trochee. This has the advantage of render/rendering? feet consisting of superheavy syllables superfluous.

In the first section of this paper, some basic facts about the syllable structure of German are presented. In the second section, the role of the prosodic hierarchy in determining the presence of an onset is given an optimality-theoretic analysis. The analysis relies on the assumption that the prosodic constituents form a natural markedness hierarchy. The three next sections subsequently examine the behavior of [g] after [ŋ], [h] and the glottal stop in greater detail, and the claim is made that these consonants are always onsets of some syllable. The final section concludes.

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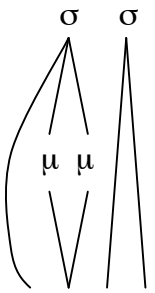
1. Syllable structure

Syllables are traditionally organized into onsets, nuclei and codas. In moraic theory, nuclei - and in some languages also codas - are moraic and thus contribute weight to the syllables they are part of, whereas onsets are nonmoraic and weightless. German syllables are maximally bimoraic, which implies that the moraic part of the syllable maximally consists of a bimoraic tense vowel or, alternatively, of a monomoraic lax vowel followed by a single moraic consonant. This is shown in (1). Stressed tense vowels are bimoraic and stand mainly in open syllables (1a), whereas lax vowels are monomoraic and obligatorily closed by a consonant (1b,c). There are no lax vowels in unambiguously open syllables such as final ones ([áu.to] but *[au.tɔ]) or in a hiatus position ([mu.zé:.ʊm] but *[mu.zɛ.ʊm], Moulton 1962). This speaks for a bimoraic minimality of the syllables, at least in those with full vowels. Word-internally, syllables are not only minimally, but also maximally bimoraic.[2]

(1) a. Word-medial tense vowels



(Miete ‘rent’)

b. Word-medial lax vowels

(Mitte ‘middle’)

c. Lax vowels in final syllables

(Müll ‘garbage’)

[2] There are exceptions to this generalization, however, though largely restricted to the initial syllable of disyllabic words, as in *Müesli, Arktik, Leutnant* and *Symptom*. The segments [s], [k] and [t] in *Müesli*, *Arktik* and *Leutnant* can be

There is a clear relationship between the vowel quality and quantity on the one hand, and the status of the following consonant on the other. If the vowel is tense, the following consonant is just the onset of the following syllable, but if the vowel is lax and followed by a single consonant and a vowel, then the consonant can be analyzed as ambisyllabic: it is both the coda of the preceding syllable and the onset of the next (see van Oostendorp, this volume, for the same observation in other Germanic languages). The difference is reflected in the orthography. In many cases, a plain onset is written with a single grapheme (as in *Miete* [mi:tə] 'rent' or *Robe* [ʁo:.bə] 'robe') and an ambisyllabic consonant with a double one (as in *Mitte* [mɪtə] 'middle' or *Robbe* [ʁɔbə] 'seal'). Reversely, one can say that a single intervocalic consonant grapheme signalizes a preceding tense vowel whereas a doubly written consonant signalizes a lax vowel (see Ramers 1999 for exceptions as well as an overview of the relevant literature).

Ambisyllabic segments like [t] in *Mitte* in (1b) and plain onsets differ on a number of respects. It has been observed by some authors (Kahn 1980, Ramers 1992, Selkirk 1984a, Wiese 1996, among others) that ambisyllabic segments display some properties of onsets and some of codas, but not all: they are not aspirated and they are not finally devoiced. This means that they are neither plain onsets nor plain codas, but just foot-internal syllable boundaries. They only appear between a stressed and an unstressed syllable. In Ito & Mester's (1994) terms, they have blurred edges, as opposed to crisp edges of syllables, in which case a syllable has its own onset or coda. This paper focuses on onsets of crisp syllables. Ambisyllabic segments are not considered.

German, as well as Dutch, English, French and many other languages, has also nonmoraic syllables: schwa syllables (2a) and semi-syllables (2b). A distinction must thus be made between nonmoraic syllables with a nucleus (schwa or syllabic sonorant) and those without a nucleus (semi-syllables).[3]

(2) Examples of nonmoraic syllables

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analyzed as projecting a semi-syllable (see below), but [p] in *Symptom* is different: [p] is partly geminate with the preceding [m] and, together, they share a single mora.

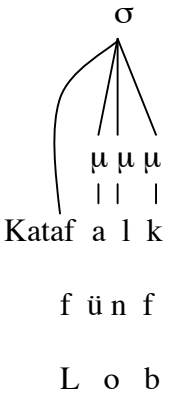
[3] See also Kager (1989) for an analysis of schwa-syllables as nonmoraic.

a. Schwa syllables (with nucleus): Lampe [lam.p͡ə]‘lamp’, Ehe [e:.ə̲]‘marriage’, Himmel [hɪm̩l̩]‘sky’, lo.ben [lo:.bn̩]‘to praise’, Eber [e:.bɐ̯] ‘boar’ , Ge.schrei [g͡ə.ʃʀa͡i̯] ‘shouting’

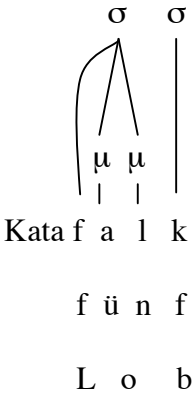
b. Semi-syllables (without nucleus): Lob [lo:.p̲]‘praise’, Katafalk [ka.ta.fal.k̲]‘catafalque’, fünf [fʏn.f̲] ‘five’, Helm [hɛl.m̲] ‘helmet’

In word-final syllables, additional consonants are not unusual. In this position, tense vowels can apparently be closed by one, lax vowels by two consonants.[4] These ‘superheavy’ syllables have the property of attracting stress - at least in the majority of the cases -, which shows that the additional consonant plays a role in the computation of weight. To account for this fact, at least two analyses are possible.[5] In one analysis, the additional consonant is moraic and part of the final syllable. The syllable is trimoraic and as such attracts stress. This solution, shown in (3a) was adopted in Féry (1997) but is rejected in this paper. The other solution, adopted here, is to let the additional consonant project a semi-syllable (3b) consisting of just an onset. Syllables are then maximally bimoraic without exception.[6]

(3) a. Moraicity of the final consonant



b. Syllabicity of the final consonant



[4] Syllable appendices, [s], [t] or combinations of these two segments, also appear in word-final position, additionally to semi-syllables, as shown in (i). They are best analyzed as adjoined at the level of the Prosodic Word, which accounts for their weightlessness and for the fact that they are mostly inflectional elements, and thus suffixes to the word, rather than to the syllable or the Foot. Appendices are not discussed in this paper.

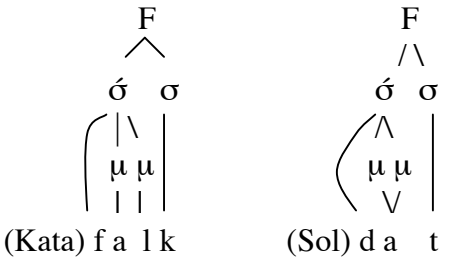
PW
F
σ
μ μ
(i) lach t ‘laugh+3rd pers. infl. suffix’

[5] Extrametricality is not an option, since these consonants add weight to their syllable.

[6] Kiparsky (this volume) analyzes final extrasyllabic consonants in Arabic as moras unaffiliated to syllables. This solution is not available for German, since final consonants are onsets, which means that they are nonmoraic.

In projecting a syllable, as in (3b), the final consonants allow the words in which they appear to have the unmarked syllable trochee pattern of the language. (Lexical stress will not be examined here, but see Féry 1998 for a detailed optimality-theoretic account).

(4)



2. Onsets

2.1 Data

German syllables can have a simple onset (5a), a complex one (5b) or no onset at all (5c). Word-initial syllables can have a so-called prefix (or appendix), which is always a coronal fricative, [ʃ] or [s], as in (5d). Syllable prefixes are not discussed in this paper.

(5) Onsets

a. Simple onsets: Tisch [tɪʃ] 'table', Idee [ʔi.dé:] 'idea', chaotisch [ka.ʔó:.tɪʃ] 'chaotic', alkoholisch [ʔal.ko.hó:.lɪʃ] 'alcoholic'

b. Complex onsets: Tritt [tʀɪt] 'kick', Gnade [gnáːdə] 'mercy', blau [blaʊ̯] 'blue'

c. No onsets: Museum [mu.zé:.ʊm], Korea [ko.ʁé:.a], Ehe [ʔé:.ə] 'marriage'

d. Prefixes: starr [ʃtaɐ̯] 'unflexible', Skript [skʀɪp.t] 'script'

Only non-initial unstressed syllables can be onsetless, as shown by the words in (5c). All other syllables have an onset. Moraic syllables generally require an onset. However, and this is crucial for the analysis proposed in this paper, not only syllables require onsets but also higher prosodic constituents, like Feet and Prosodic Words.[7] When the left edge of a syllable coincides with the left edge of a Foot or Prosodic Word, an onset is required by the higher constituent rather than by the

[7] See also the papers of Green, Kiparsky and Wiltshire in this volume for the status of consonants at the edge of Prosodic Words in different languages. See also Giegerich (1985), Kager (1995) and Kiparsky (1991) among others for

syllable. If no underlying consonant is present that could serve as an onset, a glottal stop is inserted. This is shown by the words *Idee, chaotisch* and *alkoholisch* in (5a), as well as by *Ehe* in (5c).

The prosodic hierarchy assumed here is adapted from the conventional one in (6), from Nespor & Vogel (1986), Selkirk (1984b), McCarthy & Prince (1986, 1990) and others. The syllable constituent is split into two different ones, the moraic syllable and the nonmoraic syllable. All syllables with a full vowel are moraic except for some suffixes like *-ung*, *-lich*, *-ig* and the like which have a high vowel before a back consonant, a position in which schwa is not allowed (Wurzel 1970). I analyze these suffixes as nonmoraic.

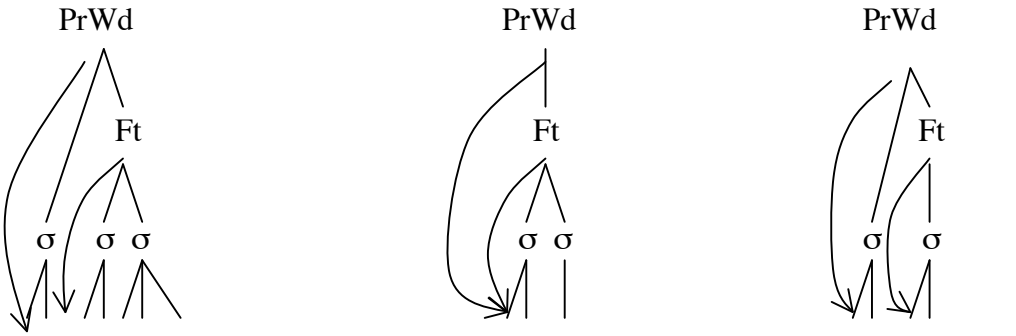
(6) Prosodic hierarchy

PrWd (Prosodic Word)
|
F (Foot)
|
σ_{μ} (Moraic Syllable)
|
$\sigma_{\text{non-}\mu}$ (Nonmoraic Syllable)

Syllables falling together with the left edge of a Foot require an onset, as shown in (7a). All higher constituents, like the Prosodic Word (and the Phonological Phrase) also require an onset, though this requirement may already be met at the level of the Foot, as in the words in (7b). But in a disyllabic word with a non-initial stress, the first syllable is not footed (see Féry 1998). The presence of a glottal stop is required at the level of the Prosodic Word. This is shown in (7c), using the word *Idee*. The association lines with an arrow are meant to emphasize the fact that onsets are associated not only to the syllable they belong to , but also to higher prosodic constituents.

proposals going in the same direction as the proposal made in this paper, namely to treat some final consonants as

(7) Onset required by Feet and Prosodic Words



a. [ka (ʔ o: t ɪ ʃ)$_F$]$_{PrWd}$ chaotisch

b. [(ʔe:ə)$_F$]$_{PrWd}$ Ehe

c. [ʔ i (de:)$_F$]$_{PrWd}$ Idee

Up to now, only syllables requiring an onset have been considered. In some instances, however, syllables are onsetless. Besides syllables like in (5c), schwa syllables with an orthographic <h> in their onset (8a) as well as those with <g> after a dorsal nasal (orthographic <n>) (8b) are also phonetically onsetless.

(8) Nonmoraic syllables without (their own) onsets

a. [h] is unpronounced: Ehe [ʔé:.ə̲] ‘marriage’, Ziehung [tsí:.ʊŋ̲] ‘draw’ (vs. Alkohol [ʔál.ko.ho:.l] ‘alcohol’, Ruin [ʁu.ʔí:.n] ‘ruin’)

b. [g] is unpronounced: Zunge [tsʊŋə] ‘tongue’, junge [jʊŋə] ‘young’ (vs. Tango [taŋ.go])[8]

Summing up what has been said, some syllables require onsets while others avoid them. A detailed overview of the onset realization is given in Table 1.

	ProsodicWord	Foot	Moraic syllable	Nonmoraic syllable
Oral cons.	Tisch ‘table’ Sénse ‘scythe’ Ge´müse ‘vegetable’	Ge´müse Aréna Lèopárd	Áuto ‘car’ Télefon	Ámeise ‘ant’ Betéiligung ‘participation’
[g] after [ŋ]	not a possible context	Linguíst, dìphtongíeren ‘to diphthongize’	Tángo, Úngarn , Ánglo	no
[h]	Horizónt, hállo háuen ‘to beat’ Hèrmelín ‘ermine’	ahói ‘ahoy!’ behárren ‘to insist’ Gehéul ‘howling’	Úhu ‘owl’ Màhagóni Álkohol	no
Glottal stop	Idée [ʔi.de:] ‘idea’ [ʔ]Eréignis ‘event’ [ʔ]Ámeise ‘ant’	[ka.ʔo:t]/ [ka.o:t] ‘chaotic person’ Beámte ‘civil servant’ [bə.ʔam.tə]/[bə.am.tə]	no	no

onsets of empty syllables.

[8] The dorsal nasal is ambisyllabic but, as mentioned before, ambisyllabic segments are not considered as onsets (they are foot-medial consonantal joints), and are ignored here.

Table 1: Onset realizations

First, an orally articulated consonant present in the input is always realized. Second, [g] after [ŋ] appears as the onset of a non-initial moraic syllable, but neither word-initially (because of the sonority hierarchy, see next section) nor as the onset of a nonmoraic syllable. Next, an unstressed syllable with a full vowel retains all input consonants except for the one with the lowest sonority, which is [h], the only phonemic laryngeal in German: [h] is not phonetically realized at the left edge of an unstressed syllable. And finally, the other laryngeal, the non-phonemic glottal stop, is also lowest in the sonority hierarchy. Its contexts of realization are even more limited than those of [h]. It is only realized in case a Foot or a Prosodic Word would otherwise be onsetless. Moreover, foot-initial [ʔ] is optional, as shown in the last row of Table 1.

2.2 An OT-analysis

In the remainder of this section, an optimality-theoretic analysis of onset preservation, deletion and insertion is sketched, the details of which are developed in the remaining of the paper. The facts to be accounted for are that plain oral consonants are just faithful to their inputs, whereas the presence of laryngeal consonants and of [g] in the context of a dorsal nasal depends to a large extent on markedness effects. OT is thus the ideal framework to account for this.

A list of the markedness constraints used in the analysis appears in (9).

(9) Markedness constraints:

a. $\textsc{Onset}_{\textsc{PrWd}}$ (Prosodic Words begin with onsets) >> $\textsc{Onset}_{\textsc{Foot}}$ (Feet begin with onsets) >> $\textsc{Onset}_{\sigma(\mu)}$ (Moraic syllables begin with onsets) >> $\textsc{Onset}_{\sigma(\text{non-}\mu)}$ (Nonmoraic syllables begin with onsets)

b. *[h]: No [h].[9]

[9] The constraints against individual segments are probably best formulated as constraints against features. See Davis (1999) for *[spread glottis] shunning [h] and aspirated stops in English. Though Davis does not use positional faithfulness, his analysis – like mine - can easily be translated into such a model: [spread glottis] is realized only when it falls together with the left edge of a foot (in English) or with the left edge of a moraic syllable (in German). This point is not pursued here.

c. *[ŋg]: No [g] after a dorsal nasal.[10]

The markedness hierarchy in (9a) expresses the fact that the higher the prosodic constituent, the more likely is it to have an onset. In other words, it is more important for a Prosodic Word to begin with a consonant than it is for a Foot, and so on.[11]

The faithfulness constraints listed in (10) come in different forms, but the intention is always the same: the output resembles the input. MAX(C) and DEP(C) posit that a non-laryngeal oral consonant in the input has a correspondent in the output and reversely. MAX(Nasal) says that the feature [nasal] in the input is also present in the output. MAX(Dorsal) requires the same for the feature [dorsal]. These constraints will be motivated in the next section. Finally, DEP(ʔ) militates against epenthesis of glottal stops.[12]

(10) Faithfulness constraints

a. MAX(C): No deletion of an oral (non-laryngeal) consonant.

b. DEP(C) : No epenthesis of an oral (non-laryngeal) consonant.

c. DEP(h), MAX(Nasal), MAX(Dorsal), DEP(ʔ)

The ranking of the markedness and faithfulness constraints is shown in (11).

(11) Ranking of the constraints

MAX(C), DEP(C), DEP(h), MAX(Nasal), MAX(Dorsal), $\text{ONSET}_{\text{PrWd}}$ >> $\text{ONSET}_{\text{Foot}}$ >> DEP(ʔ) >> $\text{ONSET}_{\sigma(\mu)}$ >> *[h], *[ŋg] >> $\text{ONSET}_{\sigma(\text{non-}\mu)}$

It is shown in Tableau 1 that MAX(C) and DEP(C) are undominated, using the word *Tisch* 'table'. Parentheses stand for Feet. The Prosodic Words always correspond to the grammatical words in the examples given. Candidate a. in Tableau 1 wins because it has a faithful onset consonant. The other

[10] The constraint *[ŋg] is phonologically and phonetically well-motivated. There is a preference for a velar gesture to be nasal rather than plosive or a sequence of a nasal plus a stop. In German, [g] is avoided in other contexts as well (see Ito & Mester, this volume), and it is also avoided in other languages (see Kager 1999).

[11] This is compatible with the aligment effect observed in languages like Tahlyihit Berber (Prince & Smolensky 1993) or Axininca Campa (McCarthy & Prince 1993) which tolerate onsetless syllables word-initially. In these languages, the relevant alignment constraints are higher ranking than ONSET_{PW}.

[12] As René Kager (p.c.) observes, this constraint can be understood as an instance of DEP(C) plus constraints identifying [ʔ] as the epenthetic, least marked, consonant.

candidates fail on MAX(C) and/or DEP(C) and are eliminated. An oral consonant in the onset is always realized in German and does not change its quality.

/tɪʃ/	MAX(C)	DEP(C)	$\text{ONSET}_{\text{PrWd}}$	DEP(ʔ)	$\text{ONSET}_{\sigma(\mu)}$	*[ŋg]	*[h]	$\text{ONSET}_{\sigma(\text{non-}\mu)}$
☞ a. (Tisch)								
b. (Isch)	*!		*		*			
c. ([ʔ]isch)	*!	*!		*				

Tableau 1: *Tisch* 'table'

It will be shown in the next sections how the OT analysis developed here accounts for the presence or absence of [g] after a dorsal nasal and of the laryngeals. All of them are unrealized when they would appear in the onset of a nonmoraic syllable and this property distinguishes them from oral consonants. However, they require different analyses, since [h] is just an ordinary phonemic segment, [ʔ] is epenthetic and [ŋg] is in allophonic variation with [ŋ]. Both [g] and the laryngeals are realized in an onset if they begin at least a nonmoraic syllable. Prosodic Words and Feet always require onsets, even at the cost of epenthesis. Moraic syllables always realize an input consonant, even weak [h], but do not epenthesize a glottal stop, and nonmoraic syllables prefer to be onsetless, which means that they do not realize [h] and [g] after [ŋ]. These facts can be accounted for with the help of a few natural constraints, taking advantage of the prosodic hierarchy.

3. [g] after the dorsal nasal

3.1 Data

It is generally assumed in the literature on the subject that the alternation between [ŋ] and [ŋg] is best explained if [g] is deleted in the coda position (Giegerich 1985, Hall 1992, Ito & Mester this volume, Wiese 1996, Wurzel 1980 among others). I propose a different analysis: [g] is pronounced only if it is in the onset of a higher prosodic constituent, but not if it would be the onset of a nonmoraic syllable. In order to motivate this proposal, the allophonic nature of [ŋ] must be made explicit. It will first be shown that some occurrences of the dorsal nasal emerge as the result of an assimilation of a tautomorphemic coronal nasal to a following dorsal stop: *Bank* [baŋk], *Ankara*

[aŋkaʁa] and the like are well formed, but other sequences like *[ŋp], *[ŋt], *[ŋç], etc. are not.[13] After that, it will be shown that the remaining occurrences of [ŋ] stand in an allophonic relation to [ŋg].

The first point, the allophony with the coronal nasal, is orthogonal to the main interest of this paper, but still necessary, because it illustrates the fact that the dorsal nasal is always non-phonemic.

In German monomorphemes, the only consonants before which the dorsal nasal stands are the dorsal stops. This restricted distribution is explained if the dorsal nasal is the product of regressive assimilation. This does not hold for the other nasals. Though the consonant following [m] in a sequence [m] + stop is usually labial, as in *Bombe, Imperfekt* and *imperial*, it may also appear before a coronal or dorsal stop, as in *Hemd* 'shirt', *Zimt* 'cinnamon', and *Imker* 'bee-keeper', or before a coronal fricative, as in *Amsel* 'blackbird'. [n] also appears before non-coronals, but only before fricatives, like labial [f], as in *fünf* 'five' or *Senf* 'mustard' and dorsal [ç], as in *Mönch* 'monk'. In short, nasals do not assimilate to a following fricative[14] but sequences of coronal and dorsal nasals plus stops are homorganic, as the result of assimilation (except for the coronal appendix segments *t* and *s*, which realize inflection morphemes and are extra-syllabic). This distribution has been accounted for by an analysis in which [m] and [n] are segments by their own rights, but [ŋ] is not (see for instance Hall 1992, Kloeke 1982, Ramers & Vater 1992 and Wurzel 1980). No detailed OT account of the assimilation is offered here. The facts are accounted for by a ranking like the one shown in (12):

(12) $\text{IDENT(labial)}_{\text{nasal}}$, $\text{IDENT(Place)}_{\text{stop}}$ >>$\text{AGREE(Place)}_{\text{nasal+stop}}$ >> *Dorsal >> $\text{IDENT (Place)}_{\text{nasal}}$

[13] Appendical segments must be eliminated from the discussion. *Sing-t* 'sing+3rd pers. sg. inflection' is realized as [ziŋt].

[14] If Padgett's (1991) representational model of continuancy, in which the feature [±continuant] is dependent on the place feature, is accepted, this fact comes as a natural conclusion. Fricatives are [+continuant] and nasals are [–continuant]. As a consequence of this contradictory specification, assimilation does not happen.

This ranking delivers the pattern just described: A coronal nasal assimilates to a following stop (before stops, labial, coronal and dorsal are found). A nasal does not assimilate to a following fricative (before fricative, only labial and coronal nasals are found).

Consider next the allophonic relationship [ŋ]~[ŋg]. A comparison of the distribution of [ŋ] with the other nasals is revealing.

(13) Distribution of [ŋ]

a. word medially: *kommen* 'to come'- *rannen* 'ran, pl.'- *langen* 'long, infl.'

b. word finally: *Lamm* 'lamb'- *rann* 'ran, sg.'- *lang* 'long'

c. not word initially: *Mama- Nase* 'nose' - Ø (*ŋa…)

d. not after ʃ: *Schnabel* 'beak'- *schmal* 'narrow' Ø (*ʃŋa…)

e. not after liquid: *Farn* 'fern', *Köln, Helm* 'helmet', *arm*, but **Farŋ*

f. only after short lax vowels: *lang, sing*, but **bauŋ, *ri: ŋ*.

g. only before unstressed vowels, often schwa, but not only:

Inge, Verengung 'narrowing' vs. *Tango, laryngal* [ŋg]

The distributional restrictions affecting the dorsal nasal find a natural explanation if [ŋ] and [ŋg] are in an allophonic relation. [ŋ] is always a coda (this must be posited, see (17a)) and [g] after [ŋ] is always an onset: [ŋ] is found in those cases in which just a coda is needed and [ŋg] when both a coda and an onset are required. Neither [ŋ] nor [ŋg] are possible word-initially or after [ʃ]: [ŋ] is not possible because it must be a coda and [ŋg] would additionally violate the Sonority Hierarchy Sequencing. Similarly, [ŋ] is not possible after tense vowels, diphthongs and liquids. Since a syllable is maximally bimoraic, in all these cases, [ŋ] or [ŋg] would the onset of a syllable, degenerate or not, and this disagrees with the phonotactics of German. However, as shown above, both [ŋ] and [ŋg] are allowed intervocalically.

Further properties of this segment which also speak in favor of an allophonic variation are the following:

- In some morphemes, [ŋ] alternates with [ŋg], as in *Englisch* [ŋ] – *Anglo* [ŋg], *Diphthong* [ŋ] – *diphthongieren* 'diphthongize' [ŋg], *Triangel* [ŋ] 'triangle' - *triangulär* [ŋg] 'triangular', (Ramers & Vater 1992, Wiese 1996).

- Verbs with a medial [ŋ] behave like verbs with a nasal plus stop sequence, as for instance [n+d] and [ŋ+k], and not like the verbs with a single medial nasal. The ablaut vowels in (14c) are *i-u* as in (14a) and not *i-o* as in (14b). Compare the following paradigms (from Vennemann 1968: 76).

(14) a. binden - gebunden 'to tie-participle' stinken - gestunken 'to stink-part.'
trinken - getrunken 'to drink-part.' sinken - gesunken 'to sink-part.'

b. spinnen- gesponnen 'to spin-part.' schwimmen-geschwommen 'to swim-part.'
rinnen – geronnen 'to run-part.'

c. klingen-geklungen 'to ring-part.' schlingen-geschlungen 'to wind-part.'
ringen – gerungen 'to wrestle-part.' singen - gesungen 'to sing-part.'

Notice that, in this case, [ŋ] alone shares the properties of [ŋg].

- The following nominal and verbal *ge*-formations also speak in favor of an analysis of [ŋ] as having the same properties as a sequence of a nasal plus an homorganic stop. Vennemann (1968) and Wurzel (1970) observe that the dorsal nasal behaves like a voiced obstruent, since the final schwa in the words of the left column is retained while the words of the middle and right columns have lost their schwa (see also Plank 1986 and Olsen 1991).

(15)

Gelände 'ground'	Gedärm 'intestines'	Gebräu 'brew'
Gebinde 'arrangement'	Gebein 'ossement'	Gefäß 'vessel'
Gestänge 'struts'	Gespann 'team'	Getier 'animals'
Gemenge 'mixture'	Gestirn 'heavenly body'	Gebell 'barking'
Gebirge 'mountain range'	Gestein 'rock'	Gewitter 'thunderstorm'

- Finally, words like *lang* 'long' or *Ding* 'thing' have a Northern German variant in which [g] is present and subject to final devoicing. These words are then realized as [laŋk] and [diŋk] (see Lass 1984, and Ito & Mester, this volume, for an analysis with local conjunction of OT constraints).

In suffixed words, [g] is sometimes realized and sometimes not. Compare the words in (16a) in which no [g] is realized with the words in (16b) where [g] is pronounced.

(16) a. [ŋ] Veréngung 'narrowing', ´Längung 'lengthening', (tief)rángig '(low) ranking', ´länglich 'oblong', ´Sänger 'singer', énger 'narrower'

b. [ŋg] laryngál, diphthongál, diphthongíeren, triangu´lär

The difference lies in the kind of suffix listed in (16a) and (16b). Suffixes *-ung* , *-ig, -lich, -er* are always unstressed and have no influence whatsoever on the stress pattern of the word they appear in. As already mentioned, they are best analyzed as nonmoraic. Suffixes like *-al* , *-ieren,* and the like are moraic and, as a consequence, they bear the main stress of the words they appear in. The analysis proposed above, according to which the difference between the realization or nonrealization of [g] lies in the moraicity of the following vowel, is thus fully confirmed.

Before we come to the OT analysis, a final point remains to be clarified. In words like *Bangladesch* and *Mangrove*, [g] is pronounced, although the syllables in which [g] appears would have an onset anyway, even if [g] would be left unpronounced. In a way, this is what the analysis predicts, since [g] is onset to a nonmoraic syllable. In another way, [g] seems superfluous, since the syllable in which it appears has two onset segments. I propose that the reason why [g] is pronounced has to do with the Syllable Contact Law (Vennemann 1986), as formulated in (20e), an additional principle of syllabification positing that a syllable contact is better if the sonority across the syllable boundary decreases (see Davis 1999b and Raffelsiefen 1995 for applications of the syllable Contact Law in OT). In other words, the onset of a syllable tends to have a lower sonority than the coda of the preceding syllable. In *Bangladesch* and *Mangrove*, the realization of [g] guarantees that the Syllable Contact Law is fulfilled (see Tableau 7).

3.2 Optimality-theoretic analysis

An optimality-theoretic analysis of the allophony between [ŋ] and [ŋg] uses the constraints listed in (17). The first one, ONSET-COND, posits that the dorsal nasal is always a coda. SONORITY (abbreviated as SON) requires that the syllable margins respect the sonority sequencing principle (Sievers 1901, Selkirk 1984a). BIMOR is the constraint limiting the number of moras to two per syllable. NUC militates against semi-syllables in requiring that syllables have nuclei. And finally, SYLLABLECONTACT says that sonority should be decreasing across syllable boundaries.

(17) Constraints regulating the allophony between [ŋ] and [ŋg]

a. ONSET-COND: [ŋ] must not be an onset.

b. SON: The sonority of the syllable margins must not increase from the nucleus to the syllable's periphery.

c. BIMOR: Syllables are maximally bimoraic.

d. NUC: Syllables have nuclei.

e. SYLLCONT: The sonority of an onset is lower than the sonority of the preceding coda.

First, Tableau 2 shows the effect of ONSET-COND on a hypothetical input /ŋase/ or /ŋgase/. I propose that both allophones are part of the input, and that in general, optimality-theoretic inputs consist of all possible allophones. The constraints on the output select the optimal candidate depending on the context. A segment with no allophone has only one input, and the constraints referring to it require complete faithfulness. If inputs consist of (relevant) allophones, it means that only part of the features realizing the output is unambiguously specified in the input. The remaining features can be changed or added, depending on the constraints on the output. Faithfulness constraints can refer to all allophones or to just one allophone, maybe the one usually chosen as unique input.

In the tableaux below the constraints MAX(Nasal) and MAX(Dorsal) are fused into one single constraint, abbreviated as MAX(N,D). These two constraints are undominated, which means that the features [nasal] and [dorsal] end up in the output whenever they are specified in the input.

The dorsal nasal [ŋ] alone contains the relevant features and is thus able by itself to fulfill MAX(N,D). Tableau 2 shows that a dorsal nasal cannot be realized in the onset: both [gazə] and [nazə] are better than [ŋgazə] or [ŋazə]. ONSET-COND is undominated.

/ŋazə/ or /ŋgazə/	ONSET-COND	BIMOR	MAX(N,D)	SON	NUC
			*		
b. [ŋ]ase	*!				
c. [ŋg]ase	*!			*	
☞ d. [g]ase			*		

Tableau 2: Hypothetical candidate *ŋase* or *ŋgase*

The interesting behavior of [ŋ] as opposed to [ŋg] intervocalically is summed up in the contrast between *Zunge* and *Tango*. The stop [g] is only realized when the following syllable requires an onset, like in *Tango* in Tableau 3 because [o] is a moraic vowel and as such requires an onset. Remember from section 2 that [g] pops up when a higher prosodic constituent requires an onset. In contrast, in *Zunge*, illustrated in Tableau 4, there is no need for [g] since a nonmoraic syllable like the final schwa syllable in this word does not require an onset.

Candidate b. in Tableau 3 violates $\text{ONSET}_{\sigma(\mu)}$ because it has no onset of its own (but just an ambisyllabic one) and is thus eliminated. Candidate c. is eliminated because [nasal] is not realized. In Tableau 4, Candidate b, with [g], is eliminated because it violates the constraint against [ŋg] and Candidate c. because of MAX(Nasal). Candidate a. with just [ŋ] is optimal.

The presence of [g] in the second syllable is thus a consequence of the need of this syllable to begin with an onset. It is the allophonic variation between [g] and [ŋg] that makes the emergence of [g] possible.

/taŋo/ or / taŋgo/	IDE NT(C)	MAX(N,D)	$\text{ONSET}_{\text{PrWd}}$	$\text{ONSET}_{\sigma(\mu)}$	*[ŋg]	$\text{ONSET}_{\sigma(\text{non-}\mu)}$
☞ a. (Ta[ŋ.g]o)					*	
b. (Ta[ŋ]o)				*!		
c. (Ta.go)		*!				

Tableau 3: *Tango*

In Tableau 4 for *Zunge*, the constraint against [ŋg] is higher ranked than the constraint requiring an onset to a nonmoraic syllable, as shown in Tableau 4. Candidate a., without [g] is thus optimal.

/tsʊŋə/ or / tsʊŋgə/	IDENT(C)	MAX(N,D)	$ONSET_{PrWd}$	$ONSET_{\sigma(\mu)}$	*[ŋg]	$ONSET_{\sigma(non\text{-}\mu)}$
☞ a. (Zu[ŋ]e)						*
b. (Zu[ŋ.g]e)					*!	
c. (Zu.ge)		*!				

Tableau 4: *Zunge* 'tongue'

Tableau 5 shows the interaction between the onset constraints and the ones regulating the allophony between [ŋ] and [ŋg].

/tsʊŋə/ or / tsʊŋgə/	ONSET-COND	BIMOR	MAX(N,D)	SON	$ONSET_{\sigma(\mu)}$	*ŋg	NUC	$ONSET_{\sigma(non\text{-}\mu)}$
☞ a. (Zu[ŋ]e)								*
b. (Zu[ŋ.g]e)						*!		
c. (Zu.ge)			*!					

Tableau 5: *Zunge*

Tableau 6 shows why *lang* is realized as [laŋ], at least in Standard German. If [g] (or [k] because of Final Devoicing) was realized, it should project either a third mora, which is excluded by undominated BIMOR, or a semi-syllable, which is avoided by NUC. A candidate without [g] is preferable since it fulfills these two constraints as well as both MAX(N,D) and *[ŋg].

/laŋ/ or / laŋg/	ONSET-COND	BIMOR	MAX(N,D)	SON	$ONSET_{\sigma(\mu)}$	*[ŋg]	NUC	$ONSET_{\sigma(non\text{-}\mu)}$
☞ a. .laŋ.								
b. .laŋg.		*!				*		
c. .laŋ.g.						*!	*	
d. .lag.			*!					

Tableau 6: *lang*

Finally, Tableau 7 for *Mangrove* shows the effect of SYLLCONT. Candidate b. violates this constraint since a nasal is less sonorous than a liquid, and is thus eliminated.

/maŋrovə/ or /maŋgrovə/	ONSET-COND	SON	MAX(N,D)	$ONSET_F$	SYLLCONT	*ŋg
☞ a. .maŋ.gro.ve						*
b. .maŋ.ro.ve					*!	

Tableau 7: *Mangrove*

This section has shown that in some cases [ŋ] and [ŋg] are allophones of each other: [ŋ] is always a coda and [g] always an onset. Furthermore, the segment [g] after [ŋ] is realized just in case the following vowel is moraic.

4. [h]

4.1 Data

This section shows that the phonetic distribution of [h] is similar to the one of [g] after a dorsal nasal: It is pronounced as the onset of a moraic syllable or of a higher constituent but not as the onset of a nonmoraic syllable. Before the optimality-theoretic analysis can be shown, the following question must be answered: How can it be decided whether [h] is present in the input when it is not realized, as in *Ehe* 'marriage', *gehe* 'go, 1st pers.sg', *Ziehung* 'draw' and the like vs. *Böe* 'gust of wind', *schneeig* 'snowy', *Museum* with no [h]? An obvious answer is that a graphemic <h> corresponds to a phonological [h].[15] This is confirmed by the following observation: if an onsetless syllable which is usually unstressed is stressed for purpose of correction or contrast, glottal stop or [h] is realized in its onset, because the syllable is then Foot-initial and needs an onset. The syllables beginning with [h] correspond to the ones with graphemic <h>. *Gehe*, for instance, is then pronounced [gehɛ́] or [gehé].

It is generally assumed that the grapheme <h> has two phonological functions: onset and lengthening (*Dehnungszeichen*), see Eisenberg (1998), Ossner (1996), Primus (1999), Ramers

[15] There is a large anount of literature on the interaction between the graphemic representation and the phonology of [h] (see for instance Eisenberg 1998, Ossner 1996, and Primus 1999), but nearly nothing in OT though this theory seems best suited for the task (however see Geilfuß-Wolfgang, in preparation and Sternefeld 1999 for proposals in this direction).

(1999). In its second role, <h> lengthens the preceding vowel. The usual view is that the two functions, which have little in common, must be reconstructed in one way or another: diachronically, phonologically or graphematically.

It is proposed here that the grapheme <h> always functions as a graphematic onset in German and that this function corresponds to its role in phonology. In other words, both graphemic and phonemic *h* are onsets. The distribution of <h> can only be understood if the syllable structure is taken to be active both in the written system and in the phonological system, as has been proposed by several phonologists (see for instance Eisenberg 1998, Ossner 1996, Ramers 1999 and Wiese 1996).

Additional words in which <h> is present are listed in (18) and (19). If <h> appears before a full vowel, it has a phonetic correspondent, see the words in (18). In this case, it is generally the onset of the main stressed vowel. As shown in (18b), it also appears marginally before a secondary stressed vowel. An exhaustive list (18b) would contain considerably less items than an exhaustive one in (18a).

If <h> appears before a schwa or a consonant or at the end of the word it is not pronounced. In these cases, illustrated in (19), it is mute.

(18) <h> is realized as [h]

a. before a vowel with main stress: Hilfe [híl.fə] ‘help’, Hütte [hʏtə] ‘hut’, heben [hé:.bn̩] ‘to lift’, Hölle [hœlə] ‘hell’, haben [há:.bn̩] ‘to have’, hólen [ho:.ln̩] ‘to fetch’, Hund [hʊnt] ‘dog’, Hai [haɪ̯] ‘shark’, Heu [hɔɪ̯] ‘hay’, hauen [háʊ̯n̩] ‘to beat’

b. before an unstressed or secondarily stressed full vowel: Alkohol [ál.ko.ho:l] ‘alcohol’, Mahagoni [ma.ha.gó:.ni], Uhu [ú:.hu] ‘owl’, Ahorn [á:.hɔʁ̯n] ‘maple’[16]

(19) <h> is mute

[16] In *Ahorn* and *Alkohol*, the syllable beginning with [h] can be analyzed as projecting a foot, but this is not possible for *Mahagoni* and *Uhu*.

a. before a schwa : Kühe [ky:.ə] ‘cows’, gehe [ge:.ə] ‘go, 1st sg.’, mähen [me:.n̩] ‘to mow’, frohe [fʁo:.ə] ‘happy, infl.’, ziehen [tsi:.n̩] ‘to draw’, leihen [laɪ̯.n̩] ‘to lend’

b. before a consonant: lahm [la:.m] ‘lame’, Kohl [ko:.l] ‘cabbage’, Rohr [ʁo:.ʁ̞] ‘pipe’, ihn [i:.n] ‘him’, Fehde [fe:.də] ‘feud’

c. word finally: Kuh [ku:] ‘cow’, froh [fʁo:] ‘happy’, nah [na:] ‘near’, rauh [ʁaʊ̯] ‘rough’, Geweih [gə.vaɪ̯] ‘antlers’

The representation of the different occurrences of graphemic <h> is given in (20). There is nothing special about (20a). [h] is just an onset, and it is phonologically realized as such. In (20b), it is also an onset, but since the syllable is nonmoraic, it is not realized in the phonology. The graphemic and phonemic representations have thus no phonetic correspondent.

In (20c) the controversial cases appear. Those are the cases for which most researchers working on the orthography-phonology correspondence assume a lengthening function for <h>. This analysis is motivated by the fact that all vowels preceding <h> are tense, and thus long when stressed. On my account, <h> has no effect on the vowel preceding it. It is not even in the same syllable. The vowel is long by virtue of being in an open syllable. <h> is the onset of a following syllable, which may or may not have a nucleus. If it precedes a moraic nucleus, it is pronounced, otherwise it is not. In this latter case, it is the onset of a semi-syllable, but of a special kind, since it has no phonetic representation.

(20) Syllabic and phonological representation of graphemic <h>

a. As the onset of a moraic syllable (corresponding to a pronounced [h])

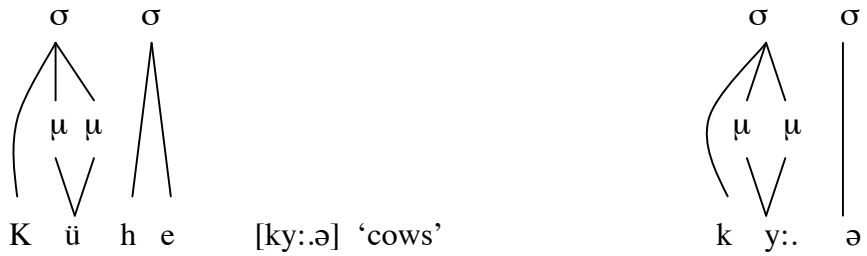
Graphemic

[hɔɣ̞] ‘hay’

Phonological/Phonetic

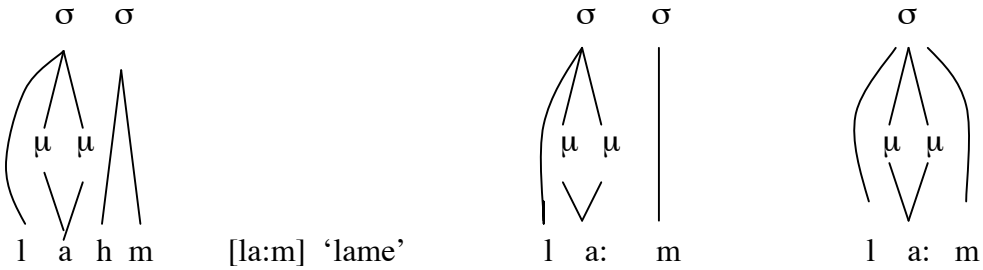
b. As the onset of a schwa syllable (unpronounced)

Graphemic Phonological/Phonetic



c. As the onset of a semi-syllable (unpronounced)

Graphemic Phonological Phonetic



This analysis is in line with the analysis of [g] in [ŋg]. Both consonants are realized only if they are onsets of a moraic syllable. A major difference between the two cases comes from the environment in which these consonants are found. [g] after a nasal always follows a closed syllable and [h] an open one.

4.2 OT Analysis

Two different aspects of the distribution of [h] must be accounted for by an OT analysis. The first one has to do with the fact that [h], like the glottal stop, cannot be in the coda[17], and the second with the fact that [h] is pronounced only if it is at the beginning of a moraic syllable or a higher prosodic constituent. The following constraint blocks the emergence of a laryngeal in the coda. This constraint is undominated and blocks the realization of a coda laryngeal in loanwords, as in *Isbollah, Brah.min, Yah.veh, Fahd* (see Davis 1999a for similar examples in English).

(21) CODA-COND: Laryngeals are onsets.

[17] See Kager & Zonneveld (1986) for a different account of the prohibition of the laryngeals in the coda in Dutch.

Consider a word like *Brahmin* in Tableau 8. The optimal candidate has no [h] in the coda of the first syllable, even if [a] would be short. This is due to the effect of CODA-COND.

/brahmin/ <Brahmin>	IDENT(C)	CODA-COND	ONS_{PrWd}	DEP(ʔ)	$ONSET_{\sigma(\mu)}$	*[h]	$ONSET_{\sigma(non\text{-}\mu)}$
☞ a. (Bra.min)							
b. (Brah.min)		*!				*!	

Tableau 8: *Brahmin*

Tableaux 9 and 10 illustrate the behavior of [h]. Inputs for *hallo* and *Kühe* agree with the graphemic representation. [h] is part of the input in both cases. Notice that [h] has no allophone. The only relevant alternation is non-realization of [h] thus, zero, and this just in case [h] is in the onset of a nonmoraic syllable. In Tableau 9 for *hallo*, the candidate with [h] is better than the other ones even if it violates *[h]: the other candidates are eliminated by higher-ranking constraints. The ranking of *[h] above $ONSET_{\sigma(non\text{-}\mu)}$ but below $ONSET_{\sigma(\mu)}$ guarantees that [h] is realized as the onset of a moraic syllable, but not as the onset of a schwa syllable. This explains why Candidate a. without [h] in Tableau 10 for *Kühe* is optimal. The segment *h* begins a nonmoraic syllable. The allophone /kyhə/ with [h] is motivated by graphemic <h> and by the rare instances of stressed second syllable.

/halo/ <hallo>	IDENT(C)	DEP(h)	$ONSET_{PrWd}$	DEP(ʔ)	$ONSET_{\sigma(\mu)}$	*[h]	$ONSET_{\sigma(non\text{-}\mu)}$
☞ a. [h]allo						*	
b. allo			*!		*		
c. [ʔ]allo				*!			
d. [t]allo	*!						

Tableau 9: *Hallo* 'hello'

/kyhə/ or / kyə/ <Kühe>	IDENT(C)	DEP(h)	$ONSET_{PrWd}$	DEP(ʔ)	$ONSET_{\sigma(\mu)}$	*[h]	$ONSET_{\sigma(non\text{-}\mu)}$

☞ a. (Kü.[ə])							*
b. (Kü.[hə])						*!	
c. (Kü.[ʔə])				*!			

Tableau 10: *Kühe* 'cows'

5. Glottal stop

Like [h], the glottal stop in German is always an onset. This restriction on the occurrence of the laryngeals has been observed in other languages as well, like some Semitic languages (see Hiller 1998 and McCarthy 1994 for an overview). Hiller observes that, due to their low sonority and their low consonantal strength, laryngeals prefer to be realized as unique segments in the onset or in the coda of syllables. This is always true in German, where the glottal stop is epenthetic, as in other languages, like French and Axininca Campa. Epenthetic status means that it corresponds to no segment in the input, and it is not signalized in the orthography.[18]

An interesting aspect of the glottal stop in German is its optionality in the foot-initial, word-internal position. Some examples were given in (11) which are repeated in (22) along with additional ones. The last example, *Pinguin*, is particularly interesting since the last syllable is not primarily stressed. However, since it is a superheavy one (two syllables in the present account), it receives a certain amount of stress and is thus perceived by some speakers and in some styles as projecting a foot, though not a primarily stressed one.

(22) Chaot [ka.ʔó:t]/ [ka.ó:t] 'chaotic person' Beamte [bə.ʔám.tə]/[bə.ám.tə] 'civil servant',
Theater [te.ʔá:.tɐ]/ [te.á:.tɐ] 'theater' Ruin [ʁu.ʔí:n]/ [ʁu.í:n] 'ruin'
Pinguin [píŋgu.ʔì:n]/[píŋgu.ì:n]

Compare also the following pairs. The function words in the expressions in the left column are stressed, or at least form their own Prosodic Word. In this case, the presence of a glottal stop is

[18] The grapheme-segment correspondence is also especially interesting since here, a segment is realized that has no graphemic correspondent. This is the opposite case of <h> which is a grapheme which is sometimes without segmental correspondent.

mandatory. In the second members, the function word has been cliticized to the preceding host word and is syllabified with it. In this case, there is no glottal stop.

(23) habe ich [ha:.bə.ʔiç] hab ich [ha:.biç] 'ich habe'

nimm ihn [nɪm.ʔi:n] nimm ihn [nɪmi:n] 'take him'

hilf ihr [hɪlf.ʔi:ɐ̯] hilf ihr [hɪl.fi:ɐ̯] 'help her'

Moulton (1962) has analyzed the glottal stop in German as a boundary sign between words. In a sense, the findings of this paper corroborate his analysis. Here too, a glottal stop in the onset of a vowel-initial syllable is more probable if the syllable coincides with a higher prosodic constituent boundary. The difference with Moulton's analysis is that here the glottal stop behaves like other segments in German. It is thus not a boundary signal (like a boundary tone) but just a segment which happens to be realized at some boundaries.

Finally, it is shown in Tableaux 11 and 12 that DEP(ʔ), the faithfulness constraint against the insertion of a glottal stop, ranks relatively high in the hierarchy, viz. between $\text{ONSET}_{\text{Foot}}$ and $\text{ONSET}_{\sigma(\mu)}$. As shown in Tableau 11, this ranking allows a glottal stop to be inserted at the beginning of a Prosodic Word or Foot but not of a lower constituent (Tableau 12). The high ranking of DEP(ʔ) expresses the fact that it is more costly to insert a consonant than to be faithful to a consonant already present in the input. In some styles DEP(ʔ) and ONSET_{F} are tied or their ranking is reversed and epenthesis is then blocked

/ide/	IDENT(C)	DEP(h)	$\text{ONSET}_{\text{PrWd}}$	ONSET_{F}	DEP(ʔ)	$\text{ONSET}_{\sigma(\mu)}$	*[ŋg]	*[h]	$\text{ONSET}_{\sigma(\text{non-}\mu))}$
☞ a. [ʔ]i.(dee)					*				
b. I.(dee)			*!			*			
c. [h]i.(dee)		*!							
d. [t]i.(dee)	*!								

Tableau 11: *Idee* 'idea'

/muzeum/	IDENT(C)	DEP(h)	$\text{ONSET}_{\text{PrWd}}$	DEP(ʔ)	$\text{ONSET}_{\sigma(\mu)}$	$\text{ONSET}_{\sigma(\text{non-}\mu)}$

☞ a. Mu.(se.um)					*	
b. Mu.(se.[ʔ]um)				*!		
c. Mu.(se.[t]um)	*!					

Tableau 12: *Museum* 'museum'

6. Conclusion

Two opposite tendencies in the behavior of German onsets have been observed: higher prosodic constituents prefer to begin with an onset, whereas lower prosodic constituents try to get rid of their onsets. A possible explanation for this contradictory tendency is that higher prosodic constituents prefer to be clearly demarcated, and one way to reach this aim is to realize an onset consonant (a crisp syllable in Itô & Mester's (1994) sense) whereas syllables belonging to the same Foot tend to blur together. Ambisyllabicity of medial consonants is the best way of blurring the boundaries between syllables. A detailed metrical theory should probably distinguish between trochaic feet with weak second syllables, viz nonmoraic ones, and feet with stronger second syllables, viz. moraic syllables, since they behave differently with respect to their onsets.

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